SIMEC MINING

SOUTH MIDDLEBACK RANGE

PROGRAM FOR ENVIRONMENTAL PROTECTION AND REHABILITATION



PEPR2014/109
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Overview

Mining in the South Middleback Range (SMR) commenced in 1986 and is expected to continue until at least 2027. This represents the continuation of iron ore mining in the Whyalla area, which commenced at Iron Knob in 1901.

The Arrium Ltd business including OneSteel Manufacturing Pty Ltd (incorporating Arrium Mining) entered voluntary administration in April 2015. GFG Alliance (GFG) completed the acquisition of Arrium's Australian businesses on 1 September 2017. GFG renamed Arrium Mining as SIMEC Mining. In this report, all further references to the company are as SIMEC Mining, or SIMEC.

SIMEC Mining's operations throughout the Middleback Ranges extend over approximately 60 km from Iron Duke in the south to Iron Princess in the north. Current mine plans and schedules target ores from around 12 pits across three distinct mining regions (see Figure 1 and Appendix A-1).

These mining regions are outlined as follows:

- South Middleback Range (SMR), incorporating Iron Duke, Iron Magnet, Iron Duchess South, Iron Knight North and South, and Iron Chieftain (all of which are the subject of this PEPR)
- North Middleback Range (NMR), referred to as the Iron Baron Mining Area (IBMA), which incorporates Iron Baron, Iron Prince, Little Baron, Baron East and Iron Queen
- Iron Knob Mining Area (IKMA), which incorporates the Iron Monarch and Iron Princess pits (East Princess and West Princess).

SIMEC Mining has a fourth mining region, Peculiar Knob (PK) south of Coober Pedy, which is currently in a Care and Maintenance mode.

All of these active mining regions are connected by rail to the Whyalla port facilities owned by SIMEC Mining.

The SMR is connected to the Whyalla Steelworks via an underground pipeline corridor, enabling Magnetite slurry produced at the SMR Magnetite Concentrator to be pumped to the Whyalla Pellet Plant for the production of iron ore pellets, providing the main feedstock to the Whyalla Steelworks. The underground pipeline corridor also accommodates a return water line between the Whyalla Pellet Plant and the SMR Magnetite Concentrator.

The SMR operations are intrinsically linked to the Whyalla Steelworks operations, and SIMEC Mining's Hematite Export Program.

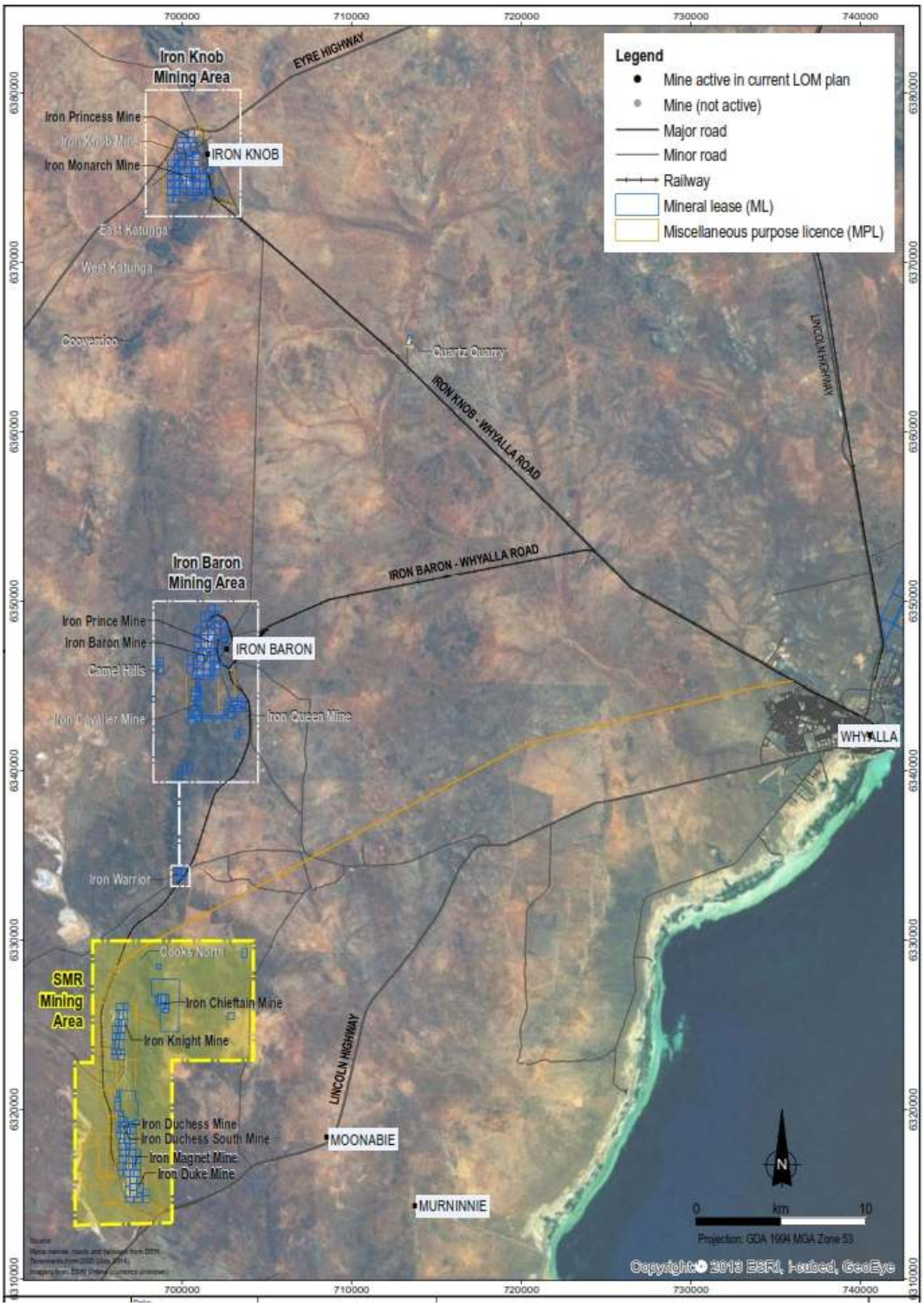


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Document Status

Rev No.	Principal Authors	Responsible Managers
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In the event that a discrepancy exists between content in the body of the proposal document and material in the appendices, the data in the body of the document is to be taken as the most current data.

This document has been developed and prepared with the assistance of Environmental Projects, commissioned by SIMEC Mining.

Revision History

Rev 0 – dated 26 September 2014; formerly submitted to DSD for assessment

Rev 1 – dated 1 December 2014; revised submission; Duchess Water storage adjustments

Rev 2 – dated 16 December 2014; revised submission; incorporating further Duchess Water storage adjustments; approved as ***MPEPR2014/109*** on 19 December 2014

Rev 3 – dated 29 June 2015; revised submission; incorporating further Duchess Water storage adjustments and final WRD design specifications; pending finalisation of all 'matters subsequent to approval' as raised in DSD's PEPR approval letter dated 19 December 2014

Rev 4 – this version dated 9 December 2016; incorporating all 'matters subsequent to approval' as raised in DSD's PEPR approval letter dated 19 December 2014; minor changes to Iron Chieftain and Iron Knight South

Rev 5 – this version dated 30 April 2018; incorporating Iron Duchess North Stage B Part 1 pit and WRD extension; an update of geochemistry information; additional waste rock and TSF analysis; analysis of potential new risks and impacts to the environment presented by TSF leachates (in response to DPC Request for Review letter dated 31 August 2017); and inclusion of new Iron Duke TSF Groundwater and surface water chemistry review (Jacobs 2018).

The Arrium Ltd business including OneSteel Manufacturing Pty Ltd (incorporating Arrium Mining) entered voluntary administration in April 2015. GFG Alliance (GFG) completed the acquisition of Arrium's Australian businesses on 1 September 2017. GFG renamed Arrium Mining as SIMEC Mining. In this report, all further references to the company are as SIMEC Mining, or SIMEC.

Declaration of Accuracy:

The following declaration is made in accordance with section 65(8) of the *Mining Regulations 2011*.

I, **Chris Smyth, SIMEC Mining's Group Manager Environment, Regulatory and Stakeholder**, have taken the following steps to review the information in this PEPR to ensure its accuracy:

- internal peer reviews by suitably qualified and experienced employees
- independent peer review by suitably qualified and experienced consultants
- a checklist process against the required 'matters subsequent to approval'
- an internal process for review and sign-off by senior management.



……

25 May 2018

Proponent Details	
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Tenement holder	OneSteel Manufacturing Pty Ltd
Name of Mining Operation	South Middleback Range Mining Area
Application date	May 2018

Abbreviations and Definitions

Abbreviation	Definition
ABS	Australian Bureau of Statistics
ALARP	as low as reasonably practicable
AMD	acid mine drainage
ANZECC	Australian New Zealand Guidelines for Water Quality
AS	Australian standard
BCM	bank cubic metres
BIF	banded iron formation
BoM	Bureau of Meteorology
BMP	Blast Management Protocol
DD	diamond drilling
DDG	dust deposit gauge
DE	Department of the Environment
DEWNR	Department of Environment. Water and Natural Resources
DMITRE	Department of Manufacturing, Innovation, Trade, Resources and Energy
DPTI	Department of Planning, Transport and Infrastructure
DPC	Department of the Premier and Cabinet
DSD	Department of State Development
DSO	direct shipping ore
EMS	Environmental Management System
EPA	Environment Protection Authority
EPBC	Environment Protection and Biodiversity Conservation
FY	Financial Year
Fe	iron
FDR	Fugitive Dust Ranking Procedure
GDP	gross domestic product
GIS	geographic information system
HGO	high-grade ore
IBMA	Iron Baron Mining Area
IFD	intensity frequency duration
IKMA	Iron Knob Mining Area
ILUA	Indigenous Land Use Agreement
LCM	loose cubic metres
LFA	Landscape Function Analysis
LGD	low-grade diluent ore
LGO	low-grade ore

Abbreviation	Definition
LGOS	low-grade ore stockpile
LMIF	lower Middleback iron formation
LOM	life of mine
MAG TSF	magnetite tailings storage facility
MARP	Mining and Rehabilitation Program
MBR	Middleback Ranges
MC	Mineral Claim
MIC	mass instantaneous charge
MGO	medium grade ore
ML	Mineral Lease
MPL	Miscellaneous Purpose Licence
MSW	mineralised waste
NGO	non-government organisations
NNTT	National Native Title Tribunal
N-SMR	Northern South Middleback Range
NMR	North Middleback Range
NPWS	National Parks and Wildlife Service
NRM	Natural Resource Management
NVC	Native Vegetation Council
OBP	ore beneficiation plant
OBP TSF	ore beneficiation plant tailings storage facility
OCA	Outback Communities Authority
PEPR	Program for Environmental Protection and Rehabilitation
PIRSA	Department of Primary Industries and Resources of South Australia
PK	Peculiar Knob
QP	Quality Procedure
RC	reverse circulation
RL	reduced level
RDA WEP	Regional Development Australia Whyalla and Eyre Peninsula
ROM	run of mine
SA	South Australia or South Australian
SAAL	South Australian Arid Lands
SACOME	SA Chamber of Mines and Energy
SANTS	South Australian Native Title Services
SAPB	South Australian Pastoral Board
SARIG	South Australian Resource Information Geoserver

Abbreviation	Definition
SEB	significant environmental benefit
SMR	South Middleback Range
S-SMR	South SMR domain
TSF	tailings storage facility
U-Th	uranium-thorium
UHF	ultra-high frequency
VWP	vibrating wire piezometer
WAHC	Whyallina Aboriginal Heritage Corporation
WRD	waste rock dump

Measurements and Symbols

Unit	Definition
ha	hectares
kL	kilolitre
km	kilometre
km/h	kilometres per hour
ktpa	kilo tonnes per annum
kWh	kilowatt hours
L	litre
m	metre
m^3	cubic metres
m^3/h	cubic metres per hour
m^3/month	cubic metres per month
m AHD	metres Australian Height Datum
mBCM	million bank cubic metre
mg/L	milligrams per litre
ML	megalitre
mm	millimetres
m RL	metres relative to/above sea level
Mt	million tonnes
Mtpa	million tonnes per annum
pa	per annum
RL	reduced level
SR	strip ratio
TDS	total dissolved solids

1 CONTEXT AND PURPOSE OF THIS DOCUMENT

This document is the **South Middleback Range** (SMR) **Program for Environmental Protection and Rehabilitation** (PEPR), previously assessed and approved on the 19 December 2014 as the new consolidated SMR PEPR. It has been identified as **PEPR2014/109**.

The 19 December 2014 PEPR approval carried some matters for SIMEC Mining's attention subsequent to approval. Revision 4 dated 9 December 2016 addressed these matters and some approved minor changes in the Iron Chieftain and Iron Knight South mining regions.

Specifically, this version (Version 5) provides the following supplementary content;

- information relating to Iron Duchess North Stage B Part 1 pit and WRD extension
- update of geochemistry information
- additional waste rock and TSF analysis
- analysis of potential new risks and impacts to the environment presented by TSF leachates (in response to DPC Request for Review letter dated 31 August 2017)
- inclusion of new Iron Duke TSF Groundwater and surface water chemistry review (Jacobs 2018).

This PEPR was prepared (and approved) in accordance with the *Mining Act 1971* and Regulations, and the requirements set out in the Department of State Development (DSD) Notice in accordance with Regulation 65 (7) of the Mining Regulations 2011, South Australian Government Gazette 50:3049-3063 (Ministerial Determination 005).

2 DESCRIPTION OF THE ENVIRONMENT

2.1 Introduction

In accordance with Ministerial Determination 005 (DMITRE 2012), the content of this section is limited to new baseline data collected since previous submissions.

SIMEC Mining has provided detailed descriptions of the SMR environment to DSD (now DPC) in the following PEPR related documents:

- OneSteel *South Middleback Ranges Mines Consolidated Mining and Rehabilitation Program* (SMR MARP) May 2007
- OneSteel Manufacturing Pty Ltd *N-SMR Mining and Rehabilitation Plan* (N-SMR MARP reference ADP2010/000014), October 2010
- OneSteel Manufacturing Pty Ltd *South SMR Mining Area Development Proposals – Iron Duchess-North Mine Extension and Iron Duke/Magnet WRD Extension*, May 2011
- Arrium Mining, *Northern South Middleback Range (N-SMR) Iron Chieftain Supplementary Mining Lease Proposal*, June 2014.

Key aspects of the existing environment are also outlined in Section 6 of this document to provide a context for the risk assessments.

2.2 Geochemistry

During mining, exposure of minerals that occur in waste rock and ore to oxygen and water enhances natural chemical weathering rates. Chemical weathering reactions can include dissolution of iron and silicate minerals in limonite and BIF which can release parameters such as iron, manganese, aluminium, silicon, potassium, sodium, calcium and magnesium. Secondary precipitation of iron minerals can also release acidity by hydrolysis. Under the right conditions, this may lead to the release of heavy metals from waste rock dump (WRD) seepage.

Iron ore in its oxide forms is usually environmentally benign, low in other potentially toxic elements and of low solubility. Where iron sulphides such as pyrite and pyrrhotite are present, however, there is the possibility that oxidation of sulphides may lead to acid mine drainage (AMD), which may be accompanied by elevated levels of dissolved toxic elements such as heavy metals (e.g. cadmium, copper), aluminium and arsenic (Parson Brinckerhoff 2007).

The hematite ores mined to date in the Middleback Ranges occur in the Lower Middleback Iron Formation, are generally low in sulphides and generally associated with carbonates, such as calcite. Dissolution of non-Fe/Mn carbonate minerals counteracts the acidity generated by sulphide mineral oxidation. Acidic drainage may result under the right hydrological conditions after the depletion of acid neutralising minerals, or when the rate of acid neutralisation is inadequate relative to the rate of acid generation. Acid neutralising capacity (ANC) can also be provided by the weathering of silicate minerals and clays; however, the buffering capacity of these minerals is generally low. Effective neutralisation is generally directly related to the abundance of non-Fe/Mn carbonate minerals. The

potential for AMD is diminished by the semi-arid climate and deep water table (e.g. springs at the break-of-slope are not known or expected).

Hutchinson Group – Middleback Subgroup

The Middleback Subgroup of the Hutchison Group consists of a mixed package of semi-pelitic and chemical sediments with amphibolite intrusives. In the Southern MBR the Subgroup is composed (in decreasing age) of the Katunga Dolomite, Lower Middleback Jaspilite (also known as the Lower Middleback Iron Formation), Cook Gap Schist, a discontinuity, and the Upper Middleback Jaspilite (or Upper Middleback iron Formation). The Lower Middleback Jaspilite contains a variety of different facies, including banded iron formation (BIF), sulphides, carbonates, graphite, silicates and oxides. (Parker 1993).

Parker (1993) found “Most of the iron ore deposits in the Middleback Range…(to be)…contained in shallowly north and south-plunging synclinal keels cross-folded or faulted about northwest-southeast and east-west axes…faulting and mylonitisation are common along the western limbs of these structures, and there are numerous basic intrusives which may have acted as impervious barriers during supergene enrichment of primary BIF”.

This similarity of geology, mineralogy and structure along the MBR allows comparison of the geochemistry and hydrogeology of SMR to other iron ore deposits in the MBR, including those in the Iron Baron Mining Area (IBMA). Consequently, recent geochemical and seepage assessments completed at IBMA have application to the waste dumps at SMR.

2.2.1 Waste Rock Analysis

Previous work by Golder Associates Pty Ltd (Golder 2016) found waste rock samples from the SMR to that date to be characterised by low sulphur content (0.03%-0.14%), with alkaline pH in all samples (9.3-9.7). Waste rock units were classified as acid consuming material (ACM) with the exception of sulphide breccia, which was potentially acid forming (PAF). The sulphide breccia represent a small fraction of waste rock materials which will only be accessed in approximately 2024 (see Appendix C).

Apart from the identified sulphide breccia, SMR waste rock geochemistry is similar to other deposits in the MBR. For current SMR operations, and given the likely earliest date to access the sulphide breccia is 2024, this allows a direct comparison of SMR waste rock with recent geochemical waste assessments completed at the IBMA.

Comparison with IBMA

In 2017, Golder Associates Pty Ltd (Golder 2017a) reviewed more than 10,000 existing geochemical samples and block models from five deposits in the IBMA to develop an initial geochemical assessment. Total sulphur was used to calculate the average maximum potential acidity (MPA) and net acid producing potential (NAPP) for each geozone, assuming the average ANC of each geozone is 0 (because of a lack of ANC information by geozone) (Golder 2017a).

The acid generating potential of the samples was classified using the DITR scheme presented in Table 1.

Table 1 Geotechnical classification criteria (DITR 2007)

Category	NAPP Value	NAGpH
PAF	> 10 kg H_2SO_4/tonne	< 4.5
PAF – Low Capacity (PAF-LC)	0 to 10 kg H_2SO_4/tonne	< 4.5
NAF	negative	≥ 4.5
AC	less -100 kg H_2SO_4/tonne	≥ 4.5
UC	positive	≥ 4.5
UC	negative	<4.5

On the basis of this preliminary work, the waste lithologies were classified as PAF–Low Capacity.

Additional geochemical test work conducted at Iron Warrior and Iron Sultan demonstrated that the majority of lithologies in these nearby locations are classified as Non Acid Forming (NAF) with some classified as Uncertain. The preliminary ABA assessment for the IBMA deposits (excluding Iron Warrior and Iron Sultan) suggests that the ore units present the greatest bulk AMD potential because of their sulphur content and volume of disturbance. However based on the results of the updated Iron Warrior and Iron Sultan geochemical assessment it is unlikely that the lithologies at IBMA will present a higher AMD risk.

Iron Warrior is the southern-most deposit in the IBMA, and lies immediately to the north of the SMR tenements (see Figure 1). The follow-up Iron Warrior geochemical assessment is discussed below.

Iron Warrior geochemistry

SIMEC Mining subsequently collected new samples from recent Iron Warrior drilling (March/April; 2018), targeting the main rock types on site as identified in the preliminary geochemical assessment. Detailed geochemical analysis of the new samples confirmed that the total sulphur is predominantly comprised of sulphate minerals and other forms of sulphur that are not acid generating (i.e. not sulphides). The conservative approach applied in the preliminary geochemical assessment (i.e. assuming that all sulphur is acid generating) can, therefore, now be updated with assessments based on empirical data. It was also confirmed that the major rock types on site contain ANC, which further reduces the net acid production potential of the site materials.

As a result of the new data, the majority of samples from the rock types tested were classified as non-acid forming (the remainder were classified as uncertain) (Golder 2017b). The uncertain classification is derived from the low paste pH and NAGpH of the clay and goethite samples.

The conservative approach applied in the preliminary geochemical assessment (i.e. assuming that all sulphur is acid generating) can, therefore, now be replaced with a more realistic approach, accounting for the various sulphur species present. In addition, the supplemental work has confirmed that rock types on site contain ANC, which further reduces the net acid production potential of the site materials. As a result of this new information, verified by the mineralogical results, the majority of samples from the five dominant rock types tested are now classified as non-acid forming or uncertain with <0.5 kgH_2SO_4/t NAPP. The uncertain classification is derived from the low paste pH and NAGpH of the clay and goethite samples.

These materials are naturally acidic and the acidity is non-sulphidic acidity likely derived from the hydrolysis of the iron minerals. As the iron minerals are naturally occurring in the landscape it is unlikely they present an increased risk to the environment through the operations (Golder 2017b).

Potential for WRD seepage

In 2017, following the Iron Warrior Geochemical Assessment (Golder 2017b), Golder examined the potential for seepage to be generated from the Iron Warrior WRD and low-grade ore stockpile (LGOS) (Golder 2017c). Golder's assessment considered both the operational and post-closure period for modelling. Golder considered rainfall infiltration rates to both the WRD and LGOS were "…likely to be much higher in the operational period than in the post-closure period given the plans for surface rehabilitation of the structures at closure and the greater likelihood that average rainfall conditions (would) be experienced over the notionally 200 year post-closure period that was modelled."

Golder developed a two-dimensional saturated-unsaturated groundwater flow model using Feflow software. The model incorporated climate effects (rainfall and evaporation), WRD and LGOS development and materials and previously determined hydrogeological data, and was designed to simulate internal water movement within the structures and predict migration away from them.

Modelling was undertaken in three stages:

- Stage 1: Steady State Modelling. The model was run to 'steady state' to establish pre-mining groundwater conditions, consistent with measured groundwater levels at the site, and interpreted groundwater flow gradients.
- Stage 2: Transient Modelling (Operational Period). The modelling simulated the progressive raising of the WRD using High, Middle and Lower Cases.

  The first simulation used the High Case rainfall and evaporation data set with the higher estimate of hydraulic conductivity and infiltration fluxes applied to the upper surface of the WRD in progressive raises. Despite the model indicating progressive increasing moisture content in the waste rock layers, groundwater levels remained constant.

  The Middle and Lower Case simulations were run using the middle and lower estimates of hydraulic conductivity, with no seepage predicted from these models.

  As a result of the outcomes of the WRD modelling, Golder did not consider it necessary to run any additional simulations on the LGOS, given its much smaller size.
- Stage 3: Transient Modelling (Post-Closure Period). Golder used the Stage 2 moisture conditions as the starting conditions for the 200 year simulation period. Golder considered that the modelling resulted in a negligible risk of seepage.

On the basis of this modelling, SIMEC Mining consider it unlikely that WRDs at SMR will perform any differently to WRDs at Warrior, given the similar geology and climate.

2.2.2 TSF Analysis

Between 2004 and 2014, there were three geochemical assessments of tailings. In 2004 and 2007 Parsons Brinckerhoff (PB) undertook geochemical testing of tailings materials, including

embankments. In 2014, Golder completed design studies for the TSF PEPR (Golder 2014a). In 2015, Golder reviewed groundwater quality in the vicinity of the TSFs (Golder 2015).

Golder (2016) reviewed the data from these reports, and found the following:

- sulphur content of all tailings samples ranged from 0.01% to 0.48%
- dolomite, a carbonate mineral with high neutralising capacity, was found to occur in both the OBP tailings (3%) and magnetite tailings (14%) samples
- the tailings and embankment materials tested by PB in 2004 and 2007 and Golder (2014a) were classified as non-acid forming
- PB (2004 and 2007) found tailings generated leachate characterised by near-neutral pH and low levels of trace elements
- Golder (2014a) indicated potential for leaching of trace elements including boron, chromium, aluminium, copper, uranium and zinc. These elements were also found to be elevated in the tailings supernatant. Aluminium, copper and zinc exceeded baseline groundwater values. The pH of the leachates and supernatant also shifted to slightly alkaline.

In January 2018, after receiving all necessary permits and approvals, SIMEC Mining installed new monitoring well CPMW01. The new monitoring bore is up-gradient of the TSFs (see Figure 23) and designed to provide background groundwater chemistry. Improved understanding of the natural groundwater background values in the catchment allows SIMEC to better assess the tailings leach potential and the implication of any leachate impacts to receptors. In February 2018, SIMEC Mining engaged Jacobs Group (Australia) Pty Ltd (Jacobs) to conduct a groundwater and surface water chemistry review, including the first round of data from CPMW01.

In summary, Jacobs found that although there have been some fluctuations in values since baseline data was first collected in 2005, only BHMB1 had exceeded any of the 2007 MARP trigger values on a few occasions, and in most cases returned to baseline conditions in observations taken in August 2017. BHMB1 is screened in basement and is adjacent to the south west corner of the TSF and not completely down-gradient and therefore subject to uncertain influences. All other monitoring bore values had remained relatively stable. Early results of the newly installed background well indicated values within the average range of TSF seep water monitoring wells since background commenced in 2005.

The groundwater chemistry investigation trigger values established from the MARP 2007 in the Iron Duke TSF EMP are based on data collected during the 2005 baseline assessment. As such, the investigation trigger values do not consider the likely receiving environment of Salt Creek, being the primary surface expression of regional groundwater flow. EPA South Australia's Environment Protection Policy (Water Quality) (EPA SA 2015) does not provide indicative water quality guidelines for saline/low pH groundwater or surface water systems located in the SA Arid Lands region.

Natural hydrogeochemical processes in part explains low pH water and elevated heavy metals present in groundwater adjacent the TSFs and Salt Creek. Furthermore, contaminants of concern which may leach from TSF material (boron, chromium, aluminium, copper, uranium and zinc) are being naturally attenuated by similar hydrogeochemical processes.

It is proposed that new chemistry trigger values are established using background groundwater chemistry data collected from CPMW01. This monitoring bore is inferred to be of sufficient distance from SIMEC's SMR operations to not be affected by anthropogenic sources. Furthermore, the monitoring bore is located downgradient of regional groundwater flow and therefore is representative of the natural evolution of groundwater chemistry along the flow path of the saline alluvial aquifer. On this basis it can be argued that whilst seepage from the Iron Duke TSFs may be migrating into the groundwater system, the current and potential beneficial use of the alluvial aquifer is not degraded therefore the Salt Creek ecosystem has also not been degraded. (Jacobs 2018, see Appendix D).

As there are currently no guidelines developed for saline inland groundwater or surface water systems it has been recommended by Jacobs (Jacobs. 2018) that new groundwater chemistry trigger values are established. Preliminary draft guidelines will therefore be developed for discussion using a combination of historical groundwater data and data from CPMW01. These draft guidelines willbe refined once a sufficient dataset of monitoring data is collected from CPMW01. The trigger values for each dissolved analyte could be applicable to groundwater adjacent Iron Duke TSFs and Salt Creek surface water.

2.3 Hydrology

The SMR operations are situated within the south-eastern boundary of the (largely) internally draining Gairdner Basin: the Spencer Gulf watershed is located to the south and east. This is a semi-arid region with average rainfalls of less than 275 mm, most of which is received during the winter. Significant short duration ex-tropical cyclone and depression related rainfall events can occur during late summer: daily rainfalls in excess of 150 mm have been recorded locally.

The rainfall intensity-frequency-duration (IFD) relationship for the SMR site indicates that 100 year 24 hour and 72 hour duration events are likely to produce rainfall depths of about 115 mm and 138 mm respectively. Figure 2 shows the design rainfall intensity chart.

Salt Creek is the only significant watercourse in the vicinity of the SMR. It appears to be a series of interconnected salt lakes or playas and may be a remnant paleochannel. Salt Creek, like all the other minor watercourses and drainages on site, is ephemeral, only receiving surface runoff following significant rainfall.

A high-level hydrological review has been undertaken to assist with operational and closure surface water planning for the SMR operation (Mining Plus Pty Ltd 2014a) and a detailed surface hydrology assessment was completed by Coffey Mining in 2011. The assessment recommends a surface water management plan appropriate to all the existing infrastructure. Surface water from within the SMR site, specifically from the main intersection to Iron Duchess, is presently diverted through a series of diversion channels, culverts and pipes to a number of locations around the mine site, including several purpose built ponds, the OBP TSF and at times, the Magnet TSF (Coffey 2011a).

Catchment and surface water estimates were completed with calculated flows for the 50 and 100 year flood lines.

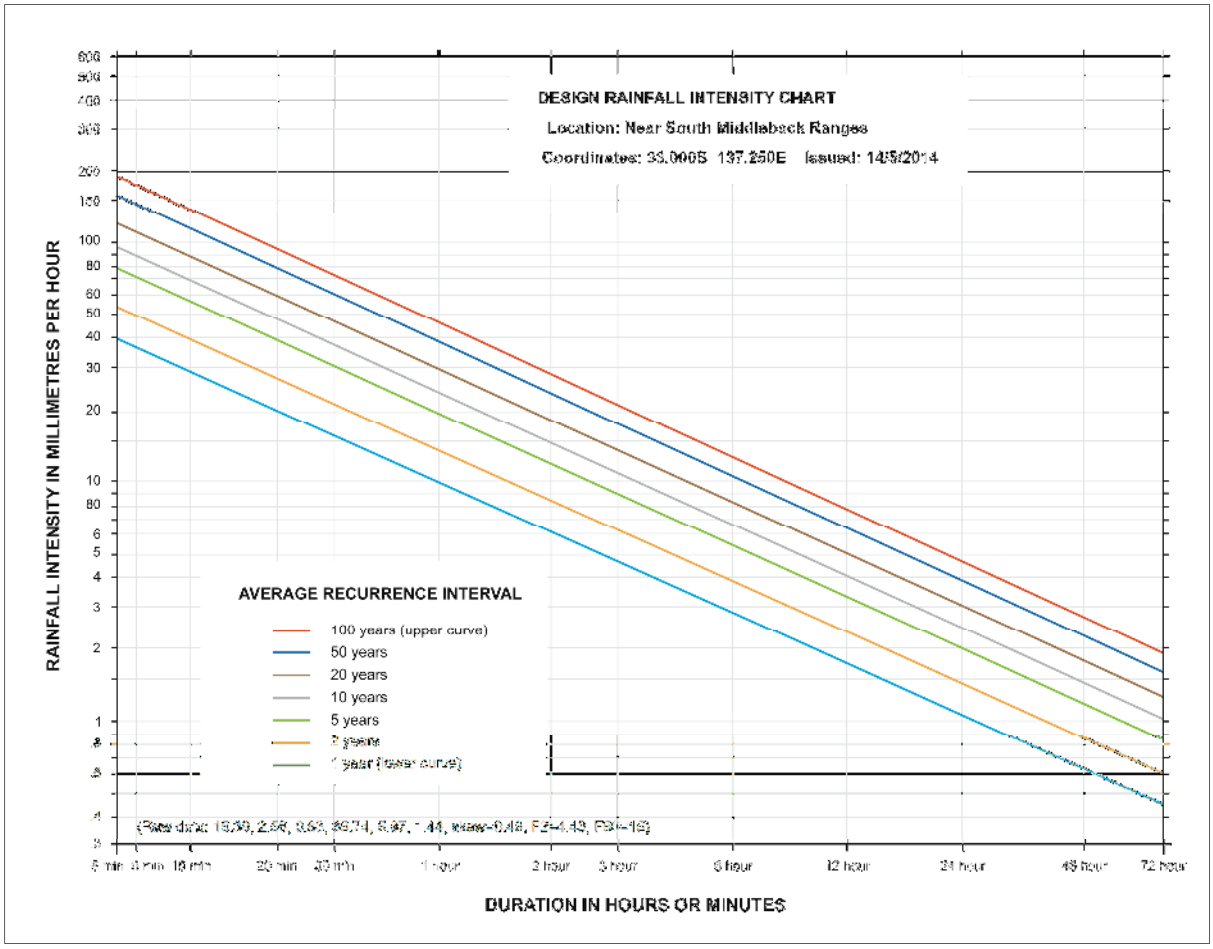


Figure 2 SMR design rainfall intensity chart

Further information regarding stormwater management during operations is included in the general description of mining operations section (see Section 3.8.8).

Further information concerning closure catchment areas and potential pit water levels from high intensity rainfall events is included in the rehabilitation and closure section – see Section 8.5.

3 DESCRIPTION OF THE MINING OPERATIONS

3.1 Tenements and Land Ownership

OneSteel Manufacturing Pty Ltd (SIMEC Mining) holds 85 Mineral Leases (MLs) and 17 Miscellaneous Purpose Licences (MPLs) in the SMR. Appendix A-2 shows the mining tenements for the SMR.

The mining tenements for the Iron Chieftain domain are listed in Table 2 and shown on Figure 3.

Table 2 Iron Chieftain tenements and titles

Tenement	Title ID	Type of title	Landowner
ML6441	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
ML2662	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML2706	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4745	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4746	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4747	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML6361	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML6362	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
MPL123	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L

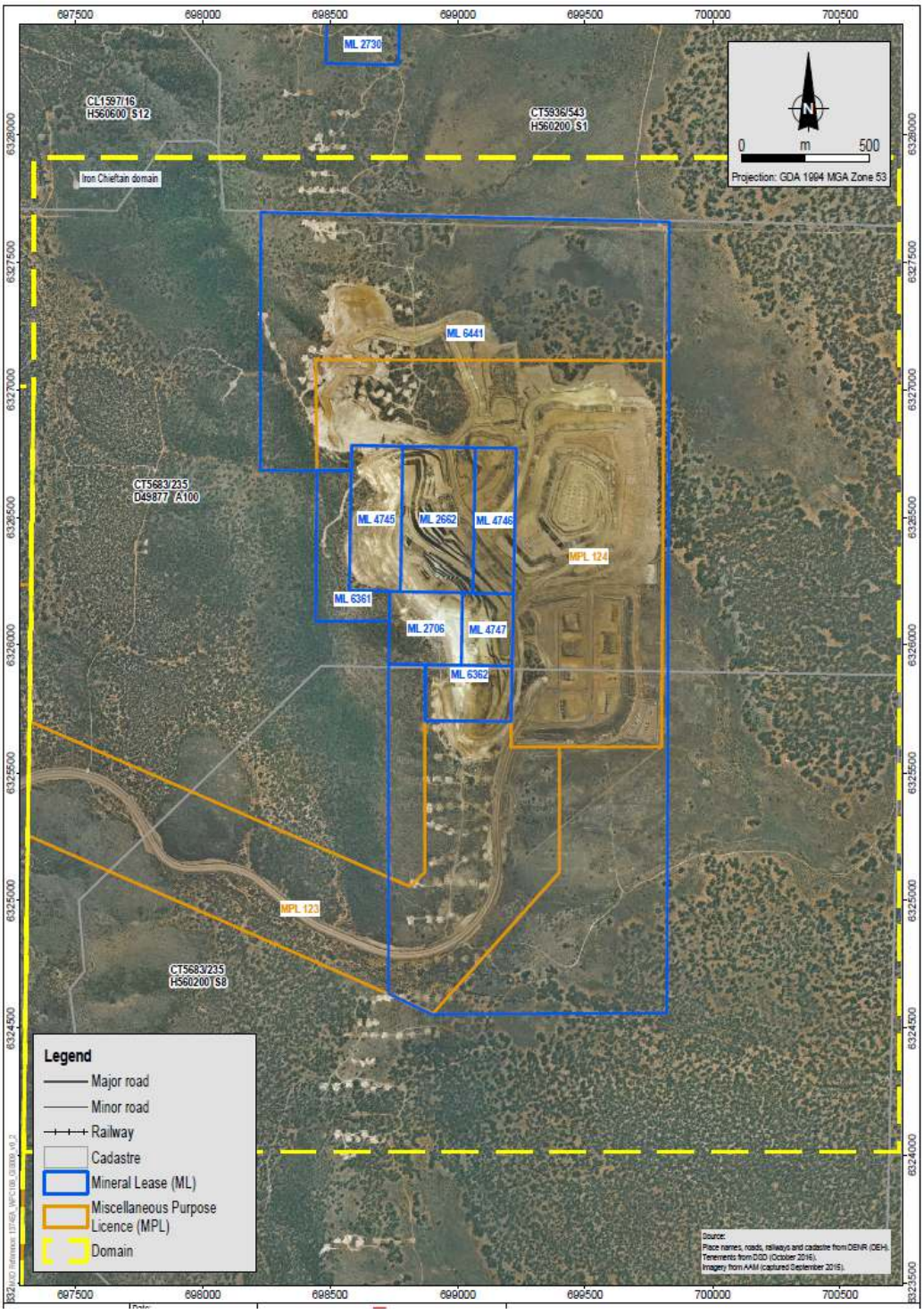


Figure 3 Iron Chieftain tenements

The mining tenements for the Iron Knight domain are listed in Table 3 and shown on Figure 4.

Table 3 Iron Knight tenements and titles

Tenement	Title ID	Type of title	Landowner
ML2657	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML2663	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML2704	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML2717	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML2718	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML2719	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4735	CR 6059/795	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4736	CR 6059/795	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4737	CR 6059/795	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4738	CR 6059/795	Unallotted Crown Land	Minister for Environment & Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4739	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4740	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4741	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4742	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4743	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4744	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4770	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4771	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4772	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4773	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4774	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
ML4775	CR 6059/795	Unallotted Crown Land	Minister for Environment and Conservation
	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
MPL51	CR 6059/794	Reserve	Ironstone Hill Conservation Park
	CR 6059/795	Unallotted Crown Land	Minister for Environment and Conservation
	CR 6059/797	Reserve	Ironstone Hill Conservation Park
	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing P/L

Tenement	Title ID	Type of title	Landowner
MPL52	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CR 6059/797	Unallotted Crown Land	Ironstone Hill Conservation Park
	CR 6059/800	Fee Simple Entirety	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
MPL54	CR5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
MPL55	CT 5683/235	Fee Simple Entirety	OneSteel Manufacturing P/L
MPL69	CL 1195/45	Crown Leasehold	Balesfold Pty Ltd
	CL 1395/49	Crown Leasehold	Commonwealth of Australia
	CL 1195/45	Crown Leasehold	Balesfold Pty Ltd
	CL1195/40	Crown Leasehold	Balesfold Pty Ltd
	CL 1195/45	Crown Leasehold	Balesfold Pty Ltd
	CR 5998/434	Unallotted Crown Land	Minister for Environment and Conservation
	CR 5318/30	Unallotted Crown Land	Minister for Sustainability, Environment and Conservation
MPL70	CR 6059/795	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing P/L
	CR 6059/794	Reserve	Ironstone Hill Conservation Park
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing P/L

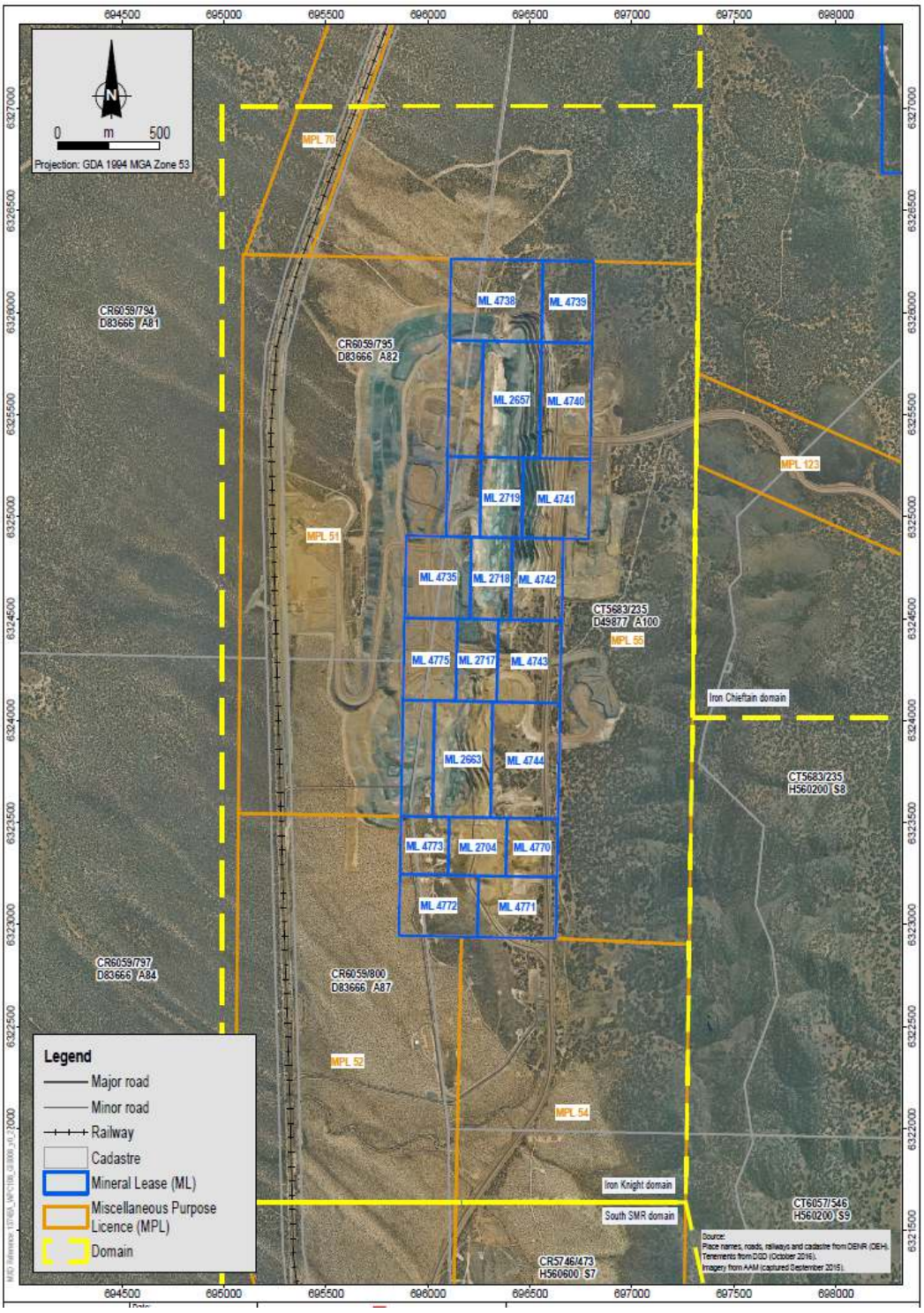


Figure 4 Iron Knight tenements

The mining tenements for the South SMR domain are listed in Table 4 and shown on Figure 5.

Table 4 South SMR tenements and titles

Tenement	Title ID	Type of title	Landowner
ML2648	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2649	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2650	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2651	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2652	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2653	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2654	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2656	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML2658	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2659	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2668	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2669	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2677	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2682	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML2683	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2701	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML2705	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML2707	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
ML2708	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
ML2709	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML2710	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML2711	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2712	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull

Tenement	Title ID	Type of title	Landowner
ML2714	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2715	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2716	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML2720	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML4714	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML4715	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML4716	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4717	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4718	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4719	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4720	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4721	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4722	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4723	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4724	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4725	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4726	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4727	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4728	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4729	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML4730	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4731	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4732	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation

Tenement	Title ID	Type of title	Landowner
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4733	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4734	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML4761	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML6055	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
ML6167	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
ML6431	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
MPL32	CR 6059/797	Reserve	Ironstone Hill Conservation Park
	CR 6059/799	Unallotted Crown Land	Minister for Environment and Conservation
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
MPL33	CR 5746/473	Unallotted Crown Land	Minister for Environment and Conservation
	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
MPL34	CR 6059/797	Reserve	Ironstone Hill Conservation Park
	CR 6059/799	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
MPL53	CR 5746/473	Unallotted Crown Land Reserve	Minister for Environment and Conservation
	CR 6059/797	Reserve	Ironstone Hill Conservation Park
	CR 6059/800	Fee Simple Entirety	Minister for Environment and Conservation
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
MPL67	CR 6059/797	Reserve	Ironstone Hill Conservation Park
	CR 6059/798	Unallotted Crown Land	Minister for Environment and Conservation
	CR 6059/800	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
MPL71	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
MPL72	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull
MPL73	CR 6059/797	Reserve	Ironstone Hill Conservation Park

Tenement	Title ID	Type of title	Landowner
	CR 6059/798	Unallotted Crown Land	Minister for Environment and Conservation
MPL74	CR 6059/798	Unallotted Crown Land	Minister for Environment and Conservation
	CT 5868/217	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
MPL135	CT 6057/546	Fee Simple Entirety	Mark Dean Turnbull, Kathleen Iris Turnbull, John Simon Turnbull and Nigel James Turnbull

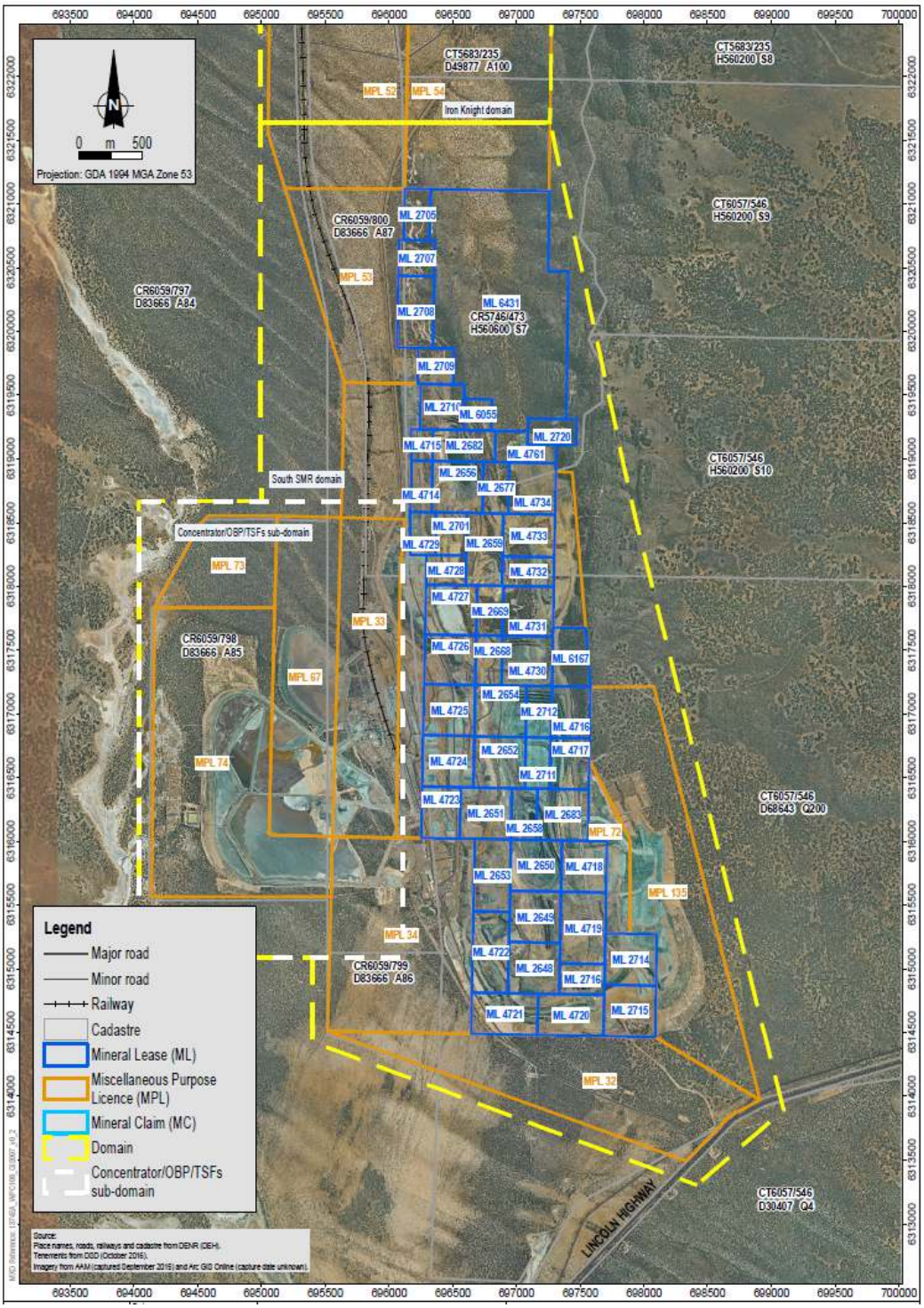


Figure 5 South SMR tenements

The purpose of each MPL tenement is shown in Table 5.

Table 5 Purpose of MPL tenements

Tenement	Domain	Purpose
MPL32	South SMR	Access road from the Lincoln Highway to the mine site
MPL33	South SMR	The use of a tramway The operation of a crushing plant and other facilities relating to operations Waste rock dump The provision of a corridor to contain a power line and buried pipelines The operation of a tailings storage facility The operation of a haulage road and access road Low-grade ore stockpiles
MPL34	South SMR	The operation of a tramway and access road Waste rock dumps Tailings storage facility
MPL51	Iron Knight	Waste rock dumps The provision of a corridor to contain a power line and buried pipelines The operation of a tramway and access road
MPL52	Iron Knight	Part of a haul road from Iron Knight North open pit mine to the treatment plant west of Iron Duke North Waste rock dumps The provision of a corridor to contain a power line and buried pipelines The operation of a tramway and access road Low-grade ore stockpiles Water catchment/storage dam
MPL53	South SMR	Part of haul road from Iron Knight North open pit mine to the treatment plant west of Iron Duke North The provision of a corridor to contain a power line and buried pipelines The operation of a tramway and access road Waste rock dump Low-grade ore stockpiles
MPL54	Iron Knight	Operation of explosives storage and associated workshop facilities Operation of access roads for the explosives storage facility Operation of a haul road between Iron Knight and the ore treatment plant west of Iron Duke North Waste rock dump Low-grade ore stockpiles Water catchment/storage dam
MPL55	Iron Knight	Waste rock dump Haul road operation Ore stockpiling
MPL67	South SMR	Low-grade beneficiation plant

Tenement	Domain	Purpose
		Tailings storage facility
MPL69	Pipeline corridor	Service corridor to contain a power line and buried pipelines to transport concentrate and return water
MPL70	Pipeline corridor	Service corridor to contain a power line and buried pipelines to transport concentrate and return water
MPL71	South SMR	Waste rock dump
MPL72	South SMR	Waste rock dump
MPL73	South SMR	Tailings storage facility
MPL74	South SMR	Tailings storage facility
MPL123	Iron Chieftain	Haul road between Iron Knight and Iron Chieftain
MPL135	South SMR	Waste rock dumps

Three MLs are located to the north and east of the Iron Chieftain mining domain (see Appendix A-2). The activity on these MLs is confined to exploration. Table 6 provides details of these tenements.

Table 6 Additional MLs tenements and titles

Tenement	Title ID	Type of title	Landowner
ML2729	CT 5936/543	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
ML2730	CT 5963/543	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd
ML2660	CT 5936/543	Fee Simple Entirety	OneSteel Manufacturing Pty Ltd

3.2 Reserves, Products and Markets

3.2.1 Geological environment

The SMR lies at the southern end of the Middleback Ranges (MBR). Figure 6 and Figure 7 show the regional geology of both the MBR and the SMR.

Hematite in the MBR occurs as stratabound Palaeoproterozoic deposits of the Lower Middleback Iron Formation (LMIF), which is part of the Hutchison Group. The Hutchison Group forms part of the Cleve Subdomain of the Gawler Craton, and lies on its western edge. The Cleve Subdomain comprises tightly folded, high-grade metamorphic rocks that are mainly derived from marine shelf sediments and mafic and acidic volcanics (Parker 2012).

The Hutchison Group in the MBR is composed of the Warrow Quartzite and the Middleback Subgroup. The Warrow Quartzite is not identified at all locations. The Middleback Subgroup comprises the Katunga Dolomite, the LMIF, the Cook Gap Schist and the Upper Middleback Iron Formation (UMIF). The LMIF hosts the Middleback Ranges' hematite deposits.

MBR iron ores formed through supergene enrichment; the process selectively dissolved waste minerals and replaced them with iron ore mineralisation. Preferential enrichment occurred in carbonate facies iron formation, dolomitic marble and, to a lesser degree, silicate facies iron formation. The silicates were much less soluble than the carbonates, and resulted in patchy mineralisation in the silicate iron facies (Yeates 1990).

Magnetite was recrystallised and remobilised during a period of metamorphism and deformation. Multiple periods of uplift, erosion and weathering resulted in the oxidation of magnetite to hematite and martite through supergene processes.

The formation of iron ore requires fluids to move through the rock. Most deposits lie on the western side of the range, adjacent to a major fault or mylonite zone along the western edge of the range, which may have provided this pathway. The process was most intense where the dolomite and carbonate facies were thickened and then subsequently exposed during the supergene process (Yeates 1990).

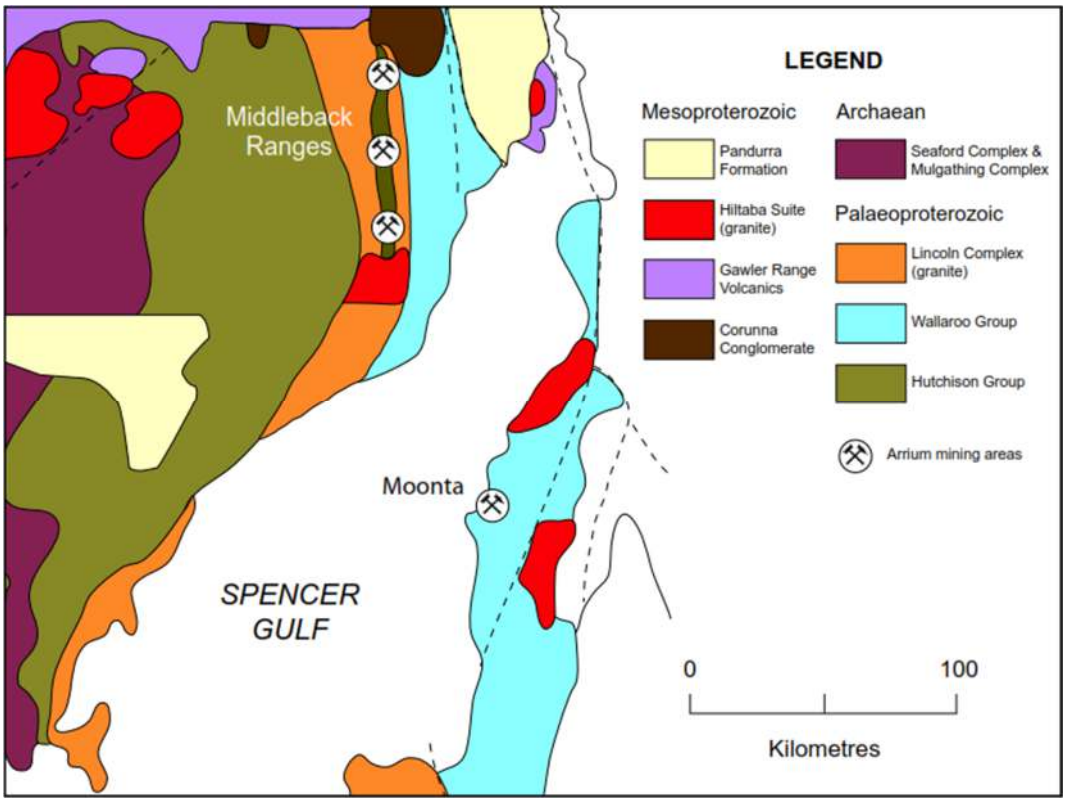


Figure 6 Diagram of Middleback Ranges regional geology

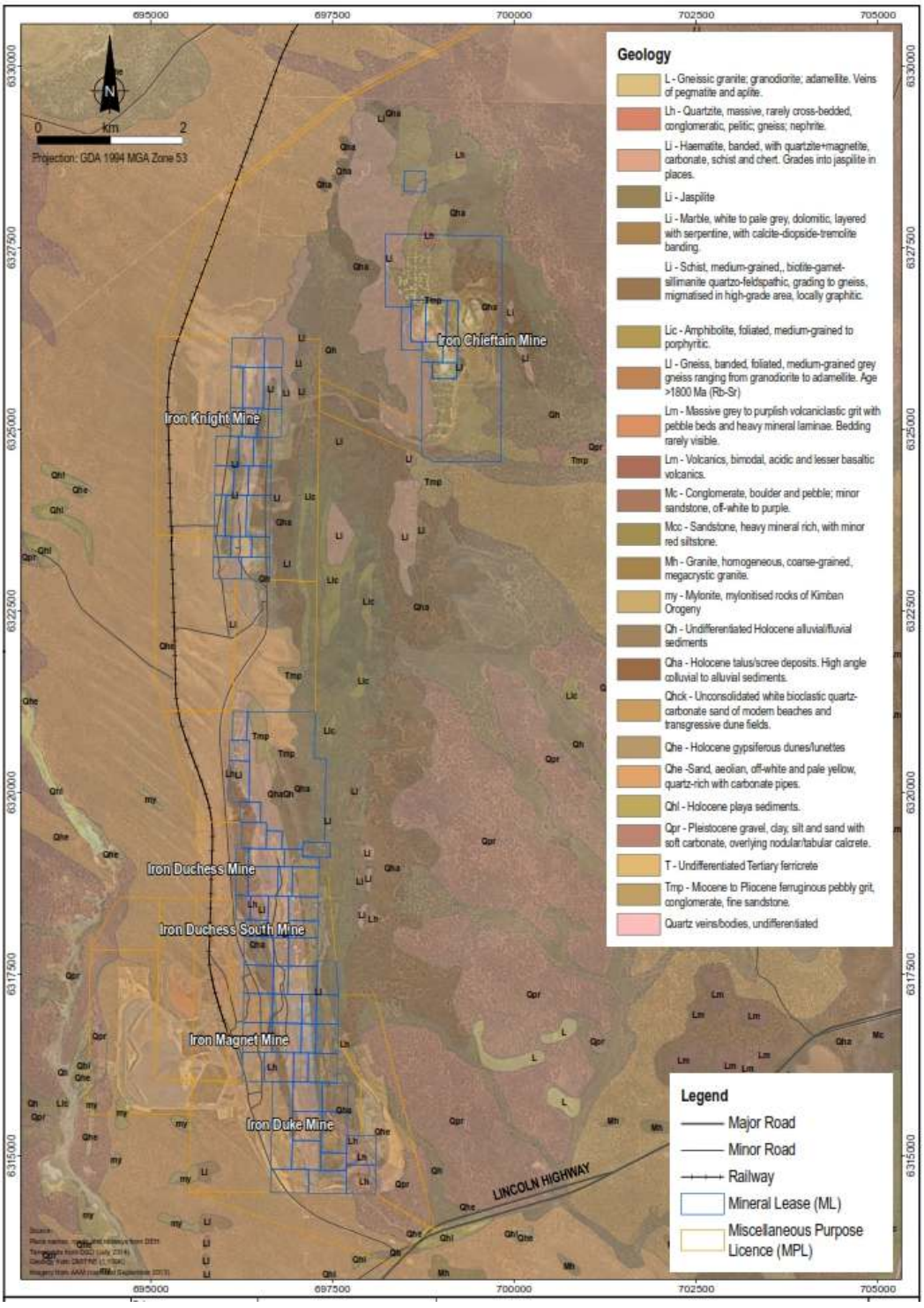


Figure 7 SMR regional geology

Iron Chieftain

The Iron Chieftain deposit is located on the eastern flank of the SMR, 11 km north-north-east of the Iron Duke pit. The deposit forms a 50–300 m outcrop of massive goethitic hematite dipping at 30 degrees to the west. The goethitic hematite is overlain by quartz hematite and quartz magnetite banded iron formation (BIF) and clays. These are interpreted to be basal LMIF. Clay schists beneath the ore body contain quartz hematite BIF lenses. Highly weathered mafic intrusives cross-cut the stratigraphy. Drill holes located north-east of the ore body intersects quartz feldspar granite at a depth of 55 m. The goethitic hematite deposit is bounded to the west by a northerly trending fault. Along the strike the deposit grades into goethitic material, which is graded at approximately 50% iron.

Figure 8 shows a geological cross-section identifying BIF, hematite and surrounding rock units.

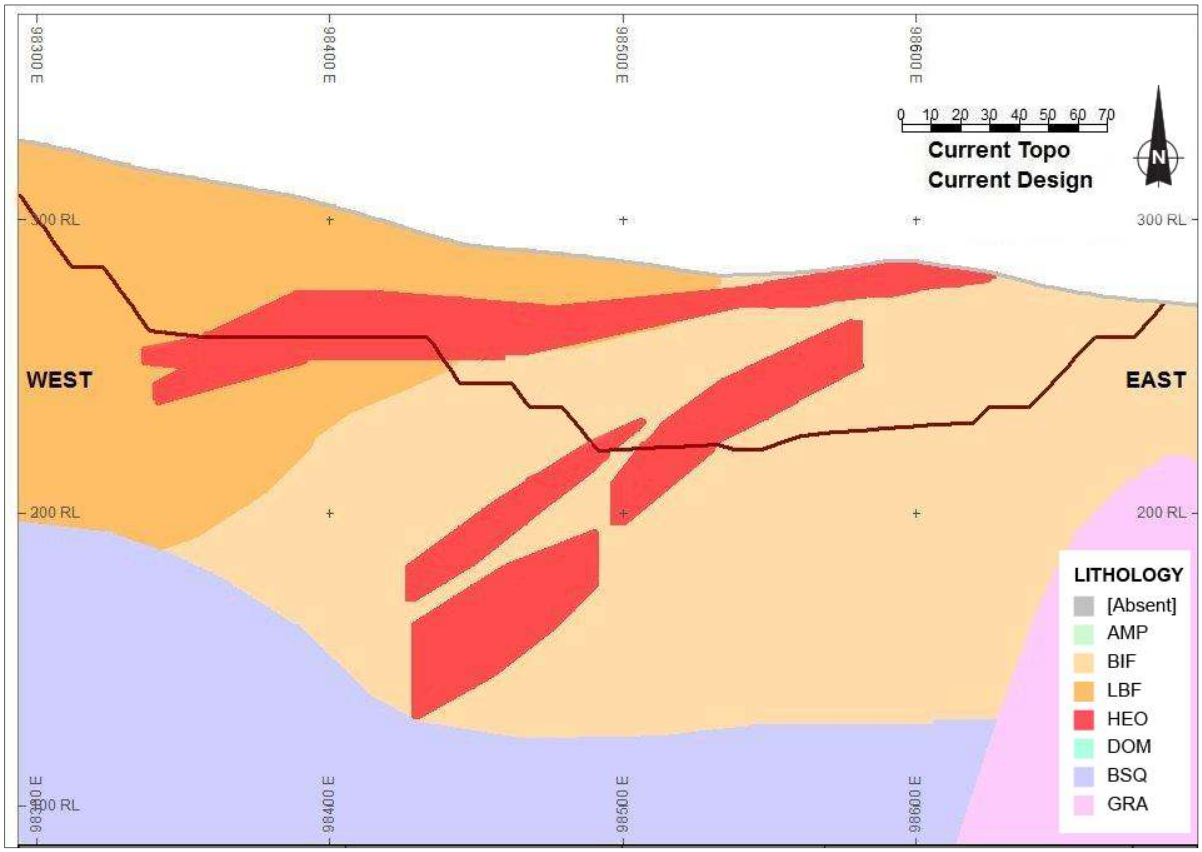


Figure 8 Iron Chieftain north – Geological cross-section

Iron Knight

Figure 9 and Figure 10 show geological cross-sections for Iron Knight North and Iron Knight South.

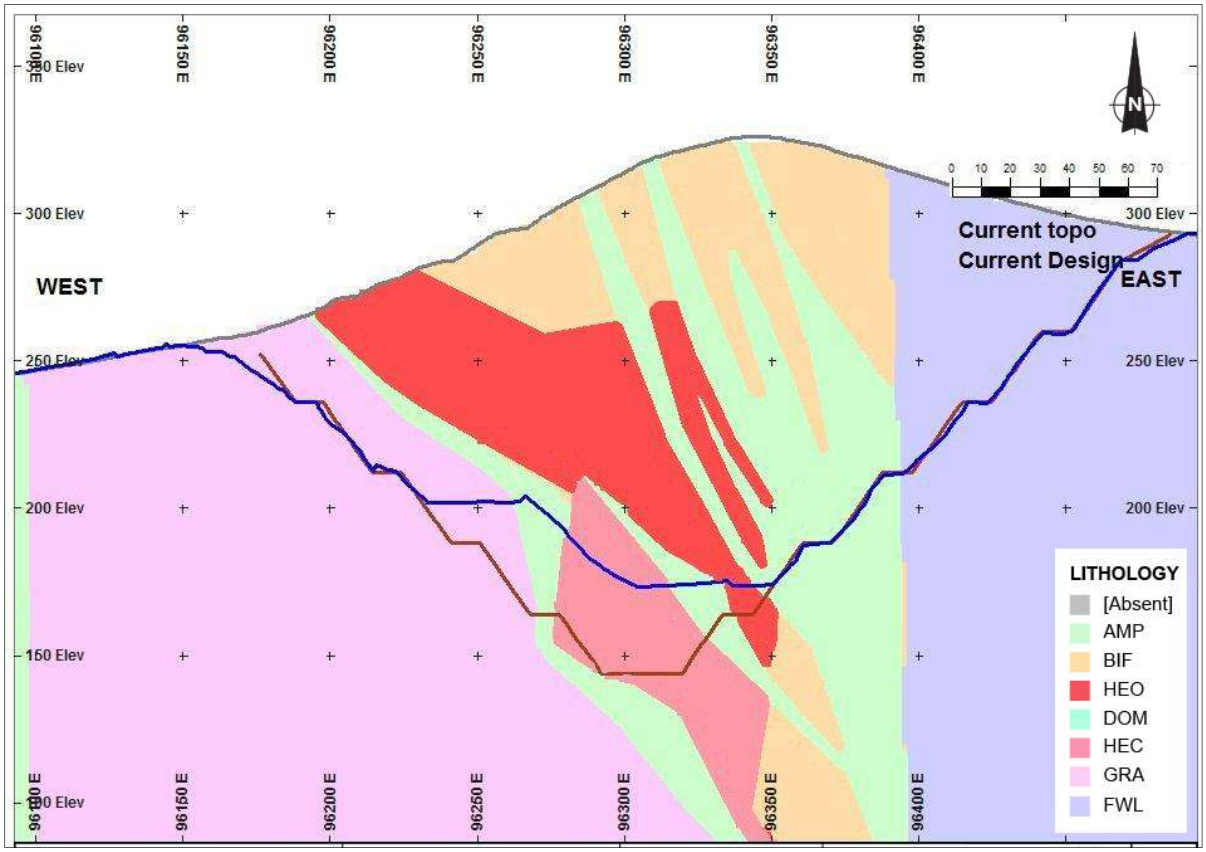


Figure 9 Iron Knight north – Geological cross-section

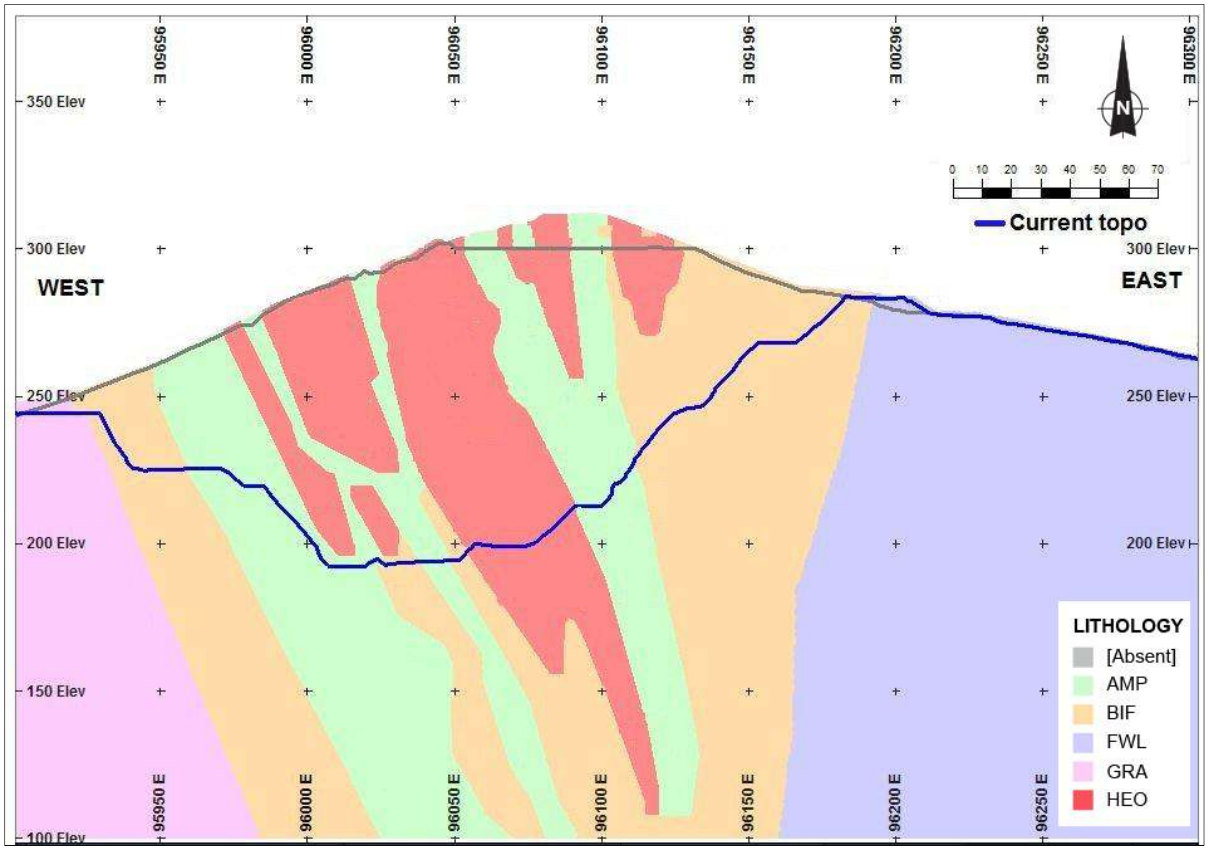


Figure 10 Iron Knight south – Geological cross-section

South SMR

Iron Duchess

The Iron Duchess iron ore deposit is located at the southern end of the MBR within the Gawler Craton geological province. This deposit is hosted within the Palaeoproterozoic Hutchison Group metasediments.

The Hutchison Group comprises a basal quartzite passing up into the Middleback Subgroup, which commences with the Warrow Quartzite overlain by the Katunga Dolomite.

These are overlain by the Lower Middleback Jaspilite which is a carbonate facies iron formation comprised of iron carbonate, silica and iron oxides that weather to porous goethite-limonite rocks at surface. Sulphide facies iron formation and graphitic metasediments are intercalated at depth. This unit becomes more siliceous and iron oxide rich higher in the sequence with prominent iron bearing silicates including iron rich talc and cummingtonite-grunerite series amphiboles. The Lower Middleback Jaspilite is found across the Gawler Craton, but is thickest and best developed in the Middleback Ranges. The Lower Middleback Jaspilite is overlain by the Cook Gap Schist, a poorly outcropping quartz-biotitemuscovite-sillimanite-garnet-tourmaline schist, which is in turn overlain by the thick Corunna Conglomerate.

High-grade hematite ore occurs in a keel structure between the limbs of a major bifurcating amphibolite dyke, which strikes roughly north–south. Hematite mineralisation also occurs beneath, and to the east of, the main amphibolite dykes, however the mineralisation zones are generally thinner and lower grade. The deeper drill-holes indicate that iron ore mineralisation preferentially replaced carbonate facies BIF. Thus it appears the principle controls on hematite mineralisation at the Iron Duchess are the presence of a favourable host, proximity to the amphibolite intrusions and proximity to supergene weathering processes.

The deposit consists of massive hematite with minor goethite and limonite forming a steeply dipping planar body. The deposit is overlain by massive quartz hematite BIF and chert. The footwall to the deposit is made up of minor BIF, various schist units and ferruginous dolomite, interpreted as the Katunga Dolomite sequence. Highly weathered mafic dykes and sills intrude the stratigraphy. The deposit is interpreted to be a northern extension to the Duchess deposit and occurs in the basal LMIF. A granitic body occurs to the west of the deposit and most of the outcrop of the enriched hematite lens is almost completely masked by BIF scree. The deposit is also masked by the fact that the ore zone often terminates before reaching the surface (Bubner et al. 1998).

Figure 11 shows a geological cross-section for Iron Duchess South.

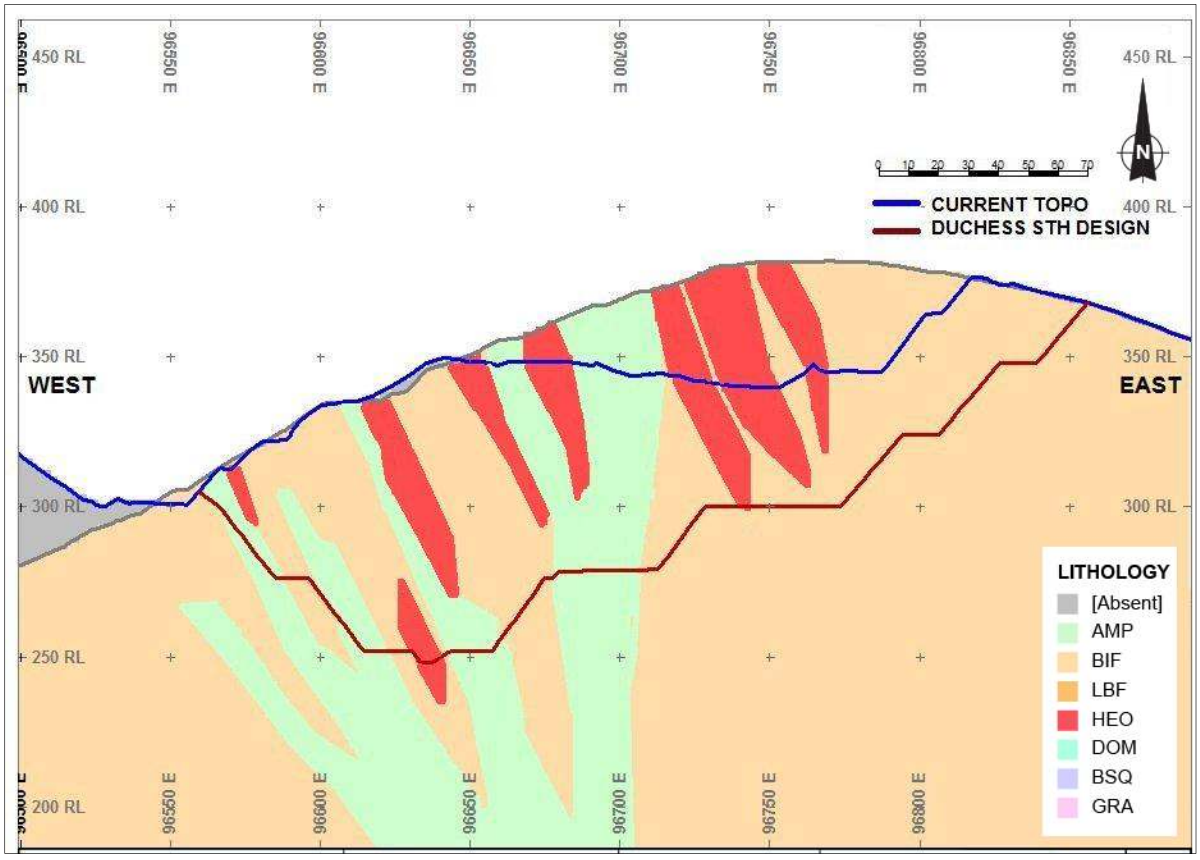


Figure 11 Iron Duchess south – Geological cross-section

Iron Duke/Magnet

The magnetite mineralisation occurs in a mix of relatively thinly-bedded underlying and overlying rock and ore types within the Katunga Dolomite. Magnetite carbonate rock is the most important ore type in the area. The strike length is approximately 2.9 km.

Hematite in the various hematite-bearing rocks is thought to be due primarily to supergene alteration of primary magnetite (although the presence of primary hematite cannot always be discounted). The hematite deposits exist in discontinuous zones along the western side of the orebody, and along faults and fractures, and dyke contacts. The hematite ore varies greatly in dip (from 30° to almost vertical at 90°) and in width (from 5 m to more than 50 m) but generally dips in an easterly direction. This supergene process at depth is especially apparent at the base of the sequence in a strata bound sense, and along both faults and fractures, and dyke contacts in a cross-cutting sense.

The hematite deposits occur up-dip from the carbonate and silica facies BIF. Hematite mineralisation has formed in a discontinuous zone along the western flanks of the ridges, with a variable easterly dip from 30° to almost vertical (90°). Hematite is the dominant ore mineral with significant goethite and minor limonite present. Ore widths are highly variable from greater than 50 m in the central areas to less than 5 m in some of the eastern areas of the Iron Duke.

Figure 12 shows a geological cross-section for Iron Duke/Magnet.

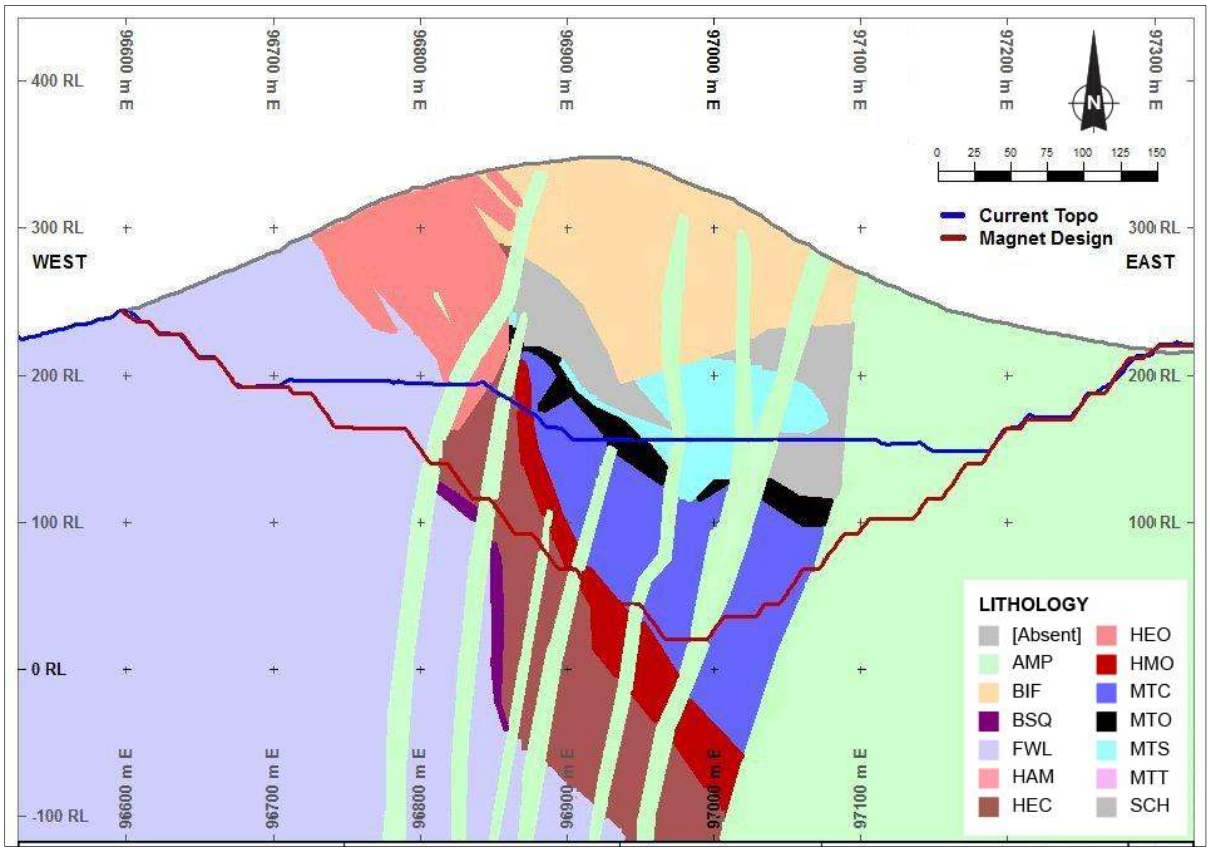


Figure 12 Iron Duke/Magnet – Geological cross-section

3.2.2 Reserves and Resources

Resources

The current known resources for the SMR domains are shown in Table 7. The information is sourced from the JORC reporting process.

Table 7 SMR total resource as at June 2014 (Fe >47%)

Class	Mass (Mt)	Avg Fe(%)
Iron Chieftain		
Measured	–	–
Indicated	23.50	53.8
Inferred	10.86	52.9
Total	34.36	53.5
Iron Knight North		
Measured	4.10	60.3
Indicated	1.65	59.5
Inferred	0.49	58.3
Total	6.24	59.36
Iron Duchess North		
Measured	3.47	59.7
Indicated	17.65	59.2
Inferred	13.82	55.9
Total	34.94	58.26
Iron Duchess South		
Measured	–	–
Indicated	1.94	57.8
Inferred	0.73	55.7
Total	2.67	57.2
Iron Duke		
Measured	–	–
Indicated	–	–
Inferred	–	–
Total	–	–
Iron Magnet (magnetite)		
Measured	44.40	40.0
Indicated	73.26	36.5
Inferred	65.24	29.4
Total	182.9	34.8

Reserves

The current known hematite reserves for the SMR domains are shown in Table 8.

Table 8 SMR total reserves as at June 2014 (Fe >53%)

Class	Mass (Mt)	Avg Fe (%)
Iron Chieftain		
Proved	–	–
Probable	9.47	54.4
Total	9.50	54.4
Iron Knight North		
Proved	1.27	58.7
Probable	0.14	57.9
Total	1.41	58.6
Iron Duchess North		
Proved	–	–
Probable	–	–
Total	–	–
Iron Duchess South		
Proved	–	–
Probable	1.32	58.1
Total	1.30	58.1
Iron Duke		
Proved	–	–
Probable	–	–
Total	–	–

Table 9 shows the currently known magnetite reserve in the Iron Magnet pits.

Table 9 Iron Magnet total reserve (magnetite) as at June 2014 (Mass-rec>20%)

Class	Mass (Mt)	Avg Fe (%)
Proved	40.25	39.2
Probable	22.11	37.2
Total	62.36	38.5

Table 10 shows the current schedule of material movement volumes of waste and ore for each of the active pits.

Table 10 Material volume movements

Pit	Ore KBCM	Waste KBCM
Iron Chieftain	1,230	12,315
Iron Knight	303	764
Iron Duchess South	432	2,976
Iron Magnet – hematite	51	28,492
– magnetite	17,363	
Total	19,379	44,547

3.2.3 Production rate and products

The two primary products are hematite and magnetite.

Hematite ore is produced into lump and fine products. Approximately 500 ktpa of lump product is used directly in the Whyalla blast furnace feedstock. The remainder of the hematite lump and fine products are exported.

Export hematite ore products are produced from direct shipping ore (DSO) and ore beneficiation plant (OBP) products to achieve customer compliant specifications for shipping.

Magnetite ore is concentrated at SMR and then pumped as slurry to Whyalla for conversion into pellets, and used primarily as the main feedstock for the Whyalla blast furnace. Excess pellets are sold into the export market.

Figure 13 shows the Magnetite concentrator feed and production forecast.

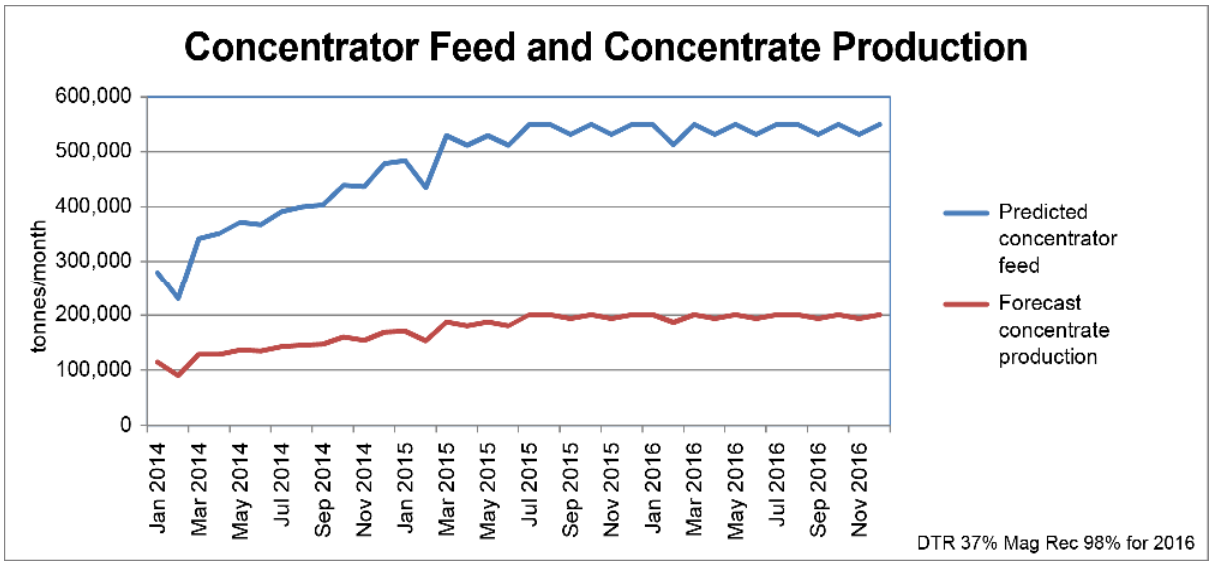


Figure 13 Magnetite concentrator feed and production forecast

Opportunities are being investigated for blending magnetite products with certain export ore blends.

The current SMR mine production rates are as follows:

- Hematite DSO – approximately 2.2 Mtpa
- Hematite OBP product – approximately 1 Mtpa
- Magnetite – approximately 1.8 Mtpa, with expansion plans to go to 2.4 Mtpa.

Figure 14 shows the DSO hematite production rate.

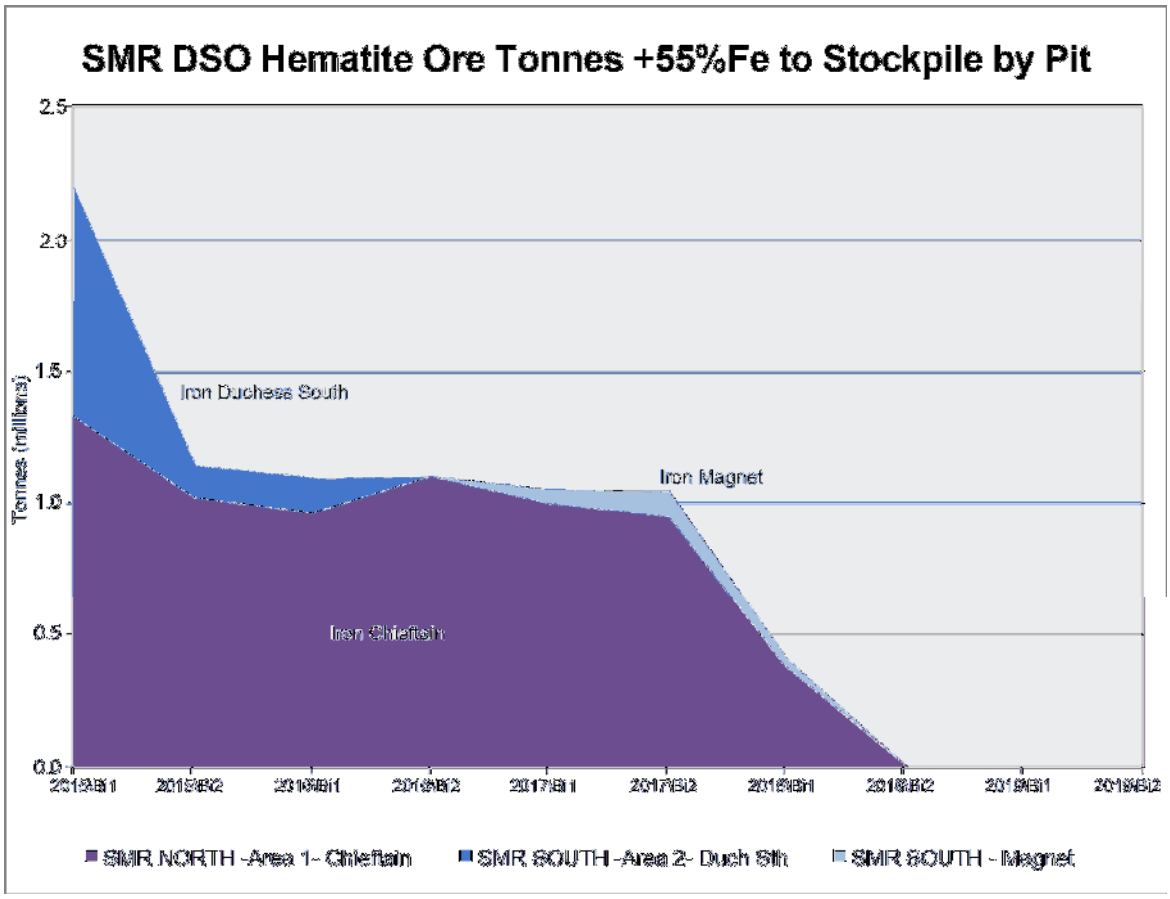


Figure 14 DSO hematite ore production rate

The SMR portions of the overall Middleback Ranges material movements are described in Figure 15.

The LOM plan is regularly updated to reflect depletions and new reserves.

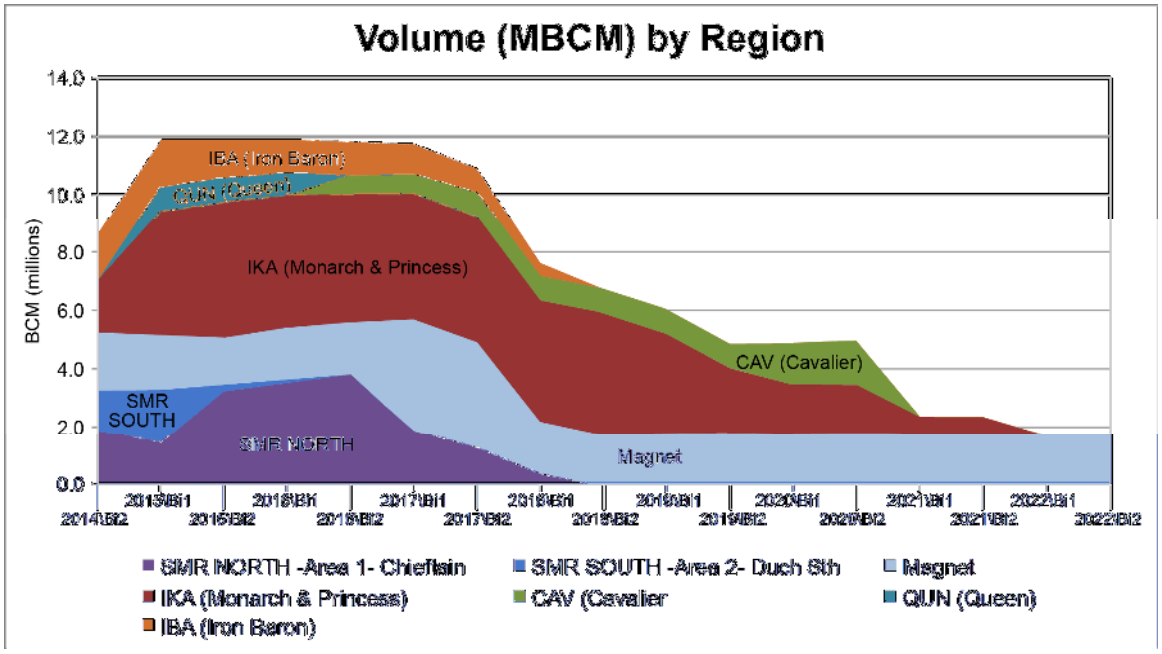


Figure 15 Current MBR LOM material movements by region, incorporating SMR

3.3 General Description and Maps of Operations

3.3.1 Overview of SMR operations

SMR operations are presented in three main operational domains:

- South SMR – incorporating Iron Duchess North and South, Iron Magnet and Iron Duke open-cut mining operations. The site has a network of haul roads and run of mine (ROM) pads, plus crushing and screening, train loading, magnetite concentrator plant, hematite OBP and associated TSF. The main process plant areas form a sub-domain within this domain.
  The S-SMR domain also incorporates heavy equipment workshops and office facilities, and provides the main access way to and from the site from the Lincoln Highway at the southern extent.
- Iron Knight – incorporating Iron Knight North and South open-cut mining operations, interconnecting haul roads, ROM pads, crushing and screening, train loading, basic site amenities and explosive storage facilities
- Iron Chieftain – open-cut mining operations, with interconnecting haul roads, ROM pads, auxiliary crushing and screening, and basic site amenities.

SMR hematite products are transported to the Whyalla port by rail and magnetite product is pumped to Whyalla via an underground pipeline. This pipeline is located within a designated pipeline corridor for both magnetite slurry and return water pipelines. The pipeline corridor traverses both the South SMR and Iron Knight domains.

Figure 16 (and Appendix A-3) shows the SMR domains.

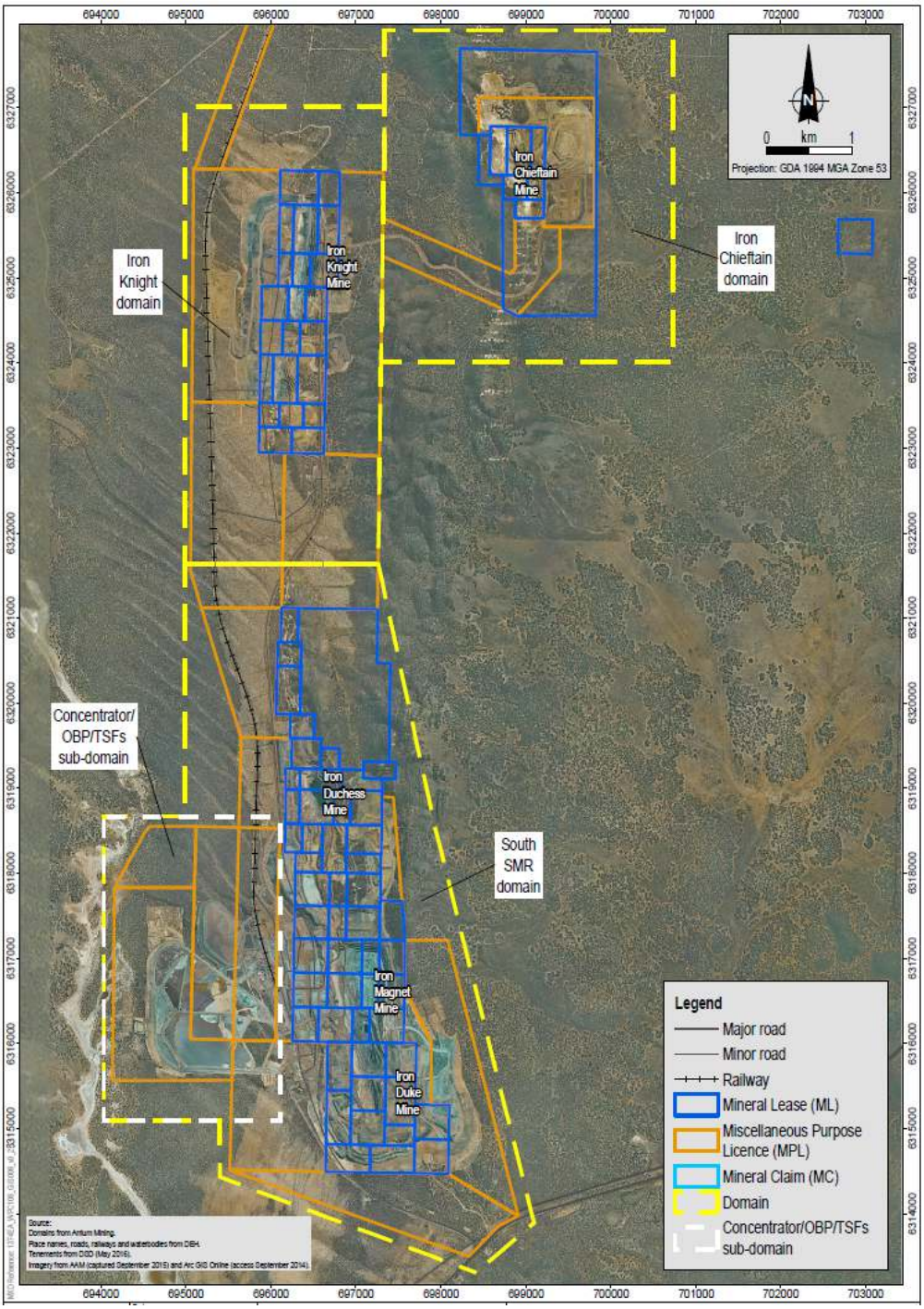


Figure 16 SMR operational domains

Each of the three SMR mining and processing domains feature waste rock dump (WRD) facilities close to the pits, in various stages of construction, and various stages of progressive rehabilitation or closure.

Details of the rehabilitation and closure plans are presented in Section 8 of this PEPR.

Supplementary operations to support mining in the SMR include:

- infill resource drilling
- geotechnical drilling
- hydrogeological investigations and monitoring wells
- exploration (including RC, DD and sonic drilling, ground and aerial geophysical surveys)
- general mining, transportation and stockpiling of waste material
- mine product handling and transportation by loader, truck and rail
- harvesting, stockpiling and reclaiming of topsoil and subsoil
- progressive rehabilitation and closure activities, including decommissioning, demobilisation, landform profiling and revegetation activities.

Ancillary operations include establishing and maintaining the following facilities:

- explosive storage facilities
- water recycling, reticulation and storage facilities
- roads, bunds, service corridors and fencing
- infrastructure, buildings and amenities
- pit dewatering, groundwater monitoring facilities
- stormwater drainage facilities
- environmental monitoring stations
- communications facilities.

Ore processing operations in the SMR include:

- crushing and screening (fixed and auxiliary)
- hematite ore beneficiation and tailings management
- magnetite ore concentration, pumping and tailings management.

3.3.2 Existing surface contours

The mining operations at the SMR have been ongoing for many years and the original topography of the area has been modified. The existing surface contours at the SMR are shown on Figure 17 (and Appendix A-4).

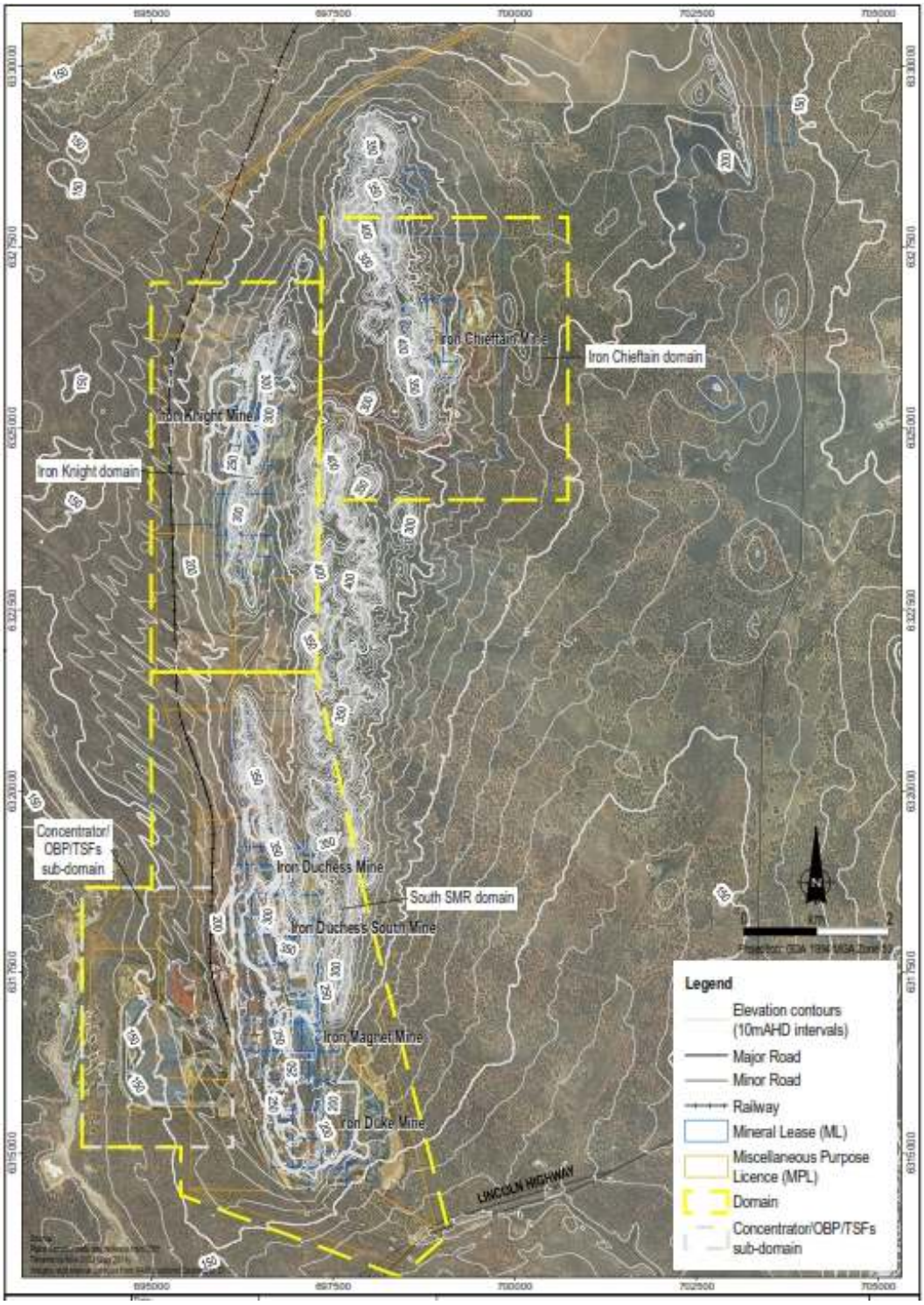


Figure 17 SMR existing surface contours

3.3.3 Mining and infrastructure locations

Figure 18 (and Appendix A-5) identifies the locations of the key mining and infrastructure developments in the SMR, in relation to tenements and recent aerial imagery.

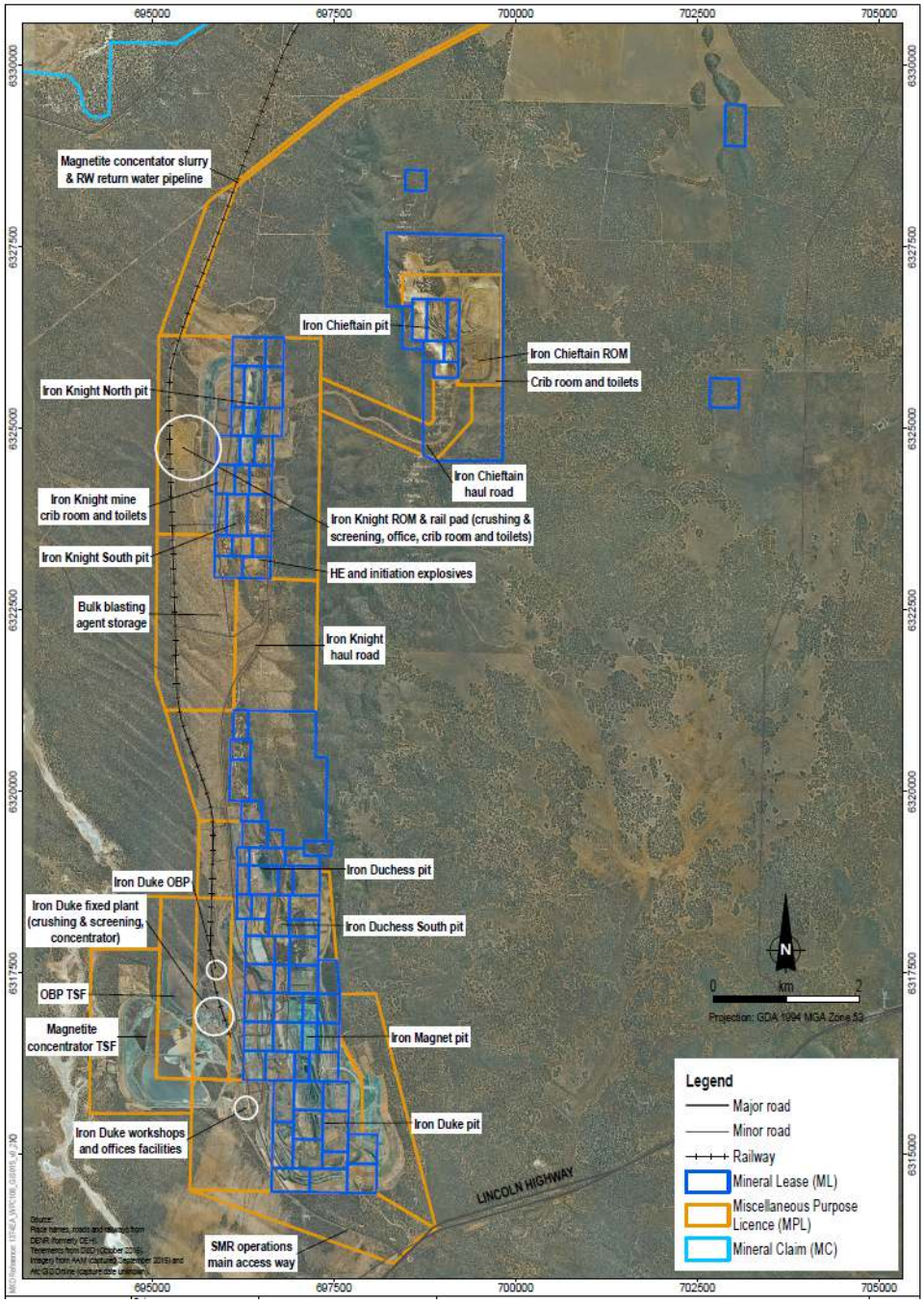


Figure 18 SMR key infrastructure locations

3.3.4 Iron Chieftain mining operations

The Iron Chieftain deposit is mined using a traditional staged open pit drill, blast, load and haul method, with pre-strip overburden activities and pits developed in a sequence that allows for a continuous presentation and delivery of ore as required, minimising waste movements. Ore from Iron Chieftain is crushed and screened using mobile processing plants. A re-optimisation of Iron Chieftain design occurred and was the subject of a Minor Change Notification submitted to DSD in June 2016, and subsequently approved on 29 July 2016. The design changes are described in Section 3.7.4.

Figure 19 shows the site layout of the Iron Chieftain operations as at March 2014.

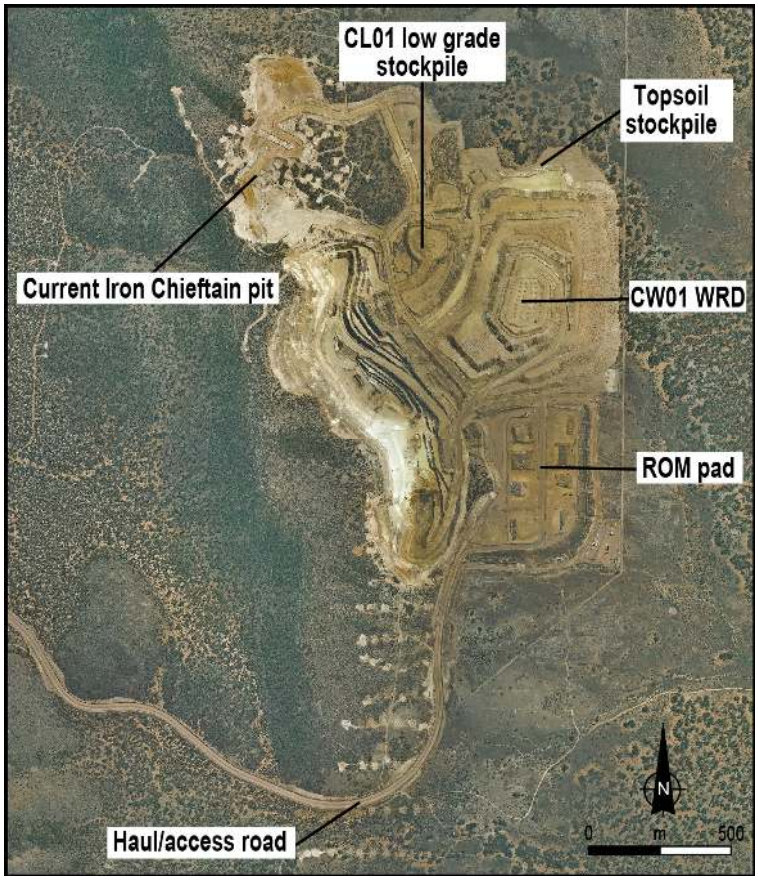


Figure 19 Iron Chieftain – Aerial view of site layout, September 2015

3.3.5 Iron Knight mining operations

Iron Knight consists of the Knight North and Knight South pits. The Knight South pit is no longer mined but has the potential for remaining ore reserves to be accessed if economic conditions support this approach.

The Knight North deposit is mined by an open pit mining method. The cut-back (widening of the open pit) includes drill, blast, load and haul activities to recover ore. Ore is stockpiled and then crushed and screened using mobile processing plants. Low-grade ore and waste materials are stockpiled.

The Knight North pit is nearing completion, with minimal economically viable reserves remaining. The completed WRDs (KSW01 and KW01) are undergoing rehabilitation with further rehabilitation works in the planning phase (see Section 8 for details).

Further mine design and cost optimisations in mid-2016 identified an opportunity to develop a small pit south of the existing Iron Knight South Pit. Mining is scheduled to commence in early January 2017. The pit is comparatively small in nature and will be mined from start to completion in a four month period. Further details are provided in Section 3.7.5.

An aerial view of the site layout is shown in Figure 20.

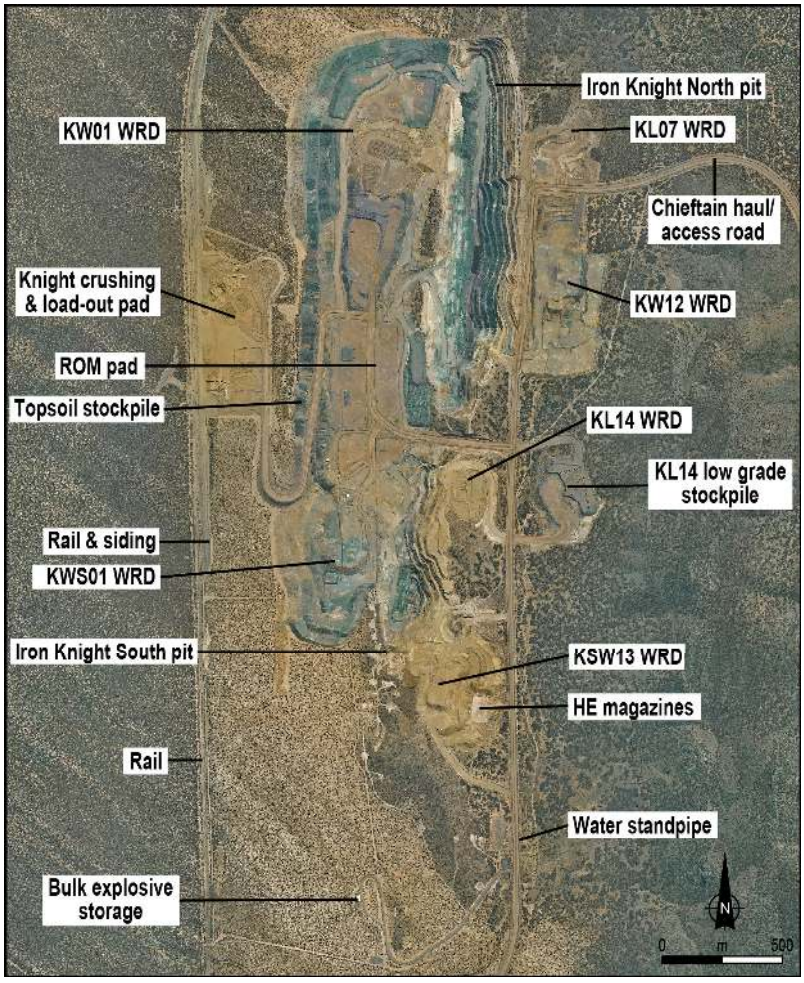


Figure 20 Iron Knight– Aerial view of site layout, September 2015

3.3.6 South SMR mining operations

Iron Duchess region

The Iron Duchess region includes the Duchess North and Duchess South pits.

The Duchess North pit contains a significant resource and mine development is scheduled to commence in July 2018. The main Duchess pit is used to store reclaimed water from the magnetite concentrator and OBP tailings operations. An aerial view of the site layout is shown in Figure 21 below.

The Duchess South pit is mined via an open pit cut-back mining process using the traditional drill, blast, load and haul method. The mine sequencing shows a continuous supply of ore from this pit leading to depletion. Ore is stockpiled and then crushed and screened using mobile processing plants. Low-grade ore and waste materials are stockpiled.

Iron Duke/Magnet

Iron Duke consists of Duke ‘a pit’ and Duke ‘b pit’. The Iron Duke pits are not currently mined due to economic conditions, but the Duke area is active in terms of the connection to the Iron Magnet mining area by pit and by infrastructure (roads, stockpiles and dumps) and are still within the operations area. Ore was last sourced from the Iron Duke pits during December 2013 and January 2014. The pit areas are bunded.

The Iron Magnet deposit is being mined by open pit mining. The ore is recovered by pre-stripping of overburden material, followed by drill, blast, load and haul activities. The sequencing of the material ensures a continuous source of magnetite ore for processing. Low-grade ore and waste materials are stockpiled. An aerial view of the site layout is also shown in Figure 21.

Three stages of the Iron Magnet pit have been designed and scheduled. These stages provide a continual source of magnetite ore to the end of the pit life.

Further topsoil and subsoil reclaiming and stockpiling is planned for the remaining development of DW03. Various sections of this area are developed simultaneously (as required) and will be rehabilitated upon completion.

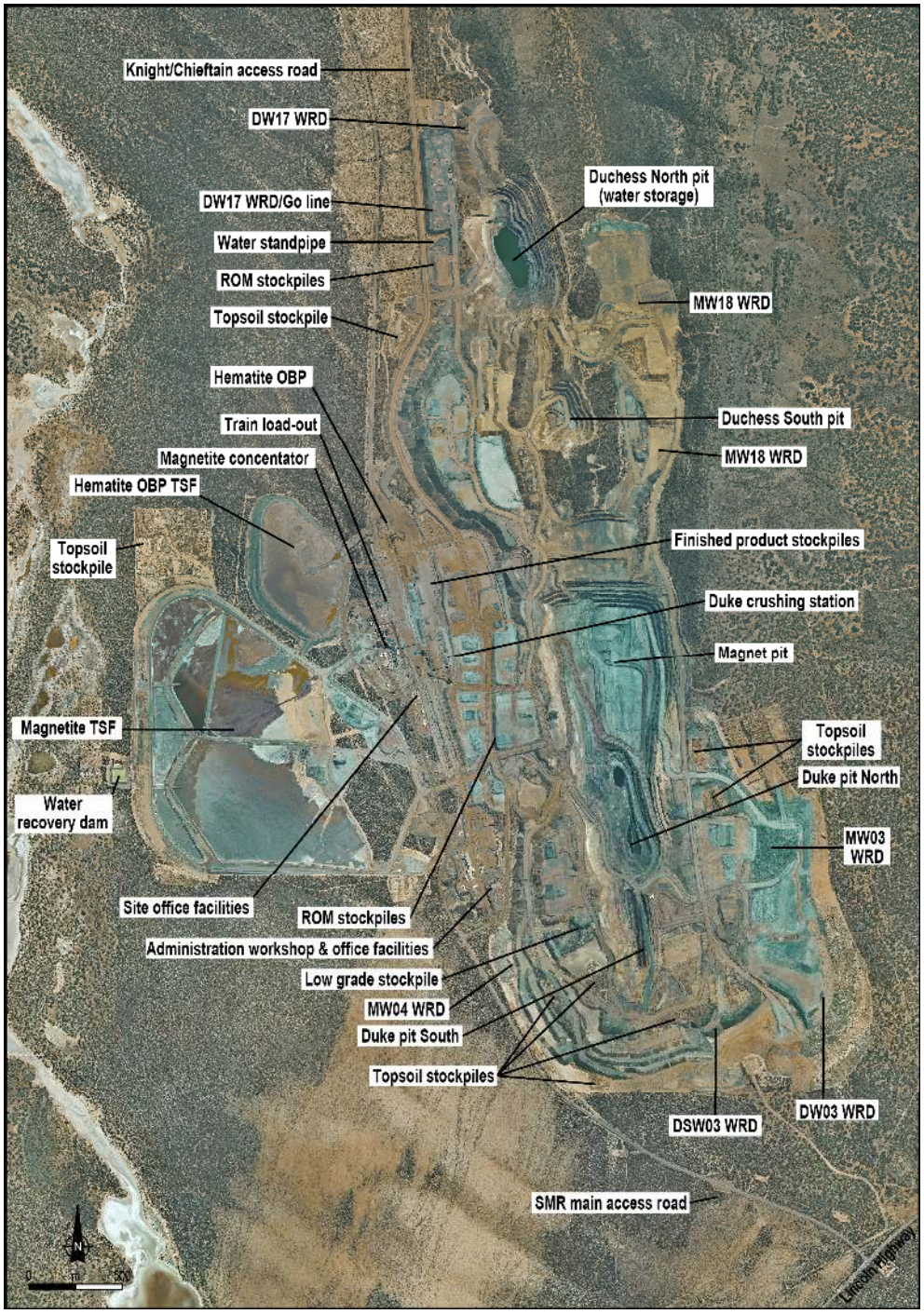


Figure 21 South SMR – Aerial view of site layout, September 2015

3.3.7 SMR processing operations

Descriptions and details of the SMR processing operations are presented in Section 3.9.

3.4 Exploration Activities

The following exploration information is provided in accordance with the SIMEC Mining Exploration Guidelines QP50_58 (Arrium Mining 2012a), which align with the DSD Exploration Guidelines.

3.4.1 Exploration program

The total exploration drilling within the SMR for FY14 was 29,031 m, of which 25,867 m was drilled at Iron Chieftain and 3164 m at Iron Duchess. This provides an indication of the current intensity of the exploration effort in the SMR. No exploration drilling occurred at Iron Knight or Iron Duke/Magnet through FY13.

The exploration program for the SMR region is ongoing with key exploration target areas identified in Figure 22.

Exploration activities include ground and aerial gravity and magnetic surveys, reverse circulation (RC) and diamond drilling (DD) and sonic drilling. Exploration targets are predominantly testing for extensions to current resource models, but also include new development sites. Some exploration tasks are undertaken to further define known resources (in-fill drilling).

The exploration targets are set using the latest geophysical data such as magnetics and gravity to identify the iron rich lithology below the BIF contact. Historical records continue to be re-examined to assist in the identification of targets and to rank exploration targets in terms of priority.

The exploration planned for FY15 includes:

- Chieftain North to Cooks North: approximately 2 km strike length of prospective lithology with numerous hematite outcrops
- Homestead: South of Chieftain, 1.8 km of sub-crop hematite-goethite and historical ore-grade intersections
- Duchess North to Knight: several economic intersections to be tested for resource additions
- Knight to Cooks North-west: re-assessment of historical mapping and drilling.

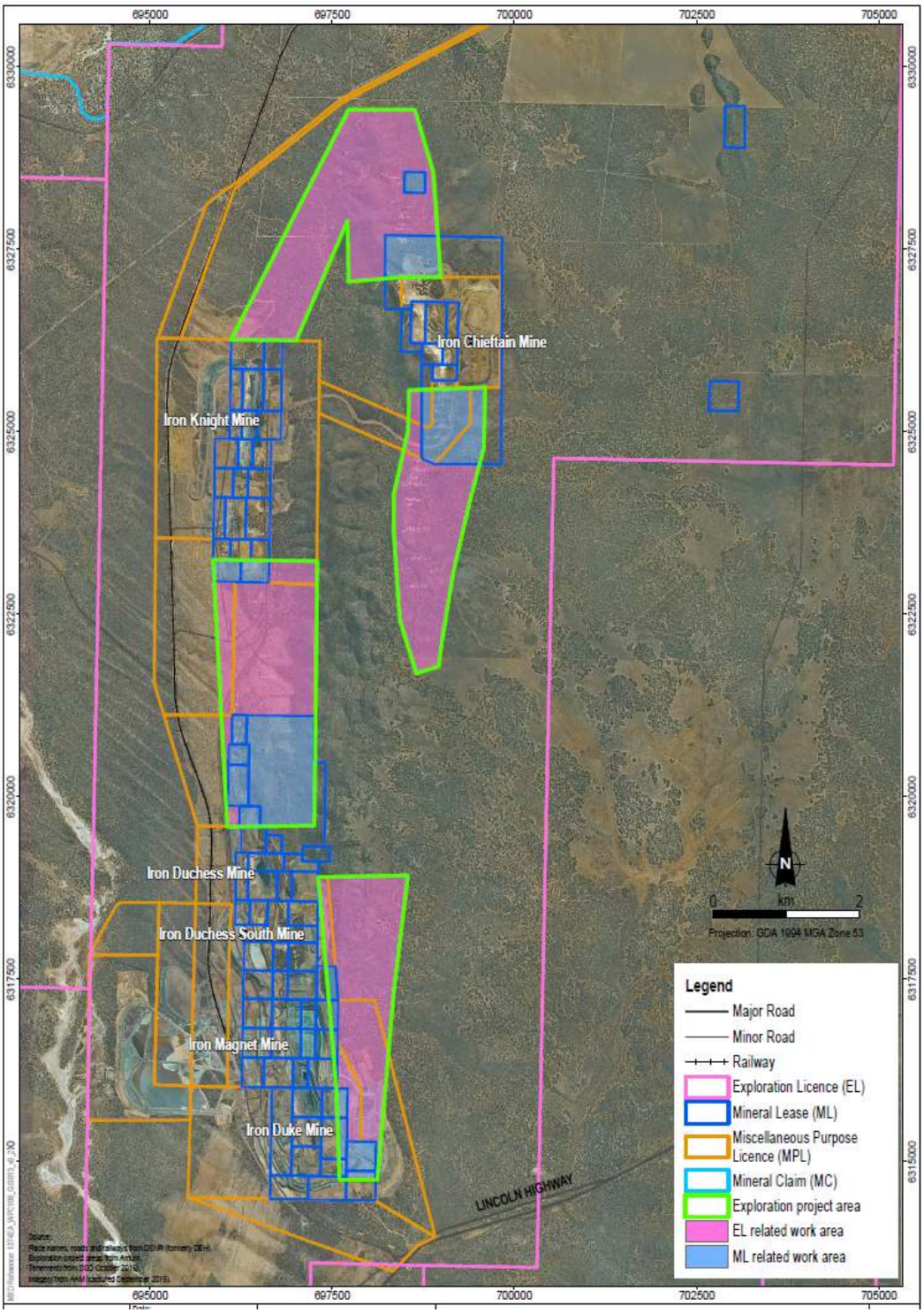


Figure 22 Key SMR exploration work areas

3.4.2 Indicative RC exploration equipment

Boart Longyear Australia Pty Ltd typically supplies the following equipment for exploration drilling programs:

- KWL 700 Track mounted drill rig
- MAN 4x4 8000 L water truck
- Isuzu 4x4 fuel and service truck
- KWL 700 MAN Truck mounted drill rig
- track mounted support vehicle with on-board Sullair compressor
- MAN twin cab 4x4 fuel and service truck
- A fleet of mine light vehicles as required (e.g. Toyota Land Cruiser utilities and troop carriers).

3.4.3 Exploration access

Existing mine access roads and tracks are used where practicable to access the proposed exploration drilling sites.

Landholders are consulted where new access tracks are required, and track options are reviewed with the SIMEC Mining Environmental Assurance Manager to ensure the best environmental outcome.

All temporary tracks are created in a manner so as to minimise impacts and are rehabilitatated as soon as work is complete.

3.4.4 Aboriginal heritage clearances

All exploration sites are subject to aboriginal heritage clearance surveys prior to works commencing. Records of previous clearances are held the in GIS database for reference during target setting phases. New clearance surveys are requested on an as-needs basis, in accordance with the protocol outlined in the Barngarla OneSteel Indigenous Land Use Agreement (ILUA) (NNTT reference SI2-13/002).

3.4.5 Field operations

Minor earthworks are generally required to establish access tracks and drill pads. Tracks, pads and sumps are located and sized to minimise impacts on the environment, and are established through consultation with SIMEC Mining's Environment Assurance Manager and the relevant landholder.

Skilled contractors rehabilitate drill holes, tracks and pads when exploration activities are complete.

Field operations occur on a seven-day week roster, predominantly day-shift for the majority of activities. There is no requirement for a campsite to be established in the SMR region.

3.4.6 Potential impacts of exploration drilling

The potential impacts identified and the associated risk assessment for impact events for exploration activities in the SMR region are discussed in Section 6, including the relevant outcomes and measurement criteria.

SIMEC Mining's exploration procedures require consideration of the existing environment and consultation with the relevant landholder prior to activities taking place. The focus is always to ensure minimal impact on both native vegetation and land owners from drill site development and operations.

3.4.7 Rehabilitation of exploration sites

The rehabilitation of exploration sites will be undertaken where further mine development is unlikely to occur. These sites will be managed as follows:

- non-development sites will be closed in accordance with DSD Information Sheet M21 – General Specifications for the Construction and Abandonment of Mineral Exploration Drill Holes
- drill holes will be capped immediately after completion
- drill hole PVC casing will be removed or cut off below the ground. Should casing need to be left above ground temporarily (e.g. for down-hole survey, monitoring water levels etc.), it will be capped immediately, and rehabilitated when the casing is no longer required
- drill cuttings will be backfilled, buried or removed from the site on completion of the exploration program
- tracks and pads will be rehabilitated by re-spreading stockpiled topsoil to the original contour profile and scarifying to promote regrowth
- the sites will be left in a neat and tidy condition.

Exploration is exempt from Significant Environmental Benefit (SEB) offset requirements for native vegetation clearance (in accordance with Part 2, Section 5 of the Native Vegetation Regulations 2003), and therefore these minor disturbances are not counted in the SEB calculations discussed in Section 4.

3.5 Hydrogeology Investigations

3.5.1 TSF hydrogeological assessment

Golder Associates (Golder) developed a revised hydrogeological seepage model as part of their assessment for the report 'Design Studies to Support a PEPR for Tailings Storage' (Golder 2014a). This seepage model is focussed on the Magnetite TSF as this facility will form the sole tailings storage facility for the combined OBP and Concentrator tailings until end of mine in 2034.

The sub-surface hydrostratigraphic units used in the seepage model are consistent with the model used by Worley Parsons in an earlier groundwater model for the 'TSF Groundwater Modelling Report' (2012). A tailings mass ratio of 3.2:1 magnetite to OBP tailings has been used as a parameter in the model (Golder 2014a).

The calibrated seepage model estimates the development of a phreatic surface downgradient of the Magnetite TSF, which is consistent with observed groundwater levels in monitoring wells MB2 and MB3, located at the toe of the western embankment to the Magnetite TSF. The location of these groundwater monitoring wells is shown in Figure 23.

The results of the modelling indicated that the seepage flux from the Magnetite TSF will decrease to below current levels once the supernatant pond is moved toward the centre of the TSF, away from the perimeter embankment (Golder 2014a). The modelling results also indicated that the existing decant causeway and tower have only a minor influence on seepage flux from the TSF.

The modelling indicates that seepage will continue to emerge downgradient of the Magnetite TSF. This seepage will be controlled by existing engineered structures, including toe drains and groundwater extraction wells; however, additional control measures may be required and will be determined based on monitoring data. Drainage measures may also be required to manage increasing pore pressures close to the embankment. Pore pressures will be monitored at all times during construction.

Given the process water is fresh water and the naturally occurring groundwater is saline, and the tailings solids and liquids are geochemically benign, there is no requirement for contaminant fate and transport modelling to be performed.



Figure 23 Iron Duke groundwater monitoring well locations

3.5.2 Duchess hydrogeological assessment

Background situation

In 2011, following a consultant review completed by Coffey Mining Pty Ltd, SIMEC Mining undertook a self-assessment of the proposed water storage in the disused Iron Duchess pit (in accordance with the "Changes To An Existing Operation" draft procedure issued by DSD and in place at that time). The self-assessment concluded that use of the pit for water storage represented a change of "Level 1 significance". Accordingly, in December 2011 SIMEC Mining submitted its assessment to DSD and implemented water storage in the Iron Duchess pit, initially on a temporary basis.

Investigations

To confirm the longer term sustainability of storing water in the Iron Duchess pit, SIMEC Mining subsequently commissioned additional assessments to ensure a complete understanding of any potential effects of water storage at this location. These additional assessments were undertaken by:

- LBW Environmental Projects, 2014
- RPS, 2015.

The assessments involved:

- investigating pit geology and structure
- investigating groundwater levels and water quality in the pit areas
- identifying aquifer parameters
- identifying potential groundwater discharge areas in the immediate region (e.g. springs, wetlands) that could be affected by potential changes to the groundwater system
- conducting groundwater modelling to assess impacts, such as groundwater mound development and dissipation
- evaluating potential impacts to creeks including runoff, sediment and overall impacts to water quality.

The assessments included development and review of a conceptual hydrogeological model that describes:

- the indicative groundwater flow regime, including likely mechanisms for recharge and discharge
- known and inferred groundwater boundary water quality (based on available information)
- aquifer structure
- potential groundwater level issues
- potential surface water level issues
- the interaction between groundwater and surface water
- estimations of the potential groundwater leakage from the base of the pit.

Conclusions and recommendations

The assessments undertaken indicate the suitability of the Iron Duchess pit for long term water storage up to a level of 200 m RL, providing up to 1445 ML storage capacity, as summarised in Table 10 below.

Table 11 Iron Duchess pit dimensions

Iron Duchess Pit	Dimension
Highest crest level	368 m RL
Lowest crest level	212m RL
Base level	148 m RL
Wall slope angle	48–52°
Proposed maximum fill level	200 m RL
Calculated maximum fill volume	1445 ML

The assessments concluded that using the Iron Duchess pit for water storage will have a limited impact on the stability of the pit.

The fault identified along the western side of the Iron Duchess pit (at around 175 m RL) is not expected to affect the stability of the western wall, given that the fault dips steeply away from the pit base. There may be potential for some water loss to occur in the event that the water level reaches a height where the fault could act as a preferential seepage pathway.

The key findings of the hydrogeological assessment are:

- The site geology comprises a suite of deformed and metamorphosed rocks including schist, banded iron formation, dolomite and quartzite. Recent groundwater investigations indicate that the regional groundwater is saline with a water table level anticipated at approximately 136 m AHD. This is approximately 10 m below the base of the Iron Duchess pit.
- It is expected that seepage of water would occur through the base of the pit through the dolomite, schist and quartzite that underlies the former ore body.
- Lateral seepage is expected to be very slow as granite bedrock outcrops at shallow depth east and west of the range. Characterisation identified that the regional granites exhibit a tight, poorly developed fracture system and that fracture porosity is expected to be low due to sealing of fracturing and faulting by hydrothermal processes due to the age and stability of the Craton.
- No data was available to characterise the site or regional hydraulic properties of the regional aquifer forming material; these can be inferred from the lithology and geological circumstance. Although it is recognised that fracturing can be important in controlling and influencing groundwater movement, there is no information to characterise this feature. Water would be expected to seep through the dolomite, schist and quartzite beneath the former ore body at the base of the Iron Duchess pit. It would be inferred that deeper percolation would occur through the basement rocks, typically comprising granitic or gneissic rock.
- The rate of seepage from the pit is expected to be greatest when the pit is at, near or above the design fill levels.

- The non-sulphide ore deposit geology indicates leaching impacts to the environment will not occur.
- The groundwater is not expected to be adversely affected by any seepage from the pit as a result of storing process water, as the groundwater is saline (SMR groundwater monitoring records indicate levels as high as 56,000 µS/cm) and the process water to be stored is fresh water.
- Groundwater modelling was used to assess the potential hydraulic impacts on the regional groundwater levels. Pit based seepage was estimated analytically and applied to the modelled pit area as “recharge”. This modelling indicated the potential for mounding to develop beneath the pit while water is being stored in the pit, and predicted rapid dissipation of groundwater head thereafter.
- Modelling identified that the area of influence of the groundwater mound beneath the pit could extend up to 550 m from the centre of the pit, at which distance groundwater levels would return to equilibrium at approximately 3.6 m higher than current background levels. Given the pit dimensions, this equates to a distance of approximately 300 m from the pit wall, still within the flanks of the range and coinciding with the edge of the vegetated zone on the western side and the location of monitoring well DMW3, some 250 m from the edge of the pit.
- Groundwater mounding is expected to dissipate considerably within two to five years of cessation of storage and will have substantially dissipated within 30 years following cessation of storage.
- It is considered unlikely that the groundwater mounding would significantly change groundwater flow and discharge in the area of the pits.
- It is considered unlikely that the storage of water within the pit will have any impact on the existing surface runoff and associated sedimentation around and downstream of the site given the proposed storage levels will retain significant freeboard within the pit, and the considerable distance to the nearest surface water system (i.e. approximately 2 km).
- The hydrogeological assessment shows storing of water in the Iron Duchess pit over the next ten years is feasible.

Vegetation

The nearest vegetation receptors to the Iron Duchess pit are nominally 250m west and 250m east of the pit.

The background groundwater levels in the areas where vegetation receptors exist are approximately 50 m below ground level to the west and greater than 50 m below ground level to the east, therefore the vegetation to the west is considered the receptor at greater risk.

Modelling of various potential scenarios suggests that groundwater mounding will extend to a distance of 300 m from the pit wall hence some mounding will extend beneath the vegetation areas, as the nearest vegetation receptors are located approximately 250 m from the pit. At this distance, groundwater elevations are predicted to rise to a maximum of 145 m AHD, which is approximately 45 m below the ground surface and 43 m below any root system that trees in the area may extend to.

Monitoring

Pit water level has been held below 180 m RL levels since March 2014.

Three monitoring bores (DMW01, DMW02 and DMW03) were installed in February / March 2015 at the locations shown in Figure 24 to allow monitoring of potential groundwater mounding, and determine if seepage is occurring.

Groundwater elevation data from these new monitoring bores indicates that there has been some increase in groundwater levels to the west of the Iron Duchess pit. The water levels at DMW02 (approximately 150 metres from the pit wall) exhibit an increase of approximately 12m to 173m AHD in the period through to June 2016.

The modelling predicted an increase in water level of up to 30 m and that average depth to groundwater (in the DMW03 region) is greater than 40 m below ground surface at this location.

Groundwater elevation monitoring at DMW03 shows the level has remained steady at around 140m AHD in the period from April 2015 through to October 2016 and there has been no response to changes in pit water levels which in turn indicates that storage of water in the Duchess pit has no influence on groundwater level at this extent from the pit. 140m AHD is below the model prediction of a maximum of 145 m AHD and some 20 m below the limit proposed in this PEPR.

Regular, monthly monitoring of installed bores DMW01-DMW03 is ongoing to continually monitor groundwater elevations and determine the possible additional influence of precipitation on groundwater levels and mounding (though it is considered unlikely that climate will be a larger influence than the water storage in the Iron Duchess Pit).

Ongoing measurement will provide data to interpret how groundwater levels fluctuate on a seasonal basis throughout the year, reflecting rainfall events and changes to water storage levels in the pit.

The Iron Duchess pit sits on the eastern edge of a large mass of low permeability granitoid basement rock (see Figure 25). The use of ‘falling head tests’ during the construction of groundwater monitoring wells will add understanding of the permeability of this rock.

Outcomes and measurement criteria

On the basis of the investigations and modelling undertaken, the following outcome statement and measurement criteria have been incorporated into Table 89 in Section 6.16 - Outcomes, Measurement Criteria and Monitoring :-

> **Outcome** – “No changes to groundwater levels that adversely impact vegetation due to Iron Duchess water storage operations”
>
> **Measurement criteria** – “Monthly groundwater monitoring records demonstrate that the groundwater level does not exceed 160 m AHD at DMW03”.

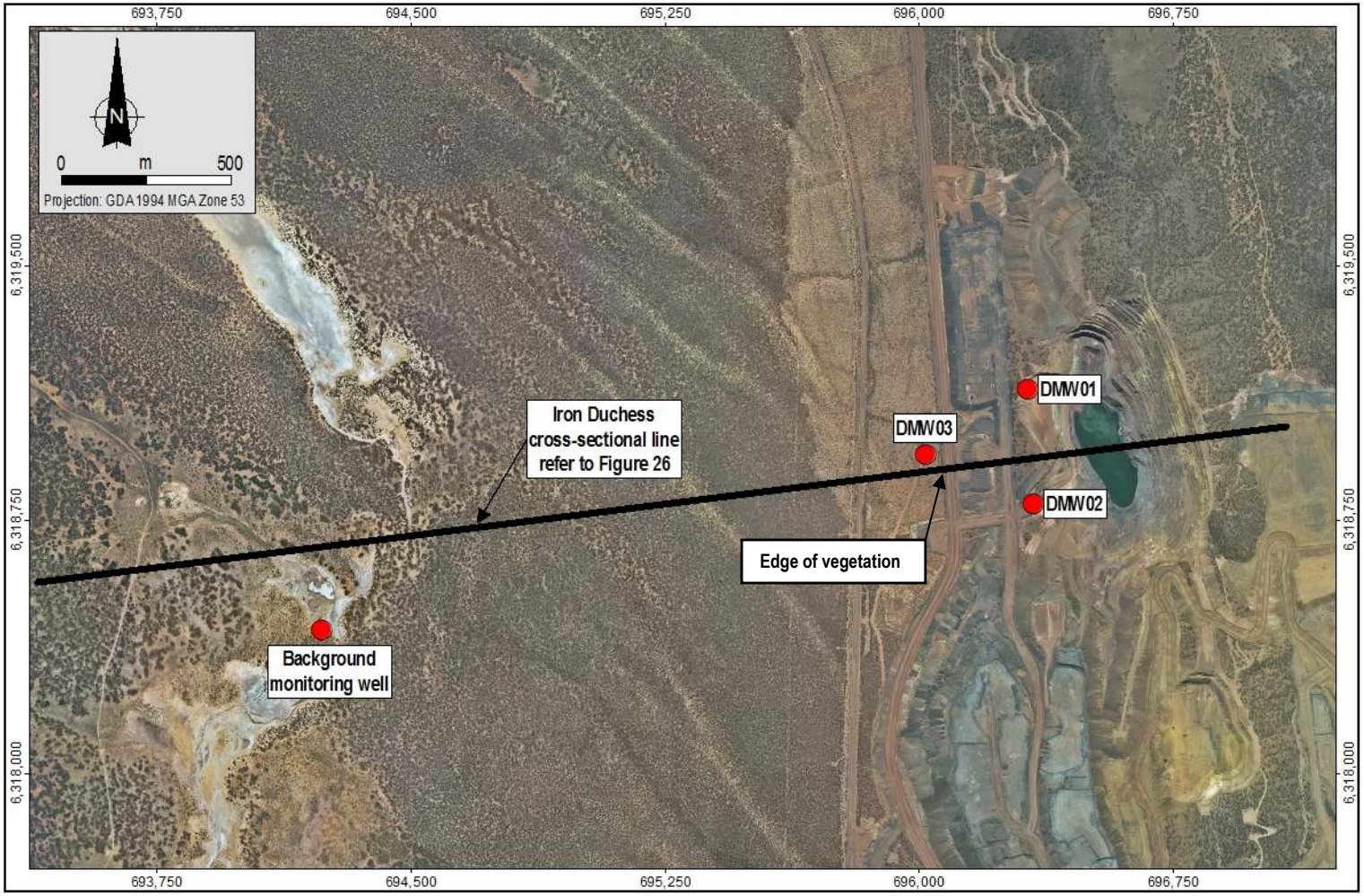


Figure 24 Iron Duchess water storage facility monitoring wells

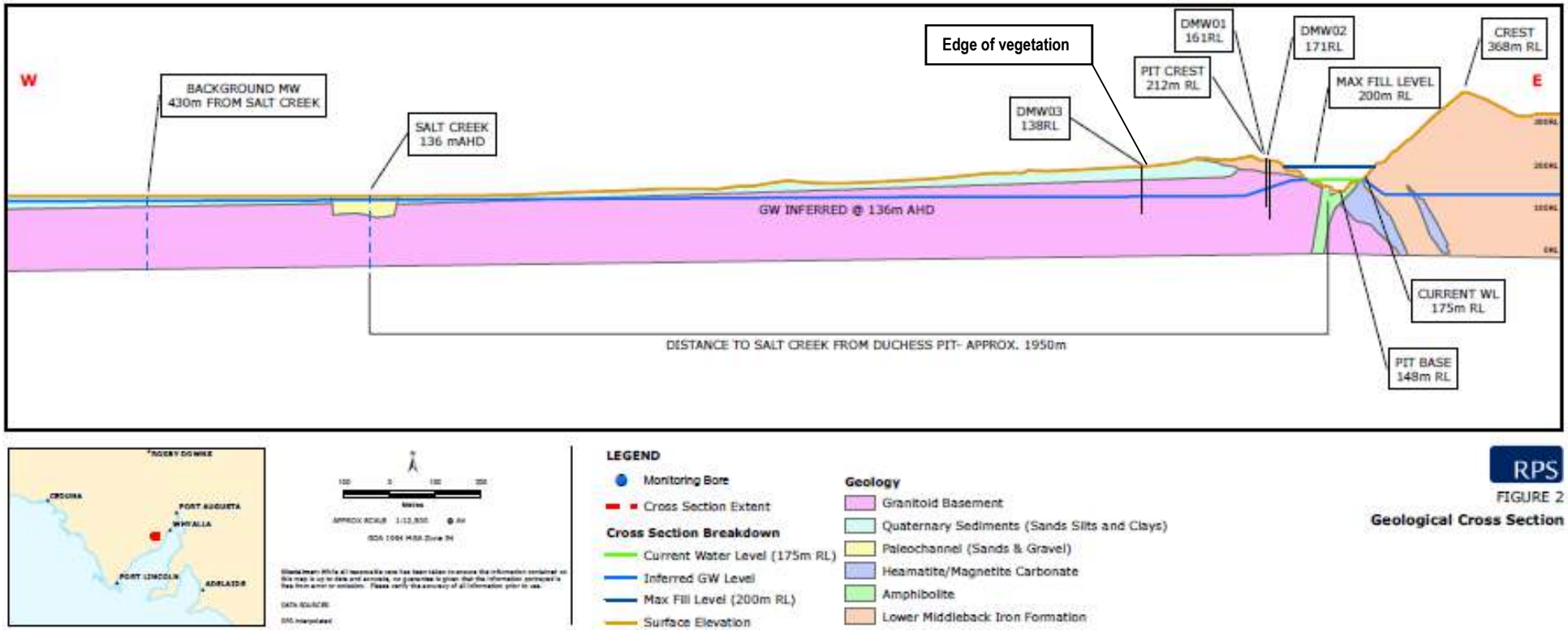


Figure 25 Iron Duchess hydrogeological and lithology cross-section

3.5.3 Groundwater and potential aquifers

Groundwater occurs within the Proterozoic sequence that forms the MBR and in the Tertiary sequence beneath the surrounding plains. Generally, the water table can be expected to broadly mimic the topography. Thus the water table beneath the central ridge of the MBR will tend to be higher than the water table beneath the surrounding plains.

Natural recharge to the groundwater system occurs via direct infiltration through the surface soils and through coarse bed load sediments in the ephemeral drainage lines. There may be some small areas of enhanced recharge at the foot of the MBR where the drainage lines spill onto the plain and the coarse bed load is deposited as alluvial fans, however these do not appear to be prominent features on aerial photographs. Greater rates of recharge would occur over the sand dunes.

A large proportion of the infiltration into the soil profile would be used to sustain the natural vegetation, and only a small amount of the infiltration would move beneath the root zone to become groundwater recharge.

Groundwater salinities >10,000 mg/L occur within the MBR. This suggests that the average natural groundwater recharge rates in the area are <0.1% of rainfall.

Experience with most existing open pits indicates that groundwater inflows, when encountered, are generally small. This suggests that the bulk hydraulic conductivity (permeability) of the rock mass is small, and that ‘aquifers’ (in the sense generally used in hydrogeology to indicate formations that yield significant amounts of groundwater to bores or seeps) are not present. From the initial appraisal of the hydrogeological setting, the more permeable parts of the sequence are expected to be associated with large-scale structures. Some jointed brittle rocks (e.g. chert or BIF) may seep some groundwater when exposed in the pit walls or in blast holes, but yields will tend to be small.

The other setting where groundwater may occur in the Proterozoic sequence is towards the base of the weathered zone.

Groundwater levels beneath the pit and the adjacent plain is inferred by known groundwater levels at the background monitoring well adjacent to salt creek and at a monitoring well along the strike at the mine workshops. It is expected that mounding has occurred beneath the Iron Duchess pit as water is being stored in this pit. The current inferred mounding remains deep (see Figure 25). The installation of monitoring wells will verify the local groundwater level and potential mounding if groundwater is intersected.

Groundwater naturally surfaces in Salt Creek due to regional hydrogeological influences associated with migrating groundwater and the Middleback Range impeding flow.

3.6 Geotechnical Investigations

3.6.1 Wall stability conditions

Wall stability at SIMEC Mining's SMR operations is governed predominantly by geological structure. The potential for instability depends on the orientation and shear strength of structures exposed in or located close behind faces and slopes.

The wall design parameters (e.g. batter heights, face angles and berm widths) at SIMEC Mining's pits are derived using the findings of geotechnical investigations and analysis. Once designs are implemented, actual stability performance is monitored closely and local adjustments are applied where necessary.

3.6.2 Wall design

Wall designs are derived from interpreted geological and geotechnical conditions, and must particularly identify possible failure mechanisms and aim to preclude or reduce the potential for such outcomes.

The design parameters are based on the assessed capacity of the rock mass in terms of overall slope performance to provide an inter-ramp angle (or angles where conditions vary with depth), and at local scale to define appropriate wall configurations (e.g. batter heights, face angles and berm widths), which comply with the required inter-ramp angle.

While an infinite number of batter-berm combinations could be used for any target inter-ramp angle, the required minimum berm widths will limit the number of practicable combinations. Berm width is a highly important consideration as berms must be capable of providing reliable protection against possible rock falls. The berms must be sufficiently wide to reliably arrest falls from the overlying batter(s).

Given there is an inherent tendency for crest loss; wider berms are more likely to maintain adequate catching capacity after possible losses. Higher batters enable wider berms to be developed for a given inter-ramp angle (when compared to shorter batters for the same inter-ramp angle).

An added benefit of fewer berms is the number and extent of common sources of rock fall is reduced.

3.6.3 Current practice

The wall designs for the SMR pits are based on 24 m high batters, typically 55° batters, and 8–12 m wide berms to give an inter-ramp angle of — 44° to — 40° for western walls which are mined within or are in close proximity to a regional shear zone. Other walls are developed with steeper batter faces (up to 70°) where the ground and structural geological conditions are interpreted to be suitable.

Where geotechnical variances in the host rock are identified, external consultants develop specific geotechnical parameters, which are applied to ensure stability of the walls. Examples of these area specific geotechnical zones include:

- at the Iron Chieftain, where layers of leached BIF have appeared in the western wall, that have required a flattening of the batter due to rilling and increase of the berm width to provide extra catch capacity
- the western and eastern walls of the Iron Knight North pit also require special consideration in terms of geotechnical factors, with wall angles, berm widths and haul road designs altered due to less stable wall mass and the introduction of pins to hold potential loose slabs in place
- the Iron Duchess, Iron Duke and Iron Magnet pits are also closely monitored and inspected regularly by external consultants to ensure the batter berm configuration applied is stable.

Aside from these specific areas of focus, precedence indicates that batters of 24 m height can be mined and managed safely at SMR and continued development is endorsed provided geotechnical assessment and monitoring practices are maintained.

3.6.4 Operational procedures

Batters are developed in 3 x 8 m high flitches. Thorough scaling is performed on all batters, on a flitch-by-flitch basis. While there is a need to work at the base of 24 m high batters, the unscaled height is a maximum of 8 m.

Only essential near-wall work is permitted and personnel engaged in such activity are trained in ground and slope awareness, and must operate within strict guidelines. Near-wall operations include drilling, sampling, charging, excavation and scaling, wall mapping and geotechnical inspection.

Access to near-wall positions by general operational personnel is restricted, and a minimum standoff distance of 10 m is applied. Work within 10 m of the walls can only be conducted once a job hazard assessment has been performed with the assistance of a geotechnical delegate, and any required controls have been put in place.

A Ground Control Management Plan (ARI reference GCMP76.02) is utilised in the management and monitoring of geotechnical stability of mining areas and has been developed utilising information obtained from various external studies carried out on the operations over time.

3.7 Mine Plan

3.7.1 Mining method

The mining method used at SMR operations is open pit mining as further described in Section 3.3 for each of the mining domains.

3.7.2 Production quantities

Ore is produced at various grades throughout the SIMEC mining regions, from which final ore blends are made to suit customer requirements.

The SMR mining area is one of four regions contributing to the LOM plan, the other regions being IBMA, IKMA and Peculiar Knob Mining Area. The LOM plan is regularly re-scheduled in accordance with the latest optimised pit designs.

The current LOM production plans for hematite and magnetite ore from the SMR areas are described in Table 12 and Table 13, and shown on Figure 26, Figure 27 and Figure 28.

Low-grade material and mineralised waste are also segregated and stockpiled for possible future blending and/or beneficiation needs.

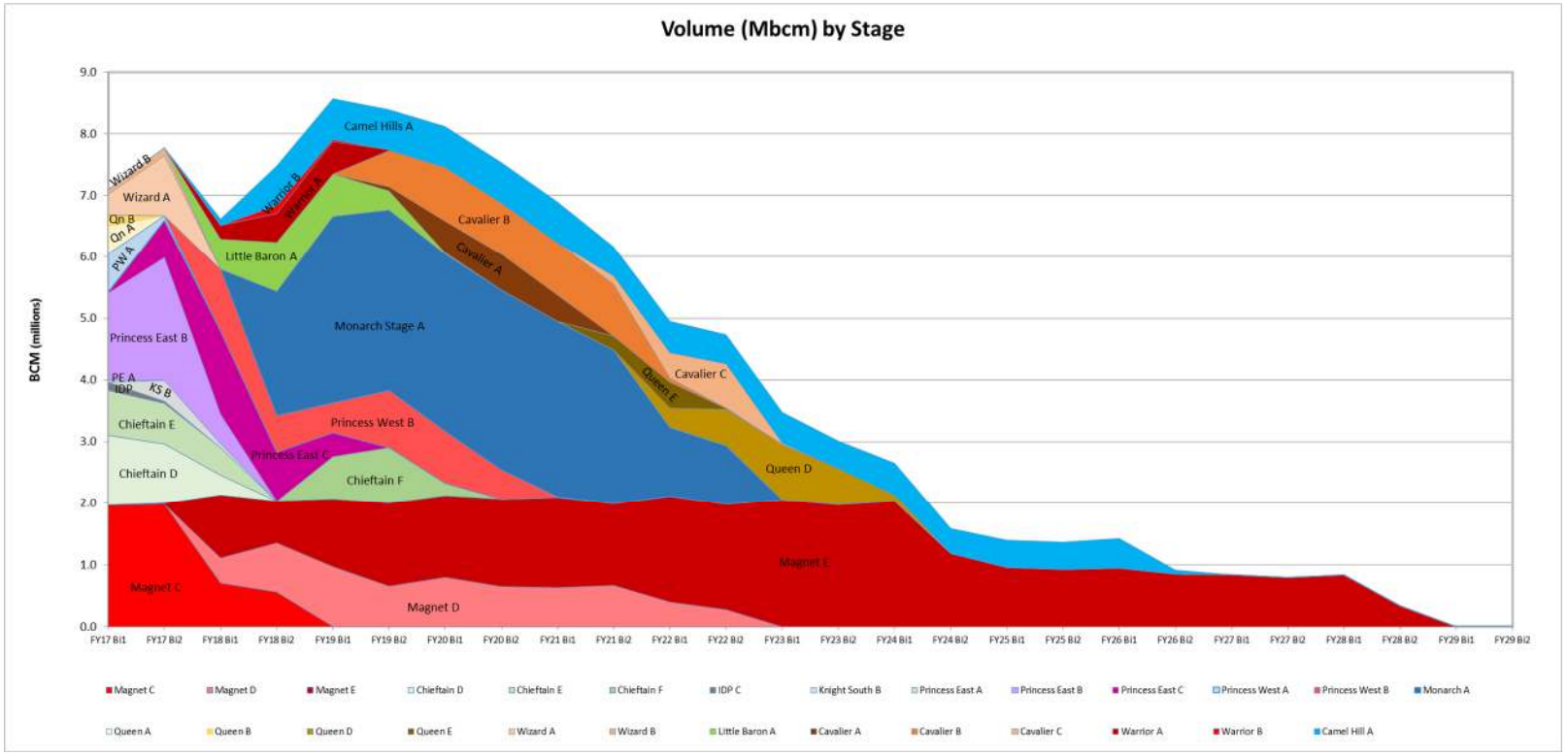


Figure 26 LOM total SMR, IBMA and IKMA production by pit and stage

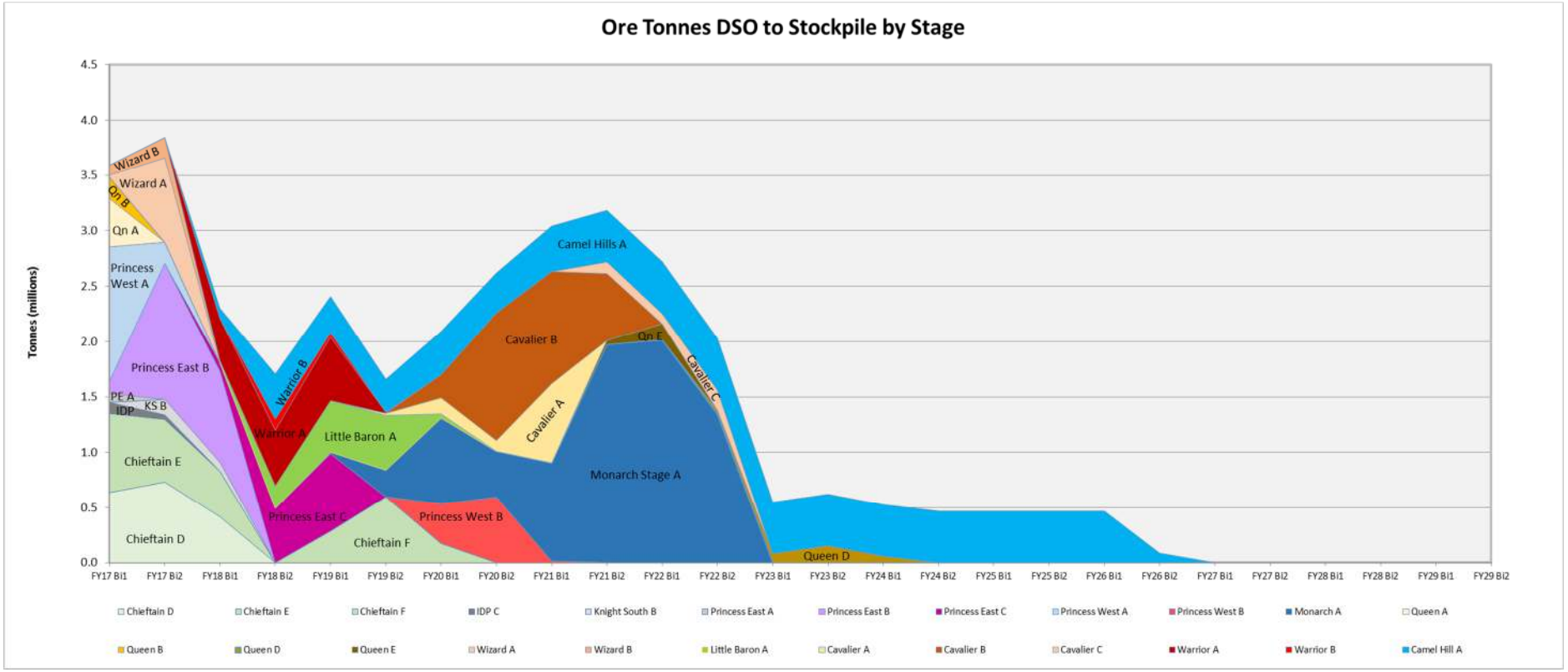


Figure 27 LOM total SMR, IBMA and IKMA hematite ore movement

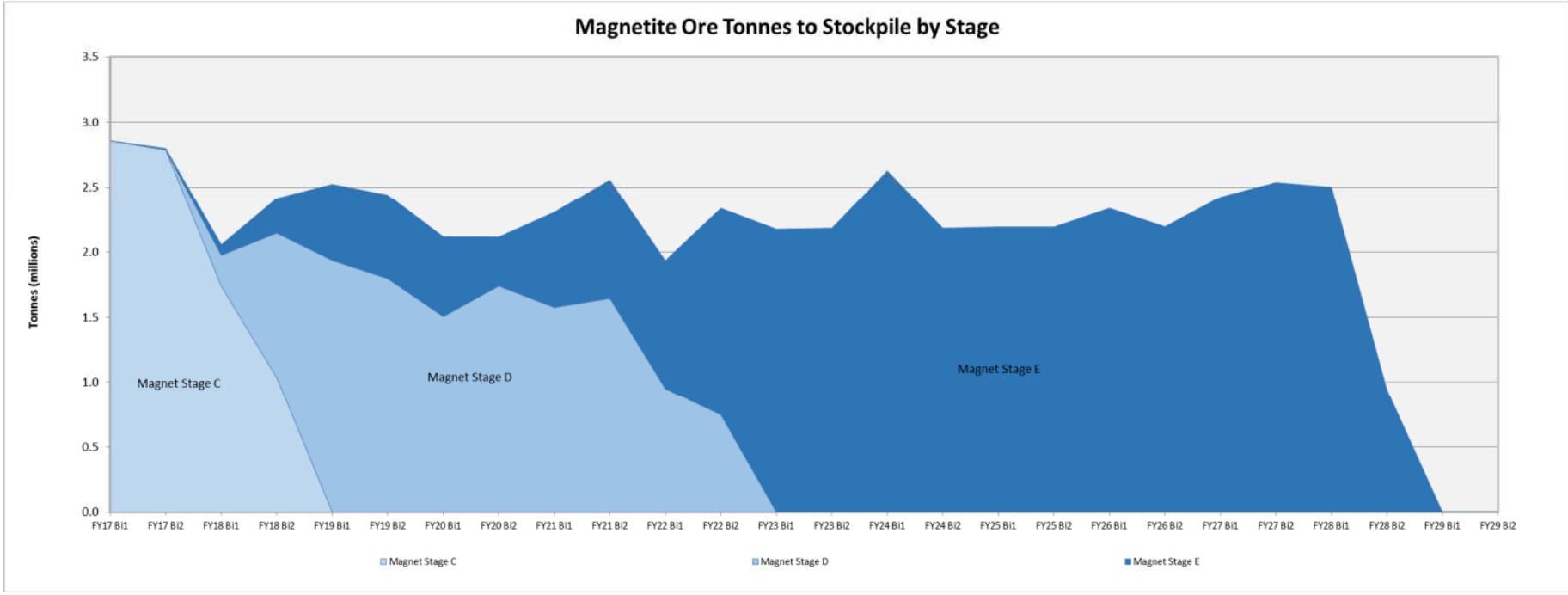


Figure 28 LOM total magnetite ore movement

Table 12 Production from LOM – Bi-yearly for SMR – Hematite ore

Total ore (+55% Fe) tonnes from stages	July–Dec 2016	Jan–Jun 2017	Jul–Dec 2017	Jan–Jun 2018	Jul–Dec 2018	Jan–Jun 2019	Jul–Dec 2019	Jan–Jun 2020	Jul–Dec 2020	Jan–Jun 2021	Jul–Dec 2021	Jan–Jun 2022	Total
Hematite	**FY17\Bi1**	**FY17\Bi2**	**FY18\Bi1**	**FY18\Bi2**	**FY19\Bi1**	**FY19\Bi2**	**FY20\Bi1**	**FY20\Bi2**	**FY21\Bi1**	**FY21\Bi1**	**FY22/Bi1**	**FY22/Bi2**	**2017–2022**
Chieftain Stage D	637,605	732,066	416,485										**1,786,156**
Chieftain Stage E	714,155	566,406	412,878										**1,693,439**
Chieftain Stage F					286,680	597,320	174,189						**1,058,189**
Duchess C	97,681	39,702											**137,383**
Knight South B		138,791	81,824										**220,615**
Total ore	**1,449,441**	**1,476,965**	**911,187**		**286,680**	**597,320**	**174,189**						**4,895,782**

Table 13 Production from LOM – Bi-yearly for SMR – Magnetite ore

Total Ore tonnes from stages	July–Dec 2016	Jan–Jun 2017	Jul–Dec 2017	Jan–Jun 2018	Jul–Dec 2018	Jan–Jun 2019	Jul–Dec 2019	Jan–Jun 2020	Jul–Dec 2020	Jan–Jun 2021	Jul–Dec 2021	Jan–Jun 2022	Total
Magnetite	**FY17\Bi1**	**FY17\Bi2**	**FY18\Bi1**	**FY18\Bi2**	**FY19\Bi1**	**FY19\Bi2**	**FY20\Bi1**	**FY20\Bi2**	**FY21\Bi1**	**FY21\Bi1**	**FY22/Bi1**	**FY22/Bi2**	**2017–2022**
Magnet Stage C	2,857,618	2,788,876	1,739,811	1,035,386									8,421,691
Magnet Stage D	1,187		235,662	1,110,924	1,936,335	1,796,068	1,505,000	1,740,000	1,575,000	1,645,000	950,000	747,025	13,242,201
Magnet Stage E		11,339	82,346	269,129	588,463	644,979	613,731	376,900	732,980	912,903	985,511		5,218,281
Total ore	**2,858,805**	**2,800,215**	**2,057,819**	**2,415,439**	**2,524,798**	**2,441,047**	**2,118,731**	**2,116,900**	**2,307,980**	**2,557,903**	**1,935,511**	**747,025**	**26,882,173**

Updated SMR mine plan

The mine plan for the next five years has been updated with proposed mine production shown in Table 14 and Figure 29 and Figure 30.

An update of the LOM plan for the SMR will be provided in the full PEPR update to be completed by 2020.

Table 14 Production from SMR – Financial year – Hematite ore

Total ore DSO + LGO (dmt)	FY18	FY19	FY20	FY21	FY22	Total
Chieftain	272,498	654,908	544,443	707,478	460,801	**2,640,128**
Duchess B	104,260	311,244	1,267,243	4,637,031	962,774	**7,282,552**
Total ore	**376,758**	**966,152**	**1,811,686**	**5,344,509**	**1,423,575**	**9,922,680**

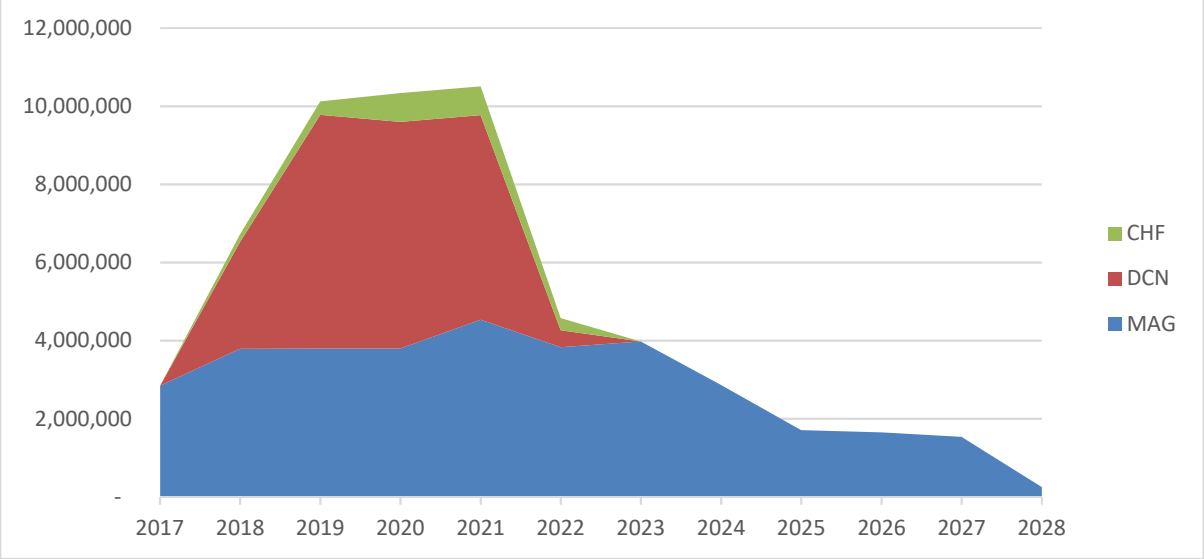


Figure 29 LOM total SMR production by pit (excluding LG dumps)

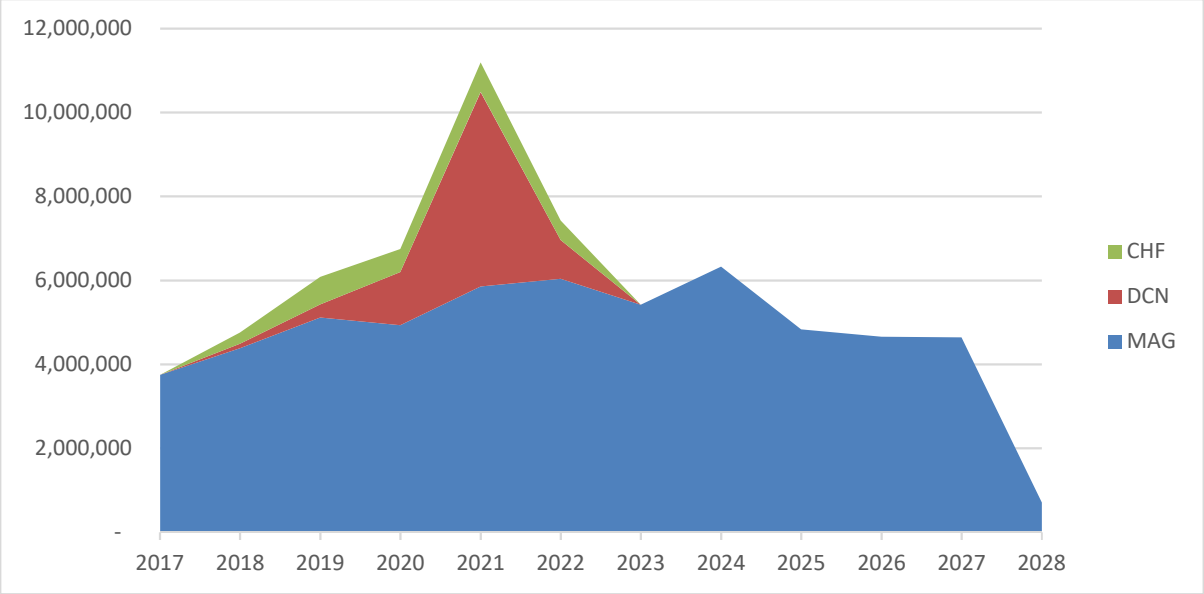


Figure 30 SMR total ore mined (dmt) by pit

3.7.3 SMR mine plan – Overview

SIMEC Mining operates under an 18-month mine plan which is updated quarterly and schedules recovery of ore from the various pits and stockpiles to achieve the overall production targets in terms of volumes and grade quality.

The mine plan details all mining activities including geology, mining, material movements and grades, dewatering, geotechnical aspects, projects and rehabilitation. It documents the movement of ore from the pit, with rehandling, blending strategies, crushing, railing and shipping to the market. The 18-month mine plan is revisited several times throughout the year and is used for the short-term planning of site operations.

Figure 31 illustrates the proximity of pits, crushing facilities and ROM pads in the SMR.

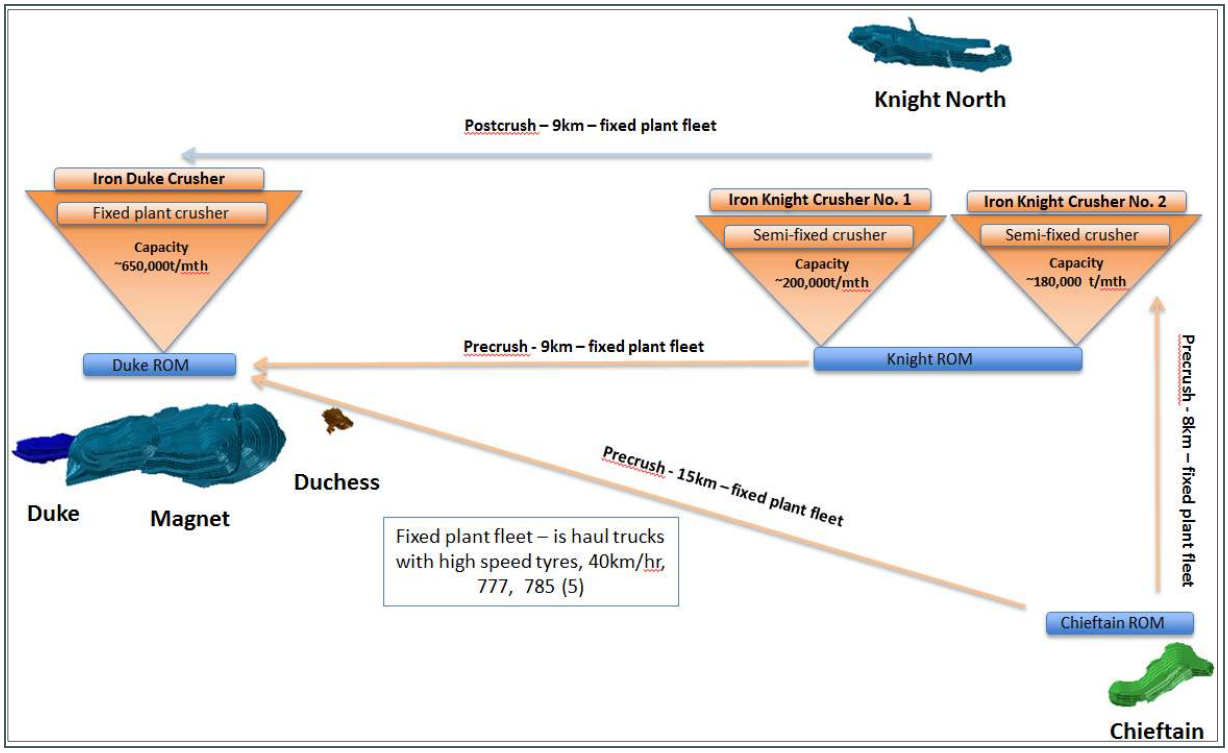


Figure 31 Proximity of pits, crushing facilities and ROM pads in the SMR

WRD general build methodology

The following steps outline the general build methodology for WRDs, and the strategies for progressively achieving final landform outcomes:

- Topsoil and subsoil is harvested and stockpiled before the WRD is built, enabling the material to be spread over the WRD during rehabilitation. The topsoil and subsoil is stored in windrows at the WRD toe for use in rehabilitating the lower WRD final slopes. Further material may be stored at high elevations during the WRD build for revegetating the higher profiles and to create the final rehabilitated profile.
- Waste material dumping begins with the first lift of the WRD. Where practicable, the outside face of each lift will be dumped first so that the rehabilitation of the WRD faces can begin at the earliest possible time.
- Once the outside face (or an entire lift) has been completed, the topsoil and subsoil will be hauled to the newly established crest.
- The face of the first lift is rehabilitated while dumping continues in the remainder of the first lift (or the beginning of the second lift). This process includes bulldozing the face to achieve the final rehabilitated angle, spreading topsoil and subsoil over the face, and contour ripping or seed boxing the face to mix soil with rock, and minimise erosion. At this point the drain will be established at the toe of the WRD.

- The process will be repeated once dumping on the outside face (or all) subsequent lifts are completed. It may not be practicable or harmonious with natural slopes to sheet upper lifts with soil.
- The process will continue until the WRD is completed and all dumped faces have been rehabilitated. This form of continuous rehabilitation means a large component of the WRD rehabilitation works will have been completed by the time the WRD itself has been completed.

Progressive achievement of final landform outcomes is expected from these strategies.

Progressive rehabilitation (examples)

A progressive rehabilitation design is developed for every WRD. Some designs are conceptual, whereas others may be well developed and partially completed.

Two examples of progressive rehabilitation actions to date are:

- Figure 21 in Section 3.3.6 provides aerial imagery that shows the south eastern section of the Duke/Magnet WRD (DW03). The lower slopes are clearly prepared for revegetation, whilst the upper lifts are still under construction.
- Figure 20 in Section 3.3.5 where the aerial imagery shows the lower faces of the north-west WRD at Iron Knight (KW01) have been progressively prepared for rehabilitation. This profile is also described in the WRD design cross section (see Figure 40).

Rehabilitation works begin at the earliest opportunity after a WRD faces become available. Progressive rehabilitation is a key part of the mine plan which features in the 18-month mine plans, the three-month mine plans and the weekly mine plans.

Rehabilitation of the SMR area is scheduled for the next five years, and these plans are aligned with the LOM plan. However, the schedules need to be regularly revised and adjusted as the mine plan itself is reviewed and optimised to suit market and prevailing ground conditions.

For example, a mine pit cannot be rehabilitated until it is formally confirmed that the pit and below is completely sterile. The same can affect WRDs, for example, if a small dump is expanded then rehabilitation work on lower benches is lost. This situation can be avoided with deferral to ensure the best overall outcome. However SIMEC Mining endeavours to progressively rehabilitate all SMR mining areas and if one area is delayed another area may become available.

Table 15 is an excerpt of a preliminary 5 year rehabilitation plan that is under development (this is subject to change as schedules are varied to suit conditions). The plan provides visibility of the staged nature of the rehabilitation actions, and allocation of resources to achieve a progressive rehabilitation schedule.

Table 15 Indicative progressive 5 year rehabilitation plan (excerpt)

Location	Timing	Total area (ha)	Year					Total (ha)
			FY15	FY16	FY17	FY18	FY19	
Chieftain pit	At closure	60						
Duchess pit	At closure	100						
Duke pit	At closure	50						
Knight pit	At closure	46						
Knight South Pit	At Closure	20				2.3		2.3
Magnet pit	At closure	86						
CW01 WRD	In progress	95	5	3	6	6	5	25
MW18 WRD	In progress	53	5	5			9	19
DW03 WRD	In progress	201	13	15	20	12	9	69
MW06 WRD	To be determined	8						
KWS01 WRD	To be determined	24				4		4
KW01 WRD	To be determined	25						
KW03 WRD	At closure	4				4		4

Further concept closure and rehabilitation designs, methodology and sections are detailed in Section 8.

3.7.4 Iron Chieftain

Sequence of mining

The 2014 PEPR described five stages of pit development. Stages ('A', 'B' and 'E') as were described in the 2014 PEPR are now complete and a re-optimisation of the Iron Chieftain pit and WRD designs, incorporating a new ROM pad and low-grade ore (LGO) WRD has been undertaken.

The original stages 'C' and 'D' from the 2014 PEPR have been amalgamated to create a new Stage 'E' Pit to the north. The re-optimised mine layout is provided in Figure 32. Iron Chieftain Stage E pit will be the only active pit, and ore will be stockpiled on the new ROM pad, adjacent to the pit.

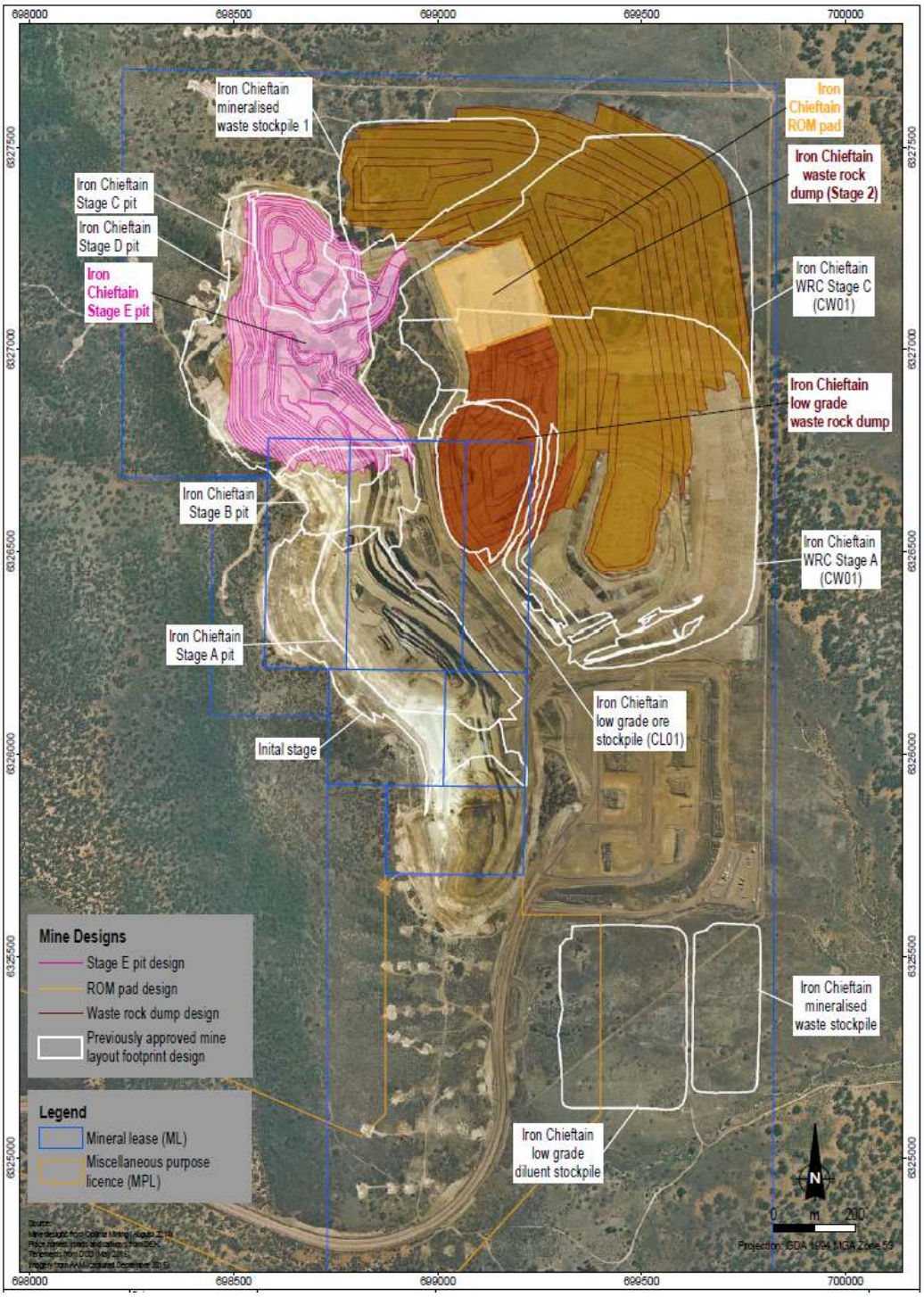


Figure 32 Iron Chieftain final site layout

Ore stockpiling and handling

Ore is stockpiled at the Iron Chieftain site on the ROM pad. It is hauled to Iron Knight by truck where it is crushed, screened and loaded onto rail as direct shipping ore (DSO).

Low-grade ore (LGO) is stockpiled on site at CL01 near CW02 for later beneficiation through the Iron Duke OBP plant. As part of the re-optimisation of design, LGO will be stored south-west of the WRD. Additional stockpiles will be created for mineralised waste currently considered uneconomic, but could be viable in the future.

WRD design and construction

The WRD design allows future expansion without the need for further footprint disturbance. The WRD profile also assists in providing a visual barrier to the high western faces of the pit and once progressively rehabilitated will blend naturally with surrounding hillocky profiles.

The WRD design delivers:

- the potential for capacity increase without increasing the footprint
- an elevated profile creating an improved visual screening of the western faces of the pits
- an undulating profile to blend with the surrounding landform
- containment entirely within land owned by SIMEC Mining.

The estimated remaining WRD storage volume for Iron Chieftain CW01 and CW02 is 15,000,000 loose cubic metres (LCM).

Figure 33 to Figure 36 further describe the Iron Chieftain designs in sectional form.

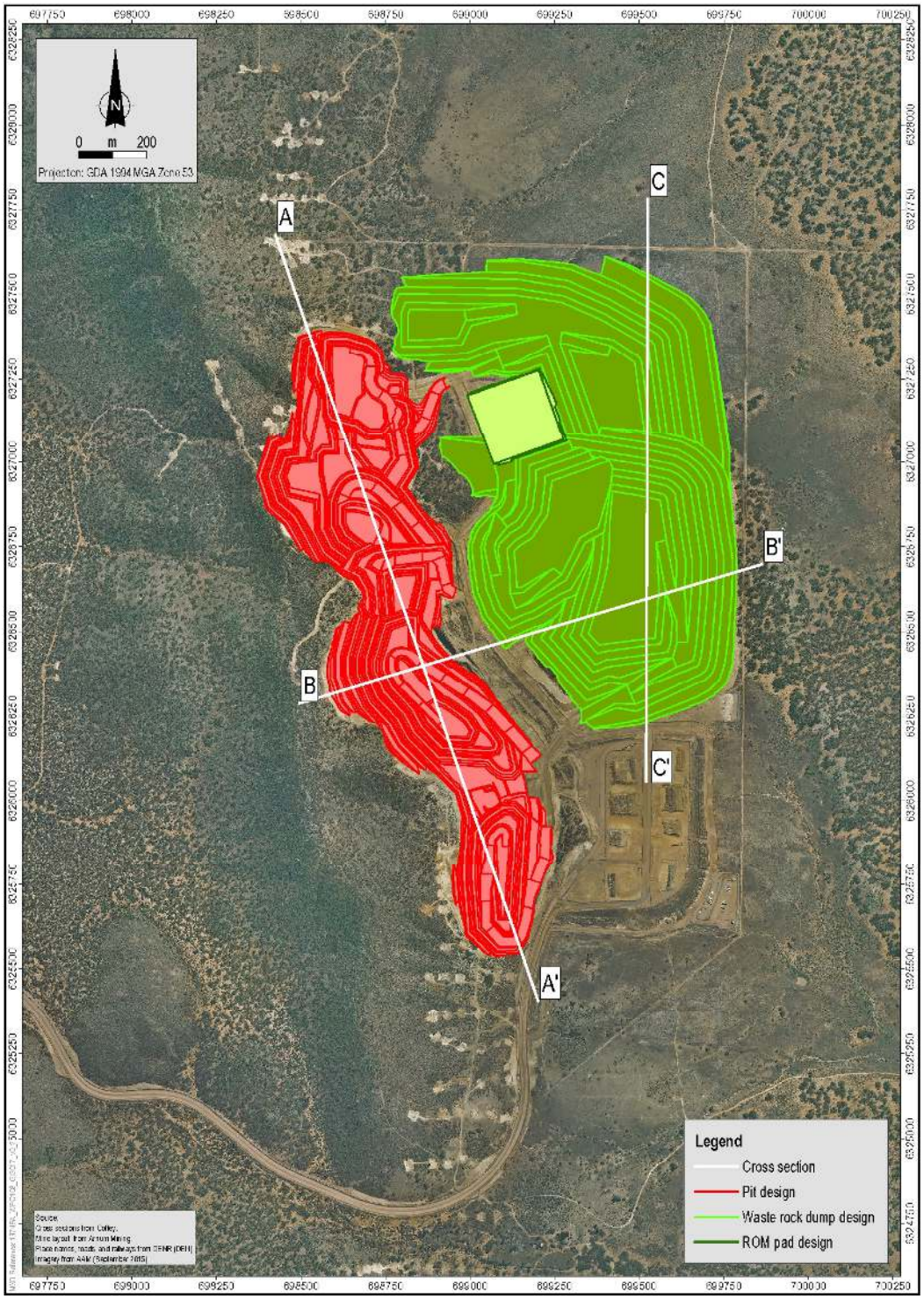


Figure 33 Iron Chieftain pit and WRD section lines

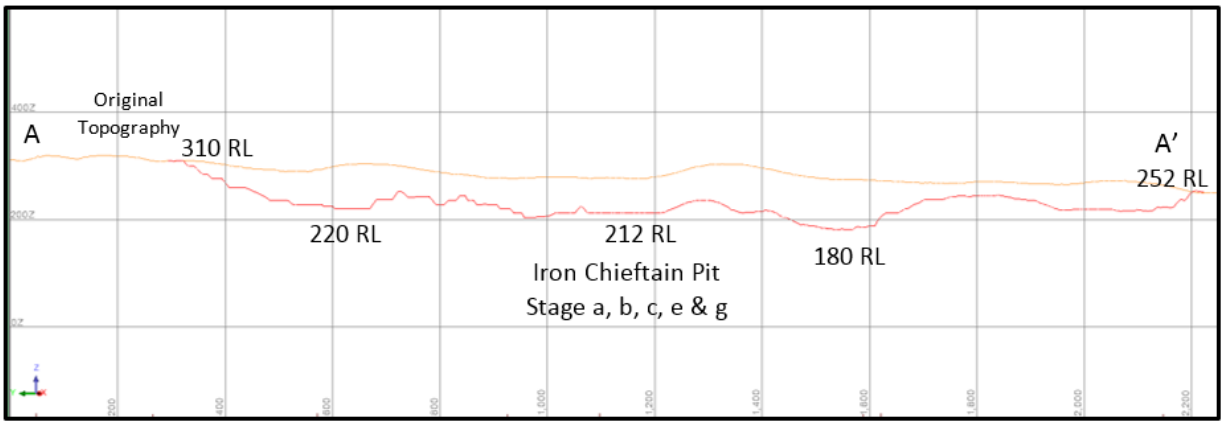


Figure 34 Iron Chieftain section A-A'

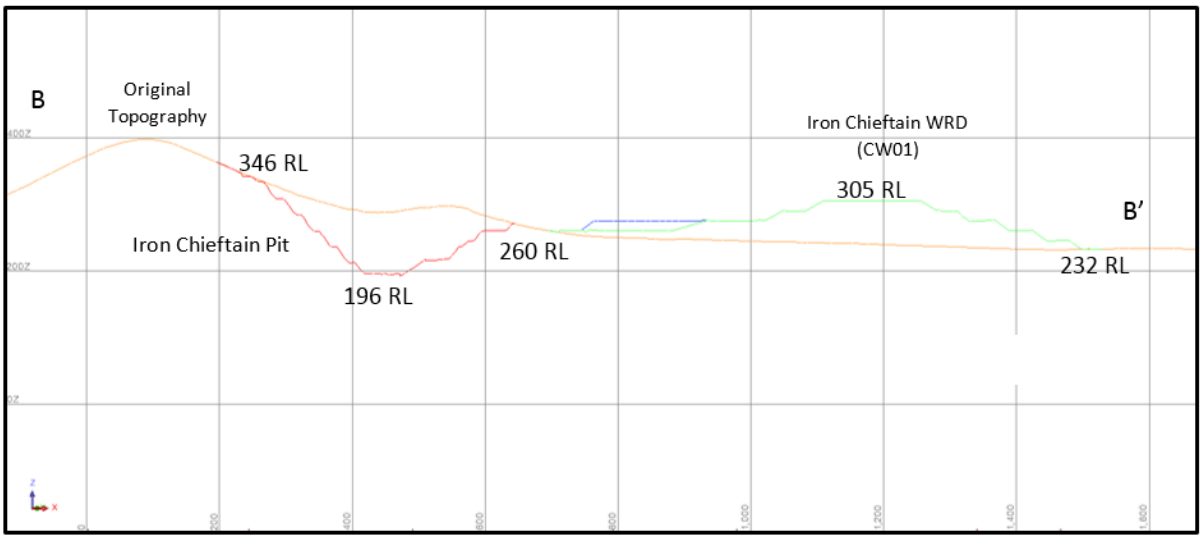


Figure 35 Iron Chieftain section B-B'

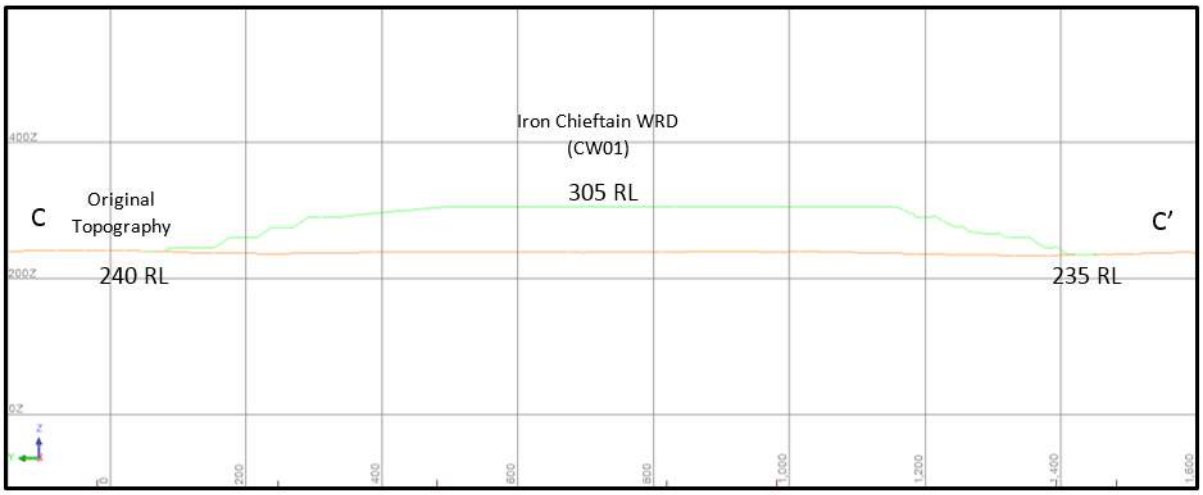


Figure 36 Iron Chieftain section C-C'

Refer to Section 8 for final closure profiles.

3.7.5 Iron Knight

Sequence of mining

No further mining of the main Iron Knight North and South pits is scheduled at this stage.

The final 900,000 BCMs mined from the Iron Knight North pit through to around February 2015 yielded approximately 1.2 Mt of ore products.

As part of further mine design and cost optimisations in mid-2016, a small satellite pit south of the existing Iron Knight South Stage-3 pit is scheduled to commence in early January 2017. The pit is comparatively small in nature and will be mined from start to completion over a four month period. Figure 37 shows the proposed pit and changes to the footprint of the associated WRD and mineralised waste/LGO stockpiles.

Closure assessment will take place in line with economic forecasts for future ore recovery options from this pit.

Figure 38 shows the final site layout for Iron Knight based on current LOM plan.

Ore stockpiling and handling

Ore is stockpiled at the Iron Knight site on the ROM pad. Post crushed material is loaded onto rail at the Iron Knight siding for direct transport via rail to the Whyalla port.

LGO is stockpiled near the ROM pad for later beneficiation via the Iron Duke OBP plant.

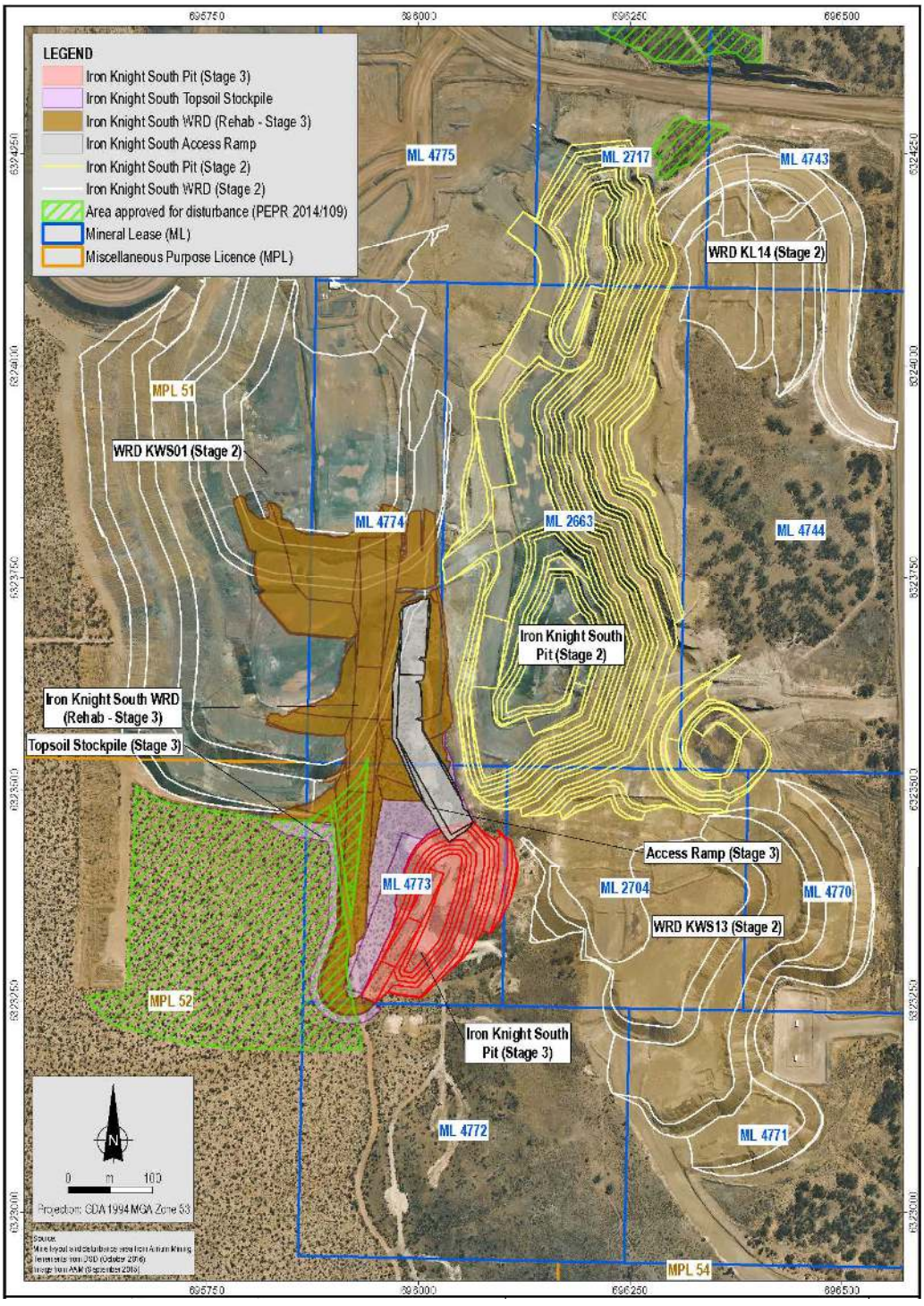


Figure 37 Iron Knight South Stage 3 design

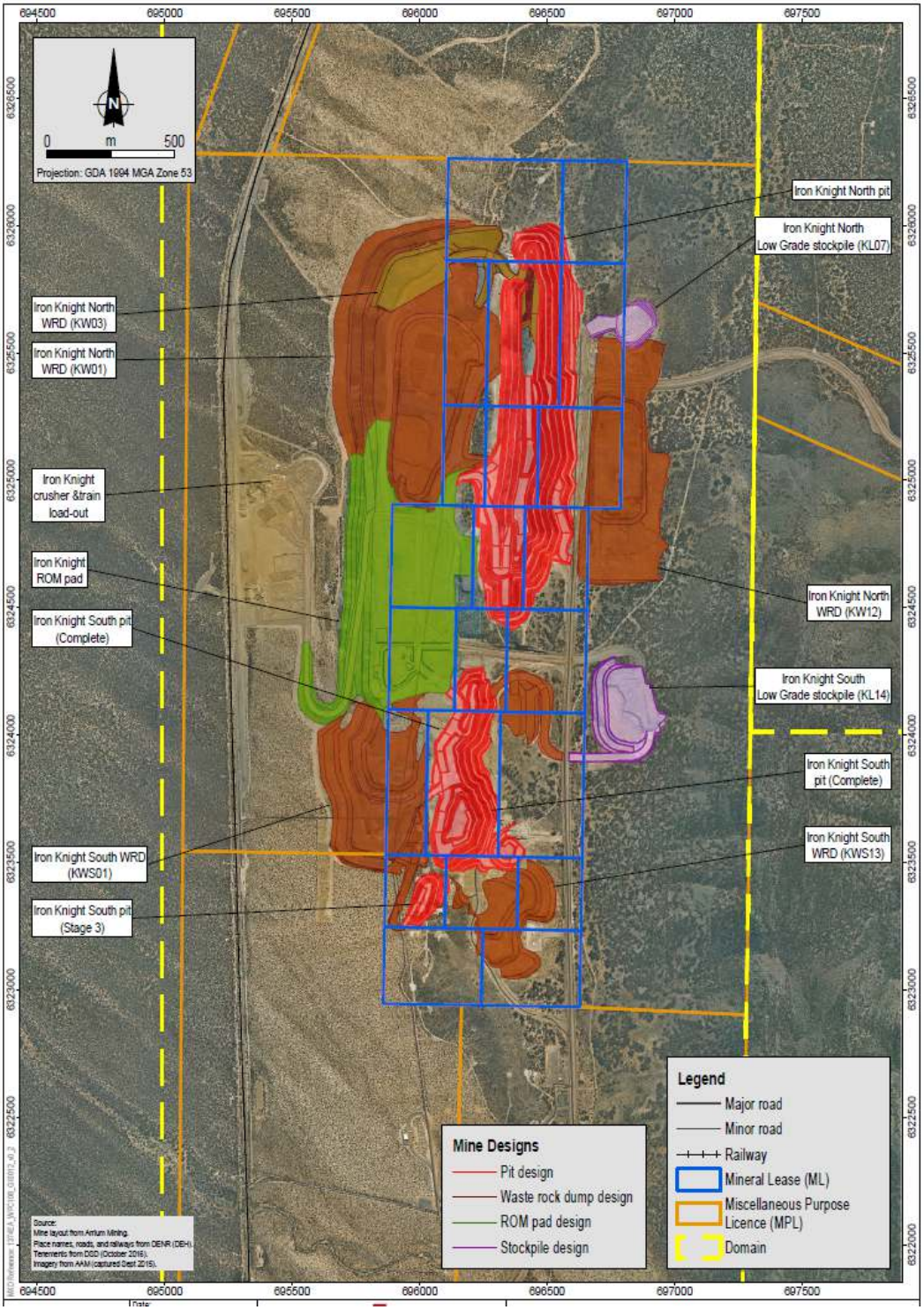


Figure 38 Iron Knight final site layout

WRD design and construction

There are historical WRDs at Iron Knight. Significant progress has been made towards achieving final landforms for Knight North and South WRDs.

Final waste volumes from Knight North mining were placed in WRD KW03 as planned.

Waste from the new Iron Knight South Stage-3 pit will be placed in WRD KWS01.

Figure 39 to Figure 42 describe the Iron Knight layouts and sections.

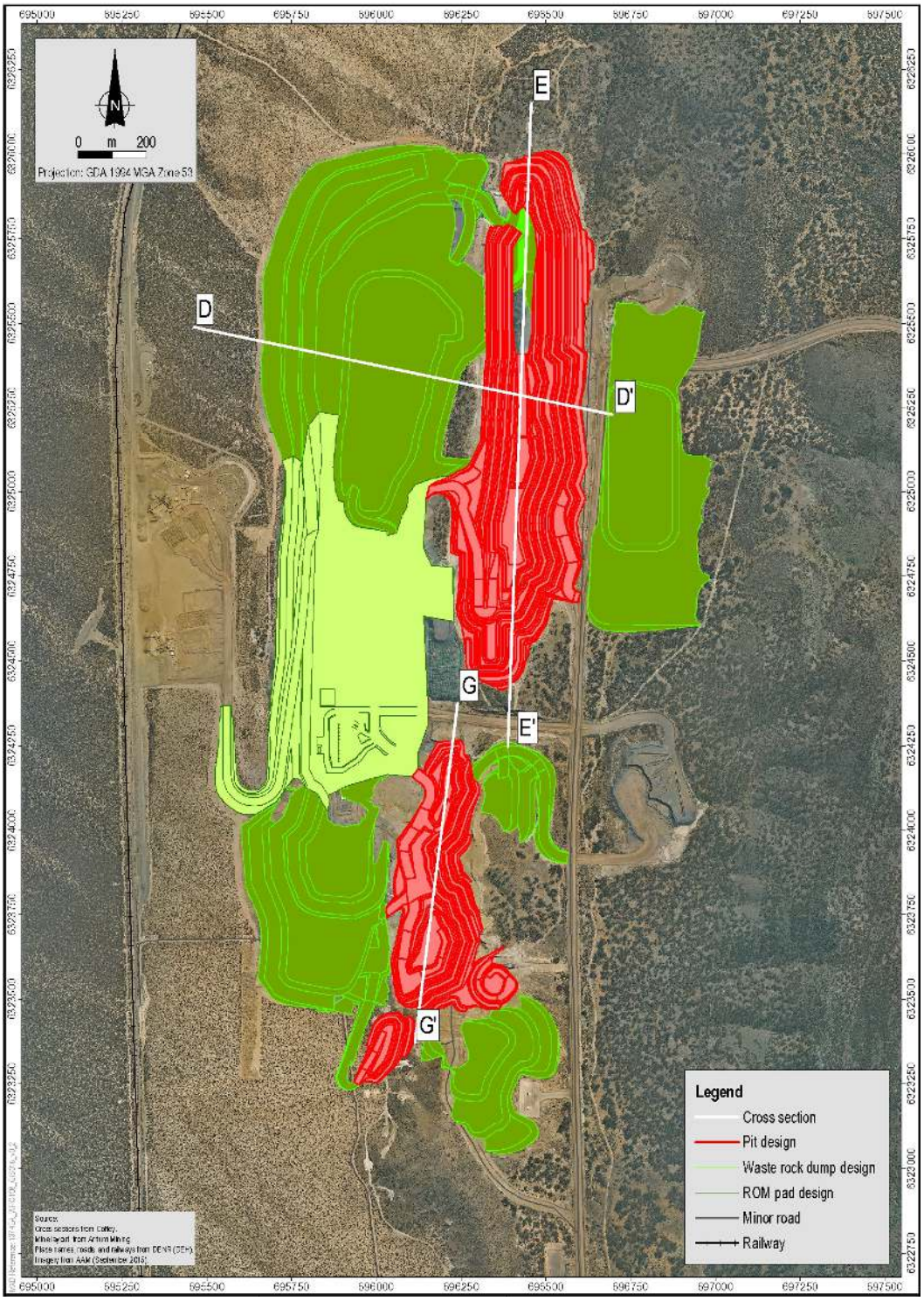


Figure 39 Iron Knight pit and WRD section lines

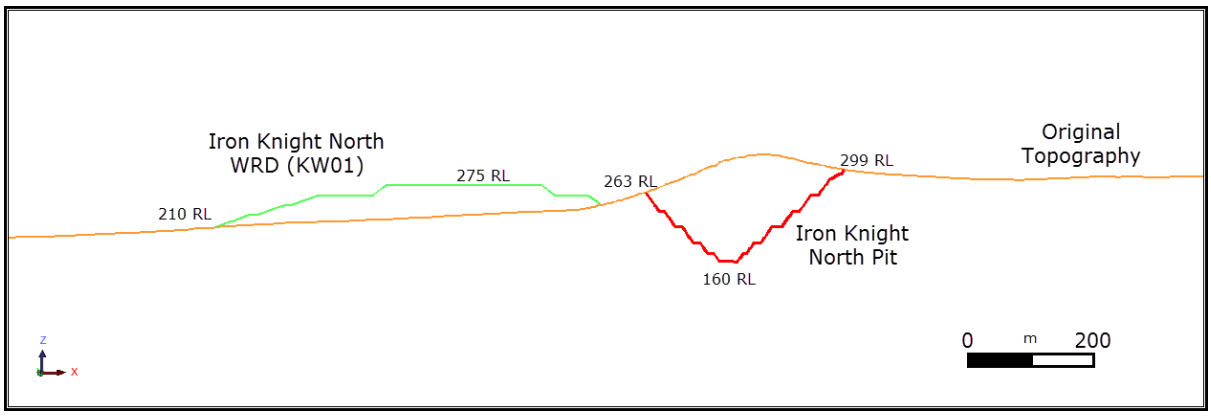


Figure 40 Iron Knight section D-D'

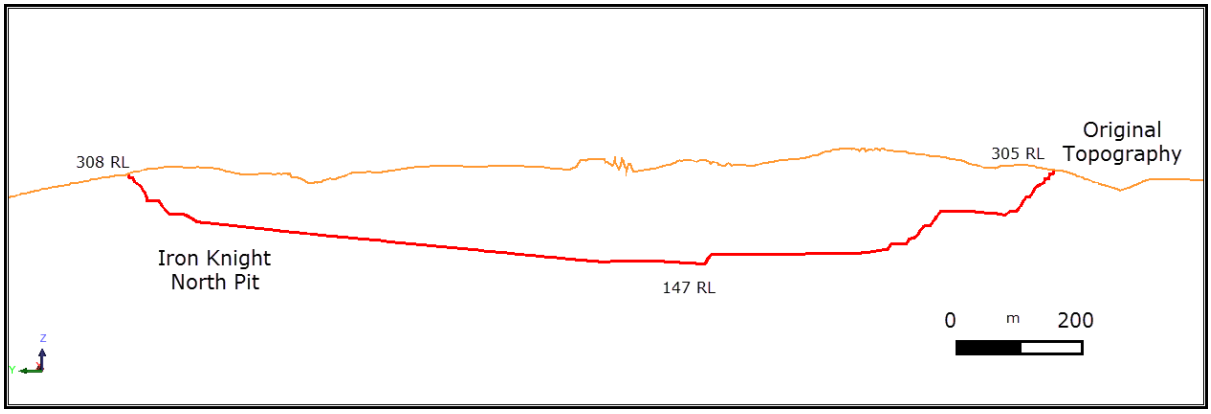


Figure 41 Iron Knight section E-E'

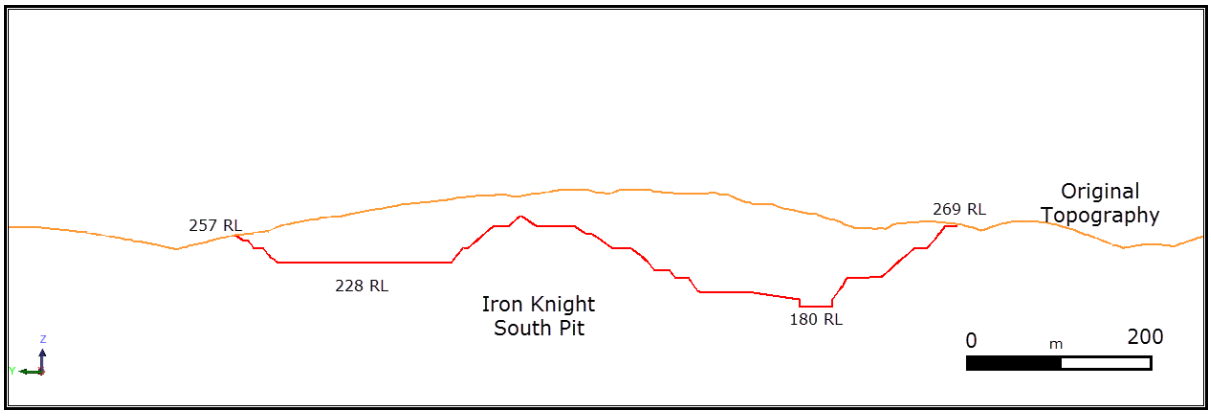


Figure 42 Iron Knight section G-G'

Figure 43 to Figure 45 describe the new Iron Knight South Pit design in sectional form.

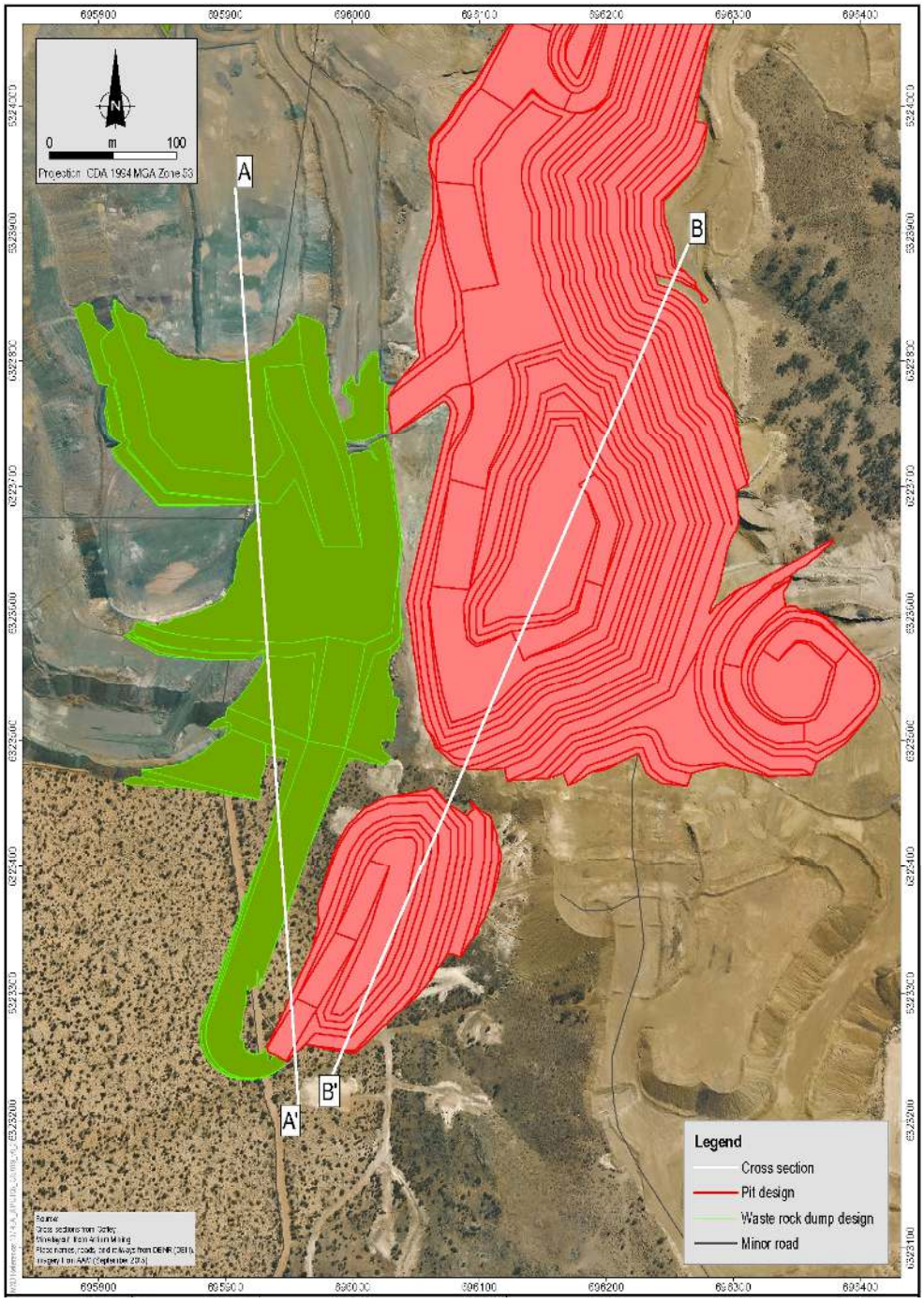


Figure 43 Iron Knight South pit and WRD section lines

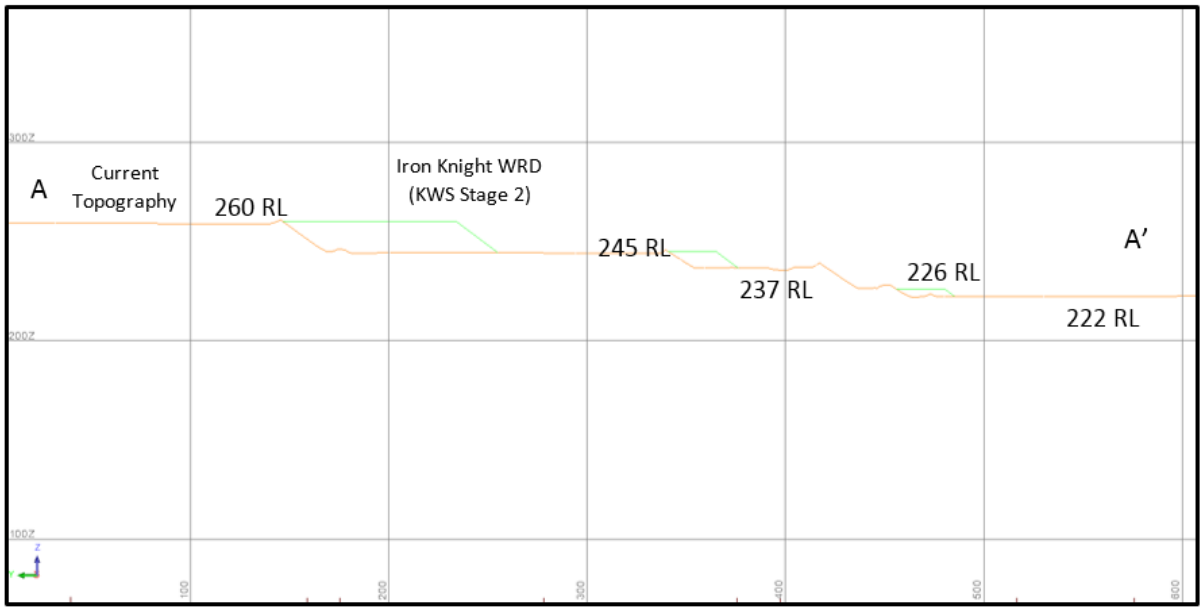


Figure 44 Iron Knight South section A-A'

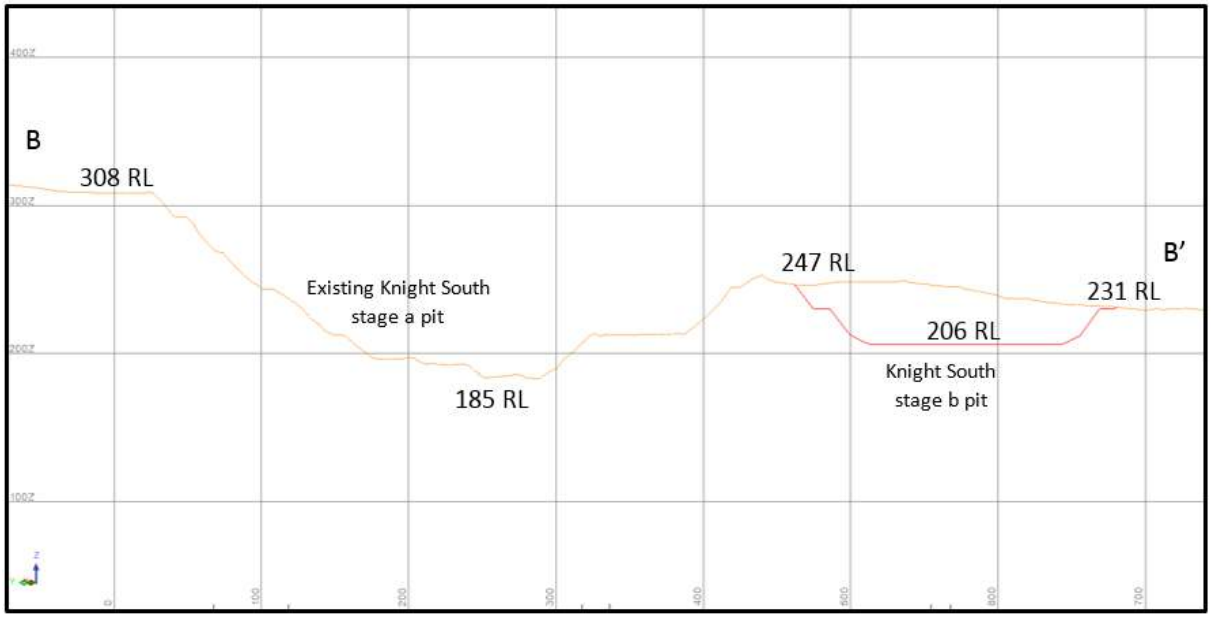


Figure 45 Iron Knight South section B-B'

Refer to Section 8 for final closure profiles.

Progressive rehabilitation

Significant progressive rehabilitation works have been achieved in the Knight mining area:

- KW01 and KW03 Final 'Foot slope' landform, seed box and/or contour rip erosion control and topsoil sheeting has been completed
- KSW01 WRD Final 'Foot slope' landform, seed box and/or contour rip erosion control and topsoil sheeting has been completed over the majority of the west face.

Sections of KSW01 remains open for current mining activities and is scheduled for final rehabilitation after the Iron Knight South Stage-3 pit is complete.

Other areas surrounding the Iron Knight may be available for rehabilitation. An assessment will be carried out to determine which areas can be included in the rehabilitation plan ensuring the rehabilitation is scheduled in a manner that does not result in duplication of rehabilitation work or damage to newly rehabilitated areas.

3.7.6 South SMR

Pit designs and mining sequences

Duchess pit: the main Duchess pit is no longer mined and is used to store recycled water from tailings recovery.

Duchess South pit: mining commenced in FY14 and will continue until approximately September 2015, yielding approximately 1.3 Mt of ore products.

This pit is mined continuously using one excavator and waste is directed to MW18 WRD. Figure 46 shows the Iron Duchess South final site layout based on current LOM plan. No further mining is scheduled beyond this.

Duchess North pit: a Duchess North extension (Stage B Part 1) is scheduled to commence in July 2018 and continue until approximately June 2021, yielding approximately 7.3 Mt of ore products. This pit is currently used to store reclaimed water from tailings recovery.

The pit will be mined continuously using one excavator and waste directed to an extension of MW18 WRD. Figure 54 shows the Iron Duchess North final site layout based on the current LOM plan. No further mining is scheduled beyond this.

Iron Duke pit: the south end mining of hematite ore from this pit ceased in January 2014. The Iron Duke 'a' and 'b' pits are in a close out phase with bunding now in place. No further mining is scheduled for the Iron Duke pit.

Iron Magnet pit: the north end is designed in three stages: Mag C, Mag D and Mag E, which are being developed concurrently. This provides flexibility for scheduling of ore and waste movement. Mag C is currently on the 148 m RL and provides magnetite ore. Mag D (176 m RL and ramp access) is situated on the western wall and currently provides waste movement enabling access to ore in that area at a later stage. Mag D also supplies small amounts of ore during development. Mag E (260 and

252 m RL) is situated on the northern end of Iron Magnet and is predominantly waste movements at this stage. This development will expand the Mag C pit allowing access to the magnetite ore below. The current design of Mag C is to 60 m RL.

Generally one excavator mines Iron Magnet with the flexibility for more excavators to be deployed to develop the Mag D and Mag E areas, depending on the availability of excavators from other SMR sites. The life of this pit extends beyond the mine plan schedules as a source of magnetite. It appears in the current LOM through to approximately 2029.

The supply of hematite ore from the Magnet pit is low and supplementary in nature.

Figure 47 shows the Iron Duke/Magnet final site layout.

Ore stockpiling and handling

Ore is stockpiled at the Iron Duke site on the ROM pad. The ore is transported to the ROM pad by haul truck.

LGO hematite is stockpiled near the ROM pad for later beneficiation through the Iron Duke OBP plant.

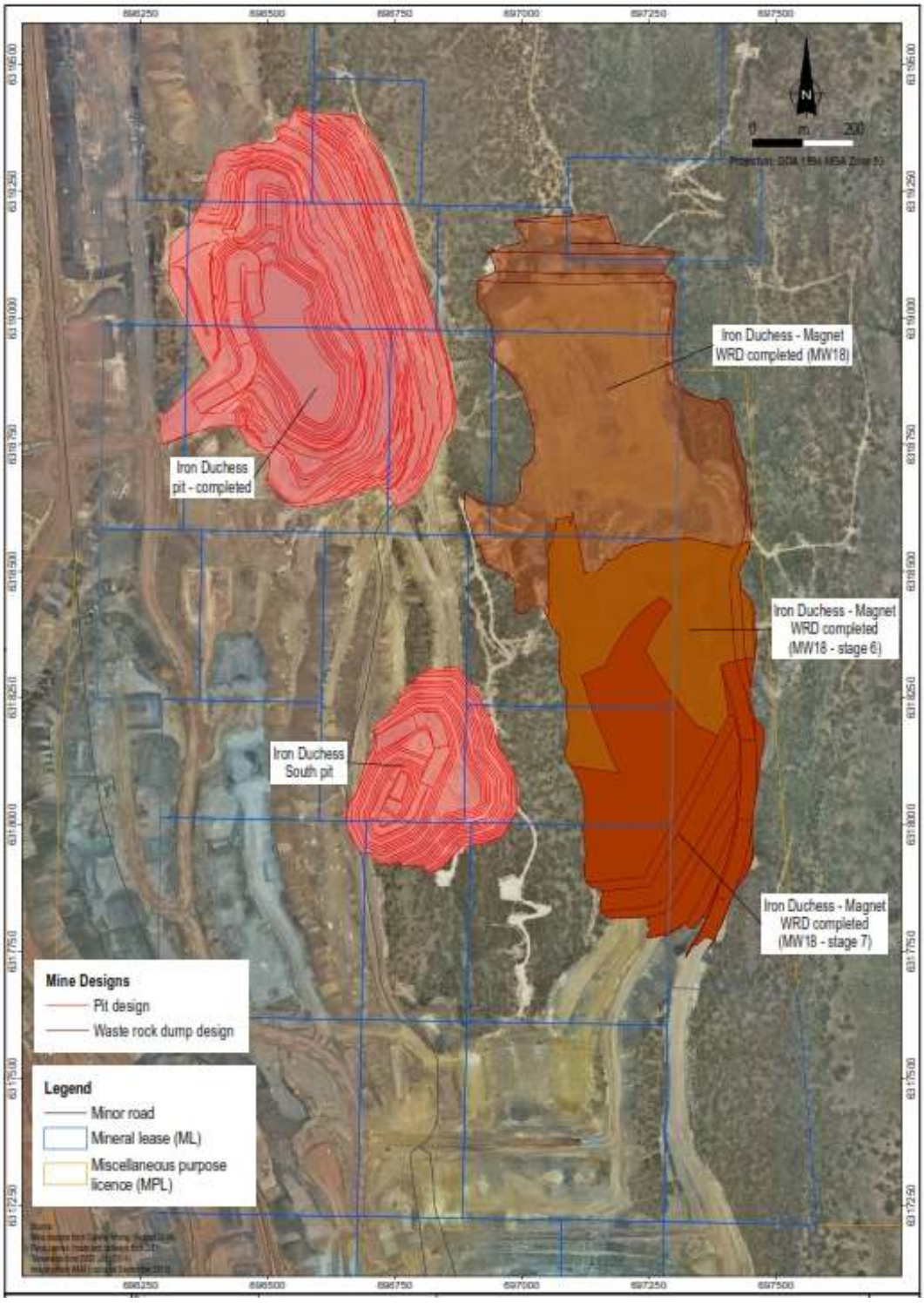


Figure 46 Iron Duchess final site layout

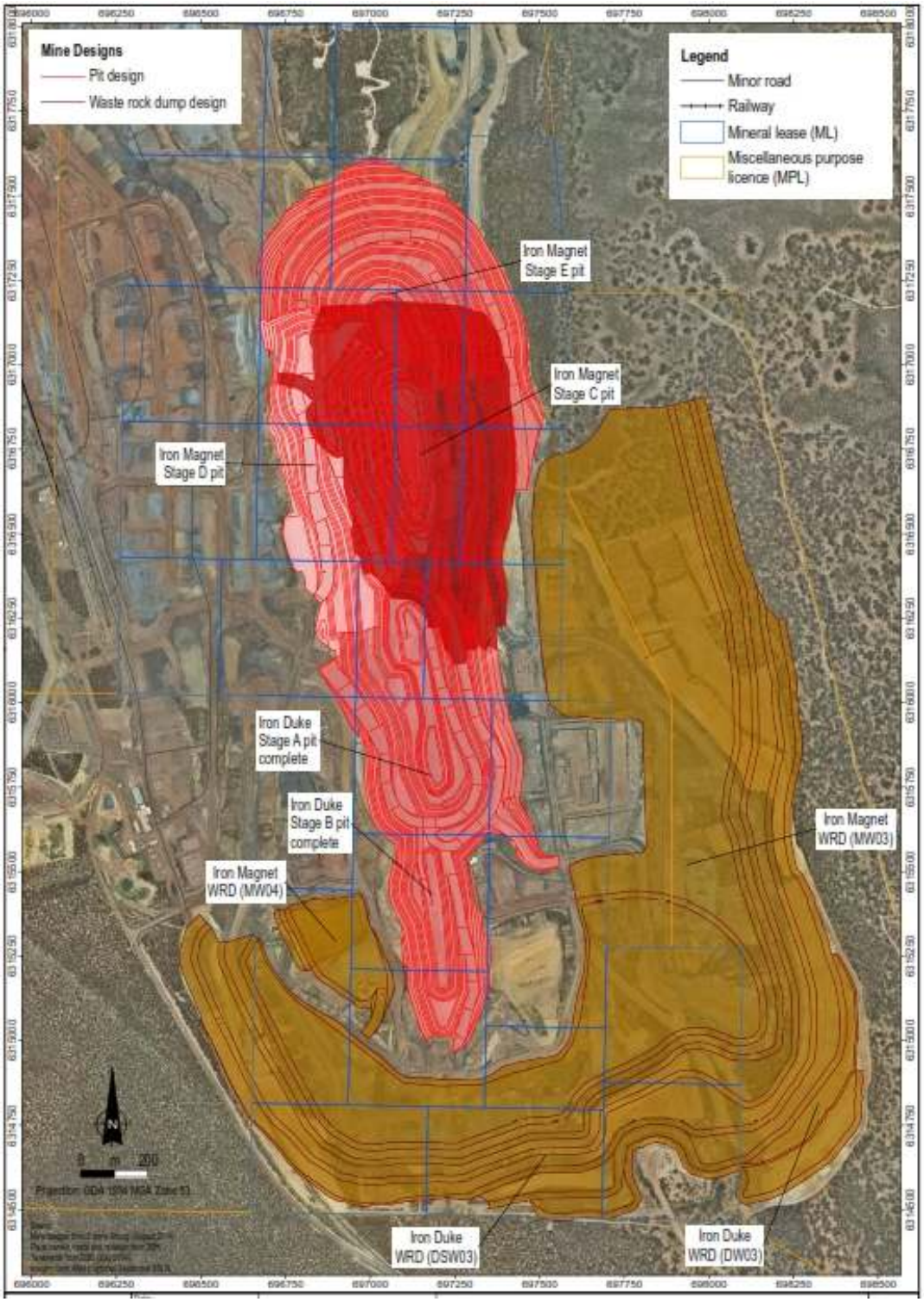


Figure 47 Iron Duke/Magnet final site layout

WRD design and construction

Details of the South SMR WRD design and construction are outlined in Section 0.

Waste from the Iron Magnet pit is directed to both MW03 to the south-east, and MW18 to the north-east (refer to Figure 47 for the general layout and to Figure 48 to Figure 53 for further cross sectional details of South SMR pit and WRD designs).

Waste from the Duchess North pit Stage B Part 1 will be directed to an extension of WRD MW18 (refer to Figure 54 for the general layout and to Figure 55 to Figure 58 for further cross sectional details of Duchess North Stage B Part 1 pit and WRD designs).

The estimated remaining WRD storage volume for Iron Magnet MW18 is 4,300,000 LCM and 21,000,000 LCM for MW03.

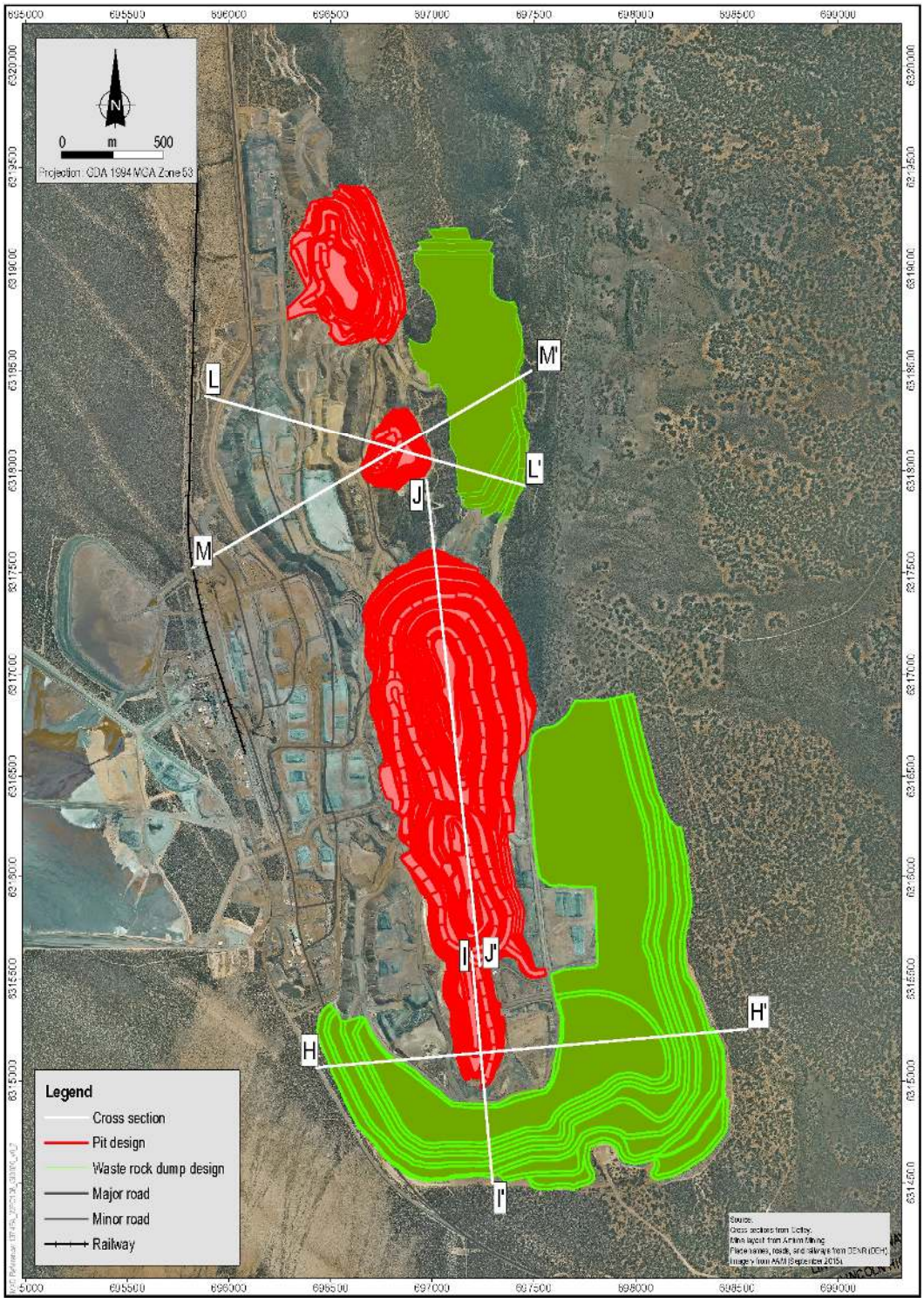


Figure 48 South SMR pit and WRD design section lines

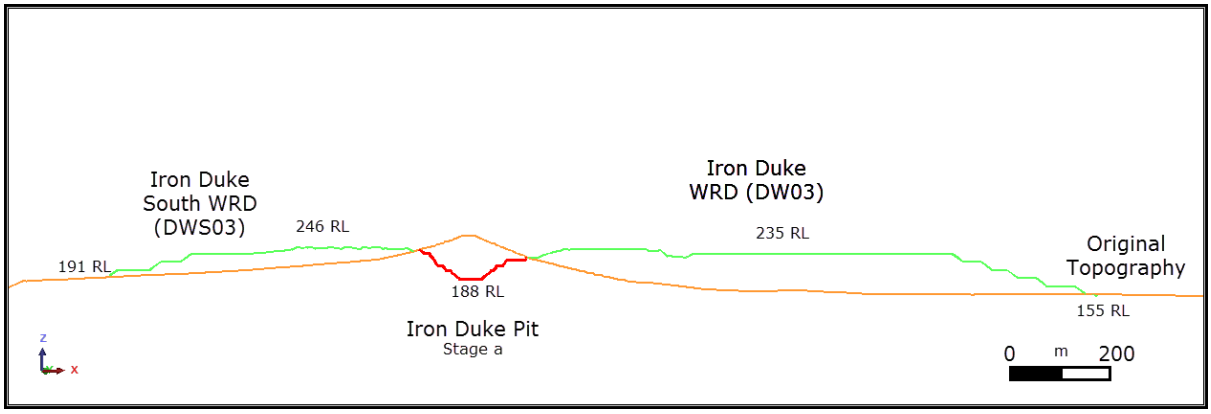


Figure 49 Iron Duke section H-H'

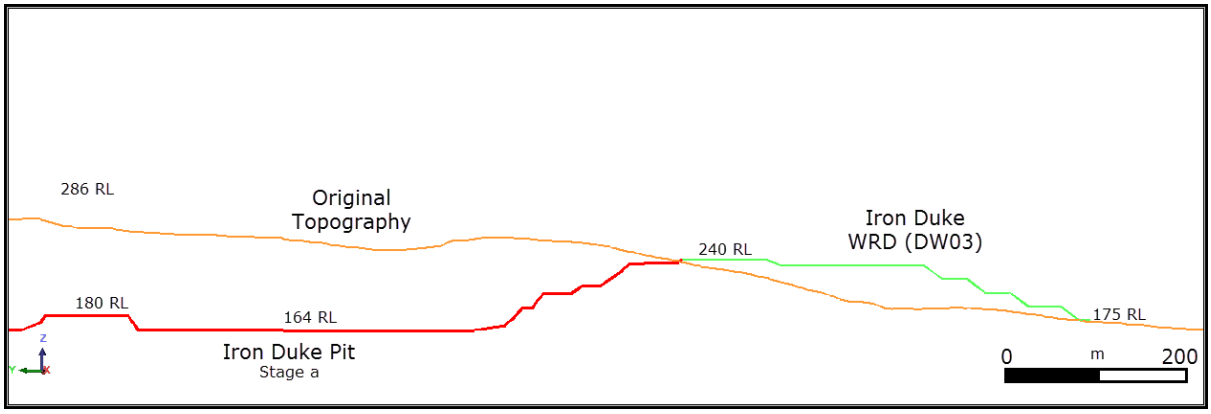


Figure 50 Iron Duke section I-I'

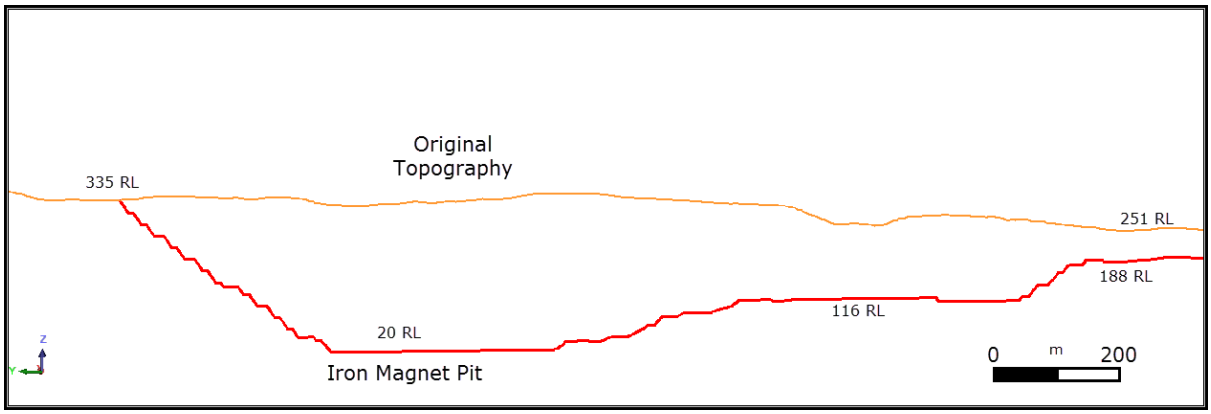


Figure 51 Iron Magnet section J-J'

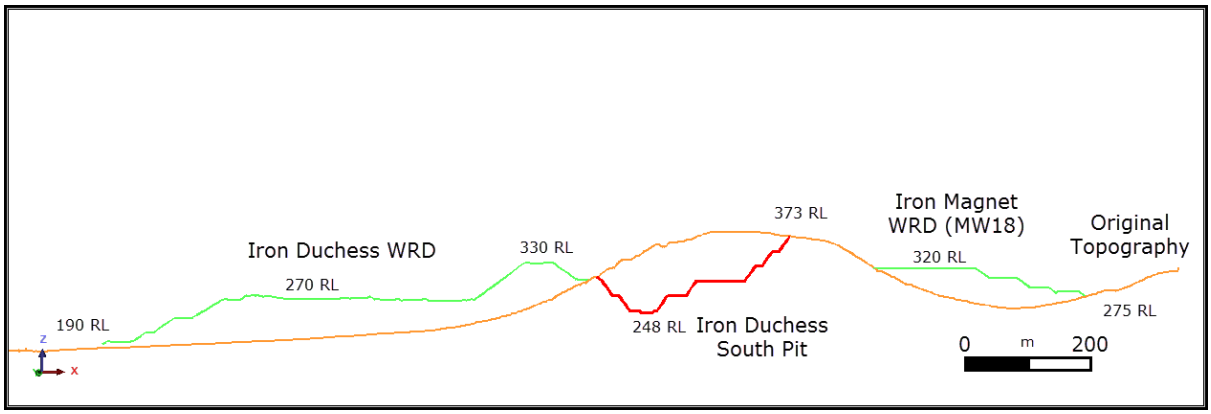


Figure 52 Iron Duchess South section L-L'

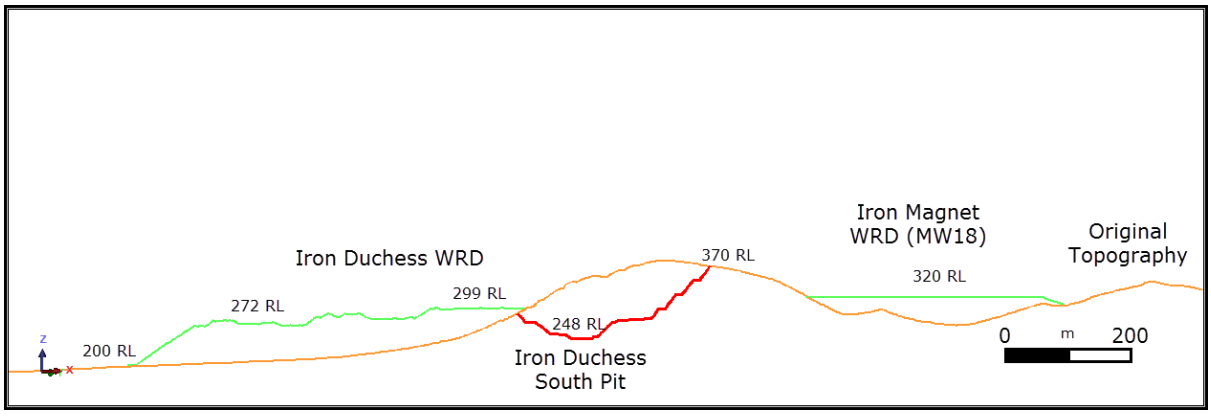


Figure 53 Iron Duchess South section M-M'

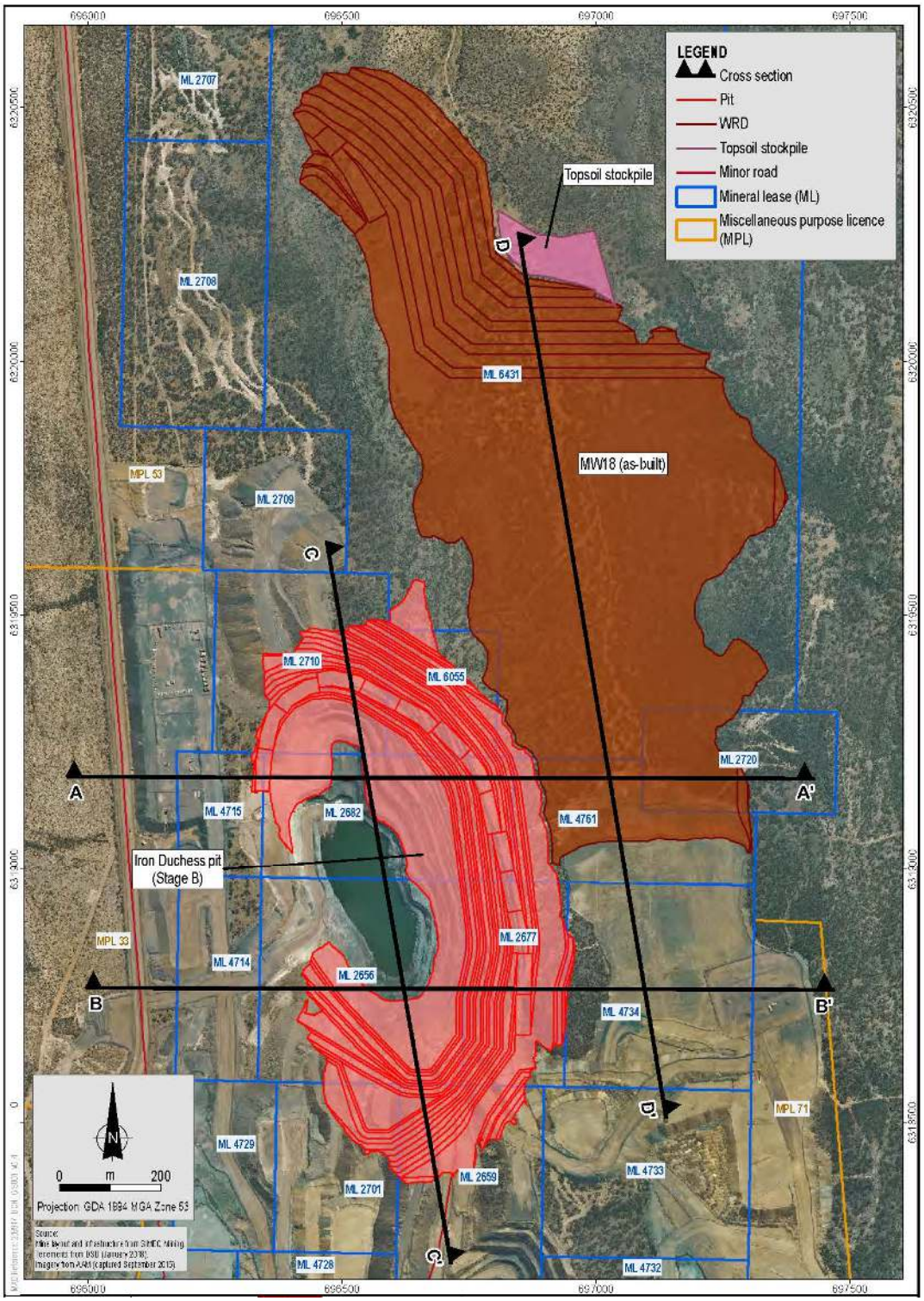


Figure 54 Iron Duchess North pit and WRD design section lines

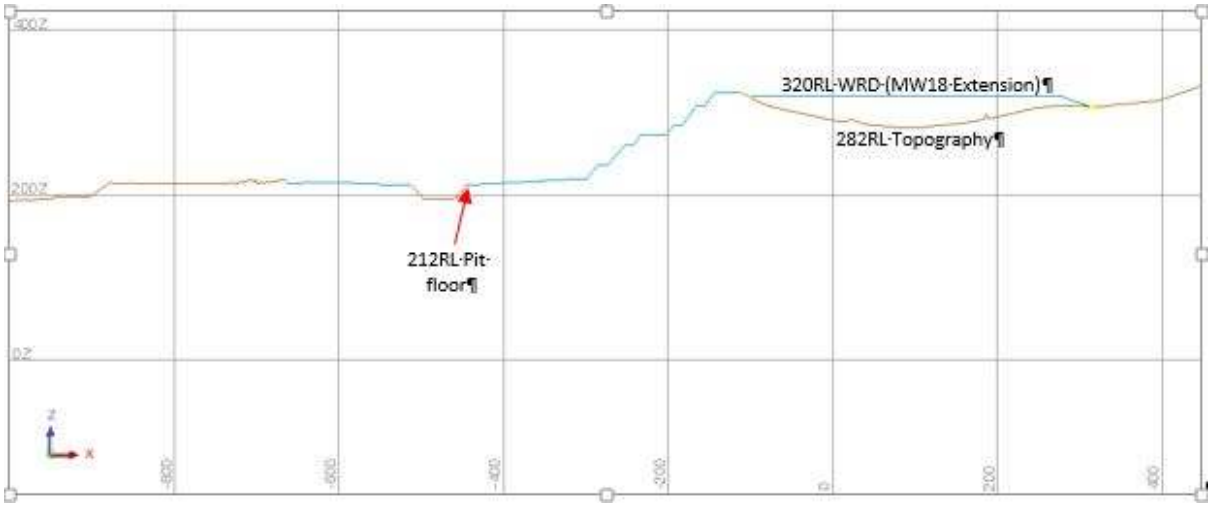


Figure 55 Iron Duchess North section A-A'

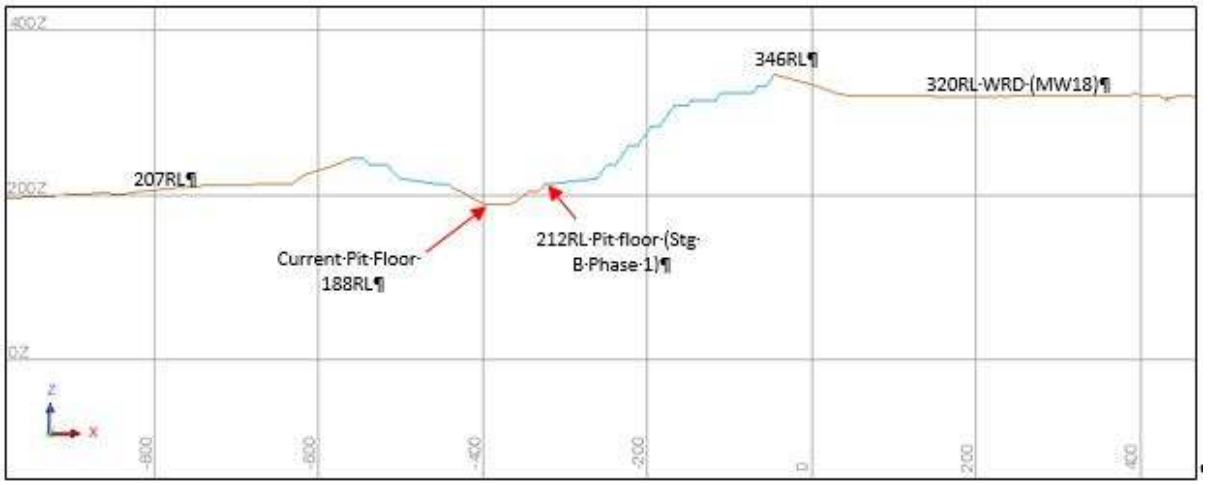


Figure 56 Iron Duchess North section B-B'

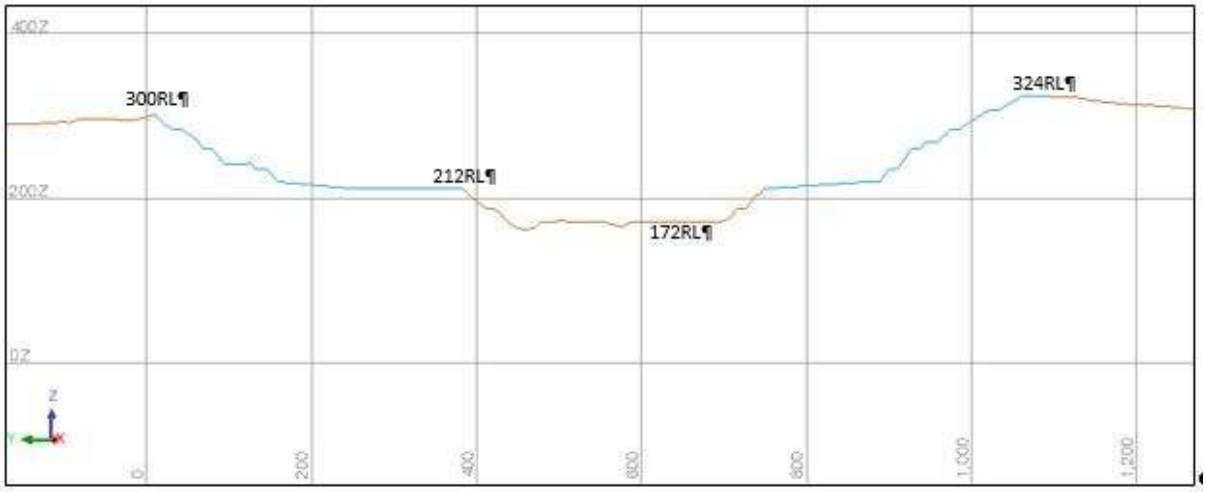


Figure 57 Iron Duchess North section C-C'

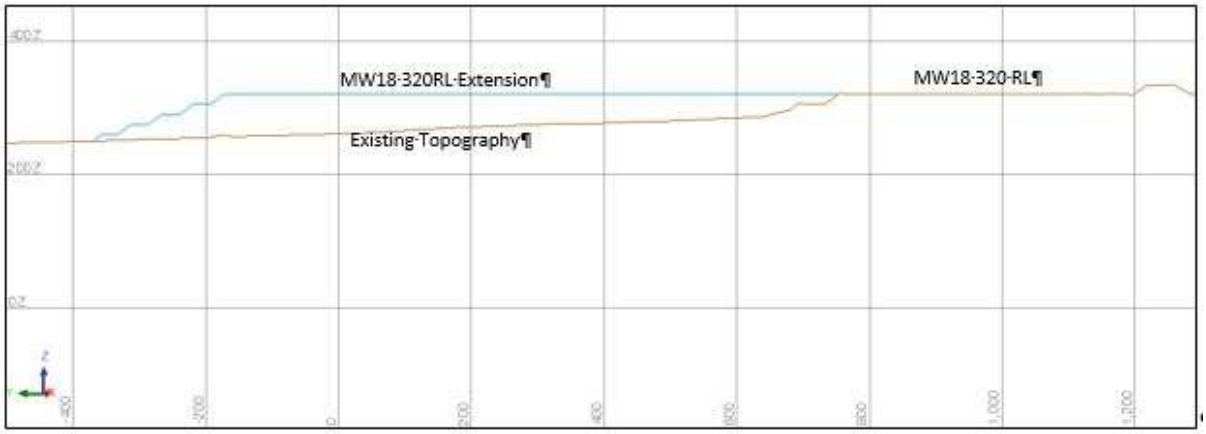


Figure 58 Iron Duchess North section D-D'

Progressive rehabilitation

There has been good progress with rehabilitating the most visible southern WRD (DW03), adjacent to the Lincoln Highway, and the lower slopes are in the early stages of rehabilitation. This work is being closely monitored as part of the rehabilitation program.

The final concept rehabilitation profiles are presented in Section 8.

3.8 General Descriptions of Mining Operations

3.8.1 Modes and hours of operation

The SMR mines operate on a continuous 24 hours a day, seven days a week basis with two 12-hour shifts every 24 hours.

3.8.2 Workforce and structure

The workforce in September 2014 comprises approximately 145 SIMEC Mining personnel and approximately 140 BGC Contracting (BGC) mining contract personnel, plus an array of small sub-contract service providers. Up to 310 personnel attend site on an average day.

BGC are the principal mining contractors managing the daily mining operations for SIMEC Mining. BGC use Rock Australia for drilling and blasting contract services.

Orica, who are contracted to manage the storage and handling of blast materials and magazines, have four on-site personnel on a rotating shift.

Bis Industries own operate and maintain the Iron Knight crushing, screening and train loading operations, with approximately eight personnel on site.

SIMEC Mining own, operate and maintain the Iron Duke crushing and screening plant, the Magnetite Concentrator Plant, and the OBP.

Vehicle movements vary, but on average, it is estimated that daily movements amount to:

- 160–180 light vehicle round trips per day
- two bus round trips per day
- 10–15 truck and service delivery round trips per day.

3.8.3 Type of equipment

Table 16 provides an indication of the mining equipment that may be in use at any point in time for the SMR operations, the approximate gross mass and noise emission data (where available).

Table 16 Typical equipment employed on SMR operations

Nominal quantity	Type	Make	Model	Size	Approximate noise emission
2	Excavator	Hitachi	EX2600	260 tonne	72 dB(A) in cab max speed, no load
1	Excavator	Hitachi	EX2500	250 tonne	72 dB(A) in cab max speed, no load
1	Excavator	Komatsu	PC2000	200 tonne	
1	Excavator	Hitachi	EX1900	192 tonne	
1	Excavator	Komatsu	PC4000	392 tonne	
1	Excavator	Komatsu	PC1250	110 tonne	89 dB(A) at 15 m operating mid gear and moving
24	Haul truck	Cat	785	250 tonne gross	89 dB(A) at 15 m operating mid

Nominal quantity	Type	Make	Model	Size	Approximate noise emission
					gear and moving
7	Haul truck	Komatsu	HD785	250 tonne	74 dB(A) at 50 m mid-range running
	Haul truck	Komatsu	HD1500	250 tonne	
	Haul truck	Cat	777	165 tonne	
	Haul truck	Cat	769	71 tonne	
	Road train	Kenworth	C510	300 tonne	
2	Rock breakers	Komatsu	PC300		<82 dB(A) cab noise
5	Track dozer	Cat	D9	48/62 tonne	74 dB(A) at 50 m mid-range running
4	Track dozer	Komatsu	D375	D375	74 dB(A) at 50 m mid-range running
	Track dozer	Cat	D10	D10	74 dB(A) at 50 m mid-range running
4	Grader	Cat	16H	16 ft blade 26 tonne	72 dB(A) in cab max speed, no load
1	Grader	Cat	14H	14ft blade	72 dB(A) in cab max speed, no load
	Grader	Komatsu	GD825	GD825	
6	Wheel loaders	Komatsu	WA900	WA900	89 dB(A) at 15 m operating mid gear and moving
	Wheel loader	Komatsu	WA600	WA600	
	Wheel loader	Komatsu	WA500	WA500	
	Wheel loader	Cat	993	993	
	Wheel loader	Cat	992	992	
	Wheel loader	Cat	990	990	
	Wheel loader	Cat	988	988	
4	Drill	DML	Single Pass DML60	DML60	<70 dB(A) at 15 m operating mid gear and moving
1	Drill	Cubex/Sandvik	QXR1120/DR580	DR580	<70 dB(A) average design

Nominal quantity	Type	Make	Model	Size	Approximate noise emission
	Drill	Gardner Denver	GD5000	GD5000	
	Drill	Atlas Copco	D65	D65	
1	Bulk explosives truck	Orica	MMU	E51	<70 dB(A) average design
1	Bobcat/Stemming loader	Cat	T590	E42	<70 dB(A) average design
6	Water truck	Komatsu	HD785	365 tonne gross	72 dB(A) in cab max speed, no load
	Water truck	Komatsu	HD405		
	Water truck	Cat	777	777	

Original Equipment Manufacturers (OEM) design mining equipment to meet required industry standards to reduce or eliminate noise, vibration and heat sources to protect the environment and operators as far as practicable. All equipment used on site is required to meet mine specification standards.

The sources of operational noise and vibration from the equipment includes, but is not limited to:

- engine operation
- operational alarms and warning systems including tramming or reversing alarms
- loading noise in truck bodies
- track noise from tramming tracked equipment
- hammer noise from drilling rigs.

Potential ignition sources include equipment engine exhaust systems, grading and dozing operations, railing operations, loading operations, electrical equipment and operating plant conveyors and screens.

3.8.4 ROM pads

ROM pads are staging areas for handling and blending ore products, which cater for the auxiliary crushing and screening requirements and other operations ancillary to mining.

The ROM pads are constructed of waste rock and topped with low-grade ore material. Drainage from the ROM pads is directed to the outer edges where silt traps have been installed.

All ROM pads and haul roads will be scarified, contoured and re-dressed with topsoil to prepare for the rehabilitation and closure phase, once mining and processing operations have finished.

3.8.5 Product handling and transportation

Ore is transported to the ROM pads and processing areas by haul trucks and road trains. Front-end loaders are used to load trucks and trains, and to handle products.

Haul roads are generally constructed from materials incorporating dust suppressants. Refer to Section 3.8.7 for further details on dust suppression.

Lump and fines ore products are transported from SMR to Whyalla by rail. Rail loading occurs at Iron Duke and Iron Knight. The loaded rail trucks are treated with water sprays before leaving the site to encrust the surface of the load.

Supplementary product trucking by road along the Lincoln Highway may be required from time to time for Whyalla Steelworks blast furnace emergency stockpile replenishment. Any additional trucking is not anticipated and approval for any additional trucking would be sought by exception on an as-needs basis and involving consultation with the community of Whyalla, the EPA, DSD and DPTI.

3.8.6 Blast management

Blasting activities within the SMR mining areas are managed in accordance with SIMEC Mining's Blasting Management Protocol (QP76.MINE.001 Blast Man Pro).

These protocols ensure:

- there are no risks to public safety on or off the mining lease areas, as a result of blasting activities
- private and public property will not be adversely affected by blasting activities
- blasting techniques and protocols minimise dust generated during blast events
- blasting only occurs in daylight hours.

Blast management procedures address the potential impacts of vibration, overpressure, fly-rock, dust and noise on the environment, personnel, equipment and surrounding land and facilities. Blasts are managed in accordance with industry best practice for explosives handling, blast design, initiation systems and impact controls. All blasts are designed and supervised by qualified, trained and experienced personnel.

Specific controls within the blast management procedures include:

- an exclusion zone of 500 m from the blast for personnel
- an exclusion zone of 300 m from the blast for equipment
- notifications prior to blasting
- clearance activities before the blast
- an allocated blasting controller (i.e. responsible shot-firer)
- emergency preparedness during the blast
- standard communication methods during the blast

- post-blast checks
- clearance at the conclusion of blasting

All potential risks and impacts are controlled and maintained below levels recommended in Australian Standard AS 2187.2: 2006.

On average, blasting will occur every five to seven days for each of the active pits.

Ammonium nitrate/fuel oil (ANFO) and, where necessary, emulsion-based explosives are used for blasting. Explosives are stored on site in accordance with the required licences. Emergency Management Plans and response equipment are in place. Emergency response personnel are trained and prepared in the event of emergencies.

Orica's explosive storage facilities at SMR are staffed 6am to 6pm, seven days per week. There are two operators on each shift and each shift works eight days on, six days off. The facilities are located south of Iron Knight, as shown on Figure 18 in Section 3.3.3.

Blast notices are placed on the mine site noticeboards at the mine site entry points, generally at least 24 hours before an event. Broadview Station or Moonabie Station is also notified by phone when blast impact zones marginally encroach on their properties. Figure 59 shows the blast exclusion zones for the SMR operations.

Blasting procedures include implementing 'blast guards' to all entry points for the affected area shortly before a blast event and a blast clearance procedure is also implemented to clear an area before blasting takes place. Radio communications are used to communicate the status of blast preparations, and to ensure evacuations of the blast management zones are complete and to confirm that blast guards are in place prior to the blast controller giving clearance to blast.

Notifications form part of the normal blasting procedures. Figure 59 shows the blast exclusion zones for the SMR operations.

Explosive types, quantities and estimated usage for FY15 are provided in Table 17.

Table 17 Explosives types, quantities and estimated usage FY15

Pit	Blast volume	Average powder factor (kg/BCM)	Total explosives (kg)	ANFO %	Heavy %	Fortis %	Total ANFO (kg)	Total Heavy (kg)	Total Fortis (kg)
Chieftain	3,616,702	0.55	1,989,186	0.80	0.20	0.00	1,591,349	0	0
Knight North	1,282,180	0.55	705,199	0.00	0.00	1.00	0	0	705,199
Duchess South	2,539,483	0.55	1,396,715	0.30	0.70	0.00	419,015	977,701	0
Iron Magnet	3,156,016	0.65	2,051,411	0.00	0.20	0.80	0	410,282	1,641,128

Table 18 summarises the types of explosive and the register storage capacities at SMR:

Table 18 Explosives type and volume stored

Explosive type	Volume
Ammonium nitrate	300 tonne
Ammonium nitrate emulsion	80 tonne
High energy explosives (HE)	5.356 kg
Initiation explosives (IE)	20,000 units

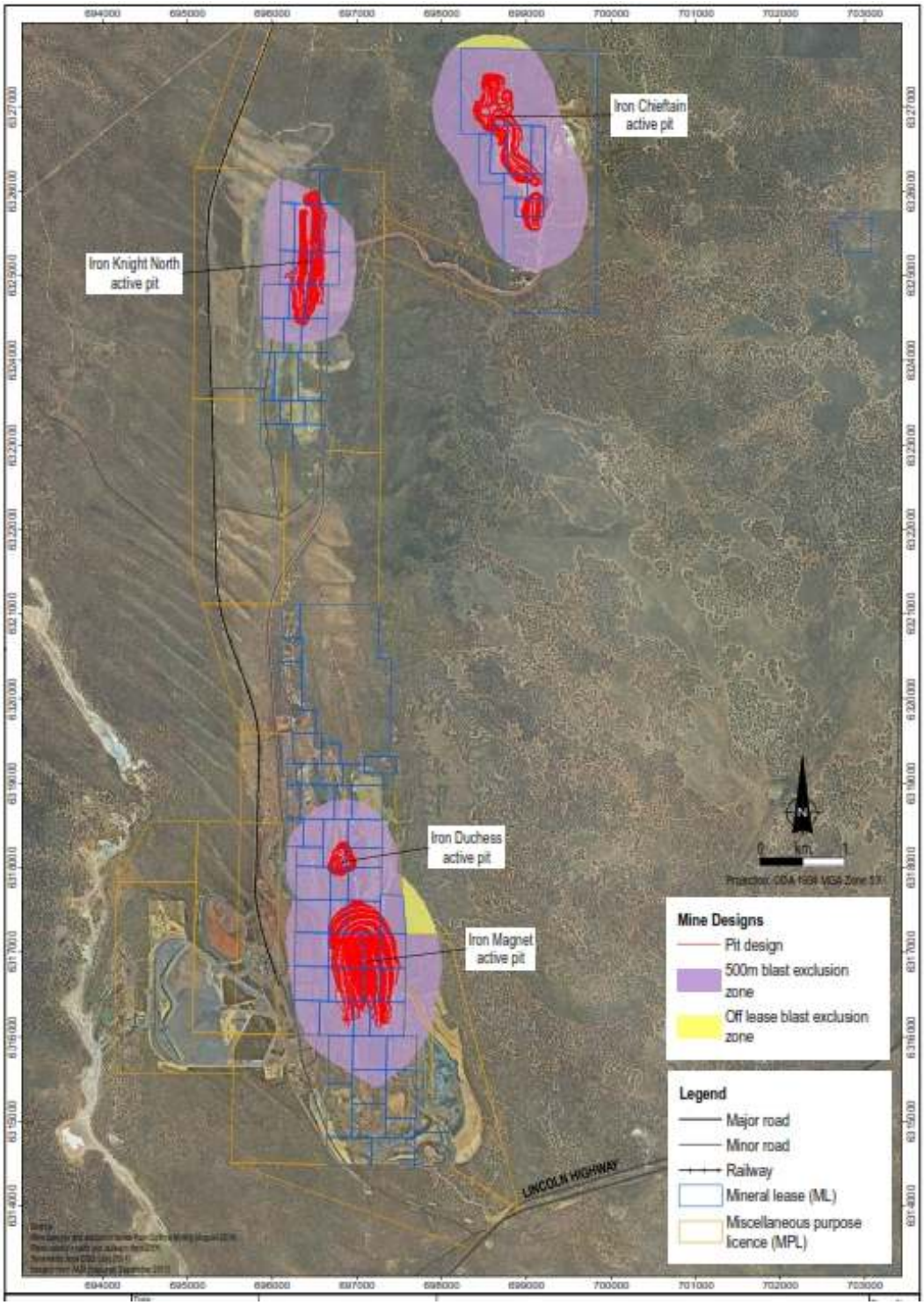


Figure 59 SMR blast exclusion zones

3.8.7 Dust management

Dust is a key environmental risk at mine sites that requires vigilant management and review.

Controls are applied to point sources (e.g. fixed plant) and fugitive sources such as roads.

A fugitive dust ranking (FDR) procedure is used to identify problem areas, and implement control measures according to the levels of dust occurring.

Water spray 'cannons' can also be used during some conditions.

Haul roads and hardstand areas

Up until 2011 all road surfaces were treated with water only. From 2011 a chemical dust suppression product was progressively introduced to all haul roads resulting in more effective and consistent dust control.

Recovered water from TSF operations is used for road dust suppression, and is distributed by standpipes and water trucks.

A magnesium chloride product is mixed with water and applied to haul roads and hardstand areas to further control dust generation.

See Section 3.12.4 for details of water use for dust suppression on haul roads and hardstand areas.

Processing plant

The fixed crushing and screening facilities at Iron Duke, and the auxiliary modular facilities at Iron Knight are fitted with dust suppression equipment, which is reviewed regularly to ensure systems are correctly maintained and optimised to minimise dust generation.

A trial 50 kt/month auxiliary screening operation at Iron Duke is managed by a dedicated water truck with sprays, soon to be replaced by a 80 kt/month screening unit with built-in dust suppression equipment.

Plant feed stockpiles and work pads are regularly conditioned by water truck sprays as required.

All operations are managed under the FDR protocol, described below.

Fugitive Dust Ranking Procedure

The FDR procedure (ARI reference QP50_68) provides a risk-based approach to management of dust emission levels across the SMR operations by providing a consistent targeted standard and system to identify and prioritise activities for control.

The FDR identifies four levels of dust emissions:

- FDR 0: low-level dust emissions. Dust is 90% transparent 50 m from the dust source (no impact)
- FDR 1: medium level dust emissions. Dust is 50% transparent 50 m from the dust source. Dust plume remains within the work area.

- FDR 2: high-level dust emissions. Dust is 25% transparent 50 m from the dust source (vision is partially obscured, discomfort to operators and impact to vegetation is likely). Visible plume leaves the work area and moves toward the tenement boundaries.
- FDR 3: very high-level dust emissions. Dust has very low visibility/transparency 50 m from the dust source (vision obscured, high level discomfort to operators and high impact on vegetation). Visible dust plume is seen to leave the mining tenements and moves toward residences or sensitive vegetation receptors.

The targeted emission level for all mining operational and construction sites is FDR1 or lower. SMR operations and construction activities are remote from communities. However high dust levels will raise safety concerns, impact on native vegetation, and increase the likelihood of third party complaints. Dust controls are implemented to achieve the targeted FDR.

The FDR table is provided as Figure 60.

All mine site personnel are trained in the FDR procedure and levels of responsibility are clearly outlined in the training and aligned with QP50_68.

FUGITIVE DUST RANKING – ARRIUM MINES (QP50.68 Att A)

FDR	Assessment			Controls	Reporting
	1. Impact	2. Roads / Vehicle Movement	3. Material Processing (Crushing & Screening / Mobile Plant)	Note: Refer to the site EMP.	Environment Incident reports. Safety Incident reports
FDR 0	**Acceptable emissions** Dust is 90% transparent 50m from the dust source			**Ensure adequate EMP controls are in place, think ahead.**	*None required*
FDR 1	**Localised impact that warrants control measures** Dust is 50% transparent 50m from the dust source Dust plume remains within the work area			**Notify your Supervisor.** **Escalate EMP dust control measures to the required level immediately**	*Record Actions in Shift Log.*
FDR 2	**Potential safety hazard/environmental impacts** Dust is 25% transparent 50m from the dust source Vision partially obscured Discomfort to operators Visible plume leaves the work area and moves toward the tenement boundaries			**Notify your Supervisor.** **Escalate EMP dust control measures to maximum immediately**	*Report an incident only if continuing without controls*
FDR 3	**Definite safety hazard/Environmental harm** Very low transparency 50m from the dust source Vision obscured High level discomfort to operators Visible dust plume is seen to leave the mining tenements and moves toward residences or sensitive vegetation receptors			**Stop activity**	*Incident report within 24 hours*

Figure 60 SIMEC Mining FDR procedure (QP50_68)

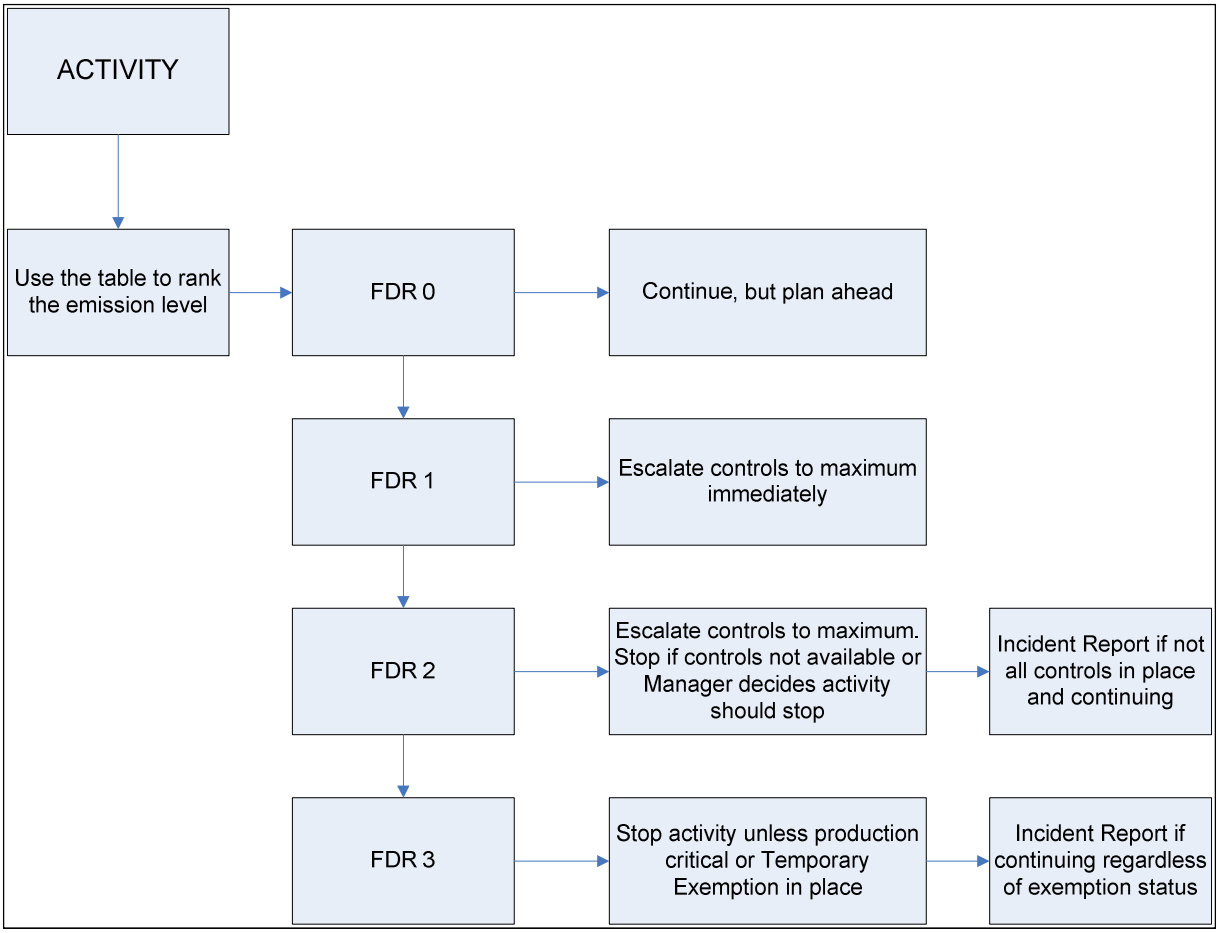


Figure 61 FDR procedure actions diagram

Dust monitoring

Dust deposition trend monitoring is measured at a number of locations in the S-SMR as shown on Figure 62 (and Appendix A-9).

SIMEC Mining predominantly uses dust deposition gauges (DDGs) located very close to operations, and directional dust deposit gauges (DDDGs) positioned further from operations, (e.g. on properties owned by adjacent landholders).

This approach allows SIMEC Mining to focus on dust deposited on a vertical surface from the direction of interest. The amount of dust deposited in this manner would be expected to exceed the amount of dust that might fall on a horizontal surface (a funnel collector) because it includes finer dust that otherwise may still have been in the air column.

By their nature, DDGs are not highly accurate measurement tools predominantly due to the required sampling frequency and weather conditions resulting in significant variation on a month-to-month basis. Nonetheless DDGs and DDDGs are useful tools for monitoring annual trends.

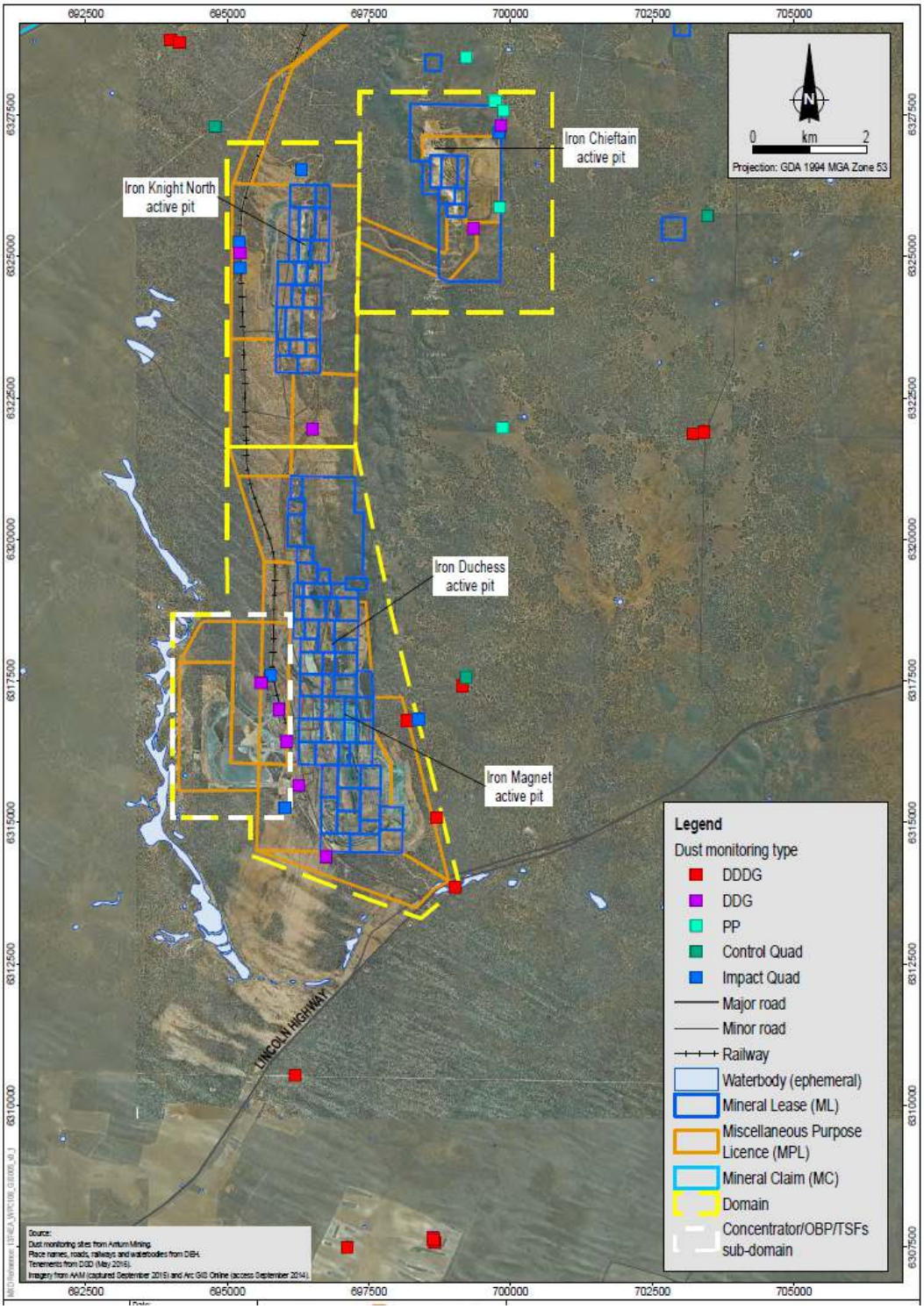


Figure 62 SMR dust-monitoring locations (indicative)

SIMEC Mining has now extended the use of a technique developed for dust assessment in the Whyalla community to characterise deposited dust in the SMR to enable further interpretation of dust trends. Samples are weighed, and analysed using XRD from which the percentage, mass and volume of each mineral present can be determined. The use of vertical dust collectors has been adapted to maximise the volume of sample collected to focus on dust from the direction of interest. This data is useful to enable assessment of trends over time.

3.8.8 Stormwater and drainage management

The WRDs will be contour-ripped or seed boxed to minimise stormwater runoff, and will be designed to retain stormwater on the dumps, to be dispersed via slow release into the topsoil vegetated zone, or lost via evaporation.

Channels will be constructed around the base of the storage facilities to collect any runoff and manage erosion on the storage facilities (i.e. WRDs, LGO stockpiles and topsoil stockpiles). The faces will be graded towards the final pit voids to direct any runoff to the open pits.

Shallow channels will be graded to direct water in a manner that minimises the likelihood of sheet erosion during significant rainfall events.

Vegetation cover will be retained for as long as possible to minimise the area of exposed soil on topsoil stockpiles that could be eroded by stormwater runoff.

Silt traps will be installed at strategic locations and will be monitored for sediment build-up after rainfall events.

Mining in the northern extension of the Iron Chieftain pit will intercept minor ephemeral flows from higher up the ridge that would have flowed down the foot slopes and been dispersed onto the plain. As required under Section 127 of the *Natural Resources Management Act 2004* (NRM Act 2004) a water affecting activity (WAA) permit has been granted for this activity.

Figure 63 (and Appendix A-10) shows the surface water drainage channels and the location of silt traps.

Iron Duchess

The Iron Duchess WRD is planned to be built in the northern part of Death Adder Valley confined on the east and the west by the ridges, and to the south by the central saddle and the existing DW18 WRD. During operations and post closure the northern end of the WRD will provide the only sloped faces (see Figure 64 and Appendix A-11). Stormwater will be retained on the flat WRD top by containment bunds and allowed to seep into the near surface store prior to being released by evaporation or directed into the Duchess pit storage for use as process water and dust control water. Stormwater runoff from the northern faces will be diverted via toe drains to a silt trap for cleaning prior to being released to the Death Adder Valley drainage channels (see Figure 64).

The WRD and pit do not intercept any of the existing drainage channels.

The ex-pit offsite, ex-pit trapped and the in-pit storm water volumes have been calculated for the ARI 5 to 100 year, 24 hour and 72 hour events (see Table 19 and Table 20).

Table 19 Iron Duchess North stormwater runoff calculations- 24 hour ARI

Catchment	Area (m^2)	Captured coefficient	Average runoff coefficient	5 yr	10 yr	20 yr	50 yr	100 yr
DAV North catchment	2,738,000		0.15	20617	24929	30761	39427	46902
Ex-pit offsite								
WRD faces	220,230		0.2	911	1374	1999	2928	3730
Ex-pit trapped								
WRD top	459,700	1	0	23077	27904	34432	44131	52498
Silt trap				1300	1300	1300	1300	1300
Total				24377	29204	35732	45431	53798
In-pit								
Duchess pit	395,560		0.65	12907	15607	19258	24683	29362

Table 20 Iron Duchess North stormwater runoff calculations- 72 hour ARI

Catchment	Area (m^2)	Captured coefficient	Average runoff coefficient	5 yr	10 yr	20 yr	50 yr	100 yr
DAV North catchment	2,738,000		0.15	25422	30474	37250	47600	56184
Ex-pit offsite								
WRD faces	220,230		0.2	1426	1968	2695	3805	4725
Ex-pit trapped								
WRD top	459,700	1	0	28455	34110	41695	53279	62887
Silt trap				1300	1300	1300	1300	1300
Total				29755	35410	42995	54579	64187
In-pit								
Duchess pit	395,560		0.65	15915	19078	23320	29800	35173

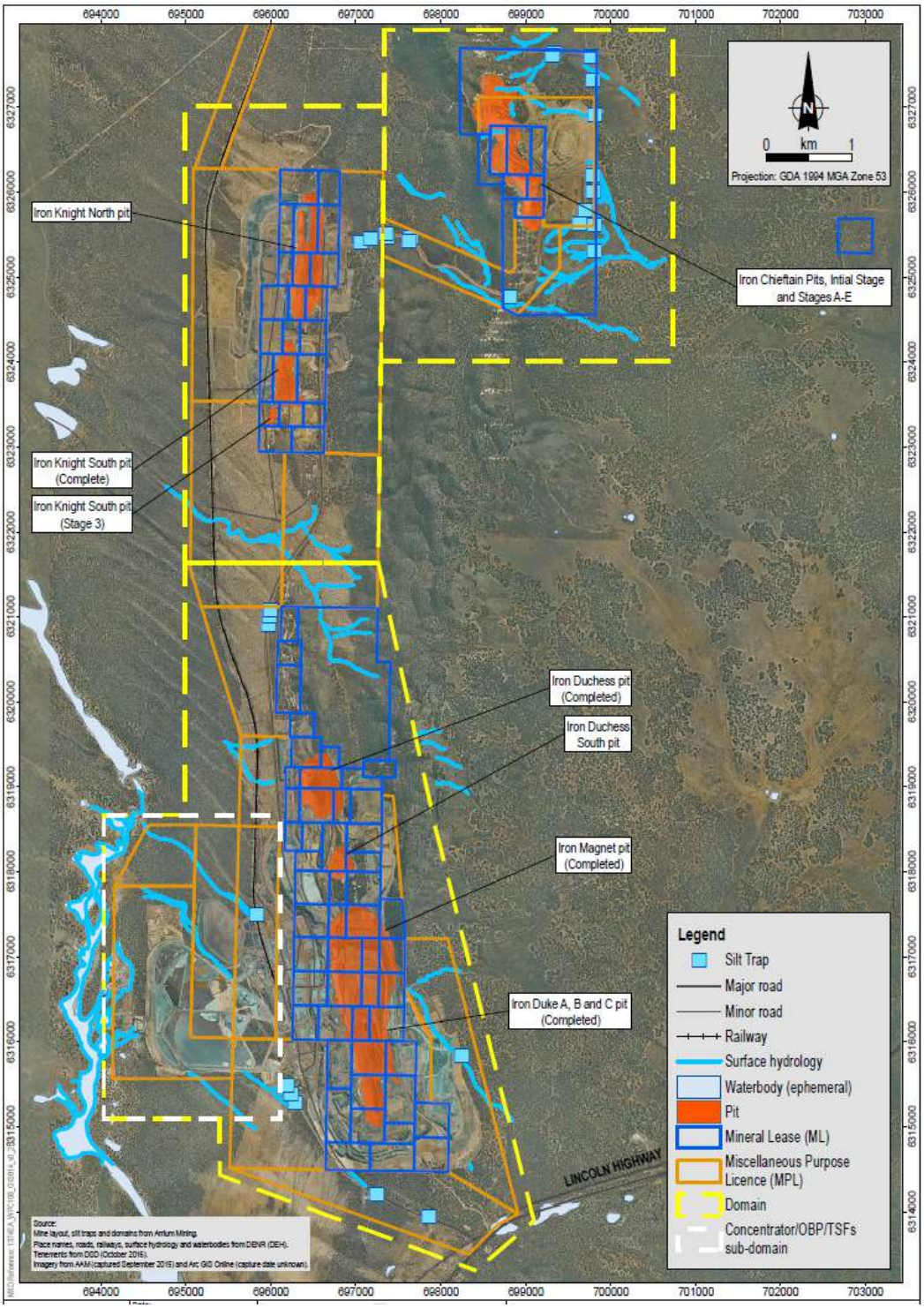


Figure 63 SMR surface water drainage channels and silt traps (indicative)

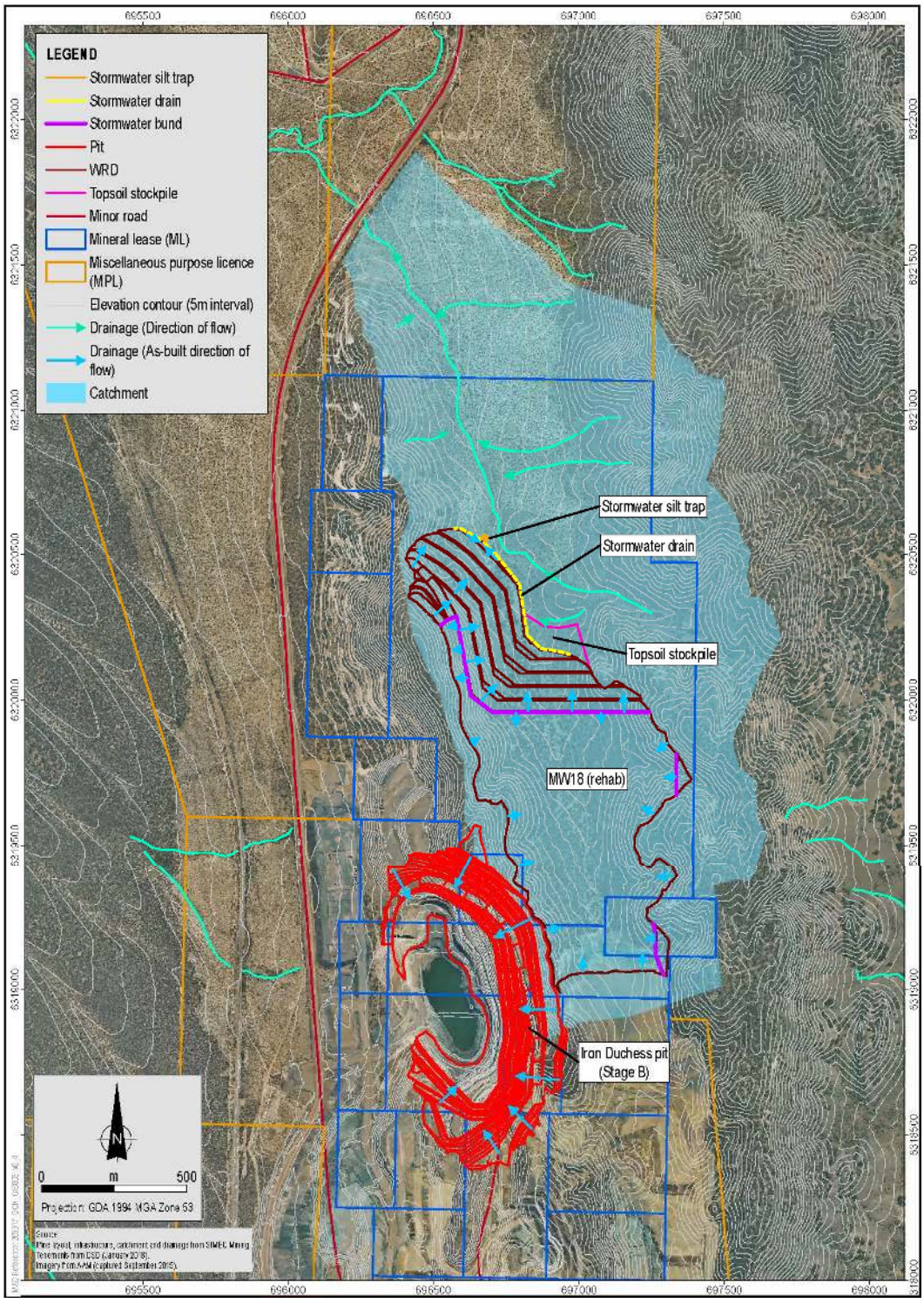


Figure 64 Iron Duchess North surface water drainage channels and silt traps (indicative)

3.8.9 Mine pit dewatering

Iron Chieftain pit

Inflows of water into the pit are not expected to require ongoing dewatering as the SMR region has relatively low rainfall, and the host material is relatively porous.

Any excess water that may pool in the pit during an extreme weather event can be diverted to the lowest available portion of the pit and allowed to dissipate naturally through evaporation or seepage.

Pooled water may also occasionally be decanted by mobile pumps and used for dust suppression.

Iron Knight pit

Stormwater accumulates in the Knight North pit. This pit is dewatered to enable mining of the lower benches. Dewatering is carried out by the use of sumps and mobile pumps to extract the water from the pit. The water is used for dust suppression.

Iron Duchess pits

The completed Duchess North pit is currently used as a water storage facility, and holds approximately 440 ML of reclaimed process water, which is transferred to the pit via pumps and pipelines from the process plant area. This water is reused for dust suppression (refer to Section 3.12.4 for further water usage details and Section 3.5.2 for detail on Duchess Pit water storage). The development of the Duchess North Stage B pit will not affect the current water storage facility.

The Duchess South pit is expected to remain dry.

Iron Duke pit

Stormwater accumulates in the Iron Duke pits. This is dewatered via the use of sumps and mobile pumps and the water is used for dust suppression.

Iron Magnet pit

Surface water and groundwater within these pits is controlled with sumps and mobile pumps. Sumps and normal dewatering practices will be used to control the groundwater in Mag C pit.

3.8.10 Product stockpiles

Stockpiles located on the mining tenements include those for:

- high-grade ore (HGO)
- medium- and low-grade ore (MGO and LGO)
- low-grade diluent ore (LGD)
- mineralised waste (MSW).

High-grade and medium-grade stockpiles are continuously built and reclaimed on the ROM pads to feed the processing plant or for blending into direct shipping streams.

The product stockpiles are generally located close to the ROM pads for future reclaim and blending or processing purposes. Table 21 provides the SMR product stockpile dimensions and capacity.

The stockpiles are constructed for safe and efficient reclamation. Front-end loaders are used to reclaim material from stockpiles and load trucks or trains. A face height of 10 m is set as the maximum safe working height for a stockpile based on safe heights for rilling of ore. Stockpiles are allowed to rill at a natural angle of approximately 37 degrees.

The dimensions and capacity of the SMR stockpiles is summarised in Table 21.

Table 21 SMR product stockpile dimensions and capacity

Stockpile	Height (m)	Footprint (ha)	Capacity (M LCM)
Iron Chieftain mineralised waste 1	45	10	2.4
Iron Chieftain low grade	33	7	0.9
Iron Chieftain mineralised waste 2	17	7	0.8
Iron Chieftain low grade diluent	35	14	
Iron Knight North KL07 low grade	25	3	0.3
Iron Knight North KL14 low grade	25	9	0.6
Iron Duchess DCDU05 low grade		2	0.6 (estimated)
Iron Duchess DCDU06 low grade		8	2.0 (estimated)
Iron Duke IDDU05 low grade		5	1.0 (estimated)

The ROM product stockpiles at the SMR operations vary significantly due to the following:

- actual ore presentation in the pit
- processing requirements and schedules
- rail capacity
- sales demand, and various other factors influencing volumes.

Table 22 provides an indicative ROM product stockpile capacity averaged over recent months.

Table 22 Indicative ROM product stockpile capacities

Stockpile	Average estimated running capacity (t)
Iron Chieftain ROM hematite high grade	27,000
Iron Knight North ROM hematite high grade	100,000
Iron Knight North ROM hematite low grade	20,000
Iron Duke ROM hematite high grade	100,000
Iron Duke ROM hematite low grade	15,000
Iron Duke ROM magnetite ore	650,000

Specific management measures used to minimise the impact of stormwater on stockpiles include:

- installation of separation drains around the edges of the stockpile areas to direct water runoff to sedimentation basins which allow filtration and percolation and avoid scouring from uncontrolled flows
- reducing the area of exposed soil to prevent erosion by stormwater
- maintaining vegetative cover for as long as possible.

Product stockpiles will be drawn down at the end of the LOM and the remaining areas will be prepared for closure in accordance with the closure plans in Section 8.

3.8.11 Topsoil and subsoil management

Topsoil and subsoil is progressively harvested and stockpiled as the WRDs and pits expand to minimise the area of exposed surfaces.

The soil stockpiles will be located at the toe or crest of a WRD lift where practicable or within the WRD footprint and then moved to the WRD faces for rehabilitation as required. Topsoil will be stockpiled uncompacted, to a maximum height of 3 m. The locations of the topsoil stockpiles will be mapped and monitored.

Stockpiled topsoil will be used on the lower slopes of WRDs to integrate the final landform and vegetation cover with the surrounding landscape.

Topsoil and subsoil materials are generally stored within the extents of the footprint of the final WRD design. In some cases, topsoils and subsoils are stored on the upper surfaces of completed WRD sections so as to minimise the need for additional vegetation clearance for stockpiling. This practice is currently evident in the Iron Magnet and Iron Duke area.

Figure 65 (and Appendix A-12) shows the locations of current topsoil and subsoil stockpiles throughout the SMR.

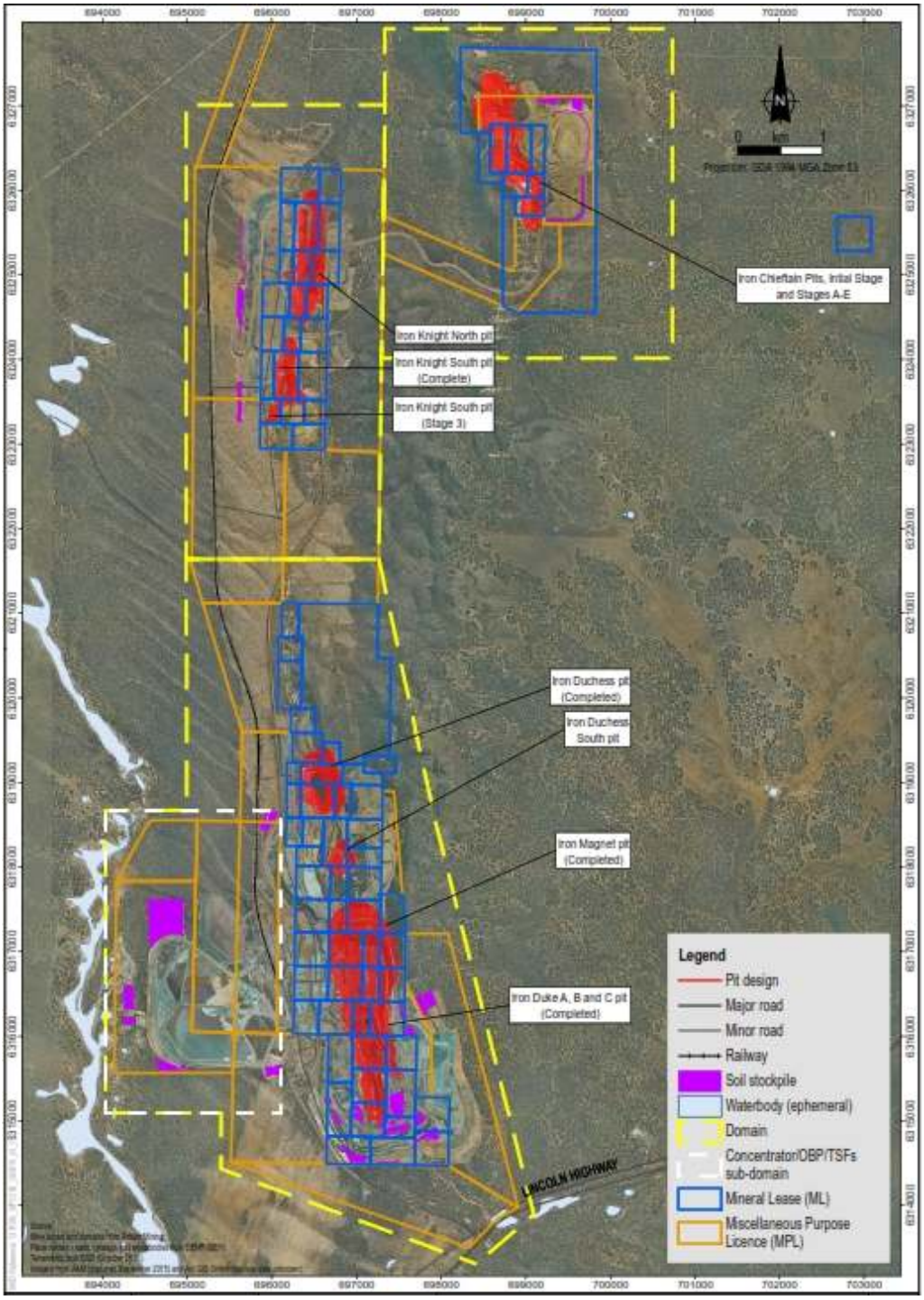


Figure 65 SMR topsoil and subsoil stockpiles

Stockpiles will be drawn-down for use in the progressive rehabilitation program, as described in Section 3.8.11. The remaining areas will be prepared for closure in accordance with the closure plans outlined in Section 8.

Table 23 and Table 24 identifies and quantifies the topsoil and subsoil stockpiles throughout the SMR.

Table 23 SMR topsoil stockpile ID's and volumes

Topsoil Stockpile ID	Volume (m^3)	Location
Top01	54,105	Iron Duke South WRD – DWS03
Top02	19,632	
Top03	26,928	
Top04	28,239	Iron Magnet WRD – MW06
Top05	25,330	
Top06	26,852	
Top07	30,021	
Top08	13,919	Iron Magnet South WRD – MWS03
Top09	8,390	
Top10	37,932	Iron Chieftain WRD – CW01
Top11	15,768	
Top12	14,444	Iron Magnet WRD – MWS03
Top13	1,520	Iron Duke WRD – DW03
Top14	6,069	
Top15	35,058	Iron Duke Magnetite Tails Dam
Top16	48,445	
Top17	19,498	
Top18	50,225	
Top19	481,889	
Top20	5,693	Iron Magnet WRD – MW06
Top21	12,522	
Top22	62,631	Iron Duke Tails Dam – OBP
Top23	51,114	Iron Knight WRD – KW01
Top24	40,251	Iron Knight South WRD – KWS01
Top25	2,578	Iron Knight WRD – KW01
Top26	2,917	
Top27	19,593	Iron Chieftain ROM Pad
Top28	36,750	
Total	**1,178,313**	

Table 24 SMR subsoil stockpile ID's and volumes

Subsoil Stockpile ID	Volume (m^3)	Location
Sub01	116,256	Iron Duke South WRD – DWS03
Sub02	4,343	
Sub03	13,039	
Sub04	39,631	Iron Magnet South WRD – MWS03
Total	**173,269**	

3.9 Crushing and Processing Operations

3.9.1 Iron Duke crushing and screening

The fixed plant crushing and screening plant processes ROM ore which is split into one of three products:

- -32 mm feed for the magnetite concentrator
- -32 mm LGO feed for the OBP
- lump and fines DSO hematite for export.

The facility consists of a ROM feed hopper feeding ore into the coarse ore bin (COB). Ore is transferred across an apron feeder that discharges over-size material into a double-toggle jaw crusher. Fines are screened after the apron feeder and bypass the crusher and feed directly onto the discharge conveyor.

The discharge conveyor takes the combined product to a scalping screen mechanism. Over-size material is scalped and conveyed to the secondary crushing station. Fines product is directed to the product stack-out system, or re-combined with the mid-size product that bypasses the secondary crusher.

The secondary crusher product combines with the tertiary crushing product. The product is then transferred to the screening station and either delivered to product stackers or returned to the tertiary crusher if over-sized.

There are sampling stations at both the discharge points from the crushing circuit; i.e. at the product stack-out conveyor and the new radial lump stacker.

Design capacity of the crusher is nominally 9.5 Mtpa.

Refer to Appendix E1 to E3 for layouts and the process flow diagram (PFD) of the Iron Duke crushing and screening facilities.

3.9.2 Iron Knight crushing and screening

There are two crushing and screening stations at the Iron Knight crushing and train loading pad. Knight-1 was commissioned in early 2011, and Knight-2 was commissioned in late 2013. Both of these facilities are operated and maintained by Bis Industries.

These facilities currently process a total of around 350–400 kt/month of lump and fines products.

Figure 66 and Figure 67 show the process flow diagrams for the Knight 1 and Knight 2 crushing and screening facilities.

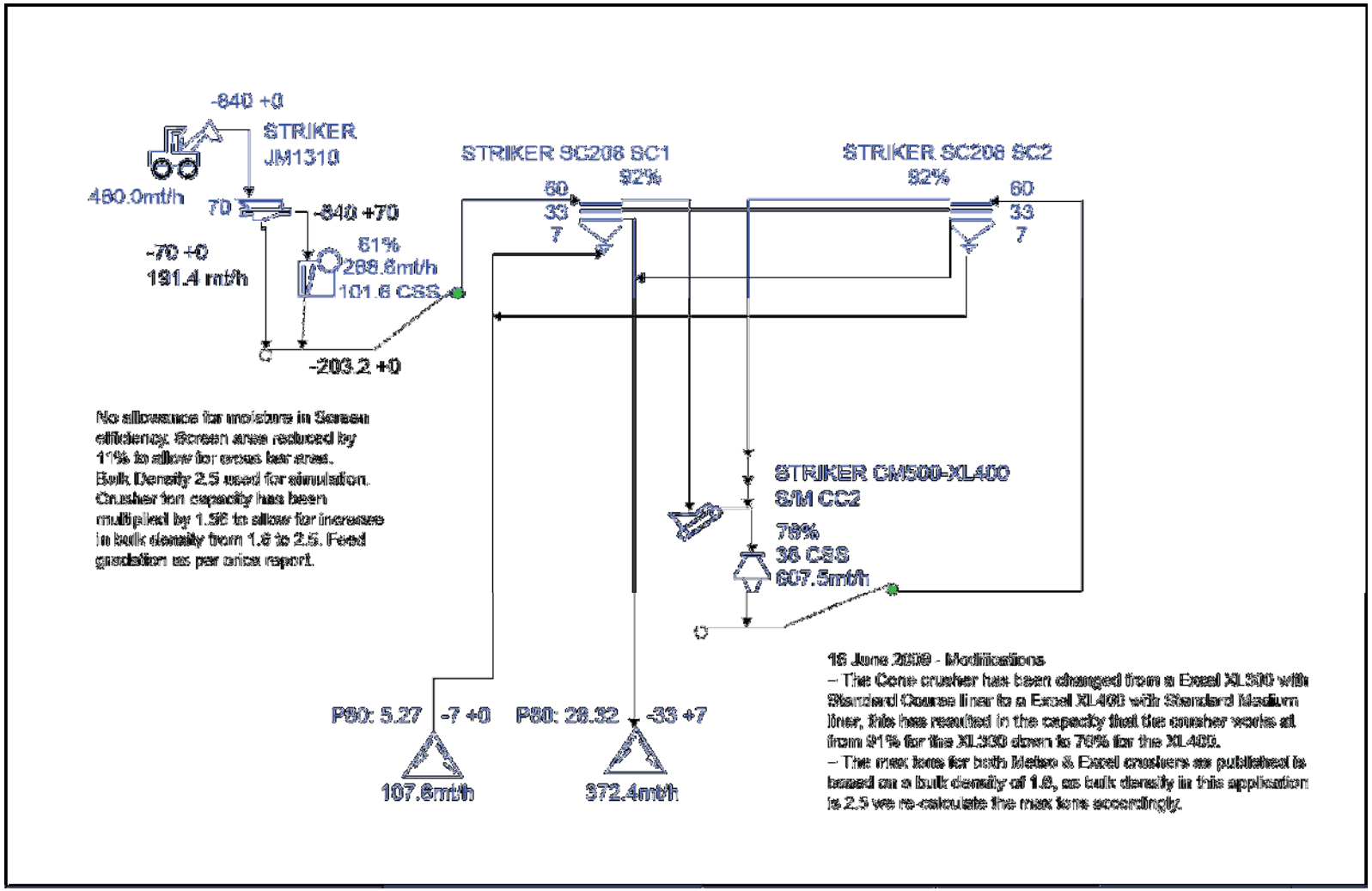


Figure 66 Knight 1 - Crushing and screening process flow diagram

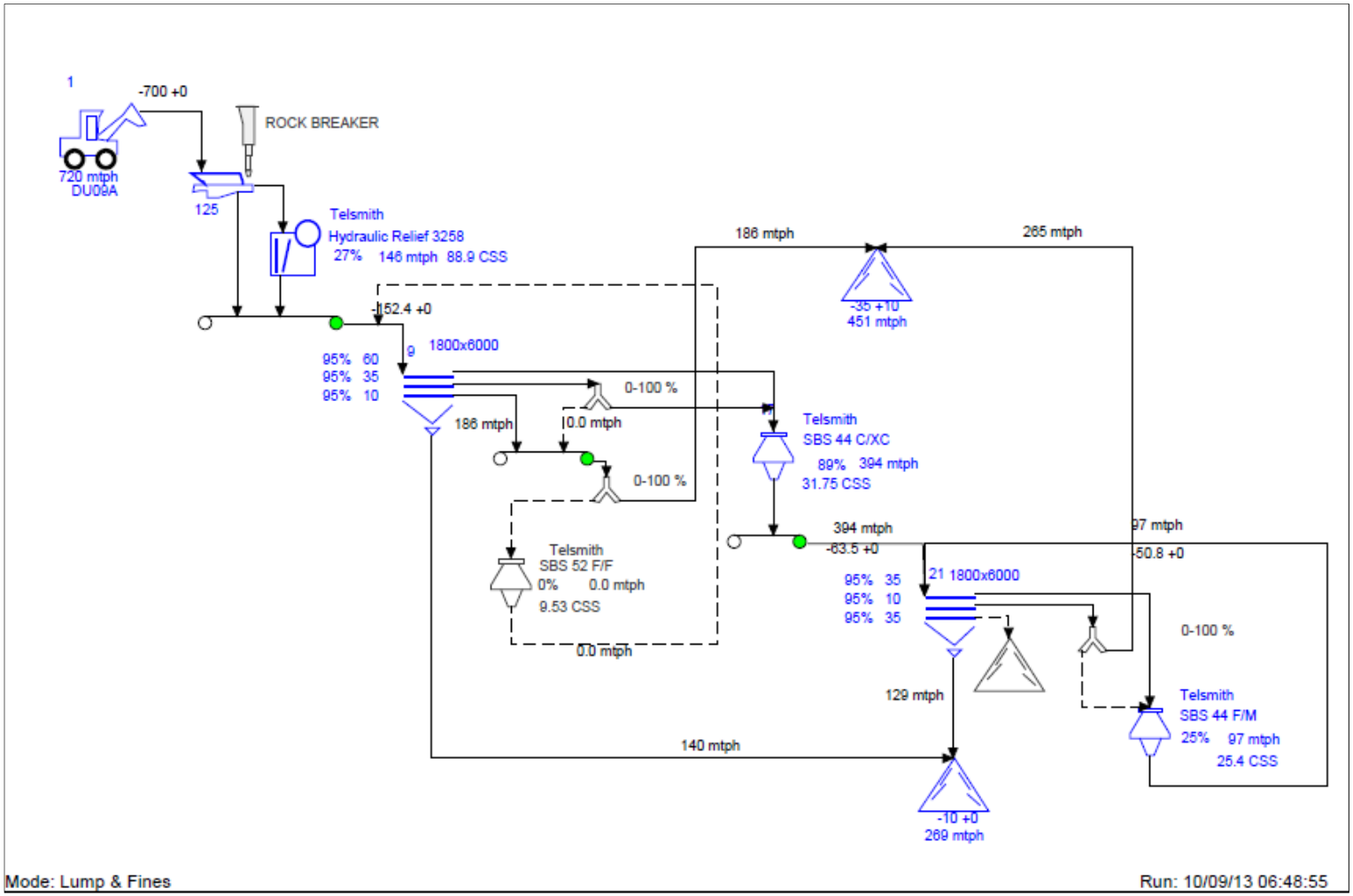


Figure 67 Knight 2 - Crushing and screening process flow diagram

3.9.3 Ore Beneficiation Plant (OBP)

The hematite OBP is designed to upgrade low-grade hematite (i.e. 47 to 53% Fe) to a high-grade (i.e. 62% Fe) lump and fines products for export.

Process description – OBP

Beneficiation feed ore (-31.5 mm) is reclaimed and discharged into a mobile feed hopper. The feed hopper feeds onto the reclaim conveyor to feed the beneficiation plant. The reclaim conveyor discharges onto a vibrating separating screen, which separates the lump (-31.5 mm +6.3 mm) and the fines (-6.3 mm) from the feed ore. Both the lump and fines are directed to separate jig feed bins.

The lump conveyor discharges to a vibrating de-sliming screen where sprays wash the -1 mm material out of the lump.

The lump jig separates the lighter reject material from the beneficiated lump ore, and the reject material passes over the end of the jig to the lump reject dewatering screen. The beneficiated lump ore is drawn out of the hopper of the jig and dewatered on the lump ore product-dewatering screen. The dewatered lump ore is transported by belt conveyor to a sample station. The lump ore product is stacked in two or more stockpiles for dewatering.

The fines conveyor discharges to a vibrating desliming screen where sprays wash the -1 mm material out of the fines. The -1 mm material reports to the cyclone feed sump, while the fines (-6.3 mm +1 mm) flows to the fines jig.

The fines jig separates the lighter reject material from the beneficiated fine ore, with the reject passing over the end of the jig to the fines reject dewatering screen. The beneficiated fine ore is drawn out of the hopper of the jig and dewatered on the fines product-dewatering screen. A belt conveyor transports the dewatered fine ore to a sample station. The fine ore is stacked for dewatering.

The -1 mm material is pumped to desliming cyclones. The overflow from the cyclones, containing mostly -0.075 mm material reports to a thickener, while the underflow, containing -1 mm +0.075 mm material, reports to the primary spirals.

Work in 2011-12 indicated significant advantages in installing a three-stage spiral circuit instead of the single stage spiral circuit installed. The spirals concentrate gravitates to a vacuum belt filter for dewatering and the spiral reject reports to the thickener. The spiral middlings reports to the spiral middlings sump. A pump transfers the spiral middlings to secondary spirals, from which concentrate, middlings and reject report to the vacuum belt filter, spiral middlings sump and thickener respectively. The vacuum belt filter discharges dewatered cake to the fines belt conveyor ahead of the fines sampling station.

The tails thickener dewaters the solids for transport to the tailings dam, and clarifies the overflow water for reuse within the plant. A flocculent is added to the thickener feed to assist with solids settling. The thickener overflow gravitates to the clarified water tank.

Tailings are withdrawn from the thickener and pumped as slurry to the tailings storage facility, which is located to the west of the western rail line. The supernatant from the tailings collects on the lower, western side of the dam and is recovered and pumped to the clarified water tank for reuse in the beneficiation process.

The site layout and process flow diagrams are provided in Appendix E4 to E6.

Iron Duke OBP tailings retreatment project (ID-OBP-TRP)

The Iron Duke hematite tailings retreatment project (ID-OBP-TRP) was initiated in 2012, and is still to be progressed.

During August 2014 all OBP tailings were diverted to a modified magnetite concentrator TSF (see magnetite concentrator TSF description below).

Detailed studies are underway to assess the commercial viability of retreating the existing OBP tailings in the TSF. This evaluation will conclude during the last quarter of 2014 and if positive will lead to the retreatment of Iron Duke OBP tailings from around August 2015.

Further details of the reclaim process, production rates, timing, potential impacts and closure plans will be issued to DSD in the form of a change notification once there is further definition and certainty about the project.

3.9.4 Magnetite concentrator

Original design (as commissioned 2007)

The original magnetite concentrator was commissioned in 2007. The design uses high pressure grinding rolls (HPGR) to reduce the ore size from 32 mm down to 0.7 mm by progressively recycling oversize material to the rolls after wet screening and magnetic removal of ground magnetite. The first screening takes place at 3 mm; the +3 mm material is recycled and the -3 mm material is subjected to rougher magnetic separation (RMS). The tailings are rejected from the plant at this first stage of magnetic separation. The magnetite concentrate is rescreened at 0.7 mm with the oversize being recycled and the undersize passed to the ball mill for further grinding.

At the ball mill the incoming material is mixed with the ball mill discharge and pumped to a set of cyclones with a P80 cut point of 38 micron. The cyclone underflow is recirculated to the ball mill and cyclone overflow enters the de-slime thickener which is sized to dewater the magnetite while slimes are removed with the thickener overflow.

The thickener underflow is diluted to the required density and pumped to the cleaner magnetic separators (CMS). The final grade concentrate is produced at the CMS with three stages of cleaning and is then thickened to 70% solids before being pumped to the slurry pumping area for storage and pumping to Whyalla.

Tailings from the rougher circuit are cycloned to separate the coarse and fine fractions. The coarse underflow is dewatered and trucked to the tailings dam for wall building. The fines tails are thickened in the tailings thickener and pumped to the tailings dam.

Modified concentrator design

The magnetite concentrator has never achieved the design capacity of 1.8 Mtpa of concentrate. As a consequence, a modified concentrator circuit was successfully commissioned in November 2013.

The key points of difference between the 1.75 Mtpa flowsheet and the flowsheet presently in operation are:

- a screening stage has been removed
- tertiary grinding capacity has been added
- an additional screening stage has been incorporated to improve product quality.

Since November 2013 the concentrator has operated at a capacity of 2.0 Mtpa. Further debottlenecking of the concentrator is anticipated over the coming 12 months with a target output of 2.5 Mtpa of concentrate. Figure 13 in Section 3.2.3 shows the magnetite concentrator feed and production rates.

The site layout and process flow diagrams are provided in Appendix E7 to E9.

3.9.5 Concentrator pipeline corridor

A dual pipeline corridor traverses a number of existing MPLs (see Section 3.1) from the SMR mining area to the steelworks at Whyalla. The pipelines transport magnetite slurry from the SMR to Whyalla, and return water to the SMR operations. Following construction of the pipelines in 2005, the corridor has revegetated.

3.9.6 Tailings Storage Facility

Mineral processing at SMR

The SMR operations currently generate tailings through two separate processes:

- hematite ore is processed at the OBP and fine tailings from this ore stream have been deposited into the OBP TSF since 2004
- magnetite ore is processed in the concentrator plant and fine tailings from this process have been deposited into the magnetite TSF since 2007.

Coarse waste is also generated from both OBP and the concentrator plant. Coarse tailings from the OBP are used around the SMR mining operations for civil works such as road sheeting. Coarse tailings from the concentrator plant are stockpiled within the magnetite TSF and used in the construction of the magnetite TSF embankments.

An aerial view of the TSF site layout is shown in Figure 68.

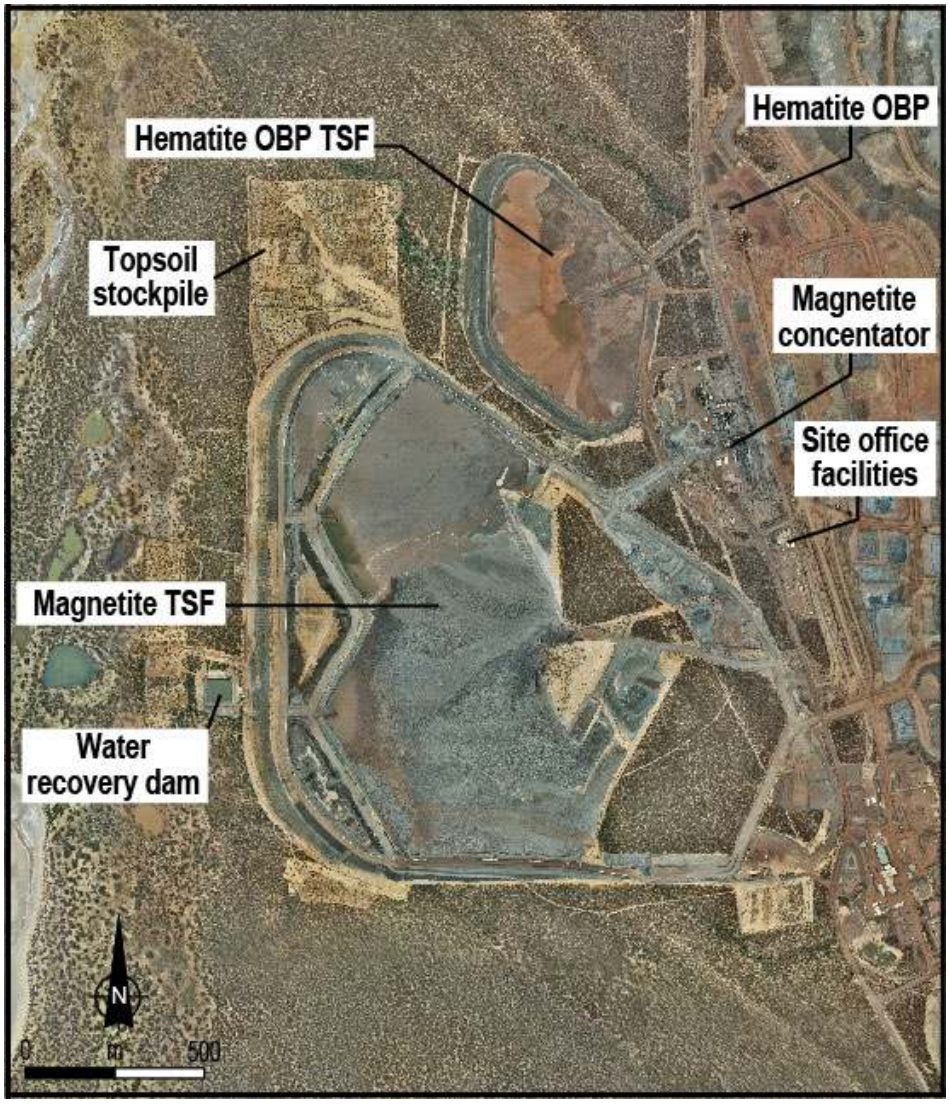


Figure 68 Tailings storage facilities – Aerial view of site layout, March 2014

Magnetite TSF operational background

Both the OBP and Magnetite TSFs were initially constructed using a central discharge and gravity decant system. The TSFs were originally designed with the intention that the decants may not be used on a long-term basis after the TSF was established. The density of tailings solids was expected to increase as high as 64% as the ore bodies being processed became less weathered with depth.

Due to mineralogy differences, the solids content of tailings entering the Magnetite TSF did not achieve the expected density delivering more water to the TSF than per the original design. This has required the decants to be maintained.

During subsequent development and re-engineering of the TSF, the Magnetite TSF has progressively transitioned to a perimeter discharge operation with gravity fed pump-out decants located along the internal wing wall embankment. The decant towers have been raised as the level of tailings has increased.

Embankment raises were planned to occur only in an upstream direction, however due to the amount of supernatant water and lower than expected tailings solids content, the internal wing wall has been raised upstream and downstream. The perimeter embankments and internal wing wall construction uses a combination of oxidised waste rock and coarse tailings, together with clayey sand from within the TSF footprint (Golder 2014b). An abutment has also been constructed on the western side of the wing wall for added geotechnical stability.

Following commissioning of the Magnetite TSF in 2007, an increase in groundwater levels was detected in groundwater monitoring wells immediately down-hydraulic gradient to the Magnetite TSF. Subsequent investigations by SIMEC Mining have proposed that seepage from the TSFs is contributing to localised groundwater mounding below and to the west of the TSF. In response to the rise in groundwater levels, a number of measures were initiated to reduce water seepage losses from the tailings facilities, including trialling polymer dosing of tailings at the Magnetite TSF.

The Magnetite TSF polymer dosing trial commenced in November 2013 following successful trials at the Iron Baron Mine (N-SMR). The benefit of direct polymer addition into the tailings discharge stream is increased water recovery from the Magnetite TSF, aided by reduced interstitial water in the settled tailings and steeper tailings beaching angles that leads to a smaller supernatant pond. The addition of polymer is intended to reduce seepage to groundwater from the TSFs by the increased recovery of water and the reduction in permeability of settled tailings.

SIMEC Mining commenced the Magnetite Expansion Project (MEP) in November 2013, concurrent with the polymer trial, which targeted an increase in the production of magnetite concentrate. As MEP production rates have increased, there has been a corresponding increase in magnetite tailings volume deposited in the Magnetite TSF with tailings tonnes per hour increasing by around 50% (Golder 2014c).

Planned tailings management at SMR

Golder Associates P/L (Golder) conducted an options assessment in 2013 (Golder 2013) to accommodate recent and proposed changes to SIMEC Mining's tailings management strategy at SMR.

A long-term tailings storage strategy was developed which proposed converting the Magnetite TSF into a perimeter discharge central decant facility (PDCD). Tailings deposition in a PDCD occurs from the perimeter embankments while a new centrally located pump-out decant will be constructed to capture supernatant water near the centre of the Magnetite TSF (Golder 2014d). A PDCD will maximise supernatant water recovery and minimise the loss to groundwater as seepage. Golder is currently undertaking the final phase (phase 7) preparation of a Master Plan to support the transition of the Magnetite TSF to a PDCD.

A new development in late July 2014 was the redirection of OBP tailings into the magnetite tailings run-down system, creating a new combined OBP/concentrator tailings stream. It is expected that future OBP tailings will continue to go to the magnetite TSF. Reprocessing of OBP tailings is currently being assessed, as outlined in Section 3.9.3.

Magnetite TSF conversion strategy

The Magnetite TSF conversion strategy (Golder 2014b) includes:

- progress conversion of the Magnetite TSF to a PDCD with embankment tailings discharge and a single, decant tower for water recovery
- raising the Magnetite TSF embankments to a proposed maximum elevation of RL 199 m, approximately 65 m above natural ground level to store the target tailings volume for the life of the facility.
- progressively directing the pond away from the embankments towards the centre of the TSF. This will establish the decant pond over the low permeability tailings where it will be maintained for the remaining life of the facility. The existing gravity decants will be decommissioned by sealing the gravity outfall pipes and grouting the concrete decant rings to prevent ingress of supernatant water developing preferential seepage flow paths.

The conversion strategy has seven phases, which are described below.

Phase 1

Preliminary works to design and initiate construction of the northern embankment raise have been completed.

Phases 2 to 6

Between November 2013 and February 2014, SIMEC Mining undertook construction works at the Magnetite TSF to begin the conversion of the TSF to a PDCD. This work involved several stages:

- Northern Embankment Raise (Phase 2)
- Southern Toe Buttress (Variation)
- Northern Void Pump-out Decant (Phase 3)
- Central Void Pump-out Decant (Phase 4)
- Southern Void Pump-out Decant (Phase 5)
- Southern Embankment Raise (Phase 6)

Phase 7

The intention of the Master Plan (Phase 7) is to manage tailings storage at the Magnetite TSF over five years, beginning March 2014, which requires a progressive lift of the Magnetite TSF embankments to RL 172 m to provide adequate storage capacity for the period. A proposed sequence for Master Plan construction activities is provided in Appendix F.

The ultimate goal of the design is to achieve a continuous perimeter embankment at a constant elevation and a centrally located supernatant pond reporting to the central pump-out decant. This will enable an even distribution of tailings around the entire perimeter of the Magnetite TSF, maintaining the decant pond over low-permeability tailings and away from perimeter embankment walls, thereby reducing seepage.

The Phase 7 design is divided into six raises of 3 m each on the western Magnetite TSF embankment. Corresponding raises will be undertaken on the northern and southern embankments matching the elevation of the western embankment. Figure 69 shows the location of Magnetite TSF embankments and tailings deposition strategy at the end of Year 1. As the embankment walls have differing base elevations, less material will be required on the northern and southern areas to keep level with the western (down-gradient) embankment crest.

The design allows for tailings deposition to cycle between each of the embankment raises to facilitate progressive construction and will also allow for increased drying time for tailings beaches. Maintaining shallow layers of tailings with adequate drying time between deposition cycles is critical to achieving the design density and shear strength of the tailings surface (Golder 2014d).

The embankments will be constructed using a combination of locally sourced, natural ‘clayey sand’ (designated ‘Material D’ in the Master Plan Technical Specification), supplemented by coarse tailings (Material A) and fine magnetite tailings (Material B). The yellowish-brown clayey/silty sand will be extracted from two borrow pits shown within the Magnetite TSF footprint (Figure 69). The material is overlain by dune sand that is not suitable as a construction material because it lacks fines. The construction contractor will physically separate the construction material and the dune sand. Oxidised mine waste (Material C) will be used for the central access causeway, embankment platforms and as an erosion protection layer on the down gradient embankment faces.

Supernatant water will initially be managed from the two existing gravity decants in the primary Magnetite TSF deposition basin and three recently constructed pump-out decants in the western wing wall voids. Subsequently, an additional pump-out decant (Central Decant 1) central to the Magnetite TSF will be incorporated for the removal of supernatant water, as shown in Figure 69.

The existing wing wall gravity decants will be decommissioned as the supernatant pond moves toward the planned central decant, while the western void decants will be retained until new ‘intermediate’ decants are installed at the toe of the tailings slope propagating from the western embankment. This will occur once the western voids are filled with tailings. Two additional decants (Central Decant 1 and 2) will ultimately be constructed in the primary Magnetite TSF basin to recover supernatant water as the pond moves east of the wing wall separating the western voids from the main basin (Golder 2014d). These two additional central decants are expected to be in place by the end of Year 4 of the master plan, and are shown conceptually in Figure 70.

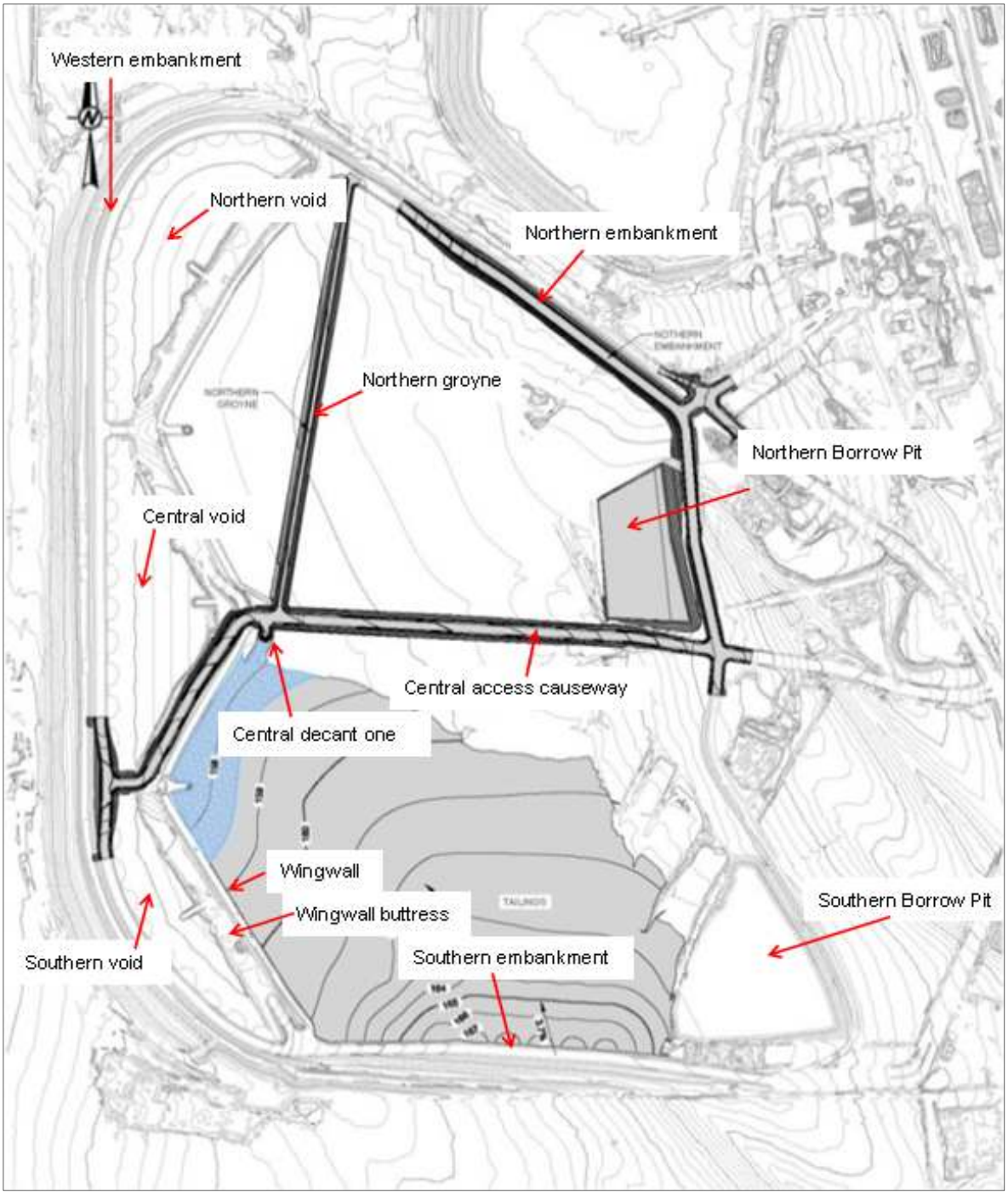


Figure 69 End of Year 1 of the Master Plan (Golder 2014b)

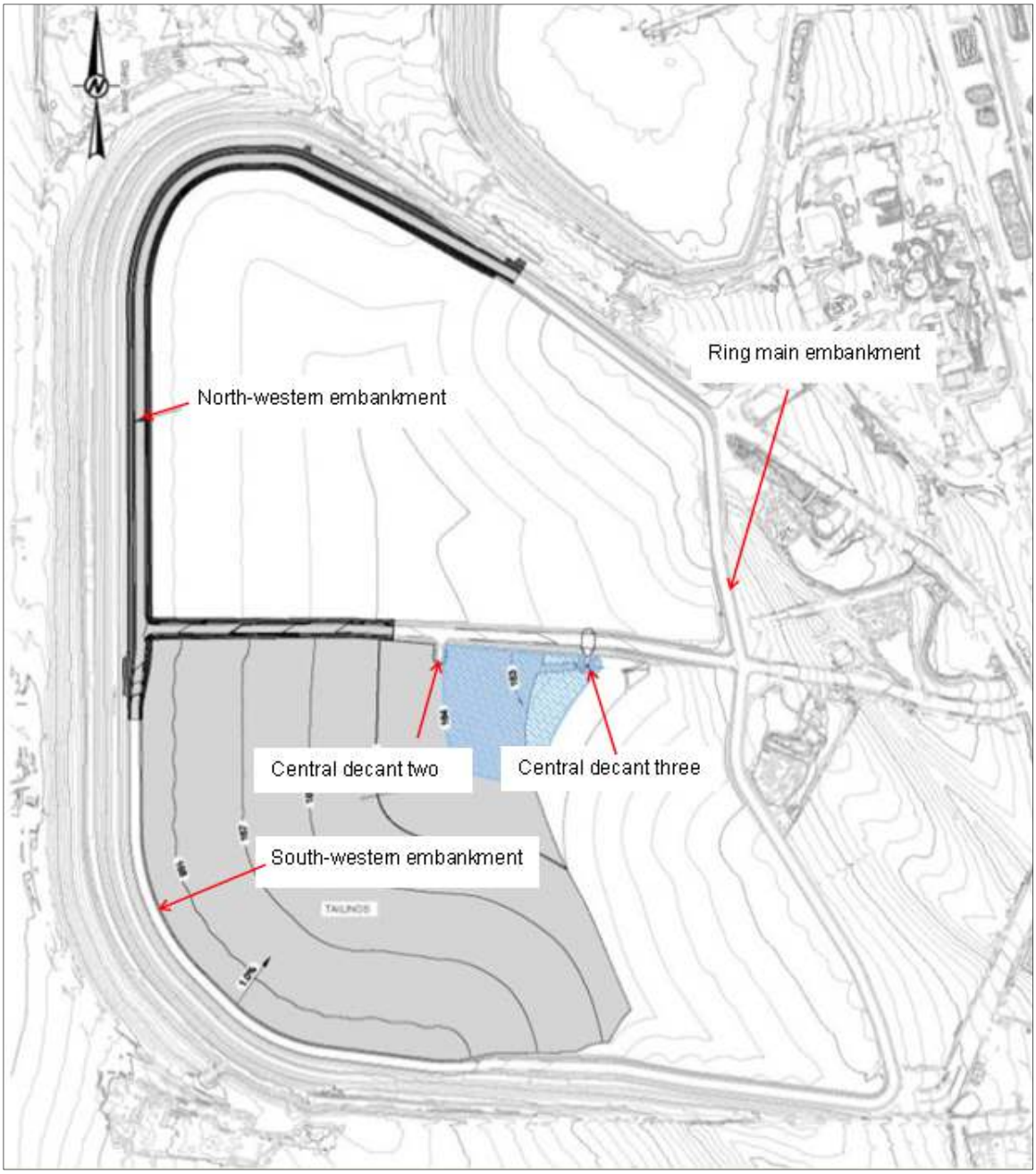


Figure 70 End of Year 4 of the Master Plan (Golder 2014b)

Master Plan staged approach

Tailings deposition will be cycled around construction activities in order to achieve the Magnetite TSF Master Plan outcomes. The timing presented for strategic deposition of tailings from each perimeter embankment is approximate timeframes and adjustments will be made based on field observations (see Appendix F).

TSF management objectives

There are three key tailings management objectives for the Magnetite TSF:

- Dry density/moisture content of tailings – the dry density and moisture content of the tailings is a critical aspect of the design because it affects shear strength and construction schedules will be delayed if target levels are not reached. Furthermore if the settlement density of tailings is not achieved then it will affect the storage capacity and further embankment raises may be needed in the future.
- Beach slope – in-line polymer dosing at the Magnetite TSF has been used continuously since November 2013 and has enabled the development of increased tailings beach angles at the point of deposition. Up to 3.7% beach slope can be achieved with polymer dosing, whereas beaching angles of only 1% can be achieved without polymer dosing. The Magnetite TSF Master Plan proposes a beach slope of 3.7% for the first 100 m from a spigot discharge point, with the beach slope flattening out to 1% closer to the decant pond. Operators will need to monitor beach slopes to ensure an even distribution of tailings and to maintain freeboard at the embankments.
- Return water clarity – the use of polymer dosing at the tailings discharge points is highly effective at separating solids from suspension, thereby improving the clarity of supernatant water returning to the raw water circuit for plant use. Removing water is a key management strategy to reduce seepage to groundwater from the Magnetite TSF and, as a consequence, it will be important to monitor polymer treatment and return water clarity to reduce the residence time of the supernatant water in the Magnetite TSF.

Magnetite TSF operation

The original Magnetite TSF design proposed that tailings from the magnetite concentrator would initially be at 58% w/w solids and subsequently progress up to 64% solids as the ore bodies being mined became less weathered with depth (Coffey Geosciences 2006).

The current tailings solids concentration delivered to the Magnetite TSF is between 43%-48%. This is within the operating range of both the thickener and underflow pumps and forecast tailings solids for the next five years are expected to remain below 52% (Golder 2014c). As a result of the lower solids content of tailings there will continue to be a higher proportion of water entering the Magnetite TSF than intended in the original design. Timeframes for decommissioning current decants will take this into account.

For TSF design purposes, an average stored dry density value of 1.6 t/m^3 was applied for the combined (OBP and Magnetite Concentrator) tailings. This dry density figure infers a design storage capacity for the Magnetite TSF of 42.3 Mm^3, accommodating LOM tailings of 67.6 Mt (Golder 2014a).

Magnetite TSF tailings deposition strategy

The projected total quantity of each tailings stream over the remaining LOM will be 6.2 Mt of OBP tailings and 61.4 Mt of Magnetite Concentrator tailings. The combined volume will be deposited in the Magnetite TSF until the mine closes in approximately 2034.

Tailings will be deposited from spigots on the perimeter embankments and the number of spigots will be adjusted to meet operational requirements over the life of mine. Generally, tailings will be beached in layers 0.2-0.3 m thick with the aim of maximising drying and consolidation.

Tailings deposition will continue around the facility until the tailings level on one side nears the operational freeboard limit of 0.3 m. Operational freeboard is defined as the vertical distance between the top of the tailings surface and the adjacent embankment crest. Tailings level reaching close or equal to 0.3 m (vertically) from the embankment crest will be the trigger to divert tailings to the opposing side of the Magnetite TSF and remove pipework to allow construction work on the embankment raise to begin. Embankment raises will occur on the side of the TSF limited by freeboard, while tailings are being discharged elsewhere. Following completion of a staged embankment raise, the pipework on the opposing embankment will be removed and the embankment raised to the same level (Golder 2014a).

The Magnetite TSF embankments will need to be raised a maximum of 45 m higher than the current crest height of the perimeter embankment wall. The final maximum height will be approximately 65 m above the natural ground level. The maximum rate of tailings rise expected is 4.5 mpa, which is higher than the industry accepted standard of 2 mpa, however, test work on tailings drying time and consolidation has shown 95% of maximum dry density can be achieved in five days in summer conditions and 17 days in winter conditions, giving ample time between deposition cycles (Golder 2014a). The maximum rise of 4.5 mpa will allow approximately 24 days for each layer to consolidate, assuming a 0.3 m tailings thickness during each deposition cycle.

Figure 71 shows the location of pipework required to deposit OBP and Magnetite Concentrator tailings in the Magnetite TSF. The proposed pipework will essentially form two ring mains and will be re-positioned as construction activities require.



Figure 71 Magnetite TSF storage facility pipeline route (Golder 2014c)

TSF water balance

A TSF water balance was updated in 2014 to aid in assessing the effectiveness of the groundwater abstraction system down-hydraulic gradient of the Magnetite TSF. The seepage model was used to estimate the amount of loss water. This data was incorporated into the 2014 Magnetite TSF water

balance calculation together with metered volumes of water recovered from the TSF decant, the embankment seepage recovery system and TSF inflow.

This water balance was used to estimate the recovery of TSF water and contrast the loss to groundwater and abstracted groundwater volumes. Figure 72 is a schematic of the TSF water cycle upon which the water balance is based. A summary of the water balance parameter input/outputs are included in Table 25.

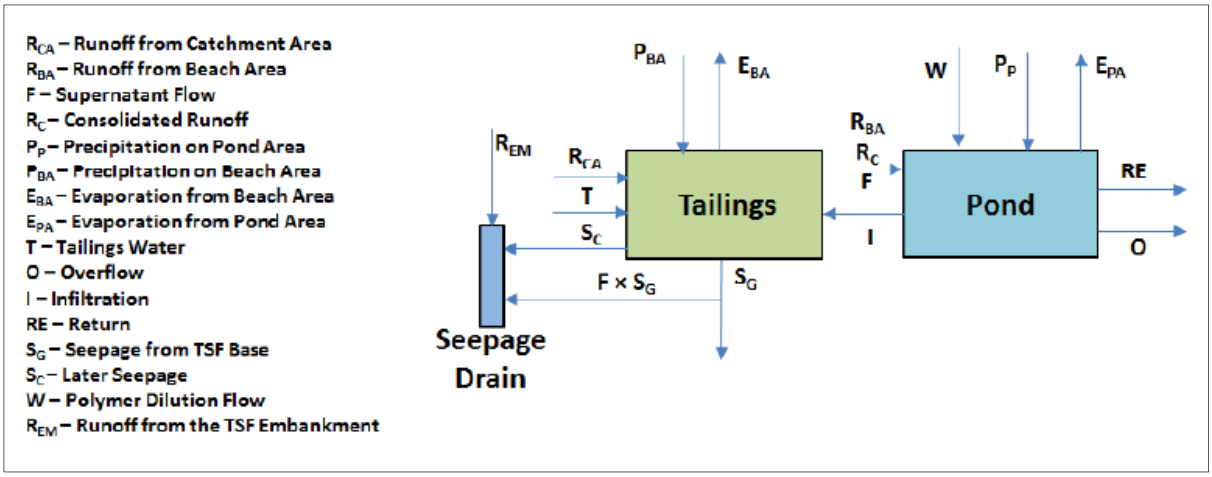


Figure 72 Magnetite TSF water balance modelling approach (Golder 2014e)

The updated 2014 water balance model indicated the following changes to the 2012 water balance:

- an increase in total water inflow – attributed to the addition of water used for polymer dilution dosing
- an increase in seepage – attributed to increased water inflows entering the Magnetite TSF
- an increase in return water – linked to increased water available in the system and improved water recovery methods i.e. polymer dosing, extraction wells
- a reduction in the amount of interstitial water retained in the Magnetite TSF tailings – resulting from improved calibration of the model using site-specific data.

Results from the 2014 water balance model are shown in Table 25. The results indicate 226,000 m^3pa is lost as outflow from the Magnetite TSF. Of this volume, approximately 56,000 m^3pa is considered seepage to groundwater storage, and the balance of seepage (170,000 m^3pa) is captured by a seepage collection drain. The volume is metered as it is returned to Ally's Dam for use in the OBP or for dust suppression.

Table 25 Magnetite TSF water balance model (Golder 2014e)

Inflow/Outflow parameter	Yearly average (m^3pa)	Percentage of tailings water (%)
Inflows		
Tailings water	2,627,000	100
Precipitation	289,000	11
Polymer water	2,159,000	82
Total inflow calculation	5,075,000	193
Outflows		
Evaporation	1,058,000	40
Seepage	226,000	8.6
Interstitial water (retained)	494,000	19
Return water	3,296,000	125
Overtopping loss	0	0
Total outflow	5,074,000	193
Other outflows		
Recovered water (return water minus polymer water)	1,137,000	43

Groundwater monitoring

The groundwater and groundwater abstraction west of the Magnetite TSF is being monitored using a network of groundwater wells, as shown in Figure 23 (see Section 3.5.1).

This network will be used to assess changes in contribution to groundwater from seepage. Rainfall records will also be compared with groundwater level trends to assess the natural rainfall recharge of the groundwater aquifer.

Regular monitoring of groundwater wells has occurred at the Magnetite TSF since October 2004. The groundwater-monitoring network consists of:

- seven Magnetite TSF monitoring wells (BHMB01-07) immediately adjacent to the Magnetite TSF embankment
- four Magnetite TSF monitoring wells down-hydraulic gradient (to the west) of the Magnetite TSF (West 1-4)
- three OBP TSF monitoring wells (OBP MB1-3) immediately adjacent to the OBP TSF embankment
- one up-hydraulic gradient monitoring well (HWE) east of the Magnetite TSF
- BHMB08 is an up-hydraulic gradient Magnetite TSF monitoring well that was lost for a period and only recently recovered
- TSF01 and TSF03 are pre-construction monitoring wells that have been lost.

There are 10 groundwater extraction wells and one caisson drilled in the sedimentary aquifer west of the Magnetite TSF (see Figure 23) in addition to the array of groundwater monitoring wells. These abstraction wells are designed to reduce seepage impacts by lowering the groundwater mound west of the Magnetite TSF where vegetation dieback has occurred.

The updated water balance model indicates that the average rate of groundwater interception (via the abstraction wells) will be greater than the estimated rate of loss to groundwater storage through the base of the Magnetite TSF. Available groundwater abstraction data indicates an average of 5.1 L/s was abstracted between 11 November 2013 and 17 June 2014, when polymer dosing of tailings commenced. This compares with the value of 1.8 L/s (56,000 m^3pa) seepage lost to groundwater estimated by the TSF seepage model (Golder 2014e).

Several groundwater monitoring wells have presented measurable reductions in groundwater levels since the abstraction system was commissioned in September 2013 to August 2014. Wells presenting notable reductions in groundwater levels include Magnetite TSF wells BHMB04–06 and West 1–3. Less pronounced groundwater level decreases were recorded in BHMB02–03. The reduction in groundwater levels is believed to be a direct response to groundwater abstraction. During 2014 some short-term upward variation is expected in these wells during the filling of the western voids in the Magnetite TSF due to increased likelihood of seepage during this stage of the transition.

A relationship between rainfall and groundwater levels has also been observed. Groundwater elevations appear to be influenced by average rainfall rates over short-term and long-term timescales. Despite groundwater reductions due to pumping, aquifer recharge from rainfall events can cause rapid increases in groundwater levels, which in turn can affect the average rate of groundwater extracted i.e. reduced groundwater recharge due to below average rainfall reduces the volume of groundwater available to be pumped (Golder 2014e).

Tailings management properties

The Magnetite TSF Master Plan was formulated using a ‘Basis of Design’ that is documented in the design report prepared by Golder (Golder 2014f). Ongoing monitoring will be required to ensure critical design values are maintained within threshold limits, using methods set out in the Programme of Geotechnical Investigation and Testing for the Future Raises of the Magnetite TSF Master Plan (Golder 2014g). The values outlined below specify the critical Magnetite TSF tailings properties intended to ensure the stability of the Magnetite TSF, the drying properties of tailings and the functionality of the tailings discharge system (Golder 2014b).

- Liquid Limit – 34% (threshold +11%)
- Plasticity Index – 8% (threshold +5%)
- Percentage passing 75 µm – 90% (threshold -10%)
- P80 – 35-45 µm (threshold +20 µm)
- D50* – 10-20 µm (threshold +20 µm)
- Specific Gravity – 2.95 to 3.4 (threshold +0.2)

- Geotechnical moisture content – 25% (target value) (threshold +5%)
- Dry Density – 1.6 t/m^3 (target value) (threshold -0.1 t/m^3).

*particle size at which 50% of the material passes by mass

The Magnetite TSF design formulated by Golder is based on a sample of tailings tested in April 2014. The trigger values and frequency of measurement for critical values will be tested according to Australian Standards. If threshold values are reached, the design will need to be reassessed.

Additional sampling and testing schedules for determining the competency of individual construction materials have been outlined in the Magnetite TSF Master Plan Technical Specification. The Superintendent may vary the frequency of testing based on observed variations in materials or construction methods (Golder 2014h).

Instrumentation and monitoring

Regular inspections and monitoring is carried out to monitor the TSF against design objectives and environmental compliance criteria. Inspections and monitoring also assist in identifying areas of the TSF that require maintenance or adjustment to achieve the operational objectives.

The observations and monitoring data are recorded and stored in a central database. All incidents are reported in accordance with the operating licence conditions (Golder 2014a).

Periodic inspections

Operators inspect key areas of the TSF daily, and inspect specific aspects of the TSF weekly. The daily inspections include:

- slurry and return water pipelines, pumps and valves for signs of leakage or wear
- active tailings discharge to check the correct operational procedures are being followed, equipment is functioning normally and the expected beach profile is developing
- the tailings water collection drains and ponds, decant pump operation, to ensure the adequacy of safety equipment and supernatant pond water levels
- the tailings freeboard
- fauna on the TSF and within the decant water collection area.

Weekly visual inspections include:

- all TSF embankments, including embankment slope and toe for evidence of seepage
- the crests, benches and slopes for signs of settling or failure (e.g. cracks developing, minor slumps) or signs of erosion
- peripheral vegetation for signs of stress
- surface diversion drains, interception trenches and external runoff control measures for erosion or sedimentation accumulation.

In addition to the daily inspections the TSF will be inspected after heavy rainfall events or flooding for:

- signs of erosion of the embankment crest, ramps and slopes

- functionality and erosion of diversion drains and drainage structures (Golder 2014a).

Groundwater monitoring

Groundwater monitoring bores have been installed around the Magnetite TSF to measure the depth of water below the ground level. Monitoring of these bores will continue at monthly intervals for at least Stage 1 of the development. This frequency may be reduced to three monthly intervals for subsequent stages if the groundwater depth stabilises for a period more than six months (Golder 2014a).

Phreatic surface monitoring

Standpipe and vibrating wire piezometers will be installed in the TSF to monitor the phreatic surface in the embankments. Vibrating wire piezometers provide a continuous record of the phreatic surface and will be placed in the tailings beach in advance of upstream raises. Standpipe piezometers are more robust (but slower to respond), and will be placed in each stage of the embankment at nominal intervals of 250 m. The piezometers will be monitored monthly and the results assessed quarterly (Golder 2014a).

Survey beacon monitoring

Survey beacons will be installed along the perimeter of the embankments at nominal intervals of 250 m to provide a cost-effective way of assessing the deformation of the embankment. Monitoring will occur at three-monthly intervals and the results assessed annually (Golder 2014a).

Tailings monitoring

The physical performance and beaching behaviour of the tailings will be monitored for the TSF during operation. Monitoring the realised tailings properties and behaviour will be integral to the staged development of the facility.

Tailings production rates, solids concentrations and the number and locations of open spigots will be recorded daily. These operational parameters will be reported together with a qualitative assessment of the tailings beaching performance. Visual observation will be supplemented with regular survey and physical characterisation of the tailings properties. Generally, the following tailings parameters are monitored regularly:

- tailings tonnages deposited
- average percentage solids
- PSD
- particle density
- the *in situ* dry density of the tailings achieved as a result of drying.

The liquefaction assessment indicates that the tailings may be liquefiable under certain extreme loading conditions. Further piezocone penetration testing (PCPT) will be required every five years to

monitor consolidation and the rate of rise and to reassess the liquefaction potential of the tailings (Golder 2014a).

Audit inspections

A technical review and operational audit of the TSF will be carried out by a suitably qualified geotechnical professional on an annual basis. The technical review will assess the performance of the TSF against the design criteria, assumptions and conditions of the operating licence. The audit will include a review of the tailings management procedures, operating manual and monitoring data (Golder 2014a).

3.9.7 Noise, vibration, dust and ignition sources – processing plant

Key point sources of noise, vibration, dust and ignition from the processing plant include;

- noise sources

- Crushing & Screening: feed hoppers, crushers, screens
- OBP: spirals, jigs, screens, pumps
- Concentrator: HP grinding rolls, screens, grinding mills, pumps
- Rail: locomotives, rolling stock
- vibration sources
- Crushing & Screening: crushers, screens
- OBP: screens
- Concentrator: HP grinding rolls, screens, grinding mills
- Rail: locomotives, rolling stock

- dust sources

- Crushing & Screening: feed hoppers, crushers, screens, conveyor transfer chutes, product stackers, stockpiles
- OBP: dry feed, product stockpiles
- Concentrator: feed hopper, conveyor transfer chutes, HP grinding rolls, dry screens
- Rail: train loading; rolling stock

- ignition sources

- 132 kV power supply and distribution throughout
- Crushing & Screening: electrical motors, feed hoppers, crushers, screens
- OBP: electrical motors,
- Concentrator: electrical motors, HP grinding rolls, screens, grinding mills, pumps
- Rail: locomotives, rolling stock

Refer to Section 3.8.3 for information relating to mobile surface equipment engaged in mining and processing plant operations.

Refer to Section 6.7 and 6.8 for impact assessments and control measures.

3.10 Wastes

3.10.1 Overburden

Information on the volumes and management of waste rock generated from mining throughout SMR are covered extensively in Section 3.7, with further details of rehabilitation and closure of these facilities in Section 8.

3.10.2 TSFs

Details of the TSFs, including the volume and composition of the tailings waste, are provided in Section 3.9.6 including Magnetite TSF tailings deposition strategy, TSF water balance, geotechnical and geochemical analysis of tailings.

The projected total tailings quantity over the remaining LOM is 6.2 Mt (from OBP) and 61.4 Mt (from the Magnetite Concentrator). It is estimated that between 50,000 to 170,000 m^3/month of TSF return water will be recovered between January 2014 and November 2016 (see Section 3.12.4).

There are no hazardous materials within the tailings. Also refer to Appendix C (Golder 2016) for a detailed summary.

3.10.3 WRDs

WRD volumes

The estimated total capacity of the SMR WRDs is provided in Table 26.

Table 26 WRD volumes

WRD location	Estimated total capacity once full to design (M m^3)
Iron Chieftain	27.6
Iron Knight North KW01	17.1
Iron Knight North ROM Base	13.2
Iron Knight North KW12	1.9
Iron Knight South KWS01	4.4
Iron Knight South KWS13	1.2
Iron Knight South KWS15	0.3
Iron Duchess dump area	40.2
Iron Duchess Stage B-1 (MW18 north)	14.0

WRD location	Estimated total capacity once full to design (M m^3)
Iron Duke/Magnet dump area – DW03, DWS03, MW03, MWS03	85.5
Iron Magnet MW18	14.2
Total	**205.6**

WRD geotechnical stability, weathering and erosion control

WRD design profiles, features and finishes have been developed through a combination of engaging independent experts, making observations of historical WRDs previously established in these mining regions, and commissioning studies and trials on variations of regolith and armouring materials. Stable SMR WRD designs reference the following observations and learnings:

- A review of as-built WRD structures within SIMEC's MBR was completed by Mining Plus in 2011. The review identified a high level of stability in historical dumps over 50 years old at the natural rill angle of 37°. These WRDs remain stable, even at substantially high 30-40m faces as evidenced in the historical WRD profiles in the Iron Knob and Iron Baron operations.
- Mining Plus 2011, *Waste Dump Review and Design, Geotechnical study* and Mining Plus 2011, *Onesteel Duchess North and Duke Magnet Waste Rock Dump Operational Strategy*, determined the development of the waste rock dump designs for all WRDs to be constructed after that time. The WRD designs incorporated specific landform slope angles and cover requirements on lower slopes at 10 degrees, mid slopes at 15 degrees and upper slopes at 20 degrees. A range of strategies and landforms have been developed for the older historic WRDs. Refer to Sections 8.2 and 8.3, Figure 95 to Figure 106, and Table 92 and Table 93 for full details of rehabilitation landforms.
- Cross ripping or seed boxing of faces helps retain water runoff and assists in vegetation regrowth, reducing erosion and loss of top soil.
- Aeolian sand deposits dominate the western flanks of the MBR and vary in depth from 1-16 m.

For the purposes of rehabilitation, the top 200-300 mm of the sandy soil is considered to be 'A' horizon topsoil due to its higher organocarbon and micro biota content that will be useful in re-establishing vegetation cover as soon as possible following rehabilitation. Sand and clay sand soils below that depth are considered to be subsoil and will be replaced between the topsoil and overburden materials in the rehabilitation horizon.

Aeolian sand top soils are very sandy and contain high proportions of both course and fine sand and are highly erodible - interrill erodibility (Ki) (3,148.689 kg.s/m^4), rill erodibility (Kr) (0.04423 s/m). Where sand soils are required to be used on rehabilitated WRD slopes it is anticipated that rill erosion gullies will appear after significant rain fall events. To counter the effects of erodibility on slopes, sandy soils will either be mixed with waste or placed very thinly on the upper slopes and allowed to infiltrate into the surface voids.

The chemical properties of the aeolian sand topsoils are suitable to establish arid zone vegetation communities and test results (Landloch 2011) indicate the following:

- pH 7.8
- electrical conductivity (EC) – 0.04 dS/m
- exchangeable sodium percentage (ESP) – 2.3%.

The chemical properties of the aeolian sand topsoils are suitable to establish arid zone vegetation communities and test results (Landloch 2011) indicate the following:

- pH 7.8
- EC – 0.04 dS/m
- ESP – 2.3%.

Eluvium soils exist on the slopes of the range in a skeletal surface band up to 300 mm in depth and are made up of decayed and eroded clay and hematite, banded iron and granitoid sands and pebbles.

Although eluvium is both highly alkaline (pH 9) and highly saline (EC of 2.5 dS/m) in situ, these soils naturally support sparse vegetation cover of salt tolerant arid zone plants from low bushes to tall shrubs and trees including but not limited to *Atriplex visicaria* (saltbush), *Triodia irritans* (spinifex), *Dodonaea lobulata* (hop bush), *Casuarina pauper* (black oak) and a variety of *Eucalyptus ssp.* It is therefore expected that these soils will support good vegetation growth post rehabilitation.

Eluvium soils display low erodibility parameters, interrill erodibility (K_i) 326,808 (kg.s/m^4), rill erodibility (K_r) (00349 s/m) and high effective hydraulic conductivity (K_e) (43 mm/h) (Landlock 2011). These values make eluvium soils desirable for use as final cover on rehabilitated WRDs slopes.

Progressive rehabilitation during operations allows for land function analysis (LFA) monitoring of final landform development and various trials of cover materials, top soil and vegetation placement and its success.

Due to the logistical difficulty in being able to harvest steep slope eluvium soils, rehabilitated WRDs are mostly sheeted with aeolian sand and clay sand topsoils. As expected some rill erosion occurs on the sheeted slopes especially following heavy rainfall events in the first twelve months. LFA stability factor data collected at completed dumps indicate significant stabilisation after twelve months due to consolidation of the soil and establishment of colonising vegetation cover.

WRD geochemical assessment

Golder undertook a review (Golder 2016) of previous geochemical assessments. The review considered the Parsons Brinkerhoff (PB) geochemical testing on selected rock samples, including waste rock and ore, in 2004 and 2007. The tests included assessing the acid forming potential and leaching potential of the different rock units that would be deposited on the WRDs or be exposed on pit faces. The tests were done on one sample of each rock unit. The results of the acid forming tests are presented in Table 27.

The following are the findings of the studies:

- the waste rock samples were characterised by low sulphur content (0.03%-0.14%), with the exception of sulphide breccia, which had a very high sulphur content (10.3%)
- most of the ore rock units, which are likely to occur on exposed faces, had sulphur content ranging from <0.01% to 0.16%, with the exception of magnetite amphibole ore, which had a sulphur value of 0.45%
- the pH of all samples was alkaline (9.3-9.7)
- the waste rock units were classified as acid consuming material (ACM), with the exception of sulphide breccia, which was potentially acid forming (PAF). It was, however, noted that the sulphide breccia represented a small fraction of waste rock materials.
- the ore rock units were classified as either non-acid forming (NAF) or acid consuming materials due to presence of calcium and magnesium carbonate.

Table 27 Acid forming potential screening test results (taken from PB 2007)

Material Type	Description	S %	pH	NAG Kg H2SO4/t	NAPP Kg H2SO4/t	ANC Kg H2SO4/t	Classification of acid forming potential
Waste Rock/exposed faces	SBX Sulphide Breccia	10.3	9.6	29	246	70	Uncertain (PAF, other than pH)
	DOM Dolomite	0.14	9.3	<0.5	-716	720	Acid Consuming Material (ACM)
	AMP Amphibolite	0.03	9.7	<0..5	-217	220	Acid Consuming Material (ACM)
Ore/ Exposed faces	MTA Magnetite Amphibole Ore	0.45	9.3	<0.5	-80	93	Non Acid Forming (NAF)
	MTC Magnetite Carbonate Ore	0.04	9.4	<0.5	-194	200	Acid Consuming Material (ACM)
	MTS Magnetite Silica Ore	0.03	9.7	<0.5	-139	140	Acid Consuming Material (ACM)
	Blind Duplicate (MTS)	0.16	9.8	<0.5	-129	130	Acid Consuming Material (ACM)
	MTO Massive Magnetite Ore	0.05	9.6	<0.5	-52	53	Acid Consuming Material (ACM)
	MTT Magnetite Talc Ore	0.14	9.6	<0.5	-47	51	Non Acid Forming (NAF)

Material Type	Description	S %	pH	NAG Kg H2SO4/t	NAPP Kg H2SO4/t	ANC Kg H2SO4/t	Classification of acid forming potential
	HMO Hematite Magnetite Ore	<0.01	9.4	<0.5	-149	150	Non Acid Forming (NAF)
	HEO Hematite Ore	0.04	9.7	<0.5	-100	100	Acid Consuming Material (ACM)
	MCH Magnetite Chlorite Ore	0.06	9.5	<0.5	-129	130	Non Acid Forming (NAF)
	HEC Hematite Carbonate Ore	<0.01	9.7	<0.5	-429	430	Acid Consuming Material (ACM)
	MHO Magnetite Hematite Ore	0.01	9.7	<0.5	-84	84	Non Acid Forming (NAF)

Exploration drill modelling indicates that Sulphide Breccia will first be intercepted at approximately 100m RL which is scheduled to be mined in 2024. Figure 73 shows the location and extent of sulphide breccia material, intersecting on the western wall at approximately 100m RL; 6316850 Northing.

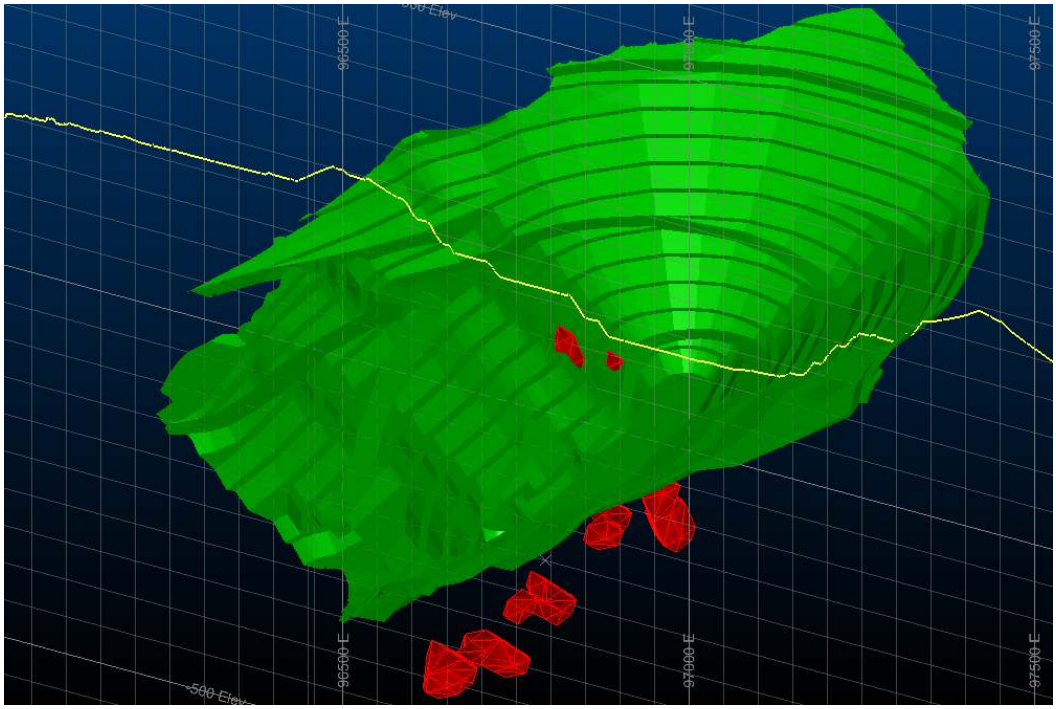


Figure 73 Magnet Pit E – Sulphide Breccia locations

Based on available geochemical data, the geochemical risk associated with waste rock materials and exposed rock faces is considered to be generally low given that the percentage volume of sulphide breccia, which has the sole potential of generating ARD, is low compared to the percentage volume of acid consuming wastes. The location and blending one part sulphide breccia with three parts of high acid consuming carbonate wastes will result in a neutral deposit.

WRD seepage assessment

In order to assess potential rainfall infiltration into SMR WRDs and seepage generation, climate data from the nearest Bureau of Meteorology weather station was assessed (Whyalla Aero, Station ID 18120, approximately 40 km north east of Iron Chieftain and Iron Knight).

Daily average (Class A) pan evaporation data were used to estimate potential evapotranspiration, employing an assumed pan coefficient (K_{pan}) of 0.7 (see Table 28), consistent with the approach taken in Golder (2015a). This data was then used to calculate the number of days each year when daily rainfall was observed to exceed potential evapotranspiration over the period 1999 to 2015 (see Table 29), leading to conditions during which infiltration into WRDs and seepage to groundwater more generally, might occur (Golder 2016).

Table 28 Average Daily ('Class A') Pan Evaporation and Estimated Evapotranspiration 1993 to 2016 (Whyalla Aero, BOM Station 18120)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Daily Average Pan Evaporation (mm)	11.2	10	8.2	5.8	4	3	3.2	4.3	6.3	7.9	9.5	10.7
Estimated Potential Evapotranspiration (mm)[1]	7.8	7.0	5.7	4.1	2.8	2.1	2.2	3.0	4.4	5.5	6.7	7.5

Note: [1]Pan coefficient (K_{pan}) assumed to be 0.7, potential ET = Pan Evaporation x K_{pan}.

Table 29 Summary of Rainfall and Evapotranspiration 1999 to 2015 (Whyalla Aero, BOM Station ID 18120)

Year	Rainfall > Evapotranspiration (days)	Total Annual Rainfall Exceeding Daily Average Evapotranspiration (mm)	Total Annual Rainfall (mm)	Total Annual Rainfall Deficit (mm)
1999	19	89	254	-1622
2000	26	107	250	-1651
2001	26	176	363	-1601
2002	12	49	139	-1696
2003	21	112	266	-1633
2004	10	39	158	-1675
2005	21	118	278	-1627
2006	12	83	192	-1678
2007	19	178	327	-1638
2008	13	69	188	-1675
2009	22	106	258	-1635
2010	23	166	346	-1607
2011	27	186	392	-1580
2012	15	109	262	-1641
2013	16	130	229	-1688
2014	16	98	211	-1673
2015	18	171	295	-1663
Average	**19**	**117**	**259**	**-1646**

On average, only 19 days per year were found to present potential conditions for WRD infiltration or groundwater recharge, with daily observed rainfall exceeding estimated average daily

evapotranspiration. These days over which rainfall was observed to exceed estimated daily evapotranspiration accounted for an annual average of 117 mm total rainfall in excess of estimated daily evapotranspiration. Daily rainfall deficit was calculated for days when observed rainfall did not exceed estimated daily evapotranspiration, resulting in an annual average rainfall deficit of approximately -1,650 mm (see Table 29).

The review of climate data from the Whyalla Aero station indicated that conditions leading to potential rainfall infiltration into SMR WRDs will likely be limited to a small number of days each year (19 days on average) and confirms that the area of SMR operations is likely to be in long term rainfall deficit. Thus the annual infiltration into SMR WRDs that could then lead to seepage to groundwater is anticipated to be very low (Golder 2016).

Due to the very low likelihood of seepage to groundwater, monitoring seepage rates and groundwater quality within or beneath the WRD's is not considered to be necessary.

Groundwater in the region is highly saline and there are no known groundwater dependent ecosystems or beneficial users.

3.10.4 Industrial and commercial wastes

The following processes will be used to manage industrial and commercial wastes generated on the mining tenements:

- general waste will be collected in large SULO bins and disposed off-site
- hard fill including rock and soil will be progressively placed on WRDs
- steel waste will be recycled as scrap
- liquid waste will be collected and stored in designated areas with periodic collection and off-site disposal by an EPA licensed contractor
- tyres from earth moving equipment will be buried under at least 20 m of waste rock material, in accordance with EPA exemptions. All other tyres will be disposed off-site by an EPA licensed contractor
- waste tracking forms and waste transport certificates will be completed for all wastes moved off site, where applicable
- wastewater from the site amenities will be treated by an on-site sewage treatment system.

Procedures and controls are implemented on site to prevent, minimise and manage site contamination, particularly in areas of the operation that present a higher risk of site contamination, such as fuel and oil storage and dispensing areas. A bioremediation pad is located at Iron Duke and is operated in accordance with EPA guidelines to remediate soils contaminated by hydrocarbon spills from across the SMR mine sites.

3.10.5 Rehabilitation and closure

The rehabilitation and closure details for WRDs and TSFs are detailed in Section 8.

3.11 Description of Supporting Infrastructure

The main support centre for the SMR mining operations is located at Iron Duke. The facilities provided, as shown on Figure 18 in Section 3.3.3, include:

- off road access, via security box
- light vehicle (LV) car park, mine vehicle car park and truck park bays
- offices
- workshop
- fuel depot
- go-line
- small medical centre.

The Iron Duke is the main gateway to all SMR mine sites, whereby a notice board and register of personnel location is recorded.

3.11.1 Water supply infrastructure

SMR main water circuits

There are three water 'systems' at the SMR operations:

1. The concentrator 'return water' circuit delivers between 450-560 m^3/h of water to the concentrator, which is made up of circulating process water, reverse osmosis (RO) plant water (around 170 m^3/h), and SA Water makeup. Some of this 'return water' is directed to the Iron Knight train loading pad and used for dust suppression at Iron Knight and Iron Chieftain.
2. The SA Water supply from Iron Knob provides between 35-45 m^3/h of water for the Iron Duke OBP and miscellaneous potable water requirements at SMR.
3. Reclaimed water from the concentrator tailings system is pumped and stored in the Iron Duchess pit (currently holding around 400 ML).

Miscellaneous water storage facilities

The concentrator 'raw water' tank holds 2.1 ML, a firewater tank also holds 1 ML, and there is a process water tank in the concentrator tank farm.

The SMR has four potable water storage tanks, fed from the SA Water supply line:

- A 400 kL tank located north of the heavy vehicle workshop
- two 50 kL tanks located east of the SMR fuel farm
- a 50 kL tank located next to the Iron Knight processed water tanks on Iron Knight haul road.

The SMR also has three water storage tanks holding reclaimed water for dust suppression:

- the Duchess 160 kL tank to west of Duchess pit

- the Knight 52 kL tank on Knight haul road
- the Chieftain 500 kL tank to south east of the Chieftain pit.

Further supplementary water piping and storage facilities are planned to make optimal use of reclaimed tailings water stored in the Iron Duchess pit.

Iron Duchess pit water storage facility

Water recovered from the concentrator and OBP tailings process is pumped to the Iron Duchess pit to be used primarily for dust suppression throughout the SMR mining area. There is potential to re-use this reclaimed water for OBP operations is being considered, to reduce the draw from SA Water for the SMR operations.

A hydrogeological assessment has been undertaken to support the use of the Duchess pit for water storage (see Section 3.5.2).

Coffey Mining (2011b) determined that storage be limited to 200 m RL which would provide for up to 1,445 ML storage capacity. Initial target levels were set at 169 m RL to store 100 ML, however experience and incremental level testing has the pit currently holding well at 175.5 m RL, which is calculated to be around 413 ML.

Details of the Iron Duchess pit are provided in Table 11 in Section 3.5.2.

Iron Chieftain dust suppression water supply

Water for dust suppression in the Chieftain area is predominantly recycled process water from the magnetite concentrator return water pipeline, which is pumped through pump station 5A adjacent to the Knight crushing and screening operations (see Figure 74).

The tapping of the concentrator return water line for dust suppression will transition to become a supplementary backup supply once the planned pipeline link from the Iron Duchess pit water storage facility has been built.

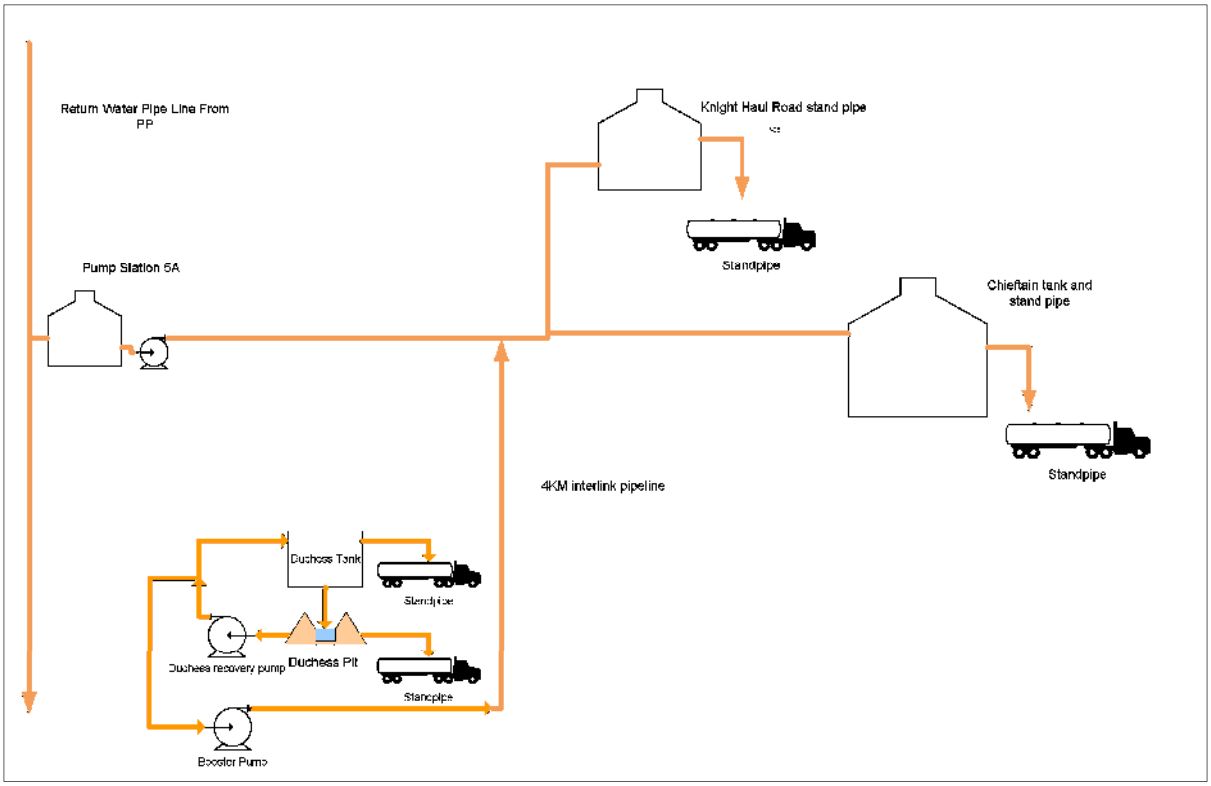


Figure 74 Chieftain dust suppression water supply

3.11.2 Mine site access

The mine site is accessed off the Lincoln Highway via a 3.5 km bituminised access road through to the mine site entrance, visitor's car park and administration office. This is clearly marked with road signs, speed limits and contacts.

Entry to the mine site is controlled by a boom gate system. Entry to the mine site requires a passport or an escort, and everyone who enters the mine site is required to pass an alcohol breath test of zero.

3.11.3 Building and office facilities

There are no camp facilities in the SMR area.

New SMR office facilities were constructed in FY12 and provide office space, meeting rooms, crib rooms and ablution facilities, as well as car parking facilities. The facilities are adjacent to a heavy vehicle and light vehicle workshop area. A former administration building has been dismantled, removed and the area remediated.

A separate demountable building nearby provides first aid facilities, training and induction facilities, and ambulance parking.

There are also workshops, offices and amenities adjacent to the main Iron Duke processing area. Further minor site amenities are located at the Iron Knight and Iron Chieftain sites.

3.11.4 SMR heavy vehicle workshop area

The SMR heavy vehicle workshop facilities are located on MPL34. The workshop is comprised of:

- the maintenance workshop (mobile fleet)
- a heavy equipment workshop (steel structure)
- concrete pads
- a boiler maker area (undercover and shielded for welding)
- a compressed air facility
- a maintenance store area
- an ablution and amenities building
- maintenance offices
- go-line ('in readiness' equipment parking area)
- a washdown bay and water reclaim pond for heavy vehicles (HVs)
- bulk fuel and oil dispensing facilities
- a spare parts lay down yard
- a tyre bay (storage and dedicated hardstand concrete tyre changing area)
- external lighting around the workshop area to enable safe operations 24 hours a day, seven days a week
- perimeter windrows constructed to delineate walkways and roadways.

3.11.5 Fuel and chemical storage

Fuels and chemicals, including explosives, are stored at SMR. Bulk diesel is stored in facilities adjacent to the main heavy vehicle workshop area that are bunded and contained in accordance with Australian Standard AS 1940:2004 - The storage and handling of flammable and combustible liquids.

Explosives are stored and used as detailed in Section 3.8.6. The explosives storage facilities include a high explosives (HE) magazine, AN/HANFO storage and a detonator magazine.

The explosives storage sites are located in accordance with AS 2187.1 – 1998 Explosives – Storage, transport and use.

3.11.6 Public roads, services and utilities

The SMR mine site is serviced by the Lincoln Highway, which is the main access way to and from the mine site.

A supplementary maintenance access way (predominantly for rail line maintenance) is provided via the Kimba/Whyalla road, from the north.

Other SMR services and utilities include:

- SA Water pipelines between SMR and Whyalla, and between SMR and Iron Knob, which are owned by OneSteel Manufacturing
- power provided by the 132 kV Electranet service line from the north, servicing lower Eyre Peninsula
- a rail corridor between SMR and the Whyalla Port facilities, owned by OneSteel Manufacturing.

3.11.7 Visual screening

Although the lease and licence conditions do not specify a visual screening requirement for SMR, SIMEC Mining's rehabilitation and closure plans provide for progressive visual screening. These works are detailed in Section 3 and Section 8.

3.11.8 Site security and emergency services

Access to all SMR areas is controlled through a single entry and exit point off the Lincoln Highway. The general public cannot enter the site. Site access is not permitted without appropriately signed vehicles, personal protective equipment (PPE) and inductions. Visitors and work personnel must report to the administration building and either undertake a site induction or be escorted whilst on site. Unauthorised access events are promptly investigated and managed.

Emergency Response and Evacuation procedures are in place and an emergency vehicle equipped for mine emergency and rescue is located on site. SIMEC Mining's emergency response capability includes emergency trained personnel, first aid facilities, a dedicated paramedic and access to other emergency response services such as the emergency services in Whyalla.

SMR mining areas (including pit, WRD, roads and infrastructure areas) have emergency access routes.

Fire fighting equipment (i.e. extinguishers, live hose reels and ancillary equipment), are installed and maintained in accordance with legislation and regulations.

Emergency response kits include equipment to fight fires and to respond to spills and medical emergencies.

Site communication is via UHF radio, telephones (fixed and mobile) an intranet and the internet.

3.11.9 Silt control and drainage

Silt control and drainage is described in Section 3.8.8.

3.11.10 Rehabilitation

All infrastructure, buildings, and equipment will be decommissioned, and removed from site when mining is complete, the areas will be remediated. Section 8 provides further details on rehabilitation and closure plans.

3.12 Resource Inputs

3.12.1 Workforce

SIMEC Mining out-sources most of the mining workforce from contract service providers. Contractors are employed for:

- mining and haulage
- crushing, screening and train loading
- mine ancillary services
- railway operations.

Further workforce details are provided in Section 3.8.2.

3.12.2 Energy usage

The following data describes the most recent power usage draws for the SMR operations. Power is drawn through two main feed lines, one for Iron Duke operations (feeding crushing and screening, magnetite concentrator, OBP and main workshop facilities) and the other for Iron Knight (N-SMR), (feeding crushing and screening operations and ancillary power for the Knight and Chieftain operations). Table 30 shows the measured power usage for the SMR operations since July 2013.

Table 30 Measured power usage for SMR operations for FY14

Month/Year	Exit 1 Iron Knight (kWh)	Exit 2 Iron Duke (kWh)	Comments
July 2013	134,468	8,666,234	
August 2013	191,413	8,146,985	
September 2013	189,423	7,848,923	
October 2013	245,884	9,547,263	Second crusher commissioned at Iron Knight
November 2013	247,774	5,765,781	Magnetite expansion upgrade at Iron Duke
December 2013	248,649	9,278,158	
January 2014	284,662	9,343,729	
February 2014	256,345	8,224,473	
March 2014	328,326	10,123,531	
April 2014	288,656	10,314,105	

Month/Year	Exit 1 Iron Knight (kWh)	Exit 2 Iron Duke (kWh)	Comments
May 2014	297,713	10,136,105	
June 2014	345,472	9,667,738	

3.12.3 Fuel usage

Fuel for all areas of the SMR is stored and distributed from the central Iron Duke heavy workshop amenities.

The diesel fuel usage for the SMR in FY14 is shown in Figure 75. This is representative of future fuel usage.

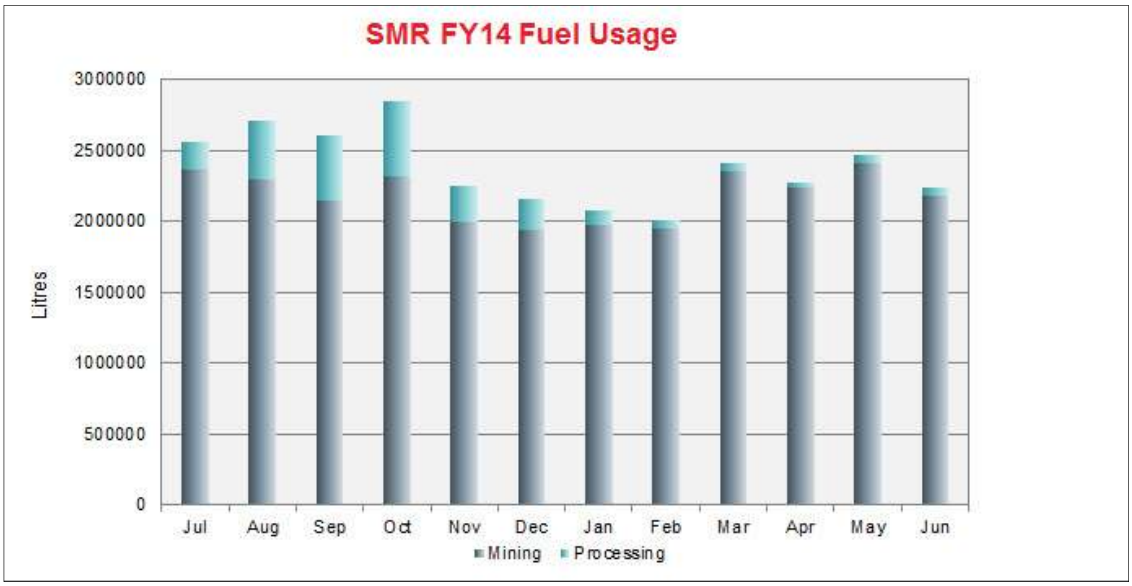


Figure 75 SMR fuel usage

3.12.4 Water usage

SIMEC Mining has a base water allowance of 156 m^3/h approved by SA Water, to meet water requirements for mining operations in the Middleback Ranges. There is some flexibility beyond this base allowance of around 10%. SA Water usage across the regions is shown in Figure 76. Refer to Figure 80 for measured usages for FY14.

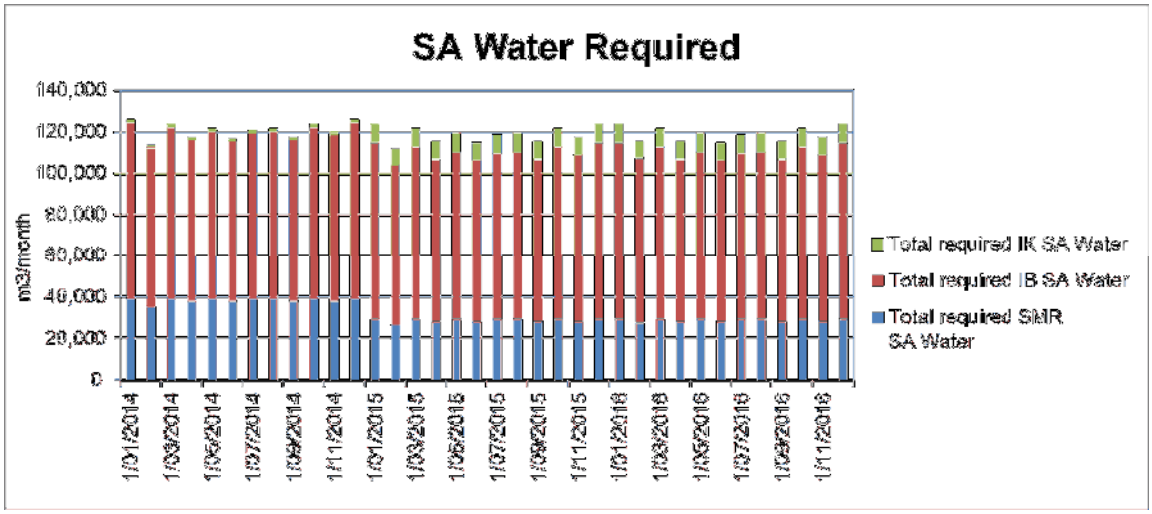


Figure 76 SA Water usage/requirement

In nominal hourly usage terms, SMR currently draws between 35-45 m^3/hr.

Figure 77 to Figure 79 describe the water balance and usage for SMR operations.

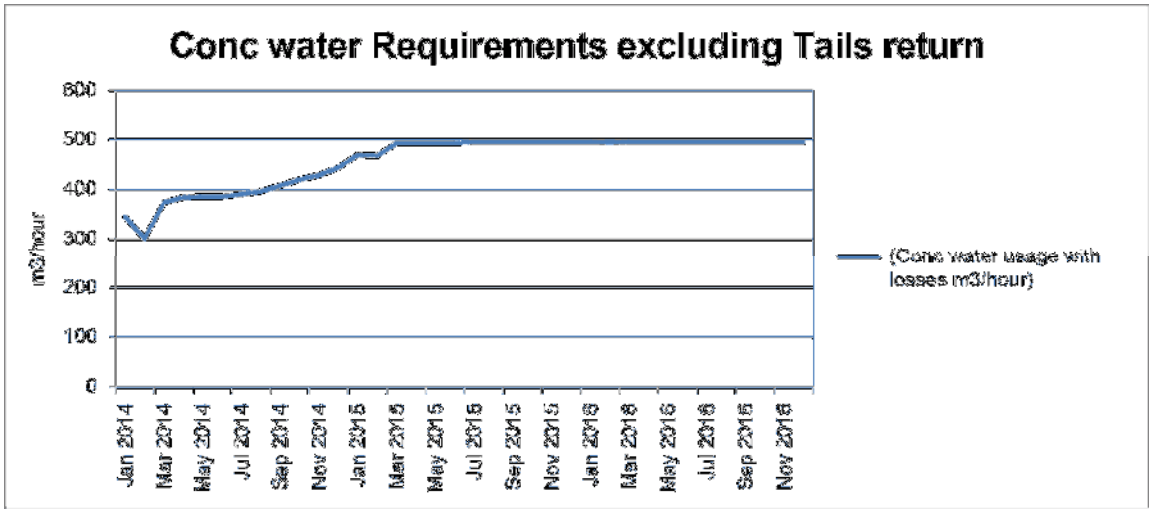


Figure 77 Magnetite concentrator water usage rates excluding tails recovery

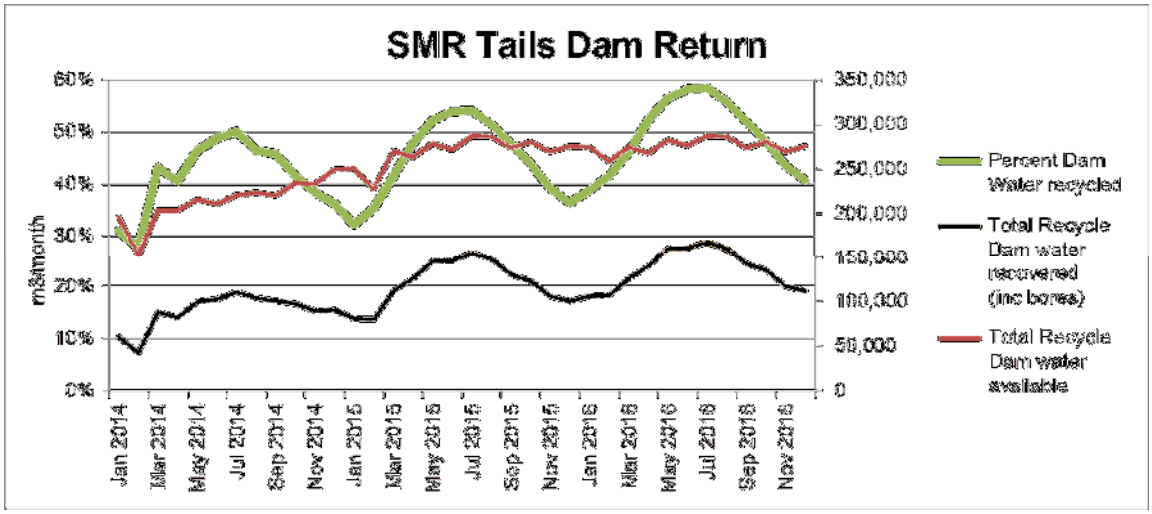


Figure 78 SMR TSF return water rates (m^3/month)

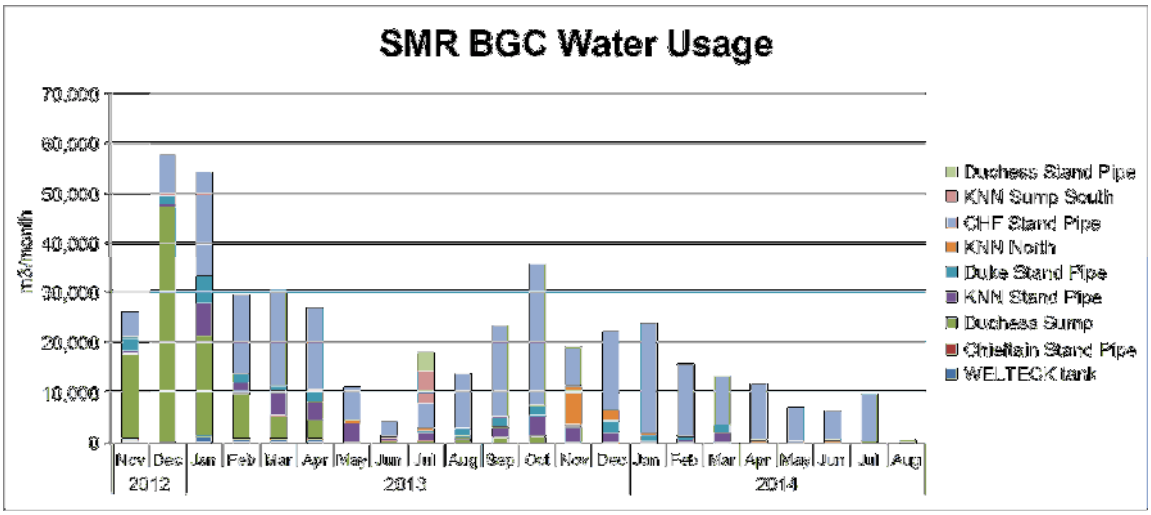


Figure 79 SMR recycled water usage – general dust suppression

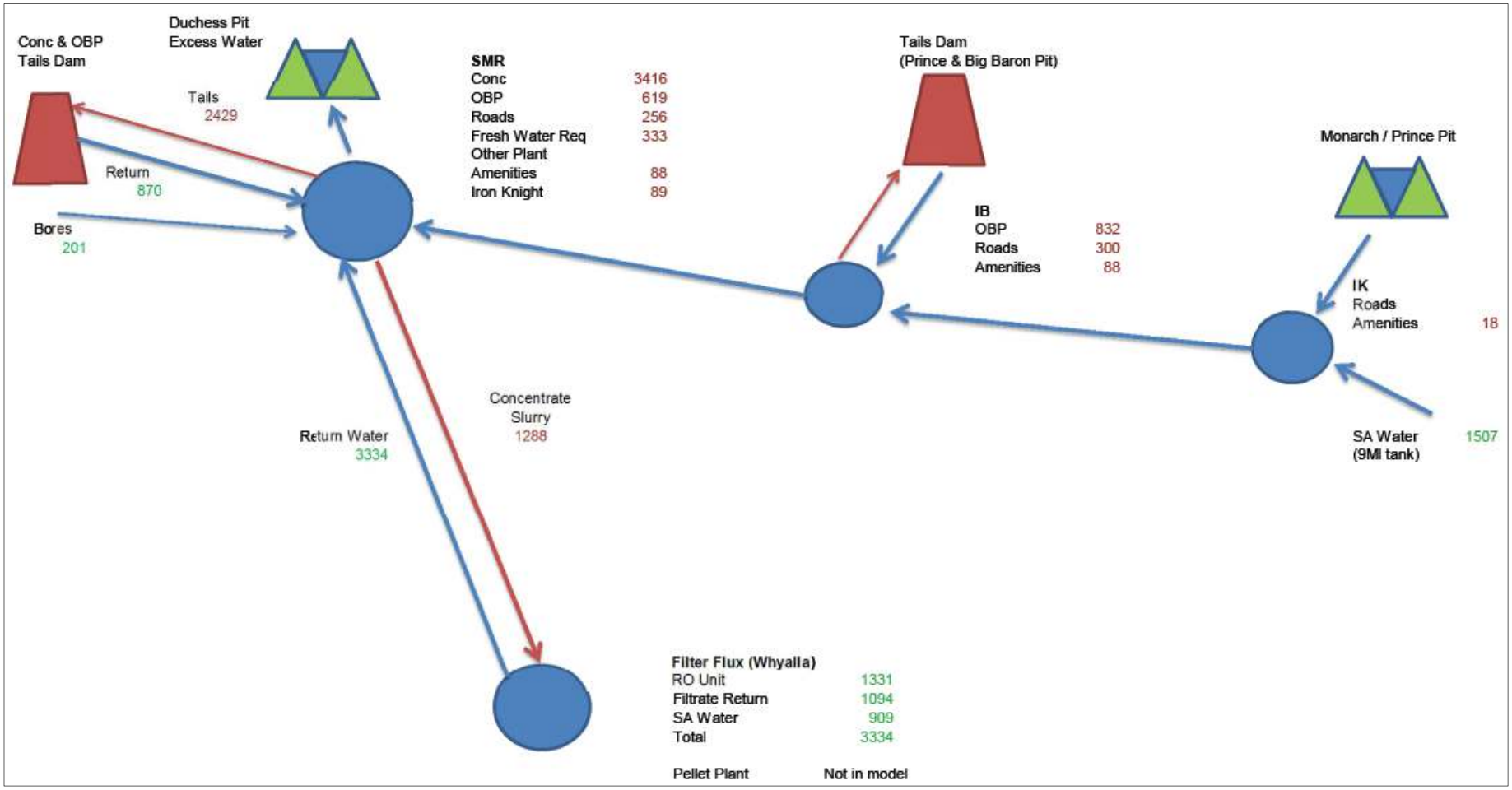


Figure 80 SMR, IBMA and IKMA water usage in ML for FY14

4 VEGETATION CLEARANCE

4.1 Introduction

Numerous vegetation surveys have been conducted across the SMR mining area including:

- *Flora Assessment of Proposed Extensions Iron Chieftain Tenements South Middleback Range for Arrium Mining Whyalla*, March 2014 (Bebbington 2014, unpublished report)
- *Caladenia tensa Micro-site Surveys of North SMR Development – Project Magnet Phase 2, Iron Chieftain ML4745 Proposed Extension for OneSteel Whyalla*, August 2009 (Bebbington 2009a, unpublished report)
- *Vegetation Assessment of Project Connolly: Iron Chieftain MLs, Iron Knight ROM Pad and Associated Haul Road for OneSteel Whyalla*, March 2009 (Bebbington 2009b, unpublished report)
- MI087 Vegetation Assessment South East WRD Extension (Bebbington 2010a)
- MI095 Proposed Duchess WRD extension and LGO (Bebbington 2010b)
- *Determination of Biological Significance: Additional Flora Survey at the SMR Site* (Badman 2004a, unpublished report)
- *OneSteel Project Magnet: Vegetation Survey March 2004* (Badman 2004b, unpublished report)
- *Determination of biological significance – South Middleback and Cook Ranges: Vegetation* (Badman 2003, unpublished report).

Based on the survey information from the above reports, Figure 81 shows the vegetation communities in the SMR area.

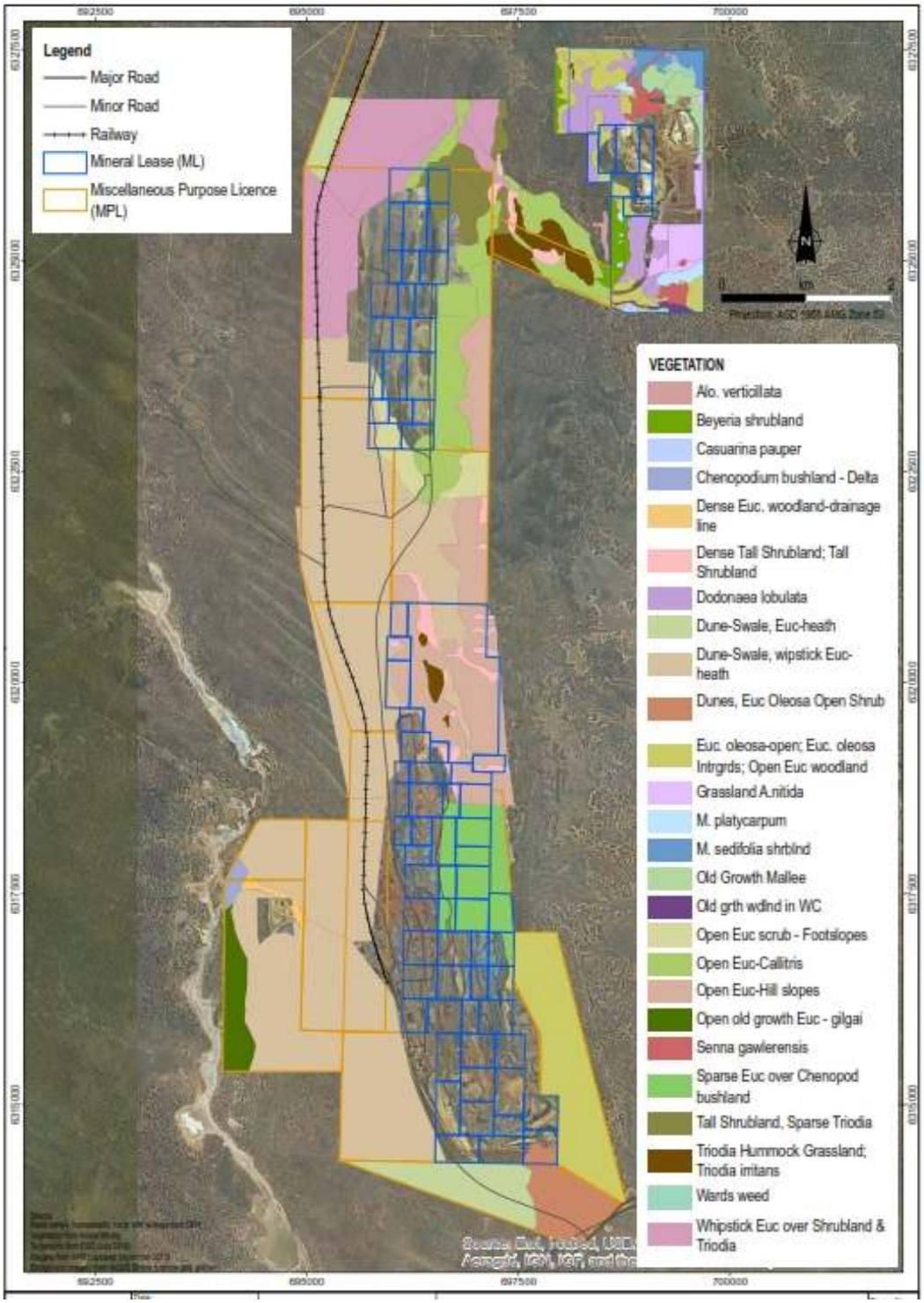


Figure 81 SMR vegetation communities

4.2 Species of Significance

Although not of National or State conservation significance, old growth *Eucalyptus oleosa* woodland in the area contains large hollows suitable for habitat for bats, birds and reptiles and therefore is locally significant under the *Native Vegetation Act 1991* "Principles of Clearance" (b).

Allocasuarina verticillata (Drooping She-oak) Low Open Woodland is present in low to moderate densities along the upper ridgelines and west facing hill slopes. *A.verticillata* Low Open Woodland is classified as moderately conserved on Eyre Peninsula and rare in the Middleback Ranges with only small numbers being recorded in the South Middleback Range. This species was recorded outside of the proposed mine layout footprint. The Iron Duchess WRD development footprint avoids the upper ridgelines.

State listed vulnerable *Santalum spicatum* is reasonably well represented in the Middleback Ranges.

Nationally listed Vulnerable *Swainsona pyrophila* is known to benefit from disturbance and has only been recorded in the area after fire or mechanical disturbance.

State listed rare *Maireana suaedifolia* Lax Bluebush was recorded in Death Adder Valley. The clearance activity is thought not to greatly impact the survival of the species within the Death Adder Valley region. Information gathered through biological surveys and communication with adjacent landholders indicated that the plant is reasonably conserved regionally. This species is far more widespread than indicated by herbarium records and is generally widespread in suitable habitat within the region (Bebbington 2010b).

Maireana suaedifolia Rare^{SA,EP} (NP&W Act Schedule 9) is classified as rare due to a paucity of records for the state and region. However as various vegetation assessors have concluded (Langley 1998, Badman 2004, Wilson P.G. 2003, Bebbington 2009) these records are inconclusive and the species is more widespread in the region and further searches are likely to find addition populations (Bebbington 2010b).

The above statements are supported by unrecorded observations (pers. obsv. Read J) within Ironstone Hill Conservation Park, Middleback Ranges and Secret Rocks.

Unquantified observations (pers. obsv. Mills G) indicate that the species has benefited from protection of the species within the Ironstone Hill Conservation Park through reduction of total grazing pressure delivered by rabbit warren destruction, the removal of all domestic stock and decommissioning of artificial water sources for other herbivores, feral goat, rabbit and over abundant native fauna (Western grey kangaroo).

A surprise observation is that the species appears to be one species to have benefited from the disturbance due to inundation of land between the Mag TSF and salt creek (pers. obsv. Mills G).

Section 6.2 provides further information on species of significance.

4.3 Area to be Cleared and SEB Ratios

Vegetation clearance has occurred over the SMR area since mining commenced. Additional clearance will be required to allow extensions to the mining operations. The current and proposed disturbance areas are shown on Figure 82. Additional clearance for Iron Duchess North Stage B Part 1 is shown on Figure 83. Figure 84 (and Appendix A-13) shows the SEB ratios used to calculate the resultant SEB offset requirements for the SMR area.

The ratios and justifications were recommended by NVC accredited vegetation consultant Larry Bebbington, based on his assessment of the condition of the vegetation (e.g. the disturbance due to weeds, past land use, grazing, impacts of adjacent land use and the presence of access tracks), and the biodiversity and conservation value of the vegetation (e.g. the conservation status and the presence of threatened fauna or associated habitat).

The majority of new vegetation clearance is associated with the extension to the Iron Chieftain and Iron Duchess mining domains. Areas approved for clearance under previous PEPRs but not yet cleared have been carried over into this document along with other contingencies for future clearance or disturbance. Table 31 provides the area to be cleared and the SEB offset required for the four SMR domains of Iron Chieftain, Iron Knight, South SMR (including Iron Duchess Stage B Part 1) and the Concentrator/OBP TSFs sub domain.

Vegetation communities within the Iron Duchess Stage B Part 1 development was described by Bebbington 2010 as Dune- swale eucalyptus heath, Open eucalyptus hill slopes, Triodia Hummock grassland and Dense tall shrubland (see Figure 81).

Table 31 SEB offset requirements for SMR

Effective SEB offset ratio	Clearance rationale	Area to be cleared (ha)	SEB offset required (ha)
Iron Chieftain domain			
10:1	Stage d pit, WRD extension, mineralised waste stockpile	60.2	602
10:1	Contingency	5.4	54
8:1	WRD extension	19.2	153.6
8:1	Contingency	2	16
6:1	WRD extension	5.6	33.6
6:1	Contingency	1	6
4:1	North mineralised waste stockpile, low-grade stockpile (no longer required however this area will be within the new proposed WRD extension)	17.7	70.8
4:1	Contingency		
2:1	WRD extension	3.5	7
Sub-total		**114.6**	**943**

Effective SEB offset ratio	Clearance rationale	Area to be cleared (ha)	SEB offset required (ha)
Iron Knight domain			
10:1	KNS01 WRD	6.36	63.6
10:1	Potentially high impact areas counted as clearance, including contingency	54.8	548
Sub-total		**61.16**	**611.6**
South SMR domain			
10:1	DW03 WRD	28	280
10:1	Iron Duchess Stage B Part1 WRD, topsoil storage, pit extension	80	800
Sub-total		**108**	**1080**
Concentrator and OBP TSF sub-domain			
10:1	TSF construction	43.4	434
10:1	Potentially high impact areas counted as clearance, including contingency	15	150
Sub-total		**58.4**	**584**
Total		**342.16**	**3218.6**

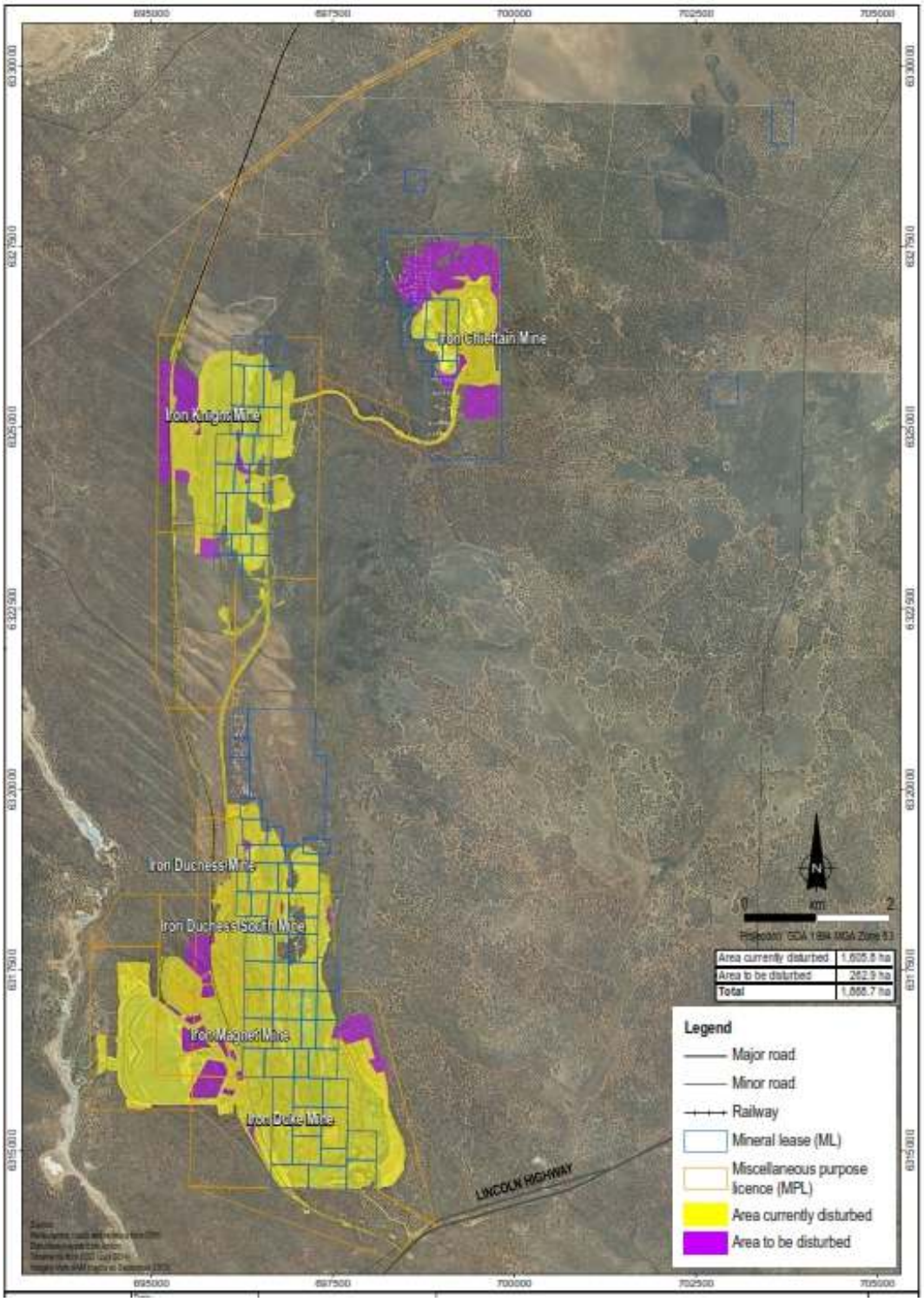


Figure 82 SMR Disturbance areas

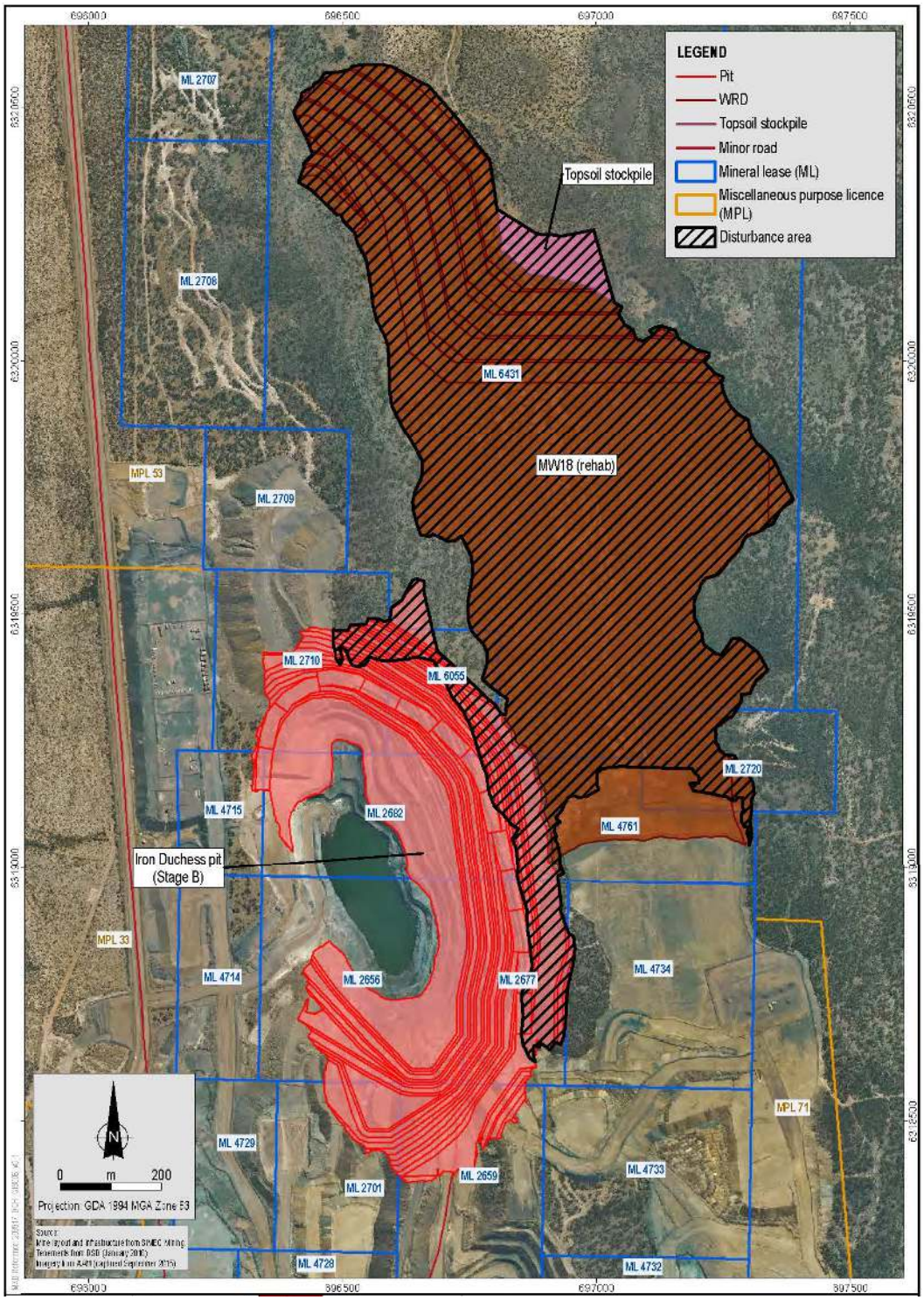


Figure 83 Iron Duchess North Stage B Part 1 Disturbance areas

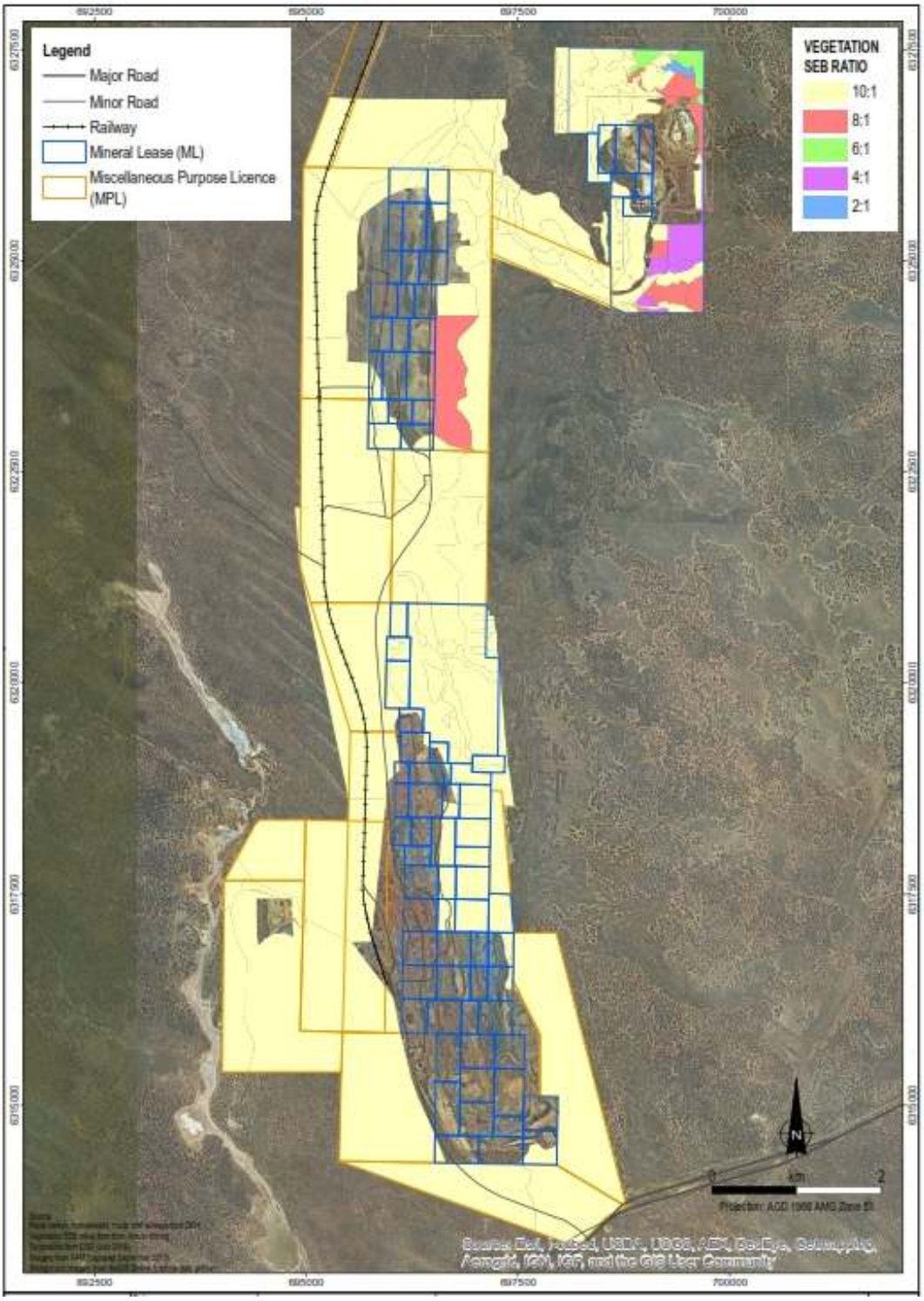


Figure 84 SMR vegetation SEB ratios reference map

4.4 SEB Offsets

SIMEC Mining has provided 19,900 ha of SEB offset area in the form of the Shirrocoe Reserve, which has been donated to the National Parks and Wildlife Service (NPWS) network and in 2010 was proclaimed as the Ironstone Hill Conservation Park under the *National Parks and Wildlife Act 1972*.

In conjunction with NPWS and the Middleback Alliance, SIMEC Mining is developing a management plan that will see SIMEC Mining's continued contribution to the park's management. Ironstone Hill Conservation Park is a pristine area of high biodiversity value and a very important area as habitat for Sandhill Dunnart and other species.

SIMEC Mining's SEB Credit bank was accessed to offset the vegetation clearance required for operations within the SMR, which includes the Ironstone Hill Conservation Park.

In the Ironstone Hill Conservation Park, 27 ha of native vegetation has been impacted by seepage of water from the SMR Magnet TSF increasing the naturally saline groundwater level to within the vegetation's rootzone. The area of impact was calculated from waypoints provided by DEWNR's Native Vegetation Unit and presented to DMITRE in July 2014. In consultation comments regarding IBMA MPEPR 2017/033, the Native Vegetation Council requested that the impacted area be deducted from the SEB credit ledger. Consequently 27 ha has been removed from the Ironstone Hill Conservation Park SEB credit ledger as of April 2018. A further 590 ha has been removed from the SEB credit ledger to account for the impact to the total area of 59 ha.

For the Iron Duchess North Stage B Part 1 development, 800 ha will be removed from the current credit of 2,914.53 ha, leaving a remaining credit of 1,524.53 ha.

The April 2018 version of the SEB ledger is included as Table 32.

Table 32 SMR SEB credit ledger

SIMEC Mining SEB credit ledger						
Description	Reference	Area disturbed (ha)	Date	Offset ratio	SEB area (ha)	Credit (ha)
Whyalla Conservation Park			2003			972
Ironstone Hill Conservation Park (Shirrocoe)			2007			19,900
TOTAL SEB CREDIT						**20,872**
SMR Project Magnet	SMR MARP 2007	356.65	2007	various	3,188.64	17,683.36
Trans-shipment pad and spurline	NVC2007/3063/010 07WLB06139	0.9	2007	10:1	9	17,674.36
BOS slag dumps	NVC 07WLB07865	10	2007	4:1	40	17,634.36
Rail passing loops	NVC2008/3164/850	1.275	2008	various	5.95	17,628.41
N-SMR (Chieftain–Knight)	N-SMR MARP 2010	335.7	2010	various	2,641.08	14,987.33
Iron Baron ore beneficiation plant (OBP)	Iron Baron Construction MARP (Jan) 2011	17	2011	8:1	136	14,851.33
NE WRD extension	SMR MARP 2007 Addendum 2011	56	2011	10:1	560	14,291.33
SE WRD extension	SMR MARP 2007 Addendum 2011	132	2011	10:1	1320	12,971.33
Iron Baron OBP (update)	Iron Baron Construction MARP 2011 (update)	8.48	2011	various	32.12	12,939.21
Iron Baron OBP surplus (credit)	WPC-056 approved 30 ha for construction, (17+ 8.48 = 25.48 used = 4.52 remaining)	4.52	2011	8:1	36.16	12,903.05
SMR access road realignment	PIRSA Notification 2011	6	2011	10:1	60	12,843.05
SMR workshop extension	Letter to PIRSA re MPL 34 activity 16/7/10	5	2011	10:1	50	12,793.05
N-SMR (Chieftain–Knight) update	WPC-081 SMR minor mine adjustments_PIRSA_7-10-11	35.29	2011	various	286.52	12,506.53
IBMA WRDs	IBMA PEPR WPC-059 (*Eucalyptus Oleosa*)	36	2011	8:1	288	12,218.53
IBMA WRDs	IBMA PEPR WPC-059 (*Casuarina pauper*)	1.4	2011	6:1	8.4	12,210.13
IBMA extension to Little Baron pit	IBMA PEPR WPC-059	0.2	2011	4:1	0.08	12,210.05
IBMA LGO temp out-of-spec	IBMA PEPR WPC-059	2.3	2011	2:1	4.6	12,205.45
IBMA surplus (credit)	IBMA PEPR WPC-059	10.9	2011	8:1	87.2	12,118.25
Iron Chieftain go-line adjustment	MPL 34_Iron Chieftain Go-Line_VCCA	0.28	2011	2:1	0.56	12,117.69
IBMA surplus (credit)	IBMA PEPR WPC-083 (credit reduced from 059)	-0.9	2012	8:1	-7.2	12,124.89

SIMEC Mining SEB credit ledger						
IBMA out-of-spec LGO stockpile	IBMA PEPR WPC-083	6.4	2012	2:1	12.8	12,112.09
Reclamation of LGO dumps PC and IBDU07	IBMA PEPR WPC-083	6	2012	2:1	12	12,100.09
IBMA boundary fence	IBMA PEPR WPC-083	2.4	2012	8:1	19.2	12,080.89
IBMA WRDs	IBMA PEPR WPC-083 (*Eucalyptus Oleosa*) Increase to WPC-059 line 19; 36+13.9=49.9	13.9	2012	8:1	111.2	11,969.69
Whyalla Steelworks Ports project rail construction	NVC 12NRM0198	2.2	2012	4:1	8.8	11,960.89
Whyalla Steelworks Ports project rail construction	NVC 12NRM0298	8.8	2012	4:1	35.2	11,925.69
Iron Baron OBP surplus (credit)	Reference line 15 (4.52 ha credit minus 1.74, Lucas workshops reference MI 165 = 2.78 ha remaining)	0	2012	8:1	0	11,925.69
Iron Princess groundwater monitoring wells	IKMA PEPR WPC-084	1	2012	8:1	8	11,917.69
Whyalla Steelworks Ports project rail construction	NVC 12NRMO875	7.2	2012	4:1	28.8	11,888.89
Iron Knob Phase 1 operations	IKMA PEPR WPC-088	75.1	2012	various	515.5	11,373.39
Iron Knob Phase 2 operations	IKMA Phase 2 PEPR WPC-103	258.67	2014	Various	1,969.66	9,403.73
NE WRD reconciled credit	SMR MARP 2007 Addendum 2011	-2.2	2014	10:1	-22	9425.73
SE WRD reconciled credit	SMR MARP 2007 Addendum 2011	-18.4	2014	10:1	-184	9609.73
SMR Project Magnet	SMR MARP 2007	-5.29	2014	Various	-47.3	9657.03
N-SMR (Chieftain-Knight)	N-SMR MARP 2010	-32.36	2014	Various	-254.6	9911.63
SMR PEPR 2014	WPC-108 Iron Chieftain domain	128	2014	Various	1039.4	8872.23
SMR PEPR 2014	WPC-108 Iron Knight domain	61.8	2014	10:1	618	8254.23
SMR PEPR 2014	WPC-108 South SMR domain	28	2014	10:1	280	7974.23
SMR PEPR 2014	WPC-108 Concentrator and OBP TSF sub-domain	58.4	2014	10:1	584	7390.23
IBMA Ph2 PEPR 2015	WPC-106; IBMA PEPR Ph2	77.5	2015	Various	467	6923.23
IBMA Ph3 PEPR 2017 (Sul, War, Qn, Cav, Bar, Emp)	WPC-106; IBMA MPEPR 2017/033	486	2017	Various	3962.7	2960.53
IBMA Warrior-Knight access and haul roads	NVC 2018-302-010	4.88	2018	Various	19	2941.53
Ironstone Hill TSF impact area	NVC	0	2018	Not offset	27	2914.53

SIMEC Mining SEB credit ledger						
Iron Duchess North Stage B Part 1	WPC-108; SMR PEPR, Rev 5, May 2018	80	2018	10:1	800	2114.53
TSF Vegetation Impact Area	WPC-108; SMR PEPR, Rev 5, May 2018	59	2018	10:1	590	1524.53
TOTAL		**2,326**			**17,957.47**	**1,524.53**

4.5 Proximity to Conservation Areas

There are seven conservation parks close to the SMR mining area. These parks are managed under the Eastern Eyre Peninsula Parks Management Plan 2014 (DEWNR 2014a). The location of the conservation parks in relation to the SMR mining area is shown on Figure 85. No conservation areas are located within the mining tenements.

Ironstone Hill Conservation Park is approximately 5 km west of the Iron Chieftain mining area. The reserve (19,650 ha) conserves predominantly mallee and mallee/spinifex vegetation, the latter of which is important Sandhill Dunnart habitat.

The Lake Gilles Conservation Park is approximately 30 km north-west of Iron Chieftain. The 65,528 ha park conserves the ephemeral Lake Gilles salt lake system that is bordered by communities of samphire. The lake and surrounding samphire provide habitat for the Slender-billed Thornbill, Thick-billed Grasswren and migratory waders. Munyaroo Conservation Park (20,139 ha) is approximately 15 km south-east of Iron Chieftain and provides an important habitat link between the coastal vegetation and the inland mallee vegetation types.

Four smaller parks lie to the west of Munyaroo Conservation Park and south of Lake Gilles and Ironstone Hill Conservation Park. These are the Heggaton Conservation Park (6476 ha), Plug Range Conservation Park (2582 ha), Sheoak Hill Conservation Park (2427 ha), and the Malgra Conservation Park (66 ha). Relatively undisturbed mallee forest and woodland associations with a Melaleuca shrub understorey dominate these parks.

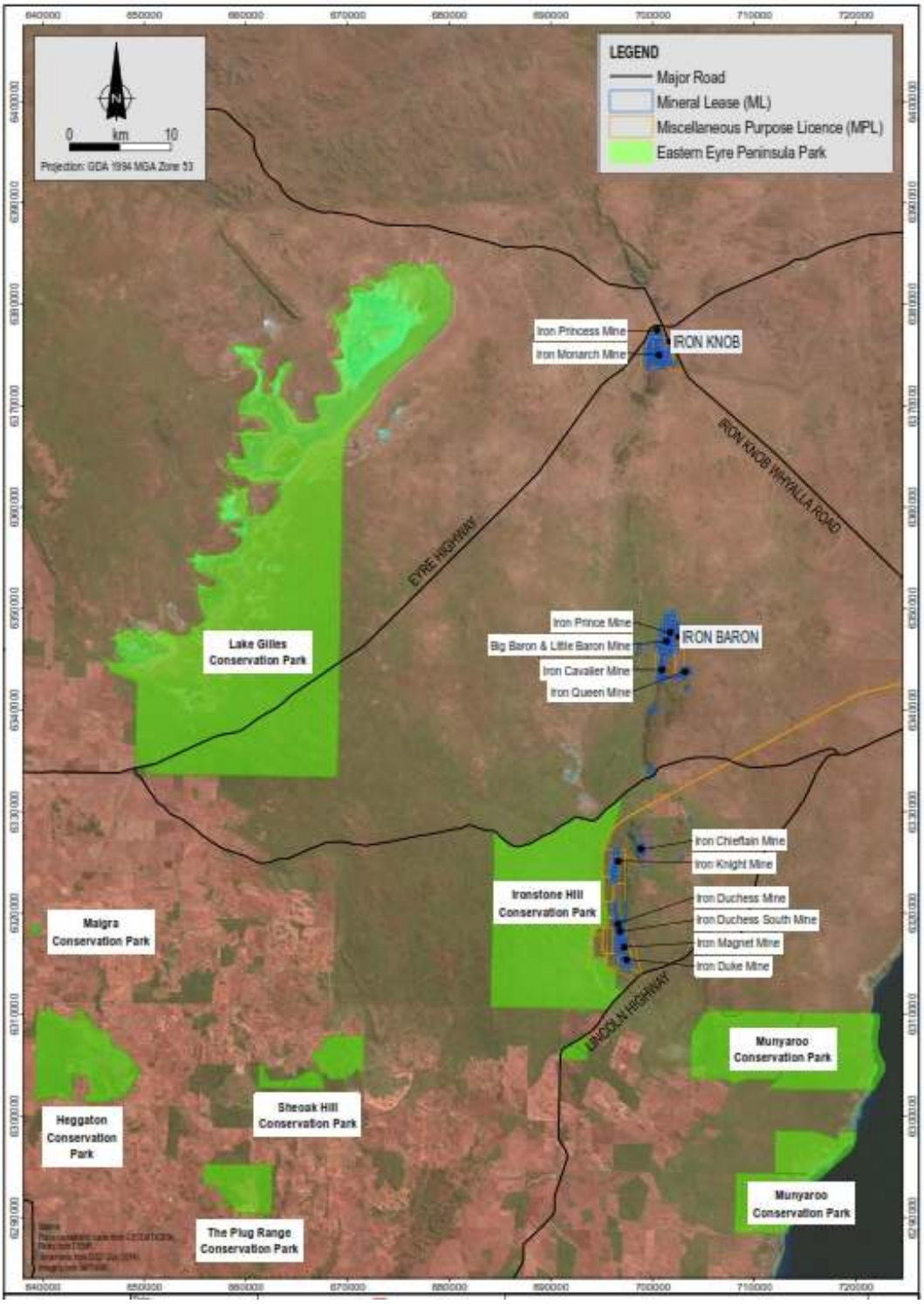


Figure 85 SMR mining area – Proximity to conservation areas

4.6 Other Heritage Agreements

A number of heritage agreements have been established over land near the Middleback Ranges. These are private conservation areas established to conserve native vegetation by agreement between the landholder and the Minister for Sustainability, Environment and Conservation under the *Native Vegetation Act 1991*. Indigenous plants and animals in the heritage agreement area are to be protected from the date of the agreement.

SIMEC Mining has purchased and de-stocked the Uplands Station pastoral sheep grazing property, located in the SMR, which now conserves vegetation communities and fauna habitat similar to those found in the region.

Three heritage agreements apply to land adjacent to the Lincoln Highway but outside the Iron Chieftain tenements to the north-east. These agreements help to conserve the mallee vegetation association of the district.

5 CONSULTATION

5.1 Community and Stakeholder Engagement Plan

SIMEC Mining recognises that achieving positive sustainable relationships with the communities in which it operates imperative to doing business well. SIMEC fosters a responsible approach to demonstrating social responsibility by promoting values and initiatives such as investment and engagement that show respect for the people and communities associated with its business (Arrium Mining and Materials 2012).

SIMEC Mining is committed to implementing good practice principles when engaging with communities and stakeholders and, as such, has agreed to support the South Australian Chamber of Mines and Energy (SACOME) Code of Practice for Community Engagement and follow the foundation principles for effective engagement:

1. **Inclusivity**: identifying and including, participants who represent all stakeholder groups.
2. **Transparency and accountability**: open and transparent processes with clear accountabilities.
3. **Clear and informed**: working cooperatively to seek mutually beneficial outcomes.
4. **Accessibility and timeliness**: process accessible to all Stakeholder groups and delivered in a timely manner and in a way that encourages deliberation and informed opinion
5. **Meaningful**: process and outcomes are considered by decision-makers and can influence the decisions made. Feedback provided to stakeholder groups on how their input influenced the outcome.

These principles have been integrated into SIMEC Mining's community and stakeholder engagement strategy and deployed for the life of mining operations in the SMR.

The primary objective of the strategy is to establish a framework to develop positive and sustainable relationships with the community and stakeholders who may be affected by SMR activities and operations. The strategy also aims to continue the process of engagement and to disseminate information, gather feedback and explore ways to address issues of community and stakeholder concern.

Specific goals of this strategy are to:

- accurately identify and consult with communities and stakeholders likely to be directly affected by the project
- clearly describe the operations, risks, benefits and potential impacts of all proposed activities to the community and stakeholders
- consistently provide timely, accurate and relevant information to community and stakeholders from project inception to completion

- establish an agreed 'two-way' process for exchanging information and feedback that is easily understood, culturally appropriate and accessible to all
- provide regular opportunities for community and stakeholders to obtain information, seek clarification and make comment on the project
- establish realistic expectations regarding the outcomes of the consultation process, including the extent to which community and stakeholder input will influence the decision-making process
- acknowledge and respond to all feedback, issues and concerns expressed by community and stakeholders in a respectful and timely manner
- work collaboratively to facilitate mutually beneficial outcomes for community and stakeholders wherever possible
- establish an agreed process for dispute resolution
- establish engagement methods that are equitable and culturally appropriate.

5.2 SIMEC Mining Sustainability Principles

SIMEC Mining has adopted the following principles as part of its operation.

- *Value for stakeholders: Operate our businesses in an efficient and financially sustainable way in order to supply products and solutions that satisfy our customer's needs and provide value to our stakeholders.*
- *Environmental protection: Optimise the eco-efficiency of our products through the product life cycle, including increased resource and energy efficiency in the production and distribution of our products and during the use of steel products. We are committed to the promotion of the recovery, reuse and recycling of steel and other products*.
- *Safety and health: Foster the wellbeing of our employees and provide them with a safe and healthy working environment*.
- *Local Communities: Demonstrate social responsibility by promoting values and initiatives that show respect for the people and communities associated with our businesses*.
- *Ethical Standards: Conduct our business with high ethical standards in our dealings with employees, customers, suppliers and the community*.
- *Stakeholder Engagement: Engage our stakeholders and independent third parties in constructive dialogue to help fulfil our sustainable development commitments (Arrium Mining and Materials 2014)*.

5.3 Key Stakeholder List

The definition of stakeholders applied in the context of this plan is the same as for the 2002 World Summit on Sustainable Development, where stakeholders were defined as '*those who have an interest in a particular decision, either as individuals or representatives of a group. This includes people who influence a decision, or can influence it, as well as those affected by it'* (MCMPR 2005, p6).

Key stakeholders for the SMR mining operations are identified in Table 33.

Table 33 SMR key stakeholders

Stakeholder group	Specific stakeholders
Project proponent	SIMEC Limited
Project team	SIMEC Mining Project Team
Directly affected landholders	Mark, Kathy, John and Nigel Turnbull
	Hayden and Emma Butts
Indigenous groups	Whyallina Heritage Aboriginal Corporation Inc.
	Barngarla Native Title Claimants
	Kokotha Mula Nation Land Council Incorporated
Surrounding landowners, residents and community groups	Bronte Plane
	Whyalla Community/Residents
	Middleback Alliance of Land Managers
	Whyalla Environmental Consultation Group (ECG)
Local government and councils	Outback Communities Authority (OCA)
	The City of Whyalla
State Government	South Australian Arid Lands (SAAL) NRM Board
	South Australian Development Assessment Commission
	Department of Premier and Cabinet (Aboriginal Affairs and Reconciliation)
	South Australian Pastoral Board (SAPB)
Regulatory body	Department of Environment, Water and Natural Resources (DEWNR)
	Department of the Premier and Cabinet (DPC) (formerly DSD)
	Department of Planning Transport and Infrastructure (DPTI)
	Environment Protection Authority (EPA)
	Native Vegetation Council (NVC)
	SA Water
	South Australian Native Title Services (SANTS)
Federal Government	Department of Defence
	Department of Sustainability, Environment, Water, Population and Communities (DSEWPC)
Non-government organisations	Regional Development Australia Whyalla and Eyre Peninsula (RDA WEP)
Natural history, environment and heritage conservation groups	Whyalla Friends of the Park
Emergency services	SA Police (Whyalla and Port Augusta police stations)
	South Australian State Emergency Service (SES)
	Whyalla Hospital

5.4 Landholders

The nearest neighbours to the SMR operations are:

- Uplands Station Homestead (owned by SIMEC Mining)
- Broadview Station Homestead
- Moola Station Homestead
- Moonabie Station Homestead
- Pine Hill Station Homestead
- 'Plane' family homestead.

Figure 86 (and Appendix A-6) indicates landholders who are next to the SMR operations and Figure 87 (and Appendix A-7) shows landholders within the region overall. Figure 88 (and Appendix A-8) shows the proximity of the neighbouring homesteads to the SMR mining operations.

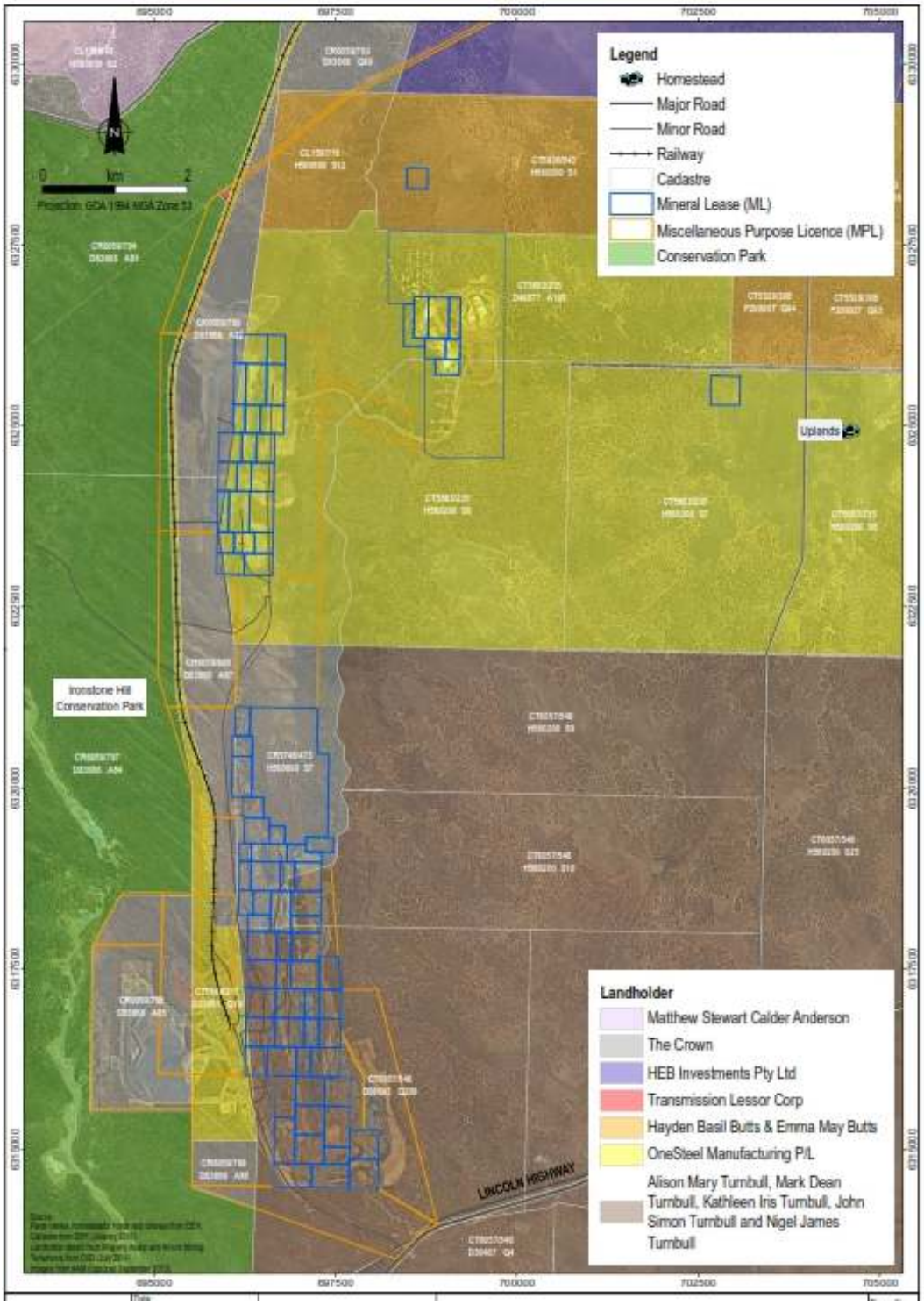


Figure 86 SMR mining area – Adjacent landholders

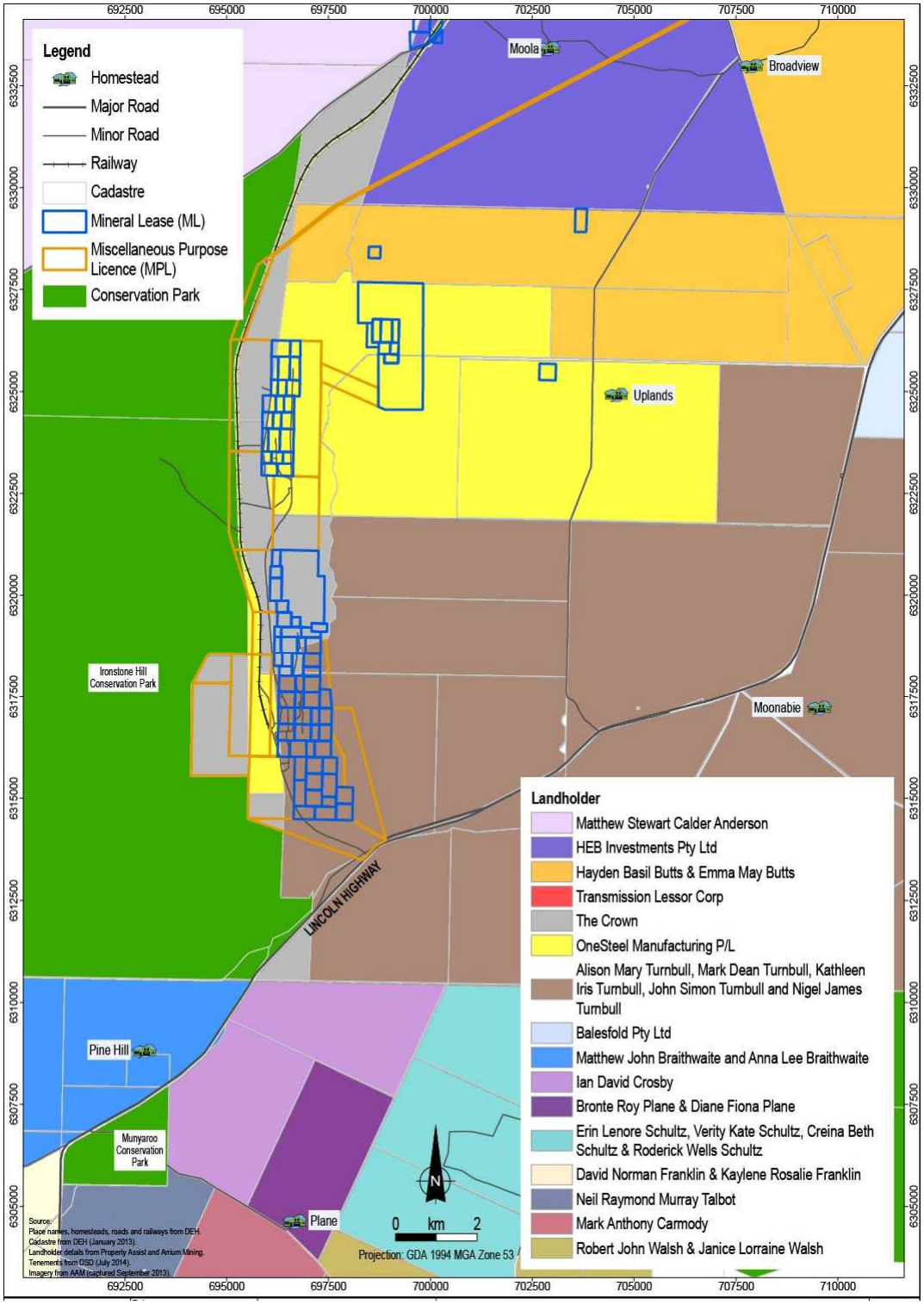


Figure 87 SMR mining area – Regional landholders

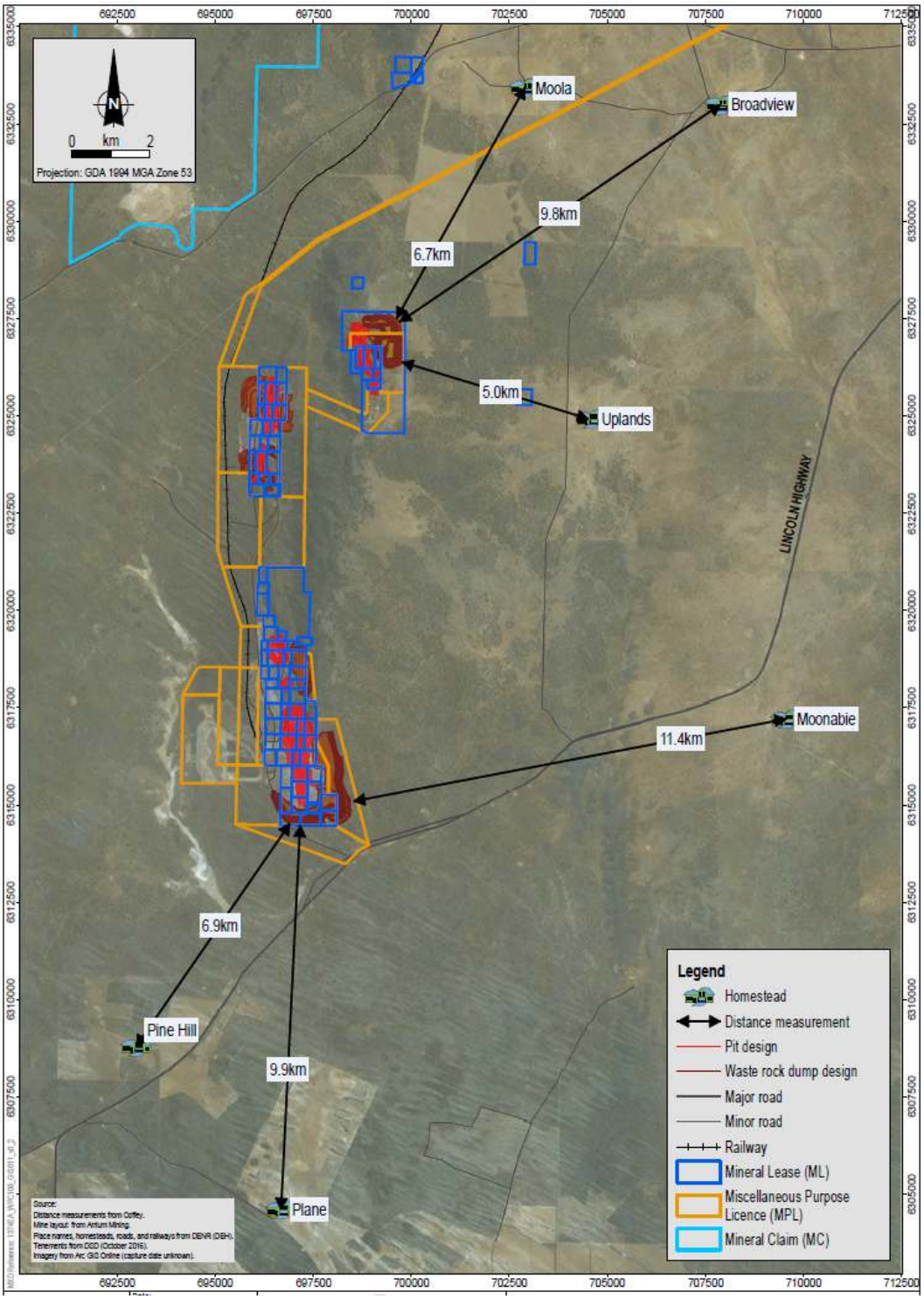


Figure 88 SMR mining area – Proximity of neighbouring homesteads

5.5 Planned Approach to Community Engagement

In order to realise the stated aims of the SIMEC Mining community engagement strategy, different tools and techniques will be employed to effectively engage the community and stakeholder groups identified above. Communication and engagement tools likely to be used to facilitate engagement with key stakeholder groups are identified in Table 34.

Table 34 Key stakeholder engagement activities

Stakeholder	Engagement mechanism	Purpose/Frequency
Directly affected landholders	Formal (written) correspondence Face-to-face meetings Telephone call/email Dedicated SIMEC Mining community contact person/s Biannual site visit and dinner	Formal correspondence including official letters and statutory forms to be issued as required in accordance with relevant Legislation (Notice of Entry, Use of Declared Equipment etc.) Face-to-face meetings to be held with directly affected landholders as agreed with individual landholders Pastoralist biannual site visit and dinner to build and maintain stakeholder relationships, last held 4 June 2014 Periodic telephone call / email to actively solicit feedback regarding impact of operations, efficacy of impact mitigation strategies, answer questions and provide update on project progress, as required Various written/verbal communications as required to: • respond to ad hoc comments, questions or requests for information (verbal or written) • acknowledge/respond to complaints and issues of concern (written) • request access to land
Landholders/ residents	Telephone calls/email correspondence Printed material Dedicated SIMEC Mining community contact person/s	Telephone call/email correspondence to individual landholders (by request) to: • solicit feedback regarding impact of operations, efficacy of impact mitigation strategies • to advise of blasting schedule Occasional distribution of printed material including information posters, newsletters and media releases to: • advertise proposed future development plans • provide project updates to the wider community • respond to issues of community interest/concern • advertise upcoming events and project milestones

Stakeholder	Engagement mechanism	Purpose/Frequency
Indigenous groups	Face-to-face meetings Site visits Formal correspondence Statutory notices Telephone/email correspondence Dedicated SIMEC Mining community contact person/s	Regular face-to-face meetings to: • establish and maintain stakeholder relationships • discuss current project plans and proposed future development • provide regular project and progress updates • report action taken in response to issues/items raised previously • identify any new issues of interest or concern and gauge community attitudes to the project • gauge community attitudes to the project • seek input to closure and rehabilitation plans • identify opportunities to facilitate mutually beneficial outcomes for SIMEC Mining and Indigenous stakeholders Site visits as required to identify sites of cultural heritage significance Formal correspondence in relation to Indigenous Land Use Agreement (ILUA) conditions Statutory notices issued in accordance with relevant legislation (Notices of Entry etc.) Ad hoc telephone and email correspondence as required

Stakeholder	Engagement mechanism	Purpose/Frequency
Whyalla community Community leaders and representatives, residents and community groups	Community consultation meetings with Whyalla Environmental Consultation Group (ECG) Printed material Media releases Dedicated SIMEC Mining community contact person/s	Regular meetings and correspondence held with the Whyalla Environmental Consultation Group (ECG) to: • discuss current project plans and proposed new development • present project schedules and updates on existing operations • discuss emergent issues and gauge community attitudes to the project • discuss impacts of operations and efficacy of impact mitigation strategies • report action taken in response to issues/items raised previously • identify any new issues of interest or concern and gauge community attitudes to the project • identify opportunities to facilitate mutually beneficial outcomes for SIMEC Mining and the IKMA community/environment • gauge community attitudes to the project • seek input to closure and rehabilitation plans Local newspaper and internal employee (SIMEC Mining and OneSteel Whyalla Steelworks) communiqués issued to: • provide ongoing information to community members about SIMEC Mining operations, project progress updates and promote upcoming events/project milestones
Regulatory bodies and government agencies	Face-to-face meetings Formal (written) correspondence Statutory notices and application forms Meeting minutes/Notes Telephone calls/email correspondence Dedicated SIMEC Mining contact person/s	Formal written correspondence including, letters, reports, statutory notices and application forms to be submitted in accordance with relevant legislation Ad hoc telephone and email correspondence to clarify statutory requirements etc. Monthly project update meetings held with DPC to: • discuss proposed new projects and further development of existing operations • present project schedules and updates on existing operations • clarify regulatory requirements • exchange applications and reports submitted to DPC for regulatory approval Meeting minutes to formally document meeting proceedings and action items Meetings and correspondence with other regulatory bodies, as required

Stakeholder	Engagement mechanism	Purpose/Frequency
Local government and councils	Face-to-face meetings Formal correspondence Meeting minutes Telephone calls/email correspondence Dedicated SIMEC Mining contact person/s	Briefing to Whyalla City Council as required to: • inform members of current and future development plans • provide relevant regular project progress updates and status of statutory applications • discuss emergent issues and gauge community attitudes to the project
NGOs, natural history, environment and conservation groups	Formal correspondence Printed material Media releases Dedicated SIMEC Mining community contact person/s	Formal letters of introduction to: • inform stakeholders about SIMEC Mining project plans • advise company contact information • identify opportunities to facilitate mutually beneficial outcomes for SIMEC Mining and interested community/stakeholder groups
Emergency services, police, ambulance	Telephone calls/emails	Communicate with local CFS to keep them informed of planned emergency response procedures Regular contact with Whyalla Police to discuss security issues as they arise

5.6 Community Support Activities

5.6.1 Community sponsorship and support

SIMEC Mining and its employees pride themselves on the support they offer to regional and local activities. From providing education and sponsorships, through to charity fundraising events, all of these activities require personal commitment and individual dedication.

SIMEC Mining's Community Support Program assists communities by supporting ongoing and sustainable initiatives that provide:

- welfare help for the less advantaged
- local youth with a range of opportunities to assist in their development for the future
- significant benefit to local communities usually in the way of major events or new or improved community facilities.

Junior development, particularly around sport, has been a recent area of focus and SIMEC Mining currently support numerous programs run by local sporting associations including:

- the Whyalla Hockey Association's Hockey in Schools Program
- the Whyalla Tennis Association's Hot Shots Program
- Whyalla Baseball Association's T-ball League
- Ardrossan Netball Club's Junior Development Program
- other sporting bodies including the Ardrossan netball, bowling and hockey associations and the Coober Pedy Football Club Juniors.

5.6.2 Community improvement program

SIMEC Mining has been actively involved in improving the visual appearance of east Whyalla through its Community Improvement Program. This has included:

- significant financial contribution to the Whyalla City Council to assist with the major overhaul of the Surf Life Saving Club building
- labour and funding contributions to assist Council and Stuart High School students with the planting of 500 native plants and trees on Hummock Hill during the period 2012 to 2013 as part of the Hummock Hill restoration project.

SIMEC Mining also made a significant donation to the City Plaza Business Association to assist with improvements in the City Plaza in 2012–2013.

5.6.3 Youth opportunities

In August 2013 OneSteel Whyalla Steelworks and SIMEC Mining became the major sponsors for the inaugural Whyalla Science and Engineering Challenge in Whyalla. The program is designed to encourage more high school students to study maths and science at senior levels and to raise awareness of careers in science and engineering. Aside from providing significant funding to stage the event, OneSteel and SIMEC released several staff members to assist with the set-up and delivery of the challenge, as well as donating a unique trophy featuring a polished sliver of railway track. This design represented a high-quality example of local science and engineering and symbolised a small part of a larger journey for the competing students.

5.6.4 Employees giving back

A large number of employees are volunteers in the local community and 'give back' in their own time. A recent survey found that nearly 70% of respondents actively volunteer, with the majority of these giving their time to assist local sporting clubs.

Since undertaking the survey, SIMEC Mining have been looking at ways to assist these employees in their volunteering efforts.

For snapshot of SIMEC Mining's Community Support Program activities and achievement in the period July 2012 to December 2013 see Figure 89.

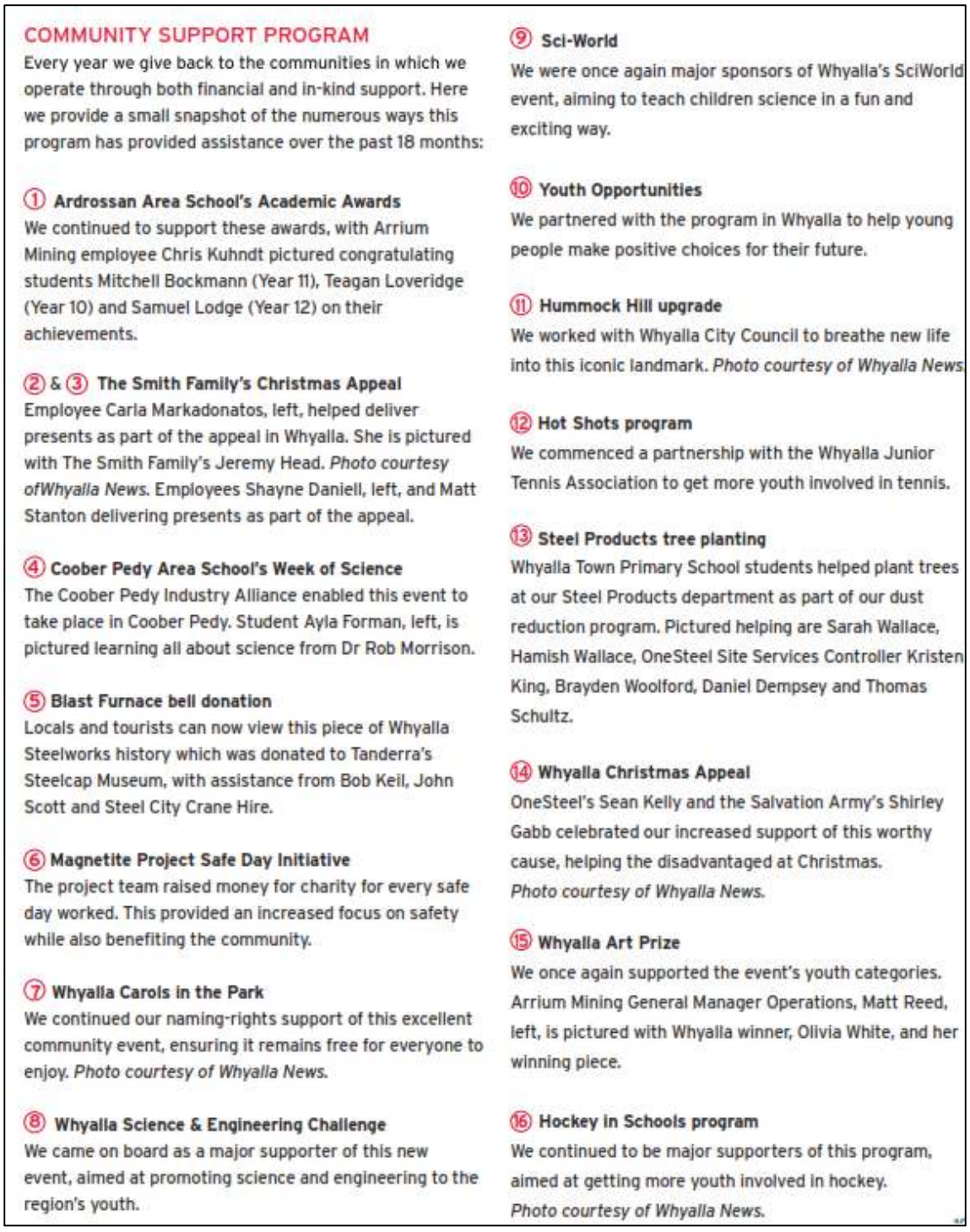
5.6.5 The Middleback Alliance

The Middleback Alliance is a cooperative framework for sustainable land management across the SMR and surrounding areas.

The Middleback Alliance is directed by three major landholders in the region (Ecological Horizons, Natural Resources Eyre Peninsula and SIMEC Mining).

By sharing resources and cooperatively delivering a works program across land boundaries, the Middleback Alliance delivers improved and sustainable land management outcomes. Achievements for 2013 include:

- removal of 1700 feral goats regionally including 1000 from the Middleback Ranges
- baiting (feral animal control)
- discovery of the Black-naped snake not previously recorded on the Eyre Peninsula (DEWNR 2014b)
- continued monitoring (trapping and micro-chipping) of nationally threatened Sandhill Dunnarts
- survey and monitoring of at least 18 active malleefowl nests (DEWNR 2013)
- other works included pest plant control and erosion mitigation on property owned by SIMEC Mining, known as 'Uplands'.



COMMUNITY SUPPORT PROGRAM

Every year we give back to the communities in which we operate through both financial and in-kind support. Here we provide a small snapshot of the numerous ways this program has provided assistance over the past 18 months:

① **Ardrossan Area School's Academic Awards**
We continued to support these awards, with Arrium Mining employee Chris Kuhndt pictured congratulating students Mitchell Bockmann (Year 11), Teagan Loveridge (Year 10) and Samuel Lodge (Year 12) on their achievements.

②&③ **The Smith Family's Christmas Appeal**
Employee Carla Markadonatos, left, helped deliver presents as part of the appeal in Whyalla. She is pictured with The Smith Family's Jeremy Head. *Photo courtesy ofWhyalla News.* Employees Shayne Daniell, left, and Matt Stanton delivering presents as part of the appeal.

④ **Coober Pedy Area School's Week of Science**
The Coober Pedy Industry Alliance enabled this event to take place in Coober Pedy. Student Ayla Forman, left, is pictured learning all about science from Dr Rob Morrison.

⑤ **Blast Furnace bell donation**
Locals and tourists can now view this piece of Whyalla Steelworks history which was donated to Tanderra's Steelcap Museum, with assistance from Bob Keil, John Scott and Steel City Crane Hire.

⑥ **Magnetite Project Safe Day Initiative**
The project team raised money for charity for every safe day worked. This provided an increased focus on safety while also benefiting the community.

⑦ **Whyalla Carols in the Park**
We continued our naming-rights support of this excellent community event, ensuring it remains free for everyone to enjoy. *Photo courtesy of Whyalla News.*

⑧ **Whyalla Science & Engineering Challenge**
We came on board as a major supporter of this new event, aimed at promoting science and engineering to the region's youth.

⑨ **Sci-World**
We were once again major sponsors of Whyalla's SciWorld event, aiming to teach children science in a fun and exciting way.

⑩ **Youth Opportunities**
We partnered with the program in Whyalla to help young people make positive choices for their future.

⑪ **Hummock Hill upgrade**
We worked with Whyalla City Council to breathe new life into this iconic landmark. *Photo courtesy of Whyalla News.*

⑫ **Hot Shots program**
We commenced a partnership with the Whyalla Junior Tennis Association to get more youth involved in tennis.

⑬ **Steel Products tree planting**
Whyalla Town Primary School students helped plant trees at our Steel Products department as part of our dust reduction program. Pictured helping are Sarah Wallace, Hamish Wallace, OneSteel Site Services Controller Kristen King, Brayden Woolford, Daniel Dempsey and Thomas Schultz.

⑭ **Whyalla Christmas Appeal**
OneSteel's Sean Kelly and the Salvation Army's Shirley Gabb celebrated our increased support of this worthy cause, helping the disadvantaged at Christmas. *Photo courtesy of Whyalla News.*

⑮ **Whyalla Art Prize**
We once again supported the event's youth categories. Arrium Mining General Manager Operations, Matt Reed, left, is pictured with Whyalla winner, Olivia White, and her winning piece.

⑯ **Hockey in Schools program**
We continued to be major supporters of this program, aimed at getting more youth involved in hockey. *Photo courtesy of Whyalla News.*

Source: Arrium Mining and Materials 2013

Figure 89 OneSteel Whyalla Steelworks and SIMEC Mining Community Support Program

5.7 Results of Community Consultation

SIMEC Mining keeps detailed records of all community consultation activities. Table 35 summarises the results of community consultation meetings and includes a record of issues raised and responses offered. Any proposed follow-up action and notification of final outcomes will always be provided directly to the community through community notices and community forums.

Table 35 Results of community engagement in the SMR

Stakeholder	Date	Matters discussed	Issues raised	Response
Key stakeholder consultations				
Mark, Kathy, John and Nigel Turnbull	20 May 2010	SE WRD extension Exploration activities	Historic agreements Mining impacts	Development of a process to resolve historic issues and an action plan to address and understand mining impacts
	May 2010 to March 2011	General updates on action plan	Access agreement	Negotiation process for access agreement established
		Specific reviews of SE WRD design process and associated tenement application	Mining impacts	Commitment to ongoing monitoring of action plan
	July 2013 to January 2014	Revised dust outcomes and measurement criteria – review process and stakeholder concerns or issues	Plant health and the impact this has on feed availability	Inclusion of: - additional indicator species - dust levels and plant health inspection indicators in dust measurement criteria and plant health criteria - land capability assessments by external consultant
				Further consultation to take place on locations of dust gauges and control sites
	May 2014	Proposed Iron Chieftain extension	Water flow management Dust management	Reassurance that areas of concern had been reviewed with appropriate government departments including DEWNR and DSD, and discussion of drainage processes included in the mine design
	May 2011 to August 2014	Access and compensation agreement Mining impacts and business interactions	Mining impacts Interactions Water supplies and fencing	Escalation process put in place for access to General Manager Development and General Manager HR
				Offer of independent mediation

Stakeholder	Date	Matters discussed	Issues raised	Response
		Escalation processes for resolution of issues	Escalation requests	Resolution of outstanding issues and access and compensation agreement in place
			Access to Senior Management	
		Independent mediation options for resolution		
	17 April 2018	Proposed Iron Duchess North pit and WRD extension	No issues raised	None required
Hayden and Emma Butts	May 2014	Proposed Iron Chieftain extension and associated tenement application process	Boundary interactions	Survey review of boundary fence and reassurance of supporting existing fencing arrangements
Bronte Plane	May 2010 to August 2014	Mining impacts complaints investigation	Dust impacts on crop yield and dust impacts on his stored rainwater quality – Mr Plane is concerned that the potential contaminants in SIMEC Mining's ores as outlined in the PEPR may be influencing rainwater quality	Independent soil and stored rainwater quality testing undertaken with no adverse impacts found
				Number of site visits on high wind days
				Number of site visits to look for impacts on vegetation with no observable impacts found
			Dust monitoring	Installation of dust monitoring equipment
				Escalation process to General Manager HR and Senior Manager Development
				Independent soil and tissue analysis carried out on the property with no impacts from mining detected
				Attempts to meet with Mr Plane to share findings of dust monitoring and independent study have been unsuccessful to date
	July 2013	Revised dust outcomes and measurement criteria – review process and stakeholder concerns or issues	Dust impacts on crop yield and dust impacts on his stored rainwater quality - Mr Plane is concerned that the potential contaminants in SIMEC Mining's ores as outlined in the PEPR may be influencing rainwater quality	Independent soil and stored rainwater quality testing undertaken

Stakeholder	Date	Matters discussed	Issues raised	Response
Mr Walsh (property east of Mr Plane and north-east of Mr Plane which he manages for the Schultz family)	July 2013	Revised dust outcomes and measurement criteria – review process and stakeholder concerns or issues	No concerns	Not required
Mr Braithwaite – Pine Hill	July 2013	Revised dust outcomes and measurement criteria – review process and stakeholder concerns or issues	No concerns	Not required
Dr Annie Lane, Regional Manager, Natural Resources Eyre Peninsula, Ironstone Conservation Park	July 2013	Revised dust outcomes and measurement criteria – review process and stakeholder concerns or issues	No concerns	Not required
Government and regulatory stakeholders				
DEWNR/SAAL	28 Mar 2014 20 May 2014 29 Jul 2014	Proposed Iron Chieftain extension	Query raised re water affecting activity (WAA) – Melissa Horgan	SIMEC Mining currently liaising with SAAL on the need for a WAA permit. Site visit to Iron Chieftain by Melissa Horgan (SAAL) to review Iron Chieftain proposal document, and to inspect actual site conditions. The need for WAA permit was confirmed from the site visit. Advice received from Melissa Horgan (SAAL) that WAA permit application is progressing and no further information is needed.
Indigenous groups				
There is an ILUA in place with local Indigenous, the details of which are confidential.				

5.8 Indigenous consultations

SIMEC Mining meets regularly with the Barngarla community representatives regarding developments in the ILUA area.

The ILUA between OneSteel (SIMEC Mining) and the Barngarla Native Title Claimants sets out clear heritage clearance protocols for both parties, and includes protocols for notifications concerning proposed changes and developments within the ILUA area.

5.9 Key Issues and Complaint Management

A key issues management process has been incorporated into SIMEC Mining Work Instruction WI50_008 Stakeholder Engagement and Communications Management.

Stakeholders and members of the community will be encouraged to contact SIMEC Mining to ask questions and discuss any issues of interest or concern throughout all phases of the project.

All stakeholder and community questions and feedback will be recorded in the complaints management database and the Landholder issues register and saved electronically in the SIMEC Mining Stakeholder Engagement Information Directory. All feedback will be acknowledged within one month of receipt and where possible, information will be provided with any proposed follow-up action and expected timeframe for resolution of issues.

Meeting notes will be made during all one-to-one discussions with stakeholders. A copy of these will be provided to all meeting attendees where practicable and saved electronically in the SIMEC Mining stakeholder engagement information directory.

5.9.1 Complaints management

SIMEC Mining has a detailed complaints management process, which sets out the protocol for managing community and employee complaints regarding SIMEC Mining performance in a way that supports the business Environmental and Social Responsibility (ESR) vision:

The SIMEC Mining ESR vision:

SIMEC Mining will strive to have a positive impact on our community, economy and environment by openly engaging our employees and stakeholders on key issues and delivering on our commitments.

We aim to operate with:

- *transparency, engagement and accountability*
- *greater transparency through sensitivity to community and early acknowledgement of issues*
- *meaningful engagement and community empowerment*
- *increased accountability to stakeholders*
- *improved relations with community and government.*

Full details of the SIMEC Mining Complaints Management protocol are set out in SIMEC Mining Work Instruction WI50_004.

6 ENVIRONMENTAL OUTCOMES AND MEASUREMENT CRITERIA

6.1 Overview and Process

6.1.1 Impact assessment

The potential environmental, social and economic impacts have been identified and assessed (see Table 36, Table 37 and Table 38). The mining operations considered include exploration, investigative works, construction, mining, and rehabilitation and closure, and other activities relevant to the mining operations.

The environmental impact of the mining operations include vegetation clearance, increased noise, vibration, light (at night), dust, changes to surface water flow, changes to groundwater levels, and changes to the stability of soils as they are disturbed and stockpiled. A series of controls and management strategies will be used to ensure these impacts are minimised, and are as low as reasonably practicable (ALARP).

Table 36 Natural environmental impacts

Aspects (impact events)	Impact receptors	Potential and likely consequences
Vegetation clearance	Flora Fauna	• loss of flora species in a localised area • displacement of fauna species locally • incursions of declared weed species
Civil constructions, mine preparatory works and investigations	Flora Fauna Soil Groundwater Surface water Air quality Visual amenity Noise, light and vibration	• reduction of flows to stormwater dependent ecosystems • loss of fauna habitat • displacement and injury to fauna • increased soil gully erosion • contaminated stormwater runoff • site (soil and groundwater) contamination • increased ground salinity and root zone flooding • increased generation of dust • increased generation of noise, vibration and light • changes to visual amenity

Aspects (impact events)	Impact receptors	Potential and likely consequences
Mining activities (including rehabilitation and closure)	Flora Fauna Soil Stormwater Groundwater Air quality Noise, vibration and light Visual amenity	• reduction of flows to stormwater dependent ecosystems • loss of fauna habitat • displacement and injury to fauna • increased soil gully erosion • increased ground salinity and root zone flooding • contaminated stormwater runoff • site (soil and groundwater) contamination • increased generation of dust • increased generation of noise, vibration and light • increased use of resources – water and energy • inappropriate disposal of industrial and general wastes resulting in amenity or site (and off site) contamination • changes to visual amenity of the area with mining activities revitalised
Exploration	Flora Fauna Visual amenity Soil Stormwater Air quality	• short-term loss of vegetation • temporary displacement and injury to fauna • temporary changes to visual amenity with clearing, increased activity of drill rigs and establishment of drill pads • generation of localised dust, noise and vibration • erosion and sedimentation as a result of exposed areas • site (soil and groundwater) contamination
Change in land use at closure	Flora Fauna Visual amenity	• re-establishment of ecosystem function • maintain regional biodiversity value • rehabilitation of worked areas previously rehabilitated into the surrounding landscape • visual amenity changes with altered landscapes

Table 37 Social impacts

Aspects (impact events)	Impact receptors	Potential and likely consequences
Civil constructions, mine preparatory works and investigations	Neighbours Visitors Highway travellers	• stimulus for job prospects provides positive outlook for community • increased nuisance dust, noise, vibration and light for nearby landholders
Mining activities	Landholders Neighbours Visitors Highway travellers	• regional community complaints • stimulus for job prospects provides positive outlook for community • increased nuisance dust, noise, vibration and light for nearby landholders • visual amenity changes for the local community, visitors to the region and passers-by (leading to complaints or concerns)
Undertaking of exploration activities	Whyalla and surrounding community	• increased confidence in SIMEC Mining and the future of Whyalla and the region • visual amenity of rehabilitated drill pads and access roads
Change in land use	Regional community Landholders Visitors	• no new changes to land use

Table 38 Economic impacts

Aspects (impact events)	Impact receptors	Potential and likely consequences
Further extraction of natural resources	Regional communities Regional businesses	• increased regional employment opportunities • increased regional small business opportunities • increased education and training opportunities • increased financial security regionally • increased state revenue • increased use of public road and rail networks • further depletion of available hematite resources
Change in land use	Local community	• increased opportunities for alternate employment • continued confidence in the local real estate market

Aspects (impact events)	Impact receptors	Potential and likely consequences
		• continued confidence in local business ventures

The impact assessment will be revised and updated, as required, as the SMR development progresses over its estimated 30-year mine life.

The impact events identified for activities associated with the SMR development have been compiled and assessed in terms of the receptor or receiving environment which may potentially be affected. This may include:

- native vegetation and fauna
- weeds, pest animals and pathogens
- soil
- stormwater (capturing surface water and flooding aspects)
- groundwater
- air quality
- visual amenity, nuisance noise and light
- blasting (and vibration)
- waste disposal
- public safety
- adjacent land use and third-party property (pastoral pasture and cereal crops)
- heritage (Aboriginal and European)
- traffic
- post-closure aspects.

6.1.2 Control and management strategies

The incorporation of control and management strategies includes both design control measures (to reduce impact prior to it occurring) and management measures undertaken as part of the activity.

These strategies have been developed in accordance with recognised industry standards. Where the primary risk is higher than 'Low', controls and/or management strategies will be implemented to reduce that risk. These include any necessary changes to design.

SIMEC Mining will review and update the certified AS/NZS ISO 14001 Environmental Management System (EMS) (see Section 9) to ensure controls and management strategies presented in this PEPR are appropriately integrated.

6.1.3 Completion of risk assessment

A risk assessment is undertaken before controls and/or management strategies are applied to establish inherent risk rankings. A second risk assessment is undertaken with the controls and/or management measures applied to determine a residual risk ranking. SIMEC Mining considers these residual risks to be appropriate and acceptable, providing the relevant controls and/or management strategies are implemented.

The following risk assessment matrix (consistent with AS 4360 Risk Management and DMITRE MG2 guidelines) forms part of SIMEC Mining's business risk management systems, and is used to determine the risk of identified impacts presented in the following sections (see Figure 90).

LIKELIHOOD	1 Negligible	2 Minor	3 Medium	4 Major	5 Extreme
5 Almost certain	High	High	Very High	Very High	Very High
4 Likely	Moderate	High	High	Very High	Very High
3 Possible	Low	Moderate	High	Very High	Very High
2 Unlikely	Low	Low	Moderate	High	Very High
1 Rare	Low	Low	Moderate	High	High

Source: SIMEC Mining Quality Procedure, QP29_13, Risk Management

Figure 90 SIMEC Mining risk assessment matrix

The qualitative measures of likelihood are:

- **Almost certain**: The event is expected to occur in most circumstances. Not surprised if it happens.
- **Likely**: The events will probably occur in most circumstances. Not surprised if it happens.
- **Possible**: The event might occur at some time. Would not be surprised either way, whether it happens or not.
- **Unlikely**: The event could occur at some time. Surprised if it happens.
- **Rare**: The event may occur only in exceptional circumstances. May happen, but it would be a shock.

The qualitative measures of social, environmental and legal consequences are:

- **Negligible**: No lasting effect. Low-level impacts on biological or physical environment. Limited damage to minimal area of low significance. Public concern limited to local complaints. Ongoing scrutiny/attention from regulator. Low-level legal issue. On the spot fine. Technical non-compliance, prosecution unlikely.
- **Minor**: Minor effects on biological or physical environment. Minor short-medium term damage to small area of limited significance. Minor adverse local public or media attention and complaints.

Significant hardship from the Regulator. Reputation is adversely affected with a small number of site-focused people. Minor legal issues, non-compliances and breach of regulation. Minor prosecution or litigation possible.

- **Medium**: Moderate effects on biological or physical environment but not affecting ecosystem function. Moderate short-medium term widespread impacts. Attention from media and heightened concern from local community. Criticism by the NGOs, significant difficulties in gaining approvals. Environmental credentials moderately affected. Serious breach of regulation with investigation or report to authority with prosecution and/or moderate fine possible.
- **Major**: Serious environmental effects with some impairment of ecosystem function (e.g. displacement of a species). Relatively widespread medium-long term impacts. Significant national media attention. May lose license to operate or not gain approval. Environmental/management credentials tarnished. Major breach of regulation with potential major fine and/or investigation and prosecution by authority. Major litigation.
- **Extreme**: Very serious environmental effects with impairment of ecosystem function. Long term, widespread effects on significant environment (e.g. unique habitat, national park). Serious public or media outcry (international coverage). Damaging NGO campaign. Licence to operate threatened. Reputation severely tarnished. Share price may be affected. Investigation by authority with significant prosecution and fines. Very serious litigation, including class actions.

6.1.4 Leading indicator measurement criteria

Leading indicator criteria have been developed where the desired outcome relies heavily on a management strategy to reduce the risk. These leading indicators are detailed in internal operational plans and programs, and have been designed to provide an early warning that the control or management strategy is not adequate and, as a consequence, there is a risk the outcome will not be achieved.

6.1.5 Outcome and measurement criteria

Outcomes and measurement criteria have been developed to monitor the effectiveness of the controls and/ or management strategies specifically implemented by SIMEC Mining for primary risks ranked higher than ‘Low’.

The process by which required outcomes and measurement criteria for the SMR operations have been determined is outlined in Figure 91.

A summary of the operational and closure outcomes, measurement criteria and associated monitoring actions is included in Section 6.16.

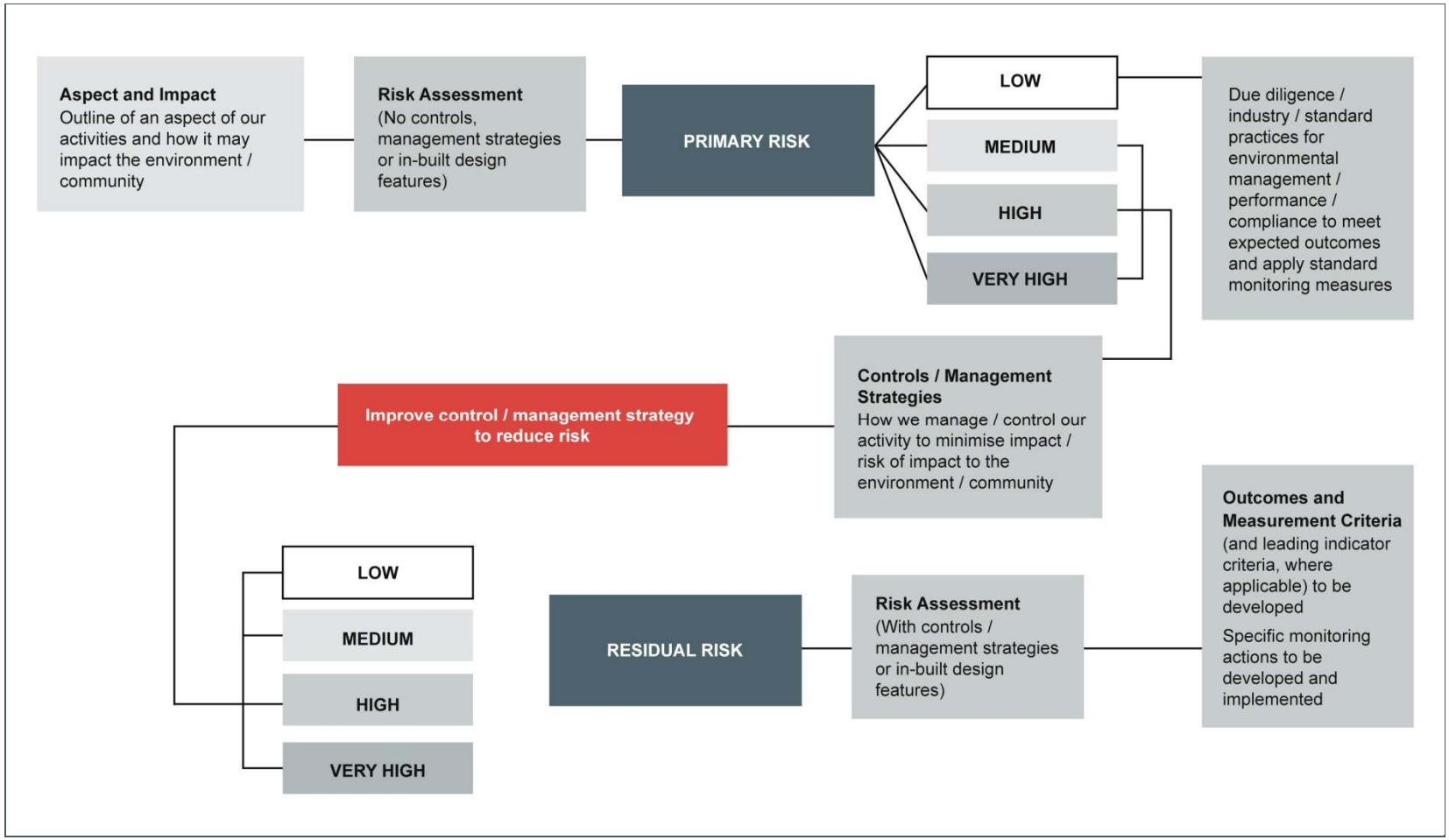


Figure 91 The process for determining outcomes and measurement criteria

6.1.6 New environmental risks

The new impacts and associated risks for SMR operations presented in this PEPR, are detailed in Sections 6.2 to 6.15 below.

The impact and risk assessment for the SMR will be reviewed and the PEPR updated accordingly if new risks are identified during operations or as the Mine Plan is modified.

6.2 Native Vegetation and Fauna

6.2.1 Context

The SMR is unique as it forms an important boundary between biogeographic areas. The result is an intergrade between native species that depend upon Mallee habitats and those that are associated with more arid chenopod shrublands. This separation is notable as it provides a natural boundary to the distribution of native species resulting in the most eastern limits of several more arid species (i.e. Western Yellow Robin (*Eopsaltria griseogularis*), Rufous Tree Creeper (*Climacteris rufa*), and Sandhill Dunnart (*Sminthopsis psammophila*)). As these species occur at the edge of their range, these populations are considered to be more at risk of threats to local extinction than populations in the centre of a species distribution.

Habitat values are considered excellent throughout the project area generally, due to the variety of niches available for native fauna and the diversity of vegetation.

Iron Chieftain

The vegetation within the Iron Chieftain area consists of natural woodland, old growth Open Mallee with large hollows, Low Chenopod Shrubland, Tall Shrubland, Tussock and Hummock Grassland and modified pasture, with various classifications from slightly to highly modified, as a consequence of sheep and feral animal grazing (Bebbington 2014).

Although not of national or state conservation significance, old growth *Eucalyptus oleosa* (Red mallee) woodland in the area contains large hollows suitable for habitat for bats, birds and reptiles and is therefore locally significant under the *Native Vegetation Act 1991* 'Principles of Clearance' (b).

SIMEC Mining owns and manages Uplands Station for conservation purposes and while it is expected there is an extensive presence of old growth Mallee with suitable tree hollows within this reserve, SIMEC Mining will undertake a wider assessment to determine the true extent and significance of aged *Eucalyptus oleosa* communities. SIMEC Mining would consider moving entire tree trunks with suitable hollows and constructing artificial hollows outside the mining tenements on Uplands Station to mitigate the loss of habitat.

Allocasuarina verticillata (Drooping She-Oak) Low Open Woodland is present in low to moderate densities along the upper ridgelines and west-facing hill slopes. *A. verticillata* Low Open Woodland is classified as moderately conserved on Eyre Peninsula and rare in the Middleback Ranges with only

small numbers recorded in the SMR. Drooping She-Oak plays an important role in the ecosystem within the soil and has a symbiotic relationship with specialised root zone bacteria that provide micro niches for other locally rare plant species (including spider orchids and fungi). Most of the records show these plants exist outside the mine design layout, but SIMEC Mining will nonetheless monitor any impacts to these plant communities and protect existing stands.

Although domestic stock was removed from Uplands Station in 2009, feral goats remain and pose the greatest threat to the She-Oak in this area, SIMEC Mining aims to eradicate the feral goats and to also collect She-Oak seed for revegetation in order to actively promote the recruitment of the species in suitable areas of the Middleback Ranges.

Although *Santalum spicatum* (Sandalwood) is reasonably well represented in the Middleback Ranges, seedling recruitment is minimal due to sheep and feral goat grazing. All trees recorded were estimated to be greater than 70 years old. SIMEC Mining will assess whether this species can be included in a revegetation program once goats have been successfully controlled.

The EPBC Act Protected Matters Search Tool shows the plant and fauna species listed in Table 39 and Table 40 that could inhabit the area. Baseline biodiversity surveys of the area (Bebbington 2009a; GHD 2009; Bebbington 2014; Ecological Horizons 2014) have confirmed the likelihood of their presence or absence so that appropriate mitigation measures can be implemented.

Iron Knight

The vegetation on the western side of the Iron Knight ridge consists primarily of intact virgin Dense mallee over *Triodia* communities which contain Sparse to Mid-Dense understorey and provide habitat for a range of faunal species of significance. The vegetation communities are supported by alkaline sands over basal sandy clays including numerous east west dune ridges.

It is known that the nationally endangered *Sminthopsis psammophila* (Sandhill Dunnart) occurs in the area. Baseline fauna surveys have verified that the species uses a locally large area west, and in some parts east of, the full extent of the SMR. Biennial fauna monitoring is used to monitor population trends across the entire known habitat range.

Myoporum platycarpum Low Open Woodland is classified as Threatened regionally. *M. platycarpum* are generally found across the site in small groups or as scattered emergents which are difficult to define as a ‘community’. Due to the sparseness of populations they are treated as scattered emergent trees.

Eastern vegetation communities include open *Eucalyptus oleosa* woodland with emergent *Callitris verticulata, Triodia irritans* hummock grassland and tall shrubland over sparse *Triodia irritans* (Bebbington 2009b).

South SMR

South SMR is a large and diverse area dominated by the parallel north–south orientated Iron Duke/Iron Duchess ridge, the Cook Range ridge and Death Adder Valley in between.

The area west of the range is characterised by north-west–south-east orientated sandy dunes and swales.

Old growth mallee against the eastern side of the range gives way to open chenopod shrubland as you move away from the ridges.

Although Death Adder Valley has been extensively grazed in the past by stock and feral goats, it still contains a good representation of historical vegetation associations in Good condition. The 2009 wildfire, which burnt approximately 90% of the vegetation in the study area, has had a beneficial affect on the majority of species with high levels of regeneration through epicormic growth or from seed in the soil store.

The dominant *Eucalyptus oleosa* community that is found on the valley floor and lower foot slopes has a sclerophyllous understorey with small tree hollows of varying sizes (Bebbington 2011).

The eastern vegetation communities are dominated by aged fire shadow eucalyptus *E. Oleosa*/*E. gracilis*/ *Eucalyptus socialis* open scrub with tall shrub understory on deep sandy loam soils.

Overall the *E. oleosa* mallee communities are classified as Intact Level 1 with a Condition Class of S2 (Neagle 1995) and are representative of historical plant communities. Although the understorey is moderately grazed throughout and heavily grazed by feral goats in the western sections, the community still provides excellent habitat and faunal linkages to adjoining habitat to the North and South (Bebbington June 2010a).

The terrain west of the range consists of a sand dune swale sloping to the west towards Salt Creek. The area is slightly disturbed by vehicle access tracks and groundwater monitoring bore installations.

Vegetation is intact whipstick mallee, consisting of Mallee-heath dominated by beaked red mallee (*Eucalyptus socialis*) and yorrell (*Eucalyptus gracilis*) that is slightly degraded with the inclusion of access tracks and deposition of dust from mine operations. The understory is generally dominated by a shrub layer of hard leaf wattle (*Acacia sclerophylla*), sea box (*Alyxia buxifolia*), dryland bitter-pea (*Daviesia benthamii ssp. Acanthoclona*), small hop-bush (*Dondonaea bursariifolia*), sheep bush (*Geijera linearifolia*), broombush (*Melaleuca uncinated*), Matt rushes (*Lomandra spp.*) and Spinifex (*Triodia scariosa*).

The vegetation of the lake flats is dominated by mallee particularly *Eucalyptus gracilis* with *Geijera linearifolia* and *Cratystylis conocephala* (Badman 2004b). Badman also noted the presence of the State listed rare *Maireana suaedifolia;* it is now known that this plant is common on the lake flats.

Table 39 Plant species listed under the EPBC Act 1999

Species name	Common name	Status	Likelihood of species or habitat occurring
Caladenia tensa	Greencomb spider-orchid, Rigid spider orchid	Endangered	Possible as suitable habitat exists. Not recorded in the area or detected during targeted specimen searches of the area
Pterostylis sp Eyre Peninsula	Nodding Rufoushood	Vulnerable	Possible as suitable habitat exists. Not recorded in the area or detected during targeted specimen searches of the area
Swainsona pyrophila	Yellow Swainson-pea	Vulnerable	Highly likely and has previously been recorded in areas disturbed for exploration, mine facilities and waste rock dump rehabilitation

Table 40 Bird and mammal species listed under the EPBC Act 1999

Species name	Common name	Status	Likelihood of species or habitat occurring
Acanthiza iredalei iredalei	Slender-billed Thornbill (western)	Vulnerable	Possible as suitable habitat exists in the area
Leipoa ocellata	Malleefowl	Vulnerable	Unlikely as suitable habitat does not exist in the immediate vicinity, however suitable habitat does exist in areas adjacent to the proposal
Sminthopsis psammophila	Sandhill Dunnart	Endangered	Unlikely in the immediate vicinity or anywhere on the eastern side of the range due to unsuitable habitat. Not recorded during surveys

Table 41 lists the State conservation-rated species and the likelihood they occur in the area. Baseline biodiversity surveys (Bebbington 2009a and 2009b; GHD 2009; Bebbington 2014; Ecological Horizons 2014) have confirmed the likelihood of their presence or absence so that appropriate mitigation measures can be implemented.

Table 41 South Australian state conservation-rated species

Species name	Common name	Status	Likelihood of species or habitat occurring
Maireana suaedifolia	Lax Bluebush	Rare	Possible as suitable habitat exists in the area. Not recorded in the immediate area
Santalum spicatum	Sandalwood	Vulnerable	Confirmed to be present
Amytoris textitlis myall	Thick-billed Grasswren (Gawler Ranges)	Rare	Possible as suitable habitat exists in the area
Morelia spilota	Carpet Python	Rare	Confirmed to be present

The areas surrounding the proposed tenement area include habitat for abundant avian and reptilian native fauna, and scarcer larger mammals and marsupials. Key fauna habitats in the local area include the rocky outcrops associated with the Ironstone ridge that extends above the western side of the existing Iron Chieftain pit and the proposed tenement area, and provides potentially important habitat for carpet pythons and orchids. Old growth mallee with tree hollows also provides potential habitat for the carpet python, other reptiles and birds.

These habitat types are extensive in the area outside of the mining tenements and it is therefore considered unlikely that the development would have a significant overall impact on these species regionally or nationally. However continued development in the area is depleting habitat locally and therefore expanded mitigation programs will be developed.

6.2.2 Applicable legislation

The key pieces of applicable legislation are:

- *Mining Act 1971*
- *Environment Protection Act 1993*
- Environment Protection (Air Quality) Policy 2016
- *Environment Protection and Biodiversity Conservation Act 1999*
- *Native Vegetation Act 1991*
- *Natural Resources Management Act 2004*.

6.2.3 Stakeholders

The key stakeholders with an interest in flora and fauna include:

- DPC
- Department of Environment, Water and Natural Resources (DEWNR)
- Barngarla Native Title Claimants
- South Australian Arid Lands (SAAL) Natural Resource Management (NRM) Board
- Native Vegetation Council (NVC)
- adjacent landholders.

SIMEC Mining's internal stakeholders assess the options during the planning and design phase.

Consultations will continue with the DEWNR Manager Crown Lands Coastal/North Region.

SIMEC Mining update the NVC regarding any native vegetation clearances associated with new activities and SIMEC Mining's intentions for using SEB provisions already in place.

Adjacent landowners and relevant stakeholders have been regularly informed regarding the development plans as part of SIMEC Mining's ongoing Community Engagement Plan (see Section 5).

6.2.4 Potential impacts

The following activities could have potential impacts on native vegetation and fauna:

- vegetation clearance
- habitat removal
- fugitive dust
- moving vehicles, machinery and equipment
- blasting activities
- uncontrolled surface runoff
- sedimentation
- night lighting.

Standard management controls and monitoring protocols will be implemented to minimise such impacts where they cannot be prevented.

One impact source that may be difficult to manage is fugitive dust from operational areas, which is expected to drift beyond disturbed areas and tenement boundaries. SIMEC Mining have contracted external experts to search for evidence of impacts to crops and neighbouring properties from mine derived dust, however no adverse impacts attributable to mine derived dust have been found.

Iron ore dust can cause visible staining on *Maireana sedifolia* (Bluebush) up to 1000 m from the point source. This staining may occur to the north, east and south of the mine pit and associated WRD (Chieftain), however, it is unlikely these events would have an impact on native vegetation or fauna health in the region beyond localised effects adjacent to intensive processing facilities.

The potential impacts on native vegetation and fauna are summarised in Table 42.

Table 42 Impact event analyses – Native vegetation and fauna

Source	Pathway	Barrier	Environmental receptor	Consequences
Authorised and unauthorised vegetation clearance	Exploration and hydrogeological drilling Vegetation clearing Mine operations machinery	Environmental awareness training Exploration guideline procedure QP50_58 Clearance protocols and approval system QP50_65 Compliance to the *Native Vegetation Act 1991*	Native vegetation Fauna	Loss of habitat

Source	Pathway	Barrier	Environmental receptor	Consequences
Mine related dust generating activities	Airborne fugitive dust Airborne point-source dust	Dust mitigation and management strategies	Native vegetation Fauna	Reduced health of flora Loss of abundance of vegetation species susceptible to dust impact (*Maireana sedifolia, Triodia irritans, Phebalium bullatum*) Loss of habitat Reduced visual amenity with loss or staining of native vegetation Complaints with loss or staining of vegetation
Vehicle traffic, machinery and equipment	Vehicle traffic on haul roads, access roads and rail	Driver awareness Speed restrictions Existing road infrastructure will be used	Native vegetation Fauna	Interaction with vehicles and equipment causing damage to vegetation and injury/fatality of fauna
Blasting activities	Vibration and noise	Minimised vibration and noise with implementation of the Blast Management Protocol	Fauna	Reduced health of fauna
Uncontrolled surface water runoff	Surface waters along preferential pathways	Stormwater management controls and monitoring protocols	Native vegetation Fauna	Reduced health of vegetation with erosion of soil and exposure of roots Loss of habitat Reduced health of vegetation through sedimentation
Entrapment of fauna	Voids, holes and enclosures	Exploration drill hole capping or backfilling	Fauna	Injury, fatality Reduced health and wellbeing
Night time operations	Light	Lighting design and orientation to minimise spillage of light outside of work areas	Fauna	Reduced health and wellbeing of fauna

6.2.5 Control and management strategies

Native vegetation

There is no practical way of avoiding the impacts of clearing vegetation in areas approved for vegetation clearance. However, implementing the management measures set out below will reduce the extent, severity and likelihood of any consequences from clearance and any impacts will be limited to the approved areas.

The control and management strategies include:

- awareness training
- implementing SIMEC Mining's procedures for blasting, storage, handling and use of hazardous materials, managing wastes and preventing spills, and response and clean-up
- planning and design considerations, and operational procedures to manage dust sources, surface water runoff, groundwater and sedimentation on site
- implementing SIMEC Mining's procedures and checks, which require approval from the Environmental Assurance department before vegetation is cleared
- planning and design considerations, and operational procedures, to minimise impacts on native vegetation, particularly vegetation providing habitat for native fauna
- construction and operations management plans to ensure impact areas are surveyed for native vegetation, and controlled to comply with design parameters and approvals conditions
- setting aside a SEB offset area in the Ironstone Hill Conservation Park, to compensate for the areas where native vegetation clearance is required (as described in Section 4)
- commissioning field specialists to undertake native vegetation surveys and assessments, to complement in-house surveys and assessments
- undertake wider assessment to determine the true extent and significance of aged Eucalyptus oleosa communities
- monitor impacts to *Allocasuarina verticillata* communities and protect existing stands through a feral goat control program that aims to eradicate feral goats, as far as reasonably practical, from the Middleback Ranges
- collect *Allocasuarina verticillata* seed when available and actively promote the recruitment of the species in suitable areas
- include *Santalum spicatum* in revegetation programs where feral goats have been 'controlled' and de-stocking has taken place.

Fauna

The controls and management strategies that will be implemented to minimise impacts to fauna include:

- awareness training
- planning and design considerations, and operational procedures to protect fauna

- implementing threat abatement programs, in conjunction with the Middleback Landowners Alliance, to assist threatened species to recover from predation by feral cats and foxes, and habitat depletion by competing herbivores (goats)
- contributing to the bat call library, especially in regard to rarer species such as *Nyctophilus major tor* (Greater Long-eared Bat) in the Middleback Ranges
- commissioning field specialists to undertake fauna surveys and assessments, to complement in-house surveys and assessments
- consider moving entire tree trunks with suitable hollows and/or constructing artificial hollows outside of mining tenements on Uplands Station to mitigate any loss of habitat in the project area.

Table 43 provides details of risk assessments for impact events, the control and management strategies that are to be implemented, and the associated outcomes and measurement criteria for native vegetation and fauna.

6.2.6 Evaluation of residual risk

In relation to native vegetation and fauna, the impact assessment concluded that the primary risk to regional species and communities of significance would be 'Low' if planning and design is considered and undertaken appropriately and operational management measures are implemented.

Optimising the mine design to minimise vegetation clearance, and avoiding vegetation clearance in areas of high habitat value, important wildlife corridors and linkages will reduce these risks further.

Providing SEB offsets beyond the regulatory minimum obligations will help to preserve habitat areas for threatened species, which have been identified as important at a regional and state level.

Although there is a 'Low' primary risk of dust affecting flora health, there is a 'Moderate' risk that complaints of vegetation staining will be received from neighbouring landholders.

The net impact to native vegetation and fauna is considered to be of 'Low' significance to the area and the region because:

- the predominant vegetation associations to be cleared are well represented throughout the region
- conservation-significant native vegetation and fauna are well represented within the region
- the SEB provided for the clearance area
- SIMEC Mining will continue to monitor and impose strict controls.

Bebbington (2014) considers that vegetation within the area has been affected by dust emissions to varying degrees during past mining operations. The vegetation within 500 m of the mine and WRD received the heaviest deposits of dust, however, red oxide staining remains noticeable on leaf surfaces even after heavy rainfall events.

The long-term effects of dust deposition on the leaf surfaces of plants within the Middleback Ranges mining area is unknown but field observations suggest that *Maireana sedifolia* and (possibly)

Cratystylis conocephala may enter dieback following prolonged heavy exposure. Both species are covered in dense fine abaxial and adaxial hairs that may trap ultra-fine dust particles held in solution and impair photosynthetic activities. It should be noted, however, that *Maireana sedifolia* exists in the adjacent Iron Baron area despite several decades of impact from previous adjacent mining activities.

Bebbington (2014) concluded the majority of species would recover from dust accumulation over the longer term given the overall diversity of species and current vegetation health.

Although fauna adjacent to the mining areas may be affected by dust, monitoring of existing operations at the SMR shows that fauna have not been significantly affected by dust deposition.

Preliminary data suggests that sites with heavy dust loads on vegetation retained breeding populations of several species of mammals, reptiles and birds. However, the 2008 fauna study for the SMR (Read and Moseby 2008) was the first of a repetitious monitoring program comparing mine sites with control sites, and therefore the results relating to nature and extent of the impact from mine site dust on fauna are inconclusive. Subsequent monitoring surveys also indicate there are no measurable negative impacts to fauna living adjacent to operational mining areas arising from dust, light, noise or vibration.

Many more data sets will need to be collected over a long period and more habitat distribution mapping will be required to gain a greater understanding of the dust impacts on fauna.

The residual risk will be maintained as ‘Low’ with the implementation of due diligence, standard industry practices, and specific controls and management measures.

Table 43 Risk assessment – Native vegetation and fauna

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
All domains								
Unauthorised clearance of remaining native vegetation	Possible	Minor	Unnecessary vegetation disturbance during exploration will be avoided with implementation of SIMEC Mining's Exploration Guidelines QP50_58 which incorporates DMITRE guidelines and requirements of the *Mining Act 1971*, *Native Vegetation Act 1991* and the *Natural Resources Management Act 2004* All land clearance is subject to compliance assessment by the Environment Assurance Manager prior to approval by the Operations Manager in accordance with QP50_65 Construction and operations management plans will be in place to ensure impact areas are surveyed and controlled within design	Unlikely	Minor	Low	No permanent loss of abundance or diversity to native vegetation through clearance, dust/contaminant deposition, fire or other damage caused by mining operations on or off the tenements, unless prior approval under legislation is obtained	Annual aerial and/or ground surveys of operational areas demonstrates that the total area cleared does not exceed the approved area as listed in Table 31 (see Section 4.3) when compared to the September 2013 aerial image (see Figure 84).

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Loss of significant native vegetation species locally/regionally due to approved clearance	Unlikely	Minor	SEB offset provided as part of Native Vegetation Clearance approvals Revegetation of disturbed areas as per Mine Plan Mine facility design to minimise disturbance and avoid significant areas Compliance to *Native Vegetation Act 1991*	Rare	Minor	Low	N/A	N/A
Displacement of significant fauna species locally/regionally due to approved clearance	Unlikely	Minor	SEB offset provided as part of Native Vegetation Clearance approvals Threat abatement strategies in conjunction with the Middleback Alliance to assist species recover from threats posed by feral species Compliance to *Native Vegetation Act 1991* Biennial fauna surveys will be conducted to improve the understanding of the EPBC sensitivities in the region, and to collect baseline data for monitoring impacts of operations on the biodiversity of the area	Rare	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Permanent loss of abundance or diversity of native vegetation on or off tenement due to dust impacts	Possible	Minor	Dust controls are implemented in accordance with the mines 'Fugitive Dust Ranking Procedure. Dust suppression using water and/or agents will be utilised on haul roads and open areas	Unlikely	Minor	Low	No permanent loss of abundance or diversity to native vegetation through clearance, dust/contaminant deposition, fire or other damage caused by mining operations on or off the tenements, unless prior approval under legislation is obtained	Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (for Iron Chieftain and Iron Knight domains) and an impact score of 1 (for South SMR domains) (see Table 45) outside of approved clearance areas, from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC Mining dust management strategies are applied in accordance with the Mines FDR Procedure QP50_68
Permanent loss of abundance or diversity of native fauna on or off tenement due to dust impacts	Unlikely	Minor	Dust controls are implemented in accordance with the mines 'Fugitive Dust Ranking Procedure'. Dust suppression using water and/or agents will be utilised on haul roads and open areas	Rare	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Temporary loss of abundance of dust impact indicator species on or off tenement	Likely	Minor	Dust controls including postponing operations in inclement weather in accordance with the mines 'Fugitive Dust Ranking Procedure. Dust suppression using water and/or agents will be utilised on haul roads and open areas.	Possible	Minor	Moderate	No permanent loss of abundance or diversity to native vegetation through clearance, dust/contaminant deposition, fire or other damage caused by mining operations on or off the tenements, unless prior approval under legislation is obtained.	Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (for Iron Chieftain and Iron Knight domains) and an impact score of 1 (for South SMR domains) (see Table 45) outside of approved clearance areas, from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC dust management strategies are applied in accordance with the Mines FDR Procedure QP50_68

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Interaction with vehicles and equipment causing damage to vegetation and injury/fatality of fauna	Unlikely	Negligible	All fauna road kill events inside mine haulage and exploration areas will be recorded as an environmental incident Alternative road traffic strategies will be investigated if root cause analysis of native fauna fatality/injury/near miss events deems it necessary Environmental awareness training for all staff and contractors Implementation of speed limits on internal roads and prohibition of off-road driving	Unlikely	Negligible	Low	N/A	N/A
Vibration and noise from blasting activities causes ill-health, injury or fatality to fauna	Unlikely	Negligible	Implementation of Blast Management Protocol	Unlikely	Negligible	Low	N/A	N/A
Uncontrolled surface water runoff results in impacts to vegetation through significant erosion, loss of soils or siltation	Unlikely	Negligible	Planning, design and operational controls consider the management of stormwater runoff to minimise erosion, contamination, changes to natural drainage and soil instability	Unlikely	Negligible	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Entrapment of fauna through open holes and excavations	Likely	Minor	Adherence to DMITRE Information Sheet M21 – Mineral exploration drill holes – General specification for Construction and Backfilling. Where exploration drill holes are required for further field investigations, or the area is to be developed, collars will be capped Excavations will be inspected regularly for entrapped fauna	Unlikely	Negligible	Low	That there is no permanent loss of native fauna abundance caused by mining operations	Records demonstrate that incidents of drill collars not being capped immediately following exploration activities are logged and investigated and all corrective actions are closed out within 24 hours of receiving notification of the incident Annual aerial and/or ground surveys at operational areas demonstrates that the total area cleared does not exceed the approved area as listed in Table 31 (see Section 4.3) when compared to the September 2013 aerial image (see Figure 84).
Iron Chieftain domain								
Loss of visual amenity and receipt of complaints of dust staining on adjacent property vegetation	Almost certain	Minor	Dust suppression using water and/or agents FDR procedure/EMP controls	Possible	Minor	Low	No vegetation health impacts to neighbouring pastoral properties from dust generated by mining activities	Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC dust management strategies in accordance with the Mines FDR Procedure QP50_68

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Loss of abundance of palatable stock feed	Possible	Minor	Dust suppression using water and/or agents	Unlikely	Minor	Low	No vegetation health impacts to neighbouring pastoral properties and farms from dust generated by mining activities	Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC dust management strategies in accordance with the Mines FDR Procedure QP50-68
Iron Knight domain								
Loss of visual amenity and receipt of complaints of dust staining on adjacent property vegetation	Possible	Minor	Dust suppression using water and/or agents FDR procedure/EMP controls	Unlikely	Minor	Low	No vegetation health impacts to neighbouring pastoral properties and farms from dust generated by mining activities	Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC dust management strategies in accordance with the Mines FDR Procedure QP50_68

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
South SMR domain								
Loss of visual amenity and receipt of complaints of dust staining on adjacent property vegetation	Possible	Minor	Dust suppression using water and/or agents FDR procedure/EMP controls	Unlikely	Minor	Low	No vegetation health impacts to neighbouring properties from dust generated by mining activities	Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 1 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC dust management strategies in accordance with the Mines FDR Procedure QP50-68
Loss of abundance of palatable stock feed	Unlikely	Minor	Dust suppression using water and/or agents FDR procedure/EMP controls	Rare	Minor	Low	N/A	N/A
Impacts to cereal crops from mine dust	Rare	Negligible	Dust suppression using water and/or agents FDR procedure/EMP controls	Rare	Negligible	Low	N/A	N/A

6.2.7 Outcome

The outcome and measurement criteria for native vegetation and fauna are presented in Table 44.

Table 44 Outcome – Native vegetation and fauna

Outcome	Measurement criteria	Monitoring programs
No permanent loss of abundance or diversity to native vegetation through clearance, dust/contaminant deposition, fire or other damage caused by mining operations on or off the tenements, unless prior approval under legislation is obtained	Annual aerial and/or ground surveys at operational areas demonstrates that the total area cleared does not exceed the approved area as listed in Table 31 (see Section 4.3) when compared to the September 2013 aerial image (see Figure 84). Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (for Iron Chieftain and Iron Knight domains) and an impact score of 1 (for South SMR domains) (Table 45) outside of approved clearance areas, from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) See Sections 6.2.8 and 6.2.9 for assessment methodology. Mine records demonstrate that SIMEC Mining dust management strategies are applied in accordance with the Mines FDR Procedure QP50-68	Annual aerial and ground survey Construction and operational process audits ongoing throughout operations and closure Regulatory compliance audits and ISO 14001 EMS audits conducted by SIMEC Mining Environment Assurance as per audit schedule Biennial flora monitoring program undertaken by external consultants Biannual internal flora monitoring program by SIMEC Mining Environment Assurance
No vegetation health impacts to neighbouring properties from dust generated by mining activities	**Iron Chieftain** Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2	Annual aerial and ground survey Construction and operational process audits ongoing throughout operations and closure Regulatory compliance audits and ISO 14001 EMS audits conducted by SIMEC Mining Environment Assurance as per audit schedule

Outcome	Measurement criteria	Monitoring programs
	(see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) See Sections 6.2.8 and 6.2.9 for assessment methodology. Mine records demonstrate that SIMEC dust management strategies are applied in accordance with the Mines FDR Procedure QP50-68 **Iron Knight** Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) See Sections 6.2.8 and 6.2.9 for assessment methodology. Mine records demonstrate that SIMEC dust management strategies are applied in accordance with the Mines FDR Procedure QP50-68 **South SMR** Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 1 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) See Sections 6.2.8 and 6.2.9 for assessment methodology.	Biennial flora monitoring program undertaken by external consultants Biannual internal flora monitoring program by SIMEC Mining Environment Assurance Fugitive Dust Ranking (FDR) Procedure Environment Incident Reports

Outcome	Measurement criteria	Monitoring programs
	Mine records demonstrate that SIMEC dust management strategies are applied in accordance with the Mines FDR Procedure QP50-68	
That there is no permanent loss of native fauna abundance caused by mining operations	Records demonstrate that incidents of drill collars not being capped immediately following exploration activities are logged and investigated and all corrective actions are closed out within 24 hours of receiving notification of the incident Annual aerial and/or ground surveys at operational areas demonstrates that the total area cleared does not exceed the approved area as listed in Table 31 (see Section 4.3) when compared to the September 2013 aerial image (see Figure 84).	Construction and operational process audits ongoing throughout operations and closure Regulatory compliance audits and ISO 14001 EMS audits conducted by SIMEC Mining Environment Assurance as per audit schedule

* Mine derived dust descriptor: Dust that is considered to be derived from mining operations determined by characterisation, colour and the direction from which dust is deposited onto vegetation.

6.2.8 Vegetation dust impact assessment methodology – Quarterly inspections

Objective

To apply a simple visual inspection methodology to assess vegetation condition trends due to dust deposition impacts on a quarterly basis that will enable swift response to vegetation decline in the interim period between external biennial monitoring.

Methodology

Using the existing permanent flora and fauna monitoring quadrats and the associated photo point pegs, a comparison can be made to previous inspections using the following steps:

- photograph the quadrat from the photo point plotted using GPS with accuracy +/- 3 m, photo point pegs 10 m apart, centre focus on base of peg
- determine indicator species for each site
- measure the depth of dust deposition on the ground
- assess if dust staining/deposition is light or heavy
- assess if there is senescence of canopy, minor deaths or multiple deaths to indicator species
- apply the impact score: see Table 45.

Table 45 Vegetation dust impact score descriptions

Impact score	Vegetation dust impact score descriptions
1	No vegetation health impact with light visible dust staining
2	No vegetation health impact with heavy visible dust staining
3	Some vegetation canopy die back with light visible dust staining
4	Some vegetation canopy die back with heavy visible dust staining
5	<5 deaths of indicator species with heavy visible dust staining
6	Multiple deaths of indicator species with heavy visible dust staining

6.2.9 Vegetation dust impact assessment methodology – Annual monitoring

Scope

Provide a written report for each of the monitoring sites containing, but not limited to, the following:

- record and interpret data to be collected at the established impact and control sites
- provide a full vegetation species list including weeds
- establish photo point monitoring at all monitoring locations
- include photo point monitoring photos
- determine key indicator species (increasers and decreasers)
- record the total number of individual plants of each species within the monitoring quadrats, list adults and juveniles separately
- record estimates of healthy canopy cover of the adult key indicator species as a percentage of the total healthy potential
- general observations about the health and abundance of individual species including: deaths, fasciated growths, dust loads on foliage and soil surface (% cover and depth), species that are flowering and/or seeding, foliage shooting or shedding, variations in seed set abundance compared to control sites, mice, insect attack and galls present, mistletoe, grazing pressure and soil colour and temperature etc
- comment on weed species abundance
- provide GPS coordinates of all corners of the monitoring site locations
- include a map showing the monitoring locations
- comment on the significance of habitat types to fauna species
- record opportunistic fauna observations
- comment on fauna present as indicators of flora community health (e.g. ants and spiders)
- record cryptogram cover at each site
- comment on litter cover at each site

- record soil type, moisture and pH (methodologies to be discussed and determined)
- describe the landscape at all monitoring locations
- record vegetation communities present in an extended area (100 m x 100 m) at each monitoring location and provide comments on vegetation health/vigour that will add value to the report.

Quadrats

30 m x 30 m quadrats**,** four corners and photo point plotted with GPS with accuracy +/-3 m.

Plots measured with 30 m Silvan® Forestry tape or Bushnell® Laser Pro range finder accuracy +/- 1 m at 500 m.

Vegetation

Monitoring follows but not limited to:

- Vegetation Structural Formations - from Heard & Channon (1997) - adapted from Forward and Robinson (1996) (table originally derived from Specht (1972) and Muir (1997)).
- Neagle (1995) *An update of the Conservation Status of the Major plant Associations of South Australia.* Canopy Cover follows Specht 1972. Litter cover/abundance follows Braun-Blanquet 1965.
- Quadrat vegetation sampling is based on Heard & Channon (DEH -1997) *Biological Survey of South Australia Methodology*.
- Reference plant heights indicated in photographs with coloured indicator pole divided into 30cm increments.

Soil

Temperature measured with Infra Red Digital thermometer. Comparisons of soil temperature surface readings were taken from natural surfaces and surfaces visibly crusted or stained with iron ore dust. pH and moisture measured with a pH / moisture meter probe, calibrated against pH mediums.

Soil crust measurements were taken with avernier calliper

Ambient Air Temperature

Measured with a tube thermometer.

Leaf Surface Analysis

Depth of dust deposition on adaxial and abaxial leaf surfaces and identification of leaf cuticle types conducted with a 30x field microscope.

Photographs

Digital Canon® S50 on medium resolution. Photographic records include 100 m x 100 m general, 30 m x 30 m general with blackboard plot reference, individual indicator species photographs with height gauge.

6.3 Weeds, Pests and Pathogens

6.3.1 Context

The Middleback Ranges are in the north-eastern part of the Eyre Peninsula, just within the gazetted boundary for the South Australian Arid Lands (SAAL) region, which means it comes under the jurisdiction of the SAAL NRM Board for pest plant and animal control as per the NRM Act 2004.

The feral animal incursions into the region include:

- Feral cat – a true survivor that has adapted extremely well to the region and is responsible for high-level predation on native birds, reptiles and small mammals, including the Thick-billed Grasswren, Western Grasswren and Slender-billed Thornbills. Feral cats are considered to be a key contributor to the mainland extinction of many species, including the stick nest rat, which once lived in the Middleback Ranges.
- Fox – also well adapted to the region and a significant predator of many native species including lizards, birds and snakes.
- Goat – introduced as domestic animals and quickly became one of the arid zones' most prolific and successful feral animals. Feral goats are browsers and are responsible for degrading native plant communities, including species of low palatability. Sightings of feral goats and fresh goat tracks were observed during the vegetation surveys (Bebbington 2009b and 2014) and were also recorded during the fauna surveys (GHD 2009; Ecological Horizons 2014).
- Rabbit – responsible for widespread degradation of flora species particularly at the lower stratum and also greatly reducing the recruitment success of larger species due to ring barking and consumption of seedlings.

All these species pose a direct threat to many native fauna and flora either through predation or habitat destruction on a regional scale.

The significant pest plant species found during survey of the area (Bebbington 2009b and 2014) include:

- Wards weed (Carrichtera annua) – the principle weed species dominating the understorey throughout (classified as a sparse to mid-dense infestation)
- Salvation Jane (Echium plantagineum) – isolated sparse populations
- Horehound (Marrubium vulgare) – isolated sparse populations (creek lines and open areas)
- Potato weed (Galinsoga parviflora) – open areas
- Saffron thistle (Carthamus lanatus) – creek lines and open areas
- Prickly pear (*Opuntia stricta*) – isolated sparse populations.

The SMR is located in a very low risk area for *Phytophthora cinnamomi* (root-rot fungus), or Mundulla Yellows (a fatal plant disease), mainly due to the low rainfall (O'Gara et al. 2005). No evidence of either pathogen has been identified during field investigations to date.

6.3.2 Applicable legislation

The key piece of legislation that applies is:

- *Natural Resource Management Act 2004*.

6.3.3 Stakeholders

The key stakeholders who have an interest in weeds, pests and pathogens include:

- DPC
- neighbouring landholders
- DEWNR, SAAL NRM boards
- Middleback Alliance
- DEWNR – Parks and Wildlife.

6.3.4 Potential impacts

The potential impacts relating to pests, weeds and pathogens are summarised in Table 46.

Table 46 Impact event analyses – Weeds, pests and pathogens

Source	Pathway	Barrier	Environmental receptor	Consequences
New weeds Increased abundance of existing weed species	Vehicle traffic Cleared areas	Vehicle washdown SIMEC Mining Pest Plant and Animal Control Strategy QP50_62 Continuous weed mapping	Native vegetation	Impacts to native vegetation communities Breach of the NRM Act 2004
New pest animal species Increase in abundance of existing pest animal species	Migration onto site from surrounding land	Active pest management through Middleback Alliance and SIMEC Mining Pest Plant and Animal Control Strategy QP50_62	Native vegetation Fauna	Predation on native fauna Depletion of native vegetation and reduction in abundance
Plant pathogens	Imported onto site via vehicle traffic	Vehicle washdown SIMEC Mining procedures and protocols	Native vegetation	Decreased health of local native vegetation

6.3.5 Control and management strategies

SIMEC Mining implements a Pest Plant and Animal Control Strategy QP50_62.

Table 47 details the risk assessment, the control and management strategies to be implemented, and the associated outcomes and measurement criteria for pests, weeds and pathogens.

6.3.6 Evaluation of residual risk

As pest animals already exist in the area on a landscape scale, the primary risk of introducing a new pest animal or increasing the abundance of existing pest animals is 'Low'.

The risks of introducing pathogens are 'Low', and will be managed in accordance with standard operational protocols. Specific monitoring of weeds and pests will continue as part of the existing program for weed and pest control.

With due diligence, standard industry practices and specific controls and management measures, the residual risk has been determined to be 'Low'.

Table 47 Risk assessment – Weeds, pests and pathogens

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Incursions of new declared weed species or increase in abundance of existing weed species	Possible	Minor	Weed incursions are to be mapped using active searches and opportunistic sightings recorded by GPS location and controlled as per the SIMEC Mining's Pest Plant and Animal Control Strategy QP50_62	Unlikely	Negligible	Low	No introduction of new species of weeds or plant pathogens, nor a sustained increase in abundance of existing weed species compared to adjoining land	Biannual weed inspections reports and continuous weed mapping demonstrate that new weeds and existing weeds are managed by control measures as per the SIMEC Mining Pest Plant and Animal Control Strategy QP50_62 within six months of documenting the presence of new weed incursions or increase in abundance of existing weeds in the license area compared to baseline flora and fauna surveys (Bebbington 2009 and 2014)
Incursions of new pest animal species or increase in abundance of existing pest animals	Unlikely	Minor	All new pest animal species incursions and existing pest animal species will be managed in accordance with control measures described in SIMEC Mining's Pest Plant and Animal Control Strategy QP50_62 Implementation of pest animal control programs in conjunction with the Middleback Alliance of land managers Feral goats are mustered from areas adjacent to mining operations by a contractor and removed from site	Unlikely	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Introduction of plant pathogens	Unlikely	Negligible	New vehicles to site will be washed prior to entry	Unlikely	Negligible	Low	N/A	N/A

6.3.7 Outcome

The clearance of vegetation and the movement of personnel, vehicles, machinery and equipment to and from site increases the risk of introducing new weeds, and/or increasing the abundance of existing weeds. An outcome and measurement criteria for weeds is therefore required. This is summarised in Table 48.

Table 48 Outcome – Weeds, pests and pathogens

Outcome	Measurement criteria	Monitoring programs
No introduction of new species of weeds, nor a sustained increase in abundance of existing weed species in the Licence area, compared to adjoining land	Biannual weed inspections reports and continuous weed mapping demonstrate that new weeds and existing weeds are managed by control measures as per the SIMEC Mining Pest Plant and Animal Control Strategy QP50_62 within six months of documenting the presence of new weed incursions or increase in abundance of existing weeds in the licence area compared to baseline flora and fauna surveys (Bebbington 2009 and 2014)	Biennial flora monitoring conducted by independent, suitably qualified consultants Consultant's briefs to include the collection of weed incursion data Reports filed and maintained at SIMEC Mining Environment Assurance Ongoing internal audit schedule

6.4 Soil

6.4.1 Context

Soil is considered in the context of topsoil resource, erosion and soil contamination. For information regarding soil management (i.e. managing dust resulting from exposed soils) refer to Impact Assessment – Native Vegetation and Fauna (Section 6.2).

Topsoil will be stripped during clearing and site preparation and reused for onsite revegetation and rehabilitation programs. Appropriate topsoil management is required to ensure the topsoil remains viable for reuse. Activities associated with mine development may contaminate soils if appropriate management measures and controls are not implemented.

6.4.2 Applicable legislation

The key pieces of legislation that apply are:

- *Mining Act 1971*
- *Environment Protection Act 1993*
- *Natural Resource Management Act 2004*.

6.4.3 Stakeholders

The key stakeholders that have an interest in soil include:

- DPC
- neighbouring landholders
- DEWNR, SAAL NRM boards
- Middleback Alliance
- DEWNR – Parks and Wildlife.

SIMEC Mining's internal stakeholders are also involved in assessing the preferred areas for topsoil placement and their ongoing maintenance to ensure they remain viable for future reuse. The ISO 14001 certified Environmental Management System (EMS) for the site includes policies and procedures to prevent and minimise soil contamination.

6.4.4 Potential impacts

The potential impacts relating to soil are summarised in Table 49.

Table 49 Impact event analysis – Soil

Source	Pathway	Barrier	Environmental receptor	Consequences
Land clearance	Site preparation works, mining and WRD construction Exploration	Top soil management procedures (QP50_66) Stormwater control infrastructure Designated areas to be cleared	Soil Vegetation	Loss and/or degradation of topsoil resulting in poor rehabilitation outcomes
Disruption of soil profile with site development	Exploration activities Site preparation and soil stockpiling	Exploration operating procedures (QP50_58) Top soil management procedures (QP50_66)	Soil Vegetation	Soil erosion and/ or sedimentation
Hazardous substance spills	Exploration drilling Mining activities	Operating procedures Storage of hazardous substances in accordance with procedures, AS 1940 and EPA bunding guidelines	Soil Vegetation	Trigger reportable site contamination provisions, contained within the *Environment Protection Act 1993* from hazardous substances spills

6.4.5 Control and management strategies

Table 50 details the risk assessment for soil, the control and management strategies to be implemented, and the associated outcomes and measurement criteria.

6.4.6 Evaluation of residual risks

A primary ‘Moderate’ risk has been identified for topsoil management. Topsoil is an important commodity for rehabilitating the site, and the topsoil available is limited. As a consequence SIMEC Mining makes much effort to protect topsoil viability and ensure losses are minimised as much as reasonably practicable.

A ‘Low’ risk exists for soil contamination and other impacts that disturb the soil profile and topography.

With due diligence and the implementation of standard industry practices and specific controls and management measures, the residual risks of impacts affecting the amount and viability of topsoil will be reduced as far as practical. These controls and measures include design and ensuring that appropriate procedures and processes are implemented for the topsoil stripping, stockpiling and maintenance programs.

Table 50 Risk assessment – Soil

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Loss and/or degradation of topsoil resulting in poor rehabilitation outcomes	Possible	Minor	Topsoil stockpiles to be placed in designated and mapped areas with signage to allow rapid crust development, to facilitate revegetation and to prevent the accidental removal, disturbance or degradation of the resource Stripping of topsoil to ensure maximum depth of topsoil obtained and that available seed reserves within topsoil is retained Grubbed material with 'A; horizon and 'B' horizon soils to be stripped and stockpiled separately Topsoil stockpiles to be maintained to prevent establishment of weeds 'A' horizon topsoil stockpiles to be restricted to 3 m un-compacted height to maintain soil and seed function Reuse of topsoil stockpiles as soon as possible to ensure viability of seed stock is maintained	Unlikely	Minor	Low	Topsoil quality and quantity is maintained	Six-monthly inspection audits demonstrate that topsoil has been stripped, stockpiled (see Figure 65) and maintained in accordance with SIMEC Mining's Soil Management Plan (QP50_66) and that all corrective actions from audits logged and closed out within 60 days or as otherwise agreed with the Regulator

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Soil erosion and/or sedimentation	Unlikely	Minor	Most stormwater will drain into the pits Exploration activities to be carried out with minimal disturbance and areas re-instated to current condition if further exploration/mining activity does not eventuate Consideration will be given to gradient and stormwater runoff to minimise the potential for erosion. Exploration blade work will be kept to a necessary minimum, with rolling rather than grading being the preferred strategy Bund windrows and 'v' drains will be constructed around the base of WRDs Existing WRDs to be rehabilitated to minimise any erosion issues Silt traps will be installed in natural drainage channels where stormwater cannot be contained on site Stage clearances to maintain vegetative cover for as long as possible Minimisation of the area of exposed soil that could be eroded by stormwater by maintaining vegetative cover for as long as possible	Unlikely	Negligible	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Trigger reportable site contamination provisions, contained within the *Environment Protection Act 1993* from hazardous substances spills	Unlikely	Minor	Any potentially contaminating activities will be managed in accordance with industry and regulatory guidelines All rubbish will be contained and removed weekly (daily from specific exploration or other temporary worksites) All chemicals will be stored in accordance with AS 1940 and EPA bunding guidelines No underground storage or transfer pipes for potentially hazardous substances Hydrocarbon spills will be contained immediately, collected and disposed of at SIMEC Mining's bioremediation pad Spills greater than 20 litres reported on the environment incident reporting system and corrective actions tracked and closed out in accordance with ISO 14001 EMS procedures	Unlikely	Negligible	Low	N/A	N/A

6.4.7 Outcome

The outcome and measurement criteria for soil are presented in Table 51.

Table 51 Outcome – Soil

Outcome	Measurement criteria	Monitoring programs
Top soil quality and quantity is maintained	Six-monthly inspection audits demonstrate that topsoil has been stripped, stockpiled (see Figure 65) and maintained in accordance with SIMEC Mining's Soil Management Plan (QP50_66) and that all corrective actions from audits logged and closed out within 60 days or as otherwise agreed with the Regulator	Audit records Annual aerial survey

6.5 Stormwater

6.5.1 Context

In general, there is little surface water in the northern part of Eyre Peninsula, and no permanent streams. Catchments in the Middleback Ranges do, however, feed a number of ephemeral watercourses and gilgais.

The SMR sites are well drained and for the current situation no streams of any significance intercept any of the pits. Minor diversions around the tailings storage facilities are sufficient to avoid the collection of water during high rainfall events. Based on geomorphology the toes of the TSF are well above the credible flood reach of the chain of salt lakes to the west of the operations and no formal flood analysis has been undertaken.

The Iron Duke/Magnet pit has intercepted the upper catchment of the southern Death Adder Creek in a manner that does not allow the creek to be diverted around the pit. This creek rarely flows, and may not flow for several successive years. The risk of flooding was assessed in the 2007 MARP and it concluded that the risk was small, and that on-site staff could take appropriate action if an event did occur. A heavy storm event (75 mm in February 2014) resulted in some ponding on the Iron Magnet pit floor. This water was removed by water cart and used for dust suppression on the haul roads. The ponding on the pit floor did not interrupt production. Despite the upper catchment of the southern branch of Death Adder Creek being cut off by the Iron Magnet pit, the terminal lagoons adjacent to the highway filled to capacity.

The development of the proposed mine pits, operating pads, haul roads, stockpiles and WRDs will change the natural water catchment and drainage systems adjacent to Iron Chieftain. There are no permanent surface water flows in the project area – flowing water only occurs in a brief period after

heavy or extended rainfall events. All water courses within the project area flood onto plains within SIMEC Mining's property (i.e. Uplands Station).

All stormwater that falls within the water catchment upslope or within the pit crests will flow into the pits. Stormwater that falls outside of the pit crest catchment will land on haul roads, open areas or WRDs. This stormwater will either be:

- retained behind bund walls and disposed of via evapotranspiration
- allowed to continue along natural drainage channels after settlement of fines and filtering through silt traps.

Uplands Station experiences significant soil erosion due to previous land degradation. SIMEC Mining has implemented mitigation measures, which include stormwater intervention and revegetation, in an attempt to address these issues. The mine pit interception of upper catchment stormwater will also assist these efforts.

A water affecting activity (WAA) permit has been granted under section 127 of the *Natural Resources Management Act 2004* (NRM Act 2004) for this change in the flow regime.

Hydrological risk

All the watercourses and drainages in the immediate vicinity of the SMR are ephemeral. However, flows will occur periodically during the late summer months of February and March, when the potential exposure to high intensity rainfall is greatest. Consequently runoff will report to the watercourses in the vicinity of the site and, on occasion, flows may be high and may cause flooding if appropriate measures have not been implemented.

The hazard that such flooding poses to on-site facilities depends, amongst other things, on:

- the magnitude of the flood event
- the proximity of the facility to the watercourse in flood
- the sensitivity of the facility to flooding
- the level of protective flood measures provided to the facility.

While the latter three factors can be controlled or engineered to some degree, the magnitude of the naturally occurring rainfall-runoff events that may lead to flooding cannot be controlled (Mining Plus 2014a).

6.5.2 Applicable legislation

The key pieces of legislation and policies that apply are:

- *Natural Resource Management Act 2004*
- *Mining Act 1971*
- *Environment Protection Act 1993*

- *Environmental Protection and Biodiversity Conservation Act 1999*
- *Native Vegetation Act 1991*.

6.5.3 Stakeholders

The key stakeholders who have an interest in stormwater include:

- DPC
- SAAL NRM boards
- NVC
- adjacent landholders.

SIMEC Mining's internal stakeholders assess options during the planning and design phase of mining activities. The engineering design for ongoing operation will include features to eliminate stormwater risk, and the strategies outlined in management plans for construction and operational activities aim to minimise the residual risks of stormwater impacts.

Adjacent landowners and other relevant stakeholders are involved in regular meetings and discussions held as part of SIMEC Mining's ongoing Community Engagement Plan (see Section 5).

6.5.4 Potential impacts

The potential impacts relating to stormwater are summarised in Table 52.

Increased soil gully erosion, increased sedimentation, loss of topsoil and mobilisation of contaminants are likely to occur if adequate management measures and controls are not implemented.

Table 52 Impact event analysis – Stormwater

Source	Pathway	Barrier	Environmental receptor	Consequences
Hazardous materials spills and other contaminant sources	Stormwater drainage	Operational infrastructure designs to divert stormwater around contaminant sources Appropriate infrastructure for storage of hazardous materials SIMEC Mining procedures for hazardous materials storage, use and spills response	Surface water Groundwater Soil	Stormwater leaving the site creates an impact to sensitive receptors due to high suspended solids or other contaminants

Source	Pathway	Barrier	Environmental receptor	Consequences
Exposure and destabilising of soils	Stormwater drainage	Construction and closure design which incorporates stormwater control and management infrastructure Staged vegetation and topsoil stripping Closure designs to incorporate long-term controls	Natural drainage channels Rehabilitation efforts Gilgais	Stormwater leaving the site creates an impact to sensitive receptors due to high suspended solids or other contaminants Stormwater leaving the site creates soil erosion
Alteration of natural drainage lines	Stormwater drainage Earthworks	Mine, WRD and infrastructure designs and layout Fixed stormwater management and controls Temporary stormwater management and controls Closure designs to incorporate long-term controls	Natural vegetation and topography Natural drainage lines Third party property	Alteration of natural drainage lines leads to reduction of flows to stormwater dependent ecosystems (including post-closure) Alteration of natural drainage lines generates flooding on neighbouring land
Geochemistry of WRDs	Stormwater drainage through waste material	Annual average rainfall deficit of approximately -1,650 mm Inert waste	Natural drainage lines	Negative effect or surface water quality

6.5.5 Control and management strategies

Table 53 provides details of the stormwater risk assessment, with the control and management strategies to be implemented, and the associated outcomes and measurement criteria.

SIMEC Mining is committed to installing and implementing reasonable engineering and procedural controls that maintain the characteristics of the natural drainage systems to ensure:

- there are no adverse impacts to water dependent ecosystems caused by operations
- no stormwater results in loss, or contamination of soil on or off the tenements
- no water runoff from the tenements results in flooding of adjacent areas (off tenement), to an extent greater than could reasonably be expected to occur before mining operations were established on the tenement.

Construction and mining activities will be undertaken with appropriate management measures and controls put in place to ensure that stormwater is protected from contamination sources and that

erosion and sedimentation is minimised through the installation of silt traps, culverts and gully head armouring where required.

Management measures, bunding standards and controls for hazardous materials handling, use and storage, and for storing, reusing, recycling and disposing of waste will minimise the risk of contamination to stormwater.

6.5.6 Evaluation of residual risks

The primary risk associated with surface water is considered to be ‘Low’ to ‘Moderate’.

With implementation of due diligence, standard industry practices and specific controls and management measures, the residual risk has been determined to be ‘Low’.

Table 53 Risk assessment – Stormwater

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Stormwater leaving the site creates an impact to sensitive receptors due to high suspended solids (siltation) or other contaminants	Possible	Minor	Operational infrastructure designs divert stormwater around contaminant sources Flood mitigation structures, retention dams, silt traps, culverts and installed drainage channels are in place and maintained All fuels, oils and other chemicals to be stored in accordance with AS 1940 and EPA bunding guidelines All spills to be cleaned up as soon as practicable and contaminated material to be moved to the bioremediation pad Spills greater than 20 litres reported on the environment incident reporting system and corrective actions tracked Drainage from WRDs, roads and mine operation hardstand areas will be diverted to siltation traps to avoid soil erosion or sedimentation of channels and retained on site	Unlikely	Negligible	Low	No water contaminated as a result of mining operations leaves the tenement areas or results in loss of or contamination of soil on or off the tenements	Records demonstrate that inspection audits of drainage silt traps (see location plan Appendix A-10) are carried out during or within 5 days after rainfall events that result in flows of stormwater, or every three months, whichever is the lesser, to determine that culverts are not blocked and that >500 mm of freeboard remains in silt traps and that spiollways are not eroded or otherwise damaged, and that all corrective actions from inspections are logged and closed out within 30 days or as otherwise agreed with the Regulator Audit of environment incident reports demonstrate that corrective clean up actions from incidents of spills within the SMR mine area have been closed out within 24 hours

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Alteration of natural drainage lines leads to reduction of flows to stormwater dependent ecosystems (including post-closure)	Unlikely	Negligible	There are no stormwater dependent ecosystems or vegetation communities with in the SMR area Preservation of natural drainage systems where practical Flood mitigation structures, retention dams, silt traps, culverts and installed drainage channels are in place and maintained Ensure that roads that are required to be built over natural drainage channels are fitted with drains or culverts to allow natural water flows along natural drainage channels during rainfall events	Unlikely	Negligible	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Alteration of natural drainage lines generates flooding on neighbouring land	Unlikely	Negligible	Preservation of natural drainage systems where practical Flood mitigation structures, retention dams, silt traps, culverts and installed drainage channels are in place and maintained Where drainage channels are located within target sites, care will be taken to minimize disruption to watercourses Roads will be constructed from appropriate aggregate and with adequate compaction to minimise the potential for wash outs during large storm events Mine pits will reduce the risk of flooding.	Unlikely	Negligible	Low	N/A	N/A
Stormwater leaving the site creates soil erosion	Possible	Minor	Flood mitigation structures, retention dams, silt traps, culverts and installed drainage channels are in place and maintained Preservation of natural drainage systems through gully head and down culvert gully armouring	Unlikely	Minor	Low	No water contaminated as a result of mining operations leaves the tenement areas or results in loss of soil on or off the tenements	Records demonstrate that inspection audits of drainage silt traps (see location plan Appendix A-10) are carried out within five days of rainfall events that result in flows of stormwater, or every three months, whichever is the lesser, to determine that culverts are not blocked and that >500 mm of freeboard remains in silt traps and that spillways are not eroded or otherwise damaged, and that all corrective actions from inspections are logged and closed out within 30 days or as otherwise agreed with the Regulator

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Negative effect on surface water quality	Rare	Negligible	None required	Rare	Negligible	Low	N/A	N/A

6.5.7 Outcome

The outcome and measurement criteria for stormwater are presented in Table 54.

Table 54 Outcome – Stormwater

Outcome	Measurement criteria	Monitoring programs
No water contaminated as a result of mining operations leaves the tenement areas or results in loss of, or contamination of, soil on, or off, the tenement/s	Records demonstrate that inspection audits of drainage silt traps (see location plan Appendix A-10) are carried out within five days of rainfall events that result in flows of stormwater, or every three months, whichever is the lesser, to determine that culverts are not blocked and that >500 mm of freeboard remains in silt traps and that spillways are not eroded or otherwise damaged, and that all corrective actions from inspections are logged and closed out within 30 days or as otherwise agreed with the Regulator	Biannual site inspections, with increased frequency during/following rainfall events

6.6 Groundwater

6.6.1 Context

The north-east of the Eyre Peninsula has very little usable groundwater. Only minor quantities of salty groundwater have been encountered during mining and exploration activities associated with iron ore in the Middleback Ranges. Small quantities of groundwater in isolated localities in the general north-eastern Eyre Peninsula area have been used for stock watering where quality permits. Many wells have been abandoned with the installation of a reticulated water supply (Clarke and Lang 1980).

Groundwater, which is not considered a usable resource due to its high salinity, is in the order of 70,000 mg/L total dissolved solids (TDS), or double that of seawater.

The Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000) suggest the environmental value of this groundwater resource is suited to industrial use given the excessive salinity recorded during previous hydrology investigations in the area. The groundwater could potentially be used for dust suppression.

The SMR mining areas are not located in an area designated as a Prescribed Wells Area and as a consequence, is not covered by a Water Allocation Plan under the NRM Act 2004.

The SMR has groundwater confined to fractured rock and unconsolidated sediment (palaeochannel) aquifers. The salinity of the groundwater held in both systems is greater than 15,000 g/L, which is considered unsuitable for livestock purposes and is not classified as potable water.

Only minor quantities of saline groundwater have been encountered during iron ore mining and exploration activities in the Middleback Ranges. Saline groundwater was identified to the west of the SMR mines within palaeochannel sediments associated with Salt Creek. A small volume of groundwater was extracted from the palaeochannel for road construction (Read 1986). A supply of saline groundwater was developed for the construction of the Iron Duke mine in the late 1980s (Australian Groundwater Consultants Pty Limited (AGC) 1988 a, b) from the shallow sediments west of the mine, but the well field is not currently in use.

In 2004 Coffey Geosciences encountered groundwater before the construction of the southern TSF west of the Iron Duke/Magnet. Regular groundwater monitoring of the TSF wells has been undertaken since their installation and all groundwater sampled in the TSF area has been analysed as saline.

The deposition of tailings into the OBP TSF (2004) and the Magnetite TSF (2007) have contributed to a localised groundwater mound rising to ground surface level in a lagoon system adjacent to Salt Creek, down slope of the TSFs. Approximately 60 ha of vegetation has been affected to various degrees due to inundation of the vegetation root systems. This issue has been managed in accordance with the agreed management plan subsequent to an Environmental Direction, issued by DSD (previously DMITRE) on 27 March 2013.

6.6.2 Applicable legislation

The key pieces of legislation that apply are:

- *Mining Act 1971*
- *Environment Protection Act 1993*
- *Environmental Protection and Biodiversity Conservation Act 1999*
- *Native Vegetation Act 1991*
- Environmental Protection Policy (Water Quality) 2015
- *Natural Resource Management Act 2004*.

6.6.3 Stakeholders

The key stakeholders that have an interest in the tailings management at the SMR include:

- DPC
- NVC
- adjacent landholders
- EPA.

6.6.4 Potential impacts

The potential impacts relating to groundwater are summarised in Table 55.

Table 55 Impact event analysis – Groundwater

Source	Pathway	Barrier	Environmental receptor	Consequences
Hazardous materials spills or leaks	Seepage or direct exposure to groundwater Incorrect storage and handling and refuelling	Minimal underground storage/distribution of hazardous materials Storage to comply with relevant standards or legislation (AS1940 EPA bunding guidelines) Refuelling in designated areas on site Drilling collars capped immediately after completion	Groundwater	Contamination of groundwater
Tailings storage	Seepage	TSF walls and floor Supernatant water recovery	Native vegetation	Saturation of vegetation root zones
Tailings storage	Leached analytes	Inert materials or leach potential not above natural attenuation	Groundwater	Changed groundwater quality
In-pit water storage	Seepage	Hydrological/geophysical assessments	Groundwater	Change to groundwater quality Saturation of vegetation root zones
Geochemistry of WRDs	Seepage	Annual average rainfall deficit of approximately -1,650 mm Regional seepage modelling indicates insignificant risk Inert waste All waste types classified as NAF or uncertain	Groundwater	Negative effect on groundwater quality

6.6.5 Control and management strategies

Table 56 provides details of the risk assessment for stormwater, the control and management strategies to be implemented, and the associated outcomes and measurement criteria.

The Magnetite TSF Management Plan strategies are as follows:

- Design and implementation of water recovery approach: The Iron Duke groundwater recovery system has been operational since the 26 September 2013. Extracted volumes will continue to be tracked and reviewed on a weekly basis.
- Monthly groundwater monitoring: Remote level loggers have been installed in the majority of Iron Duke monitoring wells to collect detailed information on groundwater levels. Each logger takes eight readings per day and the loggers are downloaded monthly, interpreted and reported.
- Reduce groundwater levels to below root zone: Monthly monitoring of groundwater levels is undertaken as a minimum and monitoring has been weekly since the bore field has been operational. SIMEC Mining has a target to reduce groundwater levels to >1 m below ground surface level.
- Monitor effected zone vegetation responses. SIMEC Mining monitors affected vegetation on a quarterly basis.
- Develop a full water balance for the sustainable operating state of the TSF: A water balance was received by SIMEC Mining as part of the draft 'Design Studies to Support a Program for Environment Protection and Rehabilitation for Tailings Storage' provided to DSD in November 2013 and is updated on an annual basis.
- Water recovery from the TSF (trial in-line flocculation dewatering process): Water recovery has been promising when there has been sufficient water entering the decants. The aim is to dewater 100% of the tailings stream with an expected water recovery of 50–60%.
- A central decant system is a confirmed goal of the long-term work: Evaluation of full perimeter discharge and a central decant for the TSF: the central decant study is complete and a five-year strategic plan developed and in place. Assessment of the flocculation trial is also complete demonstrating benefits to beaching angle control and water recovery.

The Iron Duchess water storage management strategies are as follows:

- storage of water in the Iron Duchess pit will be monitored and controlled to ensure that nearby vegetation root zones are not affected by rising groundwater levels
- groundwater monitoring well data from the three installed monitoring wells (as shown on Figure 24), have validated the hydrogeological assessments which were used to determine the groundwater level trigger point to ensure vegetation root zones are protected from groundwater mounding
- groundwater monitoring at the Iron Duchess facility, together with monitoring of Iron Duchess water storage levels, will be used to establish safe water storage levels, including allowances for heavy rainfall events (see Section 6.6.6)
- the groundwater level trigger point will initiate actions to limit water levels in the pit, to control further groundwater risings. Investigations will be undertaken to identify the root cause of any abnormal groundwater level rise, and management plans will be adjusted to ensure that Iron Duchess water storage operations do not adversely impact on the environment.

Based on additional information (see Sections 2.2.1 and 2.2.2), environmental impact assessments for WRD ARD seepage potential for Iron Duchess (see Table 57), and TSF groundwater leach potential (see Table 58) have been provided.

6.6.6 Evaluation of residual risks

The primary risk to and from groundwater is seepage of water from the Magnetite TSF and the Iron Duchess pit resulting in a rising groundwater mound into the vegetation root zone. As this has actually occurred below the Magnetite TSF, the inherent risk is 'Very high'. Implementing mitigation measures and changing the tailings deposition and water recovery strategies will reduce the risk, however the residual risk remains 'High'.

The risk of impacts to vegetation from groundwater mounding due to seepage from the Iron Duchess pit is inherently low due to depth of groundwater, local geology and distance to vegetation from the pit, however an outcome and measurement criteria has been developed because of the interest in groundwater mounding and vegetation impacts at the S-SMR.

Groundwater monitoring well data from the three installed monitoring wells (as shown on Figure 24), plus validated hydrogeological assessments, has been used to determine a groundwater level trigger point, as described in Section 6.6.5.

When groundwater levels measured at the Iron Duchess pit groundwater monitoring well DMW03 is nearing or is at a level of 150 m AHD, water transfers to the Iron Duchess pit will be stopped, and actions to lower the groundwater level will be implemented. This will ensure the prevention of native vegetation root zone inundation in downstream environments from the in-pit water storage activities.

Table 56 Risk assessment – Groundwater

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Trigger reportable site contamination provisions contained within the *Environment Protection Act 1993* due to hazardous substance spills	Unlikely	Negligible	All fuels and chemicals stored on site as per AS1940 and EPA bunding requirements. Minimal volumes of hazardous substances to be kept on site Refueling will be undertaken with spill controls in place Drill holes will be capped or backfilled in accordance with DMITRE Info Sheet 21 and SIMEC Mining's procedures in QP50.58 All spills to be cleaned up as soon as practicable in accordance with SIMEC Mining's spill response procedure and contaminated material to be moved to the bioremediation pad Spills greater than 20 litres reported in the environment incident reporting system and corrective actions tracked Incident reports and corrective action close out	Rare	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Inundation of vegetation root zones from the Magnetite TSF	Almost certain	Medium	Controls, procedures and contingencies as part of the Management Plan will manage the mounded and rising groundwater levels	Possible	Medium	High	No changes to groundwater levels that adversely impact vegetation due to Magnetite TSF operations	Records and reports demonstrate that SIMEC Mining is compliant with the Magnetite TSF Management Plan, and that the groundwater extraction wells are functioning (refer to Section 3.9.6) and that monthly groundwater level monitoring at location plan (see Figure 24), demonstrates a falling trend in groundwater levels below the vegetation root zone, averaged over a twelve month period and taking into account rainfall events that may naturally raise groundwater levels temporarily Biannual aerial and ground surveys demonstrates that the vegetation impact area has not increased

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Contamination of aquifers through direct exposure to hazardous materials	Rare	Negligible	Storage of fuels and other hazardous materials will be done in accordance with EPA guidelines and Australian Standards Refuelling of equipment, machinery and vehicles will be done using spill control devices SIMEC Mining spill prevention and response plans Drill holes will be capped and/or abandoned in accordance with DMITRE information sheet M21 No beneficial users of the groundwater as it is highly saline The tailings are inert, there are no hazardous materials or additives Procedures, protocols and controls for management of contamination sources in pit Incident reporting and corrective action requirements	Rare	Negligible	Low	N/A	N/A
Inundation of vegetation root zones from Duchess pit water storage	Unlikely	Negligible	Monitor groundwater levels Halt rise in pit water level and trigger investigation and actions if groundwater levels rises to above 150 m AHD in Iron Duchess monitoring well DMW03 (see Figure 24)	Unlikely	Negligible	Low	No changes to groundwater levels that adversely impact vegetation due to Iron Duchess water storage operations	Monthly groundwater monitoring records demonstrate that the groundwater level does not exceed 160 m AHD at DMW03 (see Figure 24) Annual aerial and/or ground surveys demonstrate that the total area of vegetation cleared does not exceed the approved area as per Table 31 (see Section 4.3) when compared to the

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
			Stop increase or lower pit water depth Monitor water balance to calculate water loss through seepage					September 2013 aerial image (see Figure 84)
Adverse changes to groundwater quality or quantity from Iron Duchess pit water storage	Unlikely	Negligible	Iron Duchess pit water storage is recycled process water that is near fresh Process water analysis	Unlikely	Negligible	Low	N/A	N/A
Negative effect on groundwater quality	Rare	Negligible	None required	Rare	Negligible	Low	N/A	N/A

Table 57 Environmental impact assessment – WRD ARD seepage potential

Potential impact event	Mine Life Phase	Impact Event ID	Impact Assessment				Community concerns	Uncertainties and assumptions of source, pathway or receptor	Sensitivity to change (in assumptions of source, pathway or receptor)	Forward work plan
			Source (S)	Pathway (P)	Receptor (R)	S-P-R (Y/N or uncertain)				
Contamination of groundwater from ARD seepage from WRDs **(Iron Duchess)**	Operations/Completion	WPC108-01	No Due to comparable mineralogy, Iron Duchess geochemistry can be compared with Iron Warrior. Rock types are assumed to be NAF	No Due to comparable mineralogy, Iron Duchess hydrogeology can be compared with Iron Warrior. 200-year seepage is assumed to be of negligible risk	Yes Groundwater	No	None	<u>Moderate level of certainty</u> Iron Duchess and Iron Warrior are both within the Hutchinson group – Middleback subgroup and are of such similar geology, minerology and structure that the recent geochemical and seepage assessments completed at Iron Warrior (Golder 2-17) can be compared to Iron Duchess. As result of new information, verified by the mineralogical results, the majority of samples from the five dominant rock types tested are now classified as non-acid forming or uncertain with <0.5 kgH_2SO_4/t NAPP. The uncertain classification is derived from the low paste pH and NAGpH of the clay and goethite samples. These materials are naturally acidic and the acidity is non-sulphidic acidity likely derived from the hydrolysis of the iron minerals. As the iron minerals are naturally occurring in the landscape it is unlikely they present an increased risk to the environment through the operations (Golder 2017b). Golder developed a two-dimensional saturated-unsaturated groundwater flow model using Feflow software. The model incorporated climate effects (rainfall and evaporation), WRD and LGOS development and materials and previously determined hydrogeological data, and was designed to simulate internal water movement within the structures and predict migration away from them. Modelling was undertaken in three stages: Stage 1: The model was run to 'steady state' to establish pre-mining groundwater conditions, consistent with measured groundwater levels at the site, and interpreted groundwater flow gradients. Stage 2: Transient Modelling (Operational Period). The modelling simulated the progressive raising of the WRD using High, Middle and Lower Cases. Despite the model indicating progressive increasing moisture content in the waste rock layers, groundwater levels remained constant. The Middle and Lower-Case simulations were run using the middle and lower estimates of hydraulic conductivity, with no seepage predicted from these models. Stage 3: Transient Modelling (Post-Closure Period). Golder used the stage 2 moisture conditions as the starting conditions for the 200-year simulation period. Golder considered that the modelling resulted in a negligible risk of seepage.	<u>Low sensitivity to change</u> Verification of PAF/NAFF classification through analysis of rock types from Iron Duchess is unlikely to change assumptions	Mineralogical assessment to quantify sulfur species and acid neutralising capacity Chemical assessment of sulfur species Paste pH and pH NAG testing Leach testing Conduct permeability testing and assessment of WRD materials and cover materials during operations to inform a seepage model assessment. The results to be presented in the SMR PEPR review 2019-2020

Description of likely impact	No impact	**Certainty of occurrence of Impact**	High level of certainty	**Classification of impact**	**Low** Long term, low intensity, insignificant effect	**Justification for Outcome**	Not justified due to low classification however an outcome is proposed due to stakeholder interest

Control strategies	**Certainty of effectiveness of control measures/Likely Impact**	**Sensitivity to change of assumptions (for controls)**
Monthly monitoring of ground water depth (during operations), annual analysis of ground water major elements sampled from established Duchess ground water monitoring wells. Ongoing assessment of permeability potential of all waste types. Procedures for assaying and testing of drill cuttings or excavated material, produced during the course of blast hole drilling or mining, for verifying PAF and NAF information against the model and mine plans to provide a final check that all PAF and NAF materials have been correctly identified and placed.	High level of certainty	Low level of sensitivity
Outcome (acceptable level of impact/ consequence) Developed in Conjunction with Stakeholders	**Measurement criteria**	**Leading indicator criteria**
No adverse impact to the environmental value of groundwater or groundwater dependent ecosystems as a result of AMD, chemicals or hydrocarbons from mining operations	Annual groundwater quality analysis of Iron Duchess groundwater undertaken at locations shown in Figure 23 demonstrates that levels do not elevate beyond the natural range of variability above baseline or background levels.	Any elevation of indicator values.

Table 58 Environmental impact assessment – TSF groundwater leach potential

Potential impact event	Mine Life Phase	Impact Event ID	Impact Assessment				Community concerns	Uncertainties and assumptions of source, pathway or receptor	Sensitivity to change (in assumptions of source, pathway or receptor)	Forward work plan
			Source (S)	Pathway (P)	Receptor (R)	S-P-R (Y/N or uncertain)				
Changed ground water quality due to the operation of the SMR TSF	Operations	WPC108-02	Yes Leaching of elements from stored tailings by hydrogeochemical processes	Yes Vertical seepage into the ground water table	Yes Ground water	Yes	None	<u>Low level of uncertainty</u> Uncertain source potential. The Jacobs Group (Australia) were engaged in 2018 to investigate the leach potential of elements from tailings stored in the SMR TSF. In summary Jacobs found that although there have been some fluctuations in values since baseline data was first collected in 2005, only BHMB1 has exceeded any of the 2007 MARP trigger values on a few occasions and in most cases returned to baseline conditions in observations taken in August 2017. BHMB1 is screened in basement and is adjacent to the south west corner of the TSF and not completely down-gradient and therefore subject to uncertain influences. All other monitoring bore values have remained relatively stable. Early results of the newly installed background well (CPMW01) indicate values within the average range of TSF seep water monitoring wells since background commenced in 2005. Natural hydrogeochemical processes in part explains low pH water and elevated heavy metals present in groundwater adjacent the TSFs and Salt Creek. Furthermore, contaminants of concern which may leach from TSF material (boron, chromium, aluminium, copper, uranium and zinc) are being naturally attenuated by similar hydrogeochemical processes. EPA South Australia's Environment Protection Policy (Water Quality) (EPA SA; 2015) does not provide indicative water quality guidelines for saline/low pH groundwater or surface water systems located in the SA Arid Lands region. No other ground water related receptors have been identified. There are no beneficial users of groundwater.	<u>Moderate level of sensitivity</u> It is possible that further investigation and model development could vary the source assumptions.	Establish new chemistry trigger values using background groundwater chemistry data once a sufficient dataset of monitoring data is collected from CPMW01 (PEPR update 2019 - 2020)

Description of likely impact	Minor fluctuations in dissolved analyte levels but no significant variation from background or baseline	**Certainty of occurrence of Impact**	High level of certainty	**Classification of impact**	**Low** Long term low intensity, insignificant effect	Justification for Outcome	Yes, based on uncertain source potential

Control strategies	**Certainty of effectiveness of control measures/Likely Impact**	**Sensitivity to change of assumptions (for controls)**
No changes to tailings materials, continue to deposit inert tailings and dewatering chemicals	High Level of certainty	Low sensitivity

Outcome (acceptable level of impact/ consequence) Developed in Conjunction with Stakeholders	**Measurement criteria**	**Leading indicator criteria**
No adverse impact to the environmental value of groundwater or groundwater dependent ecosystems as a result of leached elements from the TSF	Annual groundwater quality analysis of groundwater undertaken from monitoring wells OBP2, OBP3, BHMB2, BHMB3, BHMB4, BHMB5, BHMB6, BHMB7, West2 and West4, (see Figure 23) demonstrates that based on baseline conditions observed in 2005, levels do not elevate beyond the following investigation trigger levels, EC / TDS increase by more than 25%, a change in pH by more than 2 pH units, increase in one or more trace element concentration defined as follows: baseline concentration > 0.1 mg/L the major change is one order of magnitude, baseline concentration < 0.1 mg/L the major change is two orders of magnitude. Any exceedance will trigger investigation into the cause and effect of the exceedance and corrective actions assigned, the findings and the corrective actions will be reported to the Regulator within 30 days of finalisation of the report.	Increase in one or more trace element concentrations by more than twice the mean value of the baseline rounds of monitoring since 2005 plus two standard deviations, EC / TDS increase by more than 10%, a change in pH by more than 1 pH unit.

6.6.7 Outcome

The outcome and measurement criteria for groundwater are presented in Table 59.

Table 59 Outcome – Groundwater

Outcome	Measurement criteria	Monitoring programs
No changes to groundwater levels that adversely impact vegetation due to Magnetite TSF operations	Records and reports demonstrate that SIMEC Mining is compliant with the Magnetite TSF Management Plan, and that the groundwater extraction wells are functioning (refer to Section 3.9.6) and that monthly groundwater level monitoring at location plan (see Figure 24), demonstrates a falling trend in groundwater levels to below the vegetation root zone, averaged over a twelve month period and taking into account rainfall events that may naturally raise groundwater levels temporarily. Biannual aerial and ground surveys demonstrate that the vegetation impact area has not increased.	Groundwater monitoring schedule Vegetation monitoring schedule
No changes to groundwater levels that adversely impact vegetation due to Iron Duchess water storage operations	Monthly groundwater monitoring records demonstrate that the groundwater level does not exceed 160 m AHD at DMW03 (see Figure 24) Annual aerial and/or ground surveys demonstrate that the total area of vegetation cleared does not exceed the approved area as per Table 31 (see Section 4.3) when compared to the September 2013 aerial image (see Figure 84).	Groundwater monitoring schedule Vegetation monitoring schedule

6.7 Air Quality

6.7.1 Context

Air quality concerns arise predominantly from fugitive and point source emissions of dust. Emissions from vehicles, machinery and equipment are of much lesser concern because SIMEC Mining's service providers are required to only use vehicles, machinery and equipment that comply with current fume emission control standards.

The impact on adjacent landholders' native vegetation in its context as an asset for primary production and enjoyment of amenity and the potential dust impacts to native vegetation and fauna from the perspective of the *Native Vegetation Act 1991* have been addressed in Section 6.2.

This section also deals with potential impacts to neighbour's amenities and health.

Activities such as blasting, loading and hauling ore, crushing and screening, WRD construction, and open areas all have the potential to generate dust that could reduce amenity through staining, affect the health of native vegetation and fauna, degrade residential properties or could be considered a nuisance by the residents of neighbouring properties.

Winds from the north under dry conditions readily give rise to airborne dust from the mining and processing operations, which is evident from the Lincoln Highway and properties south of the highway under these conditions.

Properties directly to the south (see Figure 88) are generally in the plume path of airborne dust carried by northerly winds. Complaints of airborne dust have been received from neighbours 7 km to the south of the operations. Weather conditions producing dry northerly winds can provide significant challenges in terms of controlling visible airborne dust rising from the mine site.

SIMEC Mining takes the nature of these complaints very seriously and undertakes to formally register and respond to all complaints in a timely manner, and to take actions to minimise the emissions of dust as much as reasonably practicable.

The background dust level is estimated to be consistent with dust levels generated from the southern portion of South Australia's pastoral leasehold lands. Dust levels are highest in summer, particularly in times of drought, and under the influence of hot, dry northerly winds. Some roads in the region are unsealed.

6.7.2 Applicable Legislation

The key pieces of legislation and standards that apply are:

- *Mining Act 1971*
- *Environment Protection Act 1993*
- *Environment Protection and Biodiversity Conservation Act 1999*
- *Natural Resource Management Act 2004*.

6.7.3 Stakeholders

The key stakeholders with an interest in air quality include:

- adjacent landholders
- general public
- DPC

- DEWNR, SAAL NRM boards
- EPA.

SIMEC Mining's internal stakeholders will continue to monitor, assess and develop options during the planning, design and operational phases.

Adjacent landowners, the local community and other relevant stakeholders are involved in regular meetings as part of SIMEC Mining's ongoing Community Engagement Plan (see Section 5).

6.7.4 Potential Impacts

Mining and exploration activity in the SMR is likely to create dust and air quality issues to varying degrees outside of mining tenements, depending largely on prevailing weather conditions. The potential impacts relating to air quality are detailed in Table 60.

Table 60 Impact event analysis – Air quality

Source	Pathway	Barrier	Environmental receptor	Consequences
Dust generation from mining activities (WRD construction, dig, load, haul, blasting, rehabilitation and exploration)	Atmosphere	Fugitive Dust Ranking standard Operational procedures and controls Water carts/chemical suppressants on haul roads and open areas Blasting parameters and procedures Staged vegetation clearance	Broadview Station Moonabie Station Ironstone Hill Conservation Park Near neighbouring properties General public	Nuisance impacts to adjacent landowners homes and amenities Neighbouring residents' health Nuisance visible dust
Emissions from combustion from mining plant and equipment	Atmosphere	Vehicle maintenance	Air quality	Excursion of regulatory gaseous criteria for vehicle air emissions

6.7.5 Control and management strategies

Engineering design, operational procedures and controls for plant, equipment and infrastructure and a strict program of inspection and auditing, will be used to ensure dust from mining and exploration activities is minimised as far as is practicable.

A key control is adequate provisioning of recycled process water for use in suppressing dust. See Section 3.12.4 for further details.

SIMEC Mining is also actively trialling new dust suppression initiatives and technologies, including the use of embedded dust inhibitors in road and operating pad surfaces where traffic is high, as well as

the application of surfactants and binding agents within the crushing and screening circuits (see Section 3.8.7).

A number of dust deposit gauges (DDG) have been installed as part of a monthly monitoring program (see Appendix A-9).

The dust level fallout and impacts to neighbouring properties is monitored.

Progressive rehabilitation and closure works undertaken during operations also aids in reducing dust loads from exposed areas, including existing stockpiles and WRDs.

SIMEC Mining has an ongoing occupational health air-quality monitoring program for both fibre and respirable dust including crystalline silica located at fixed plant and mine site areas. The results have shown that personal measurements are typically well below the relevant exposure standard. SIMEC Mining has adopted a risk-based approach to the respirable dust and fibre monitoring program. If the risk levels change then the sampling strategy will be modified accordingly.

Table 61 provides details of the risk assessment, control and management strategies to be implemented, and the associated outcomes and measurement criteria for air quality.

6.7.6 Evaluation of residual risks

The underlying aspect of concern here is dust from mining and exploration operations affecting neighbouring pastoral properties, and creating a nuisance to neighbours under certain weather conditions.

The primary air quality risks have been assessed ‘Low’ to ‘High’. With the implementation of due diligence, standard industry practices, and specific controls and management measures to combat dust on the mine sites, the residual risks levels have decreased, however the aspect of visual dust being considered as a nuisance remains high due to the strong likelihood of receiving complaints from nearby residents.

The potential health risks from dust on site have been shown to be below exposure standards. By implication, health impacts off site are not likely to be any different, with distance from source likely to lessen potential impacts. Based on this and SIMEC Mining’s experience through the Whyalla Health Risk Assessment in 2003, SIMEC Mining assesses potential primary and residual risks to neighbours and near neighbour’s health due to airborne dust from mining operations to also be low.

Table 61 Risk assessment – Air quality

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Nuisance impacts to adjacent landowners homes and amenities	Unlikely	Minor	Dust mitigation strategies which include: • ensuring adequate recycled water is available for dust suppression • dust suppression on roads • staged removal of vegetation • spray capping of dry dusty fines stockpiles during hot, dry and windy conditions • implementation of specific controls under the FDR procedure for dusty activities, such as postponement of operations when dust cannot be controlled • blasting parameters and procedures specific to reducing dust generation • environmental awareness training for staff and contractors	Rare	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Impact to neighbouring residents' health	Rare	Negligible	Dust mitigation strategies Distance to receptors Dust is inert Dust monitoring Visual indicator monitoring	Rare	Negligible	Low	N/A	N/A
Excursion of regulatory gaseous criteria for vehicle air emissions	Unlikely	Negligible	Preventative maintenance of equipment and vehicles as per schedules	Rare	Negligible	Low	N/A	N/A
Mine site dust emissions are considered to be a nuisance impact by local residents and the general public	Almost certain	Minor	Compliance to the FDR procedure and associated activity EMP controls	Likely	Minor	High	No nuisance impacts to local residents and the general public from air emissions, dust and odour generated from mining operations	Records demonstrate that complaints of air emissions, dust or odour are responded to within 24 hours, are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the affected party or the Regulator

* Mine derived dust descriptor: Dust that is considered to be derived from mining operations determined by characterisation, colour and the direction from which dust is deposited onto vegetation.

** Refer to Table 45 in Section 6.2.9 for vegetation dust impact score descriptors.

6.7.7 Outcome

The outcome and measurement criteria for visual amenity, nuisance noise and light are presented in Table 62.

Table 62 Outcomes – Air Quality

Outcome	Measurement criteria	Monitoring programs
No nuisance impacts to local residents and the general public from air emissions, dust and odour generated from mining operations	Records demonstrate that complaints of emissions, dust or odour are responded to within 24 hours, are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the affected party or the Regulator	BSS Environment incident reporting records

6.8 Visual Amenity, Nuisance Noise and Light

6.8.1 Context

Mining of the Iron Duke, Iron Magnet and Iron Duchess deposits has considerably altered the natural visual amenity. The Duke and Magnet WRDs are clearly visible from the Lincoln Highway, which passes within 850 m of the toe of the most southern dumpsite.

From the south, the existing SMR crushing, screening and concentrator operations are partially visible from the Lincoln Highway, especially at night due to lighting.

SMR mining operations also generate noise. Noise will be generated by blasting, heavy machinery, equipment and vehicles will generate noise, but noise levels are not expected to increase compared to the current operations and are not expected to contravene the Environment Protection (Noise) Policy 2007. In very still night conditions the mining operations can be heard at significant distances, although there have never been any complaints of noise from neighbouring properties.

The Iron Chieftain operations are located on Uplands Station, a freehold property owned by SIMEC Mining (OneSteel Manufacturing Pty Ltd) since January 2009.

The Uplands Station homestead is approximately 5 km east of Iron Chieftain and is currently rented to the previous owner. Other neighbouring homesteads include Moola homestead (7.5 km away and currently unoccupied), Broadview homestead (10 km) and Moonabie homestead (13 km).

The WRDs will be extended northwards and the pit walls will become more visible, especially to users of the Lincoln Highway and the unsealed Kimba–Whyalla Road. The pit walls will be partially obscured by the WRD. The WRD will be progressively rehabilitated using landforms that will blend with the natural landscape.

Lighting is expected to increase with construction and mining activities occurring at night. Lighting is necessary for safety and security, and its use would be restricted to areas where it is required on site. Lighting is currently visible to highway users and to neighbouring residences and lighting is expected to increase in extent but not intensity. There have not been any complaints related to lighting from the Iron Chieftain operations to date.

6.8.2 Applicable legislation

The key pieces of legislation and policies that apply are:

- *Mining Act 1971*
- *Environment Protection Act 1993*
- Environment Protection (Noise) Policy 2007.

6.8.3 Stakeholders

The key stakeholders who have an interest in visual amenity, nuisance noise and light include:

- adjacent landholders
- highway users
- DPC
- EPA.

SIMEC Mining's internal stakeholders will continue to assess development options during the planning and design phase.

Adjacent landowners, the local community and other relevant stakeholders are involved in regular meetings as part of SIMEC Mining's ongoing Community Engagement Plan (see Section 5). Other stakeholders include workers, travellers, regional visitors and road commuters.

6.8.4 Potential impacts

The potential impacts relating to visual amenity, nuisance noise and light are summarised in Table 63.

Table 63 Impact event analysis – Visual amenity, nuisance noise and light

Source	Pathway	Barrier	Environmental receptor	Consequences
Exploration drilling	Temporary earthworks Altered landscape	Rehabilitation Plan	Neighbouring landholders Highway users and other transient receptors	Complaints of reduced visual amenity

Source	Pathway	Barrier	Environmental receptor	Consequences
WRD development	Earthworks Altered landscape	WRD development plans incorporating appropriate considerations Agreed rehabilitation criteria Progressive rehabilitation Consultation	Neighbouring landholders Highway users and other transient receptors	Complaints of reduced visual amenity
Mining operations Equipment noise Increased lighting Vegetation clearance Dust emissions	Further altered landscape Noise Night time lighting	Planning and design to incorporate appropriate considerations Community consultation SIMEC Mining procedures and protocols Rehabilitation Plan	Neighbouring landholders Highway users and other transient receptors	Complaints of nuisance noise/light

6.8.5 Control and management strategies

Table 64 provides details for the risk assessment, any control and management strategies to be implemented, and the associated outcomes and measurement criteria for visual amenity and nuisance noise and light.

Table 64 Risk assessment – Visual amenity, nuisance noise and light

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Exploration drilling resulting in complaints of reduced visual amenity, nuisance noise/light	Unlikely	Minor	Drilling to comply with DPC guidelines to minimise impact to landholders Exploration activities to be carried out with minimal disturbance and areas re-instated to current condition if further exploration/mining does not eventuate Ongoing liaison with stakeholders prior to, during and following exploration activities will occur Any complaints received will be investigated and actions put in place to achieve an agreed (by SIMEC Mining and complainant) resolution within one month of the complaint. Details will be communicated to DPC	Unlikely	Negligible	Low	N/A	N/A
Complaints of reduced visual amenity from mining and WRD development	Possible	Minor	Community engagement plan provisions WRD development plans incorporating appropriate considerations Agreed rehabilitation criteria Progressive rehabilitation	Unlikely	Negligible	Low	The contrasting and reflective aspects of WRDs and infrastructure are visually softened to blend in with the surrounding landscape	Annual audits against the staged rehabilitation strategy, with the use of annual aerial and ground surveys of the landform development and biennial flora monitoring surveys demonstrate progressive rehabilitation undertaken in accordance with staged rehabilitation strategy for SMR Mining Area (see Section 8)

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Complaints of nuisance noise and light from mining activities	Unlikely	Negligible	Community Engagement Plan provisions Operational areas are located 5–13 km from neighbouring property residences All equipment and machinery will comply with industry standards delivered through existing procurement and maintenance management procedures Design and layout incorporates consideration for visual amenity, nuisance noise and light spillage Blast Management Protocol utilises standard industry practices that minimise noise and vibration	Unlikely	Negligible	Low	N/A	N/A

6.8.6 Evaluation of residual risk

The risks associated with visual amenity were identified to have a 'Moderate' risk, based on the increased mining activity in the area. The risks associated with nuisance noise and light were rated as 'Low' risk due to the distance to receptors.

Consultation with neighbours on the WRDs (old and new) will be ongoing.

With implementation of due diligence, standard industry practices and specific controls and management measures, the residual risk has been assessed as 'Low'.

6.8.7 Outcome

The outcome and measurement criteria for visual amenity, nuisance noise and light are presented in Table 65.

Table 65 Outcomes – Visual amenity, nuisance noise and light

Outcome	Measurement criteria	Monitoring programs
The contrasting and reflective aspects of WRDs and infrastructure are visually softened to blend in with the surrounding landscape	Annual audits against the staged rehabilitation strategy, with the use of annual aerial and ground surveys of the landform development and biennial flora monitoring surveys demonstrate progressive rehabilitation undertaken in accordance with staged rehabilitation strategy for the SMR Mining Area (see Section 8)	Aerial and ground surveys of the landform development Assessment of WRD development against the closure and rehabilitation strategy (see Section 8)

6.9 Blasting and vibration

6.9.1 Context

Blasting across the SMR mine pits will occur two to three times per week on average.

Explosives are stored on site in the designated Iron Knight compounds in accordance with the relevant licences.

The proximity of existing infrastructure and housing is detailed in Section 5.

The distance to receptors are greater than 600 m, the closest being the mining contractor site facilities. Neighbouring homesteads are between five and 13 km from the proposed mine site pits.

Vibration from the use of drill rigs for blast holes and exploration is expected to be negligible.

6.9.2 Applicable legislation

The key pieces of legislation and policies that apply are:

- *Mining Act 1971*
- *Explosives Act 1936*
- *Environment Protection Act 1993*
- Environment Protection (Noise) Policy 2007
- *Work Health and Safety Act 2012*
- Work Health and Safety Regulations 2012.

6.9.3 Stakeholders

The key stakeholders with an interest in blasting and vibration include:

- DPC
- adjacent landholders.

Adjacent landowners have been informed of the development plans, and there are no issues outstanding. Landholder consultation meetings are held twice a year.

Other stakeholders include SIMEC Mining and contractor staff, travellers, regional visitors and road commuters.

6.9.4 Potential impacts

From time to time nearby landholders may notice some noise and vibration at the time of a blast, however the effects are minimised by using industry standard blasting practices and by adjusting blast parameters and process controls to suit conditions.

Blast monitoring will be conducted annually or as required to ensure impacts are understood and that blast settings are managed to minimise impacts on the public.

Blast practices will be developed to ensure that fly rock is contained within the operational area. Details of the blast management protocols are provided in Section 3.8.6.

Vibration from the use of drill rigs for blast holes and exploration is expected to be negligible.

The potential impacts relating to blasting and vibration are summarised in Table 66.

Table 66 Impact event analysis – Blasting and vibration

Source	Pathway	Barrier	Environmental receptor	Consequences
Blasting activities	Vibration via ground surface Noise via atmosphere Shock wave via atmosphere Fly rock via air Fumes via atmosphere	Short duration Industry standard blasting protocols Adjustment to blast parameters and process control Distance to receptors Community consultation and notifications Blast work instructions Limit mass instantaneous charge (MIC) Direction of initiation of the charge away from sensitive receivers SMR Blast Management Protocol (see Section 3.8.6) Planning blasts according to wind direction Correct use of suitable explosive type	Adjacent landholders Mine amenity buildings	Blasting activities leading to injury or damage from fly rock Adverse reaction or health impact from blast fume or dust Reduced amenity from blast dust Ground vibration impacting adjacent residents, infrastructure and/or SIMEC Mining infrastructure Airborne shock waves (over pressure) and noise impacting adjacent residents
Exploration drilling	Vibration via ground surface Noise via air	Short duration Drilling protocols Community consultation	Adjacent landholders	Complaints

6.9.5 Control and management strategies

Table 67 provides details of the risk assessment for blasting and vibration, any control and management strategies to be implemented, and the associated outcomes and measurement criteria.

6.9.6 Evaluation of residual risks

The primary risks associated with blasting noise and vibration range from ‘Low’ to ‘High’ risk.

The distance to sensitive receptors is more than 5 km.

Blasting is anticipated to be of low intensity. It will occur under strict conditions and will be well shielded within the pit.

With the implementation of due diligence, standard industry practices and specific controls and management strategies the residual risk is assessed as ‘High’. Should an injury occur, the risk would be ‘Major’, although the likelihood is rare due to adherence to standard industry practice.

Table 67 Risk assessment – Blasting and vibration

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Blasting activities leading to injury or damage from fly rock	Unlikely	Major	SIMEC Mining protocols for blasting activities to minimise impact, which are based on Australian Standard AS 2187.2 Explosives – storage and use – use of explosives 500 m exclusion zone for all personnel Adjustments made to blast parameters and process control as required Limit mass instantaneous charge (MIC) to reduce any release of excess energy Distance to receptors Any safety incidents relating to fly rock will be reported to DPC and SafeWork SA	Rare	Major	High	No public health, safety and nuisance impacts from air blast overpressure, vibrations, fumes, dust or fly rock caused by blasting undertaken on site	Records show that an independent investigation of recorded incidents related to blasting activities on site, demonstrates that an incident could not have been prevented through implementation and use of reasonable preventative measures and that all incidents as a result of blasting, including fly rock occurrences outside of the blast management zone or complaints related to blasting, are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator
Adverse reaction or health impact from blast fume or dust	Unlikely	Minor	Correct explosive type used in blasting as per manufacturers advice based on moisture content in boreholes and different strata formations Adjustments made to blast parameters and process control as required SIMEC Mining protocols for blasting activities to minimise impact, which are based on Australian Standard AS 2187.2 Explosives – storage and use – use of explosives	Unlikely	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Reduced amenity from blast dust	Likely	Minor	Blast management protocol includes rescheduling of blasts if the wind will blow fumes or dust towards Broadview Station Correct explosive type used in blasting as per manufacturers advice based on moisture content in boreholes and different strata formations Adjustments made to blast parameters and process control as required SIMEC Mining protocols for blasting activities to minimise impact, which are based on Australian Standard AS 2187.2 Explosives – storage and use – use of explosives	Possible	Minor	Moderate	No public health, safety and nuisance impacts from air blast overpressure, vibrations, fumes, dust or fly rock caused by blasting undertaken on site	Records demonstrate that complaints of unauthorised damage are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the affected party or the Regulator
Ground vibration impacting adjacent residents	Unlikely	Negligible	Standard Industry blast practices Limit mass instantaneous charge (MIC) to reduce any release of excess energy SIMEC Mining protocols for blasting activities to minimize impact	Unlikely	Negligible	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Air-borne shock waves (over pressure) and noise impacting adjacent residents	Possible	Negligible	Standard Industry blast practices Weather forecasts will be used to avoid the likelihood of inversion layer shock waves SIMEC Mining protocols for blasting activities to minimise impact Adequate and correct type of stemming use to contain the explosive within the blast hole	Unlikely	Negligible	Low	No public health, safety and nuisance impacts from air blast overpressure, vibrations, fumes, dust or fly rock caused by blasting undertaken on site	Records demonstrate that complaints of unauthorised damage are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the affected party or the Regulator

6.9.7 Outcome

The outcome and measurement criteria for blasting and vibration are presented in Table 68.

Table 68 Outcomes – Blasting and vibration

Outcome	Measurement criteria	Monitoring programs
No public health, safety and nuisance impacts from air blast overpressure, vibrations, fumes, dust or fly rock caused by blasting undertaken on site	Records show that an independent investigation of recorded incidents related to blasting activities on site, demonstrates that an incident could not have been prevented through implementation and use of reasonable preventative measures and that all incidents as a result of blasting, including fly rock occurrences outside of the blast management zone, or complaints related to blasting are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	Monthly safety incident report Safety KPIs Daily shift reports Mines inspection record Annual (or as required) ground vibration and over pressure monitoring

6.10 Waste Disposal

6.10.1 Context

The consumption of natural resources in the construction and mining operations and the resulting waste streams are inevitable. SIMEC Mining has adopted the waste management hierarchy of reduce, reuse, recycle (before disposal), which is embedded into the waste management procedures of the AS/NZS ISO 14001 certified EMS, in all of its operations. Provisions for waste disposal are specifically made within contracts, authority to work permits, safe work method statements and in risk assessments for all activities and projects.

Waste will be generated as part of construction and mining activities, and to a much lesser extent, as part of exploration activities.

The wastes expected during mining activities include, but are not limited to:

- construction and demolition waste
- general domestic wastes
- recyclable materials
- waste oils, lubricants, coolants and filters
- wastewater and sludge/sediments from vehicle washdown activities
- septic waste

- drill cuttings, unwanted samples, sample bags
- waste oils, lubricants, coolants and chemicals
- out-of-specification iron ore products.

Waste rock from mining will be managed in accordance with the closure and rehabilitation plans.

The following relates to non-process wastes.

6.10.2 Applicable legislation

The key pieces of legislation and policies that apply are:

- *Mining Act 1971*
- *Environment Protection Act 1993*
- Environment Protection (Waste to Resources) Policy 2010.

6.10.3 Stakeholders

The key stakeholders with an interest in waste include:

- DPC
- EPA
- adjacent landholders
- Port Lincoln highway users.

6.10.4 Potential impacts

The potential impacts relating to waste disposal are summarised in Table 69.

Table 69 Impact event analysis – Waste disposal

Source	Pathway	Barrier	Environmental receptor	Consequences
Management of industrial and general wastes not compliant to EPA requirements	Waste disposal system	Waste Management procedures Operational EMPs ISO 14001 EMS	Amenity, soil, surface water drainage channels	Contamination of soil, groundwater and surface water channels Reduction in visual amenity Attraction of feral animals Highway user complaints from incorrect waste disposal

6.10.5 Control and management strategies

Table 70 provides details of the risk assessment for waste disposal, any control and management strategies to be implemented, and the associated outcomes and measurement criteria.

Table 70 Risk assessment – Waste disposal

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Contamination of soil, surface and groundwater due to management of industrial and general wastes not being compliant to *Environment Protection Act 1993*	Unlikely	Minor	All spills are cleaned up and disposed of via the site bioremediation pads All domestic or industrial waste is disposed of in accordance with relevant legislation and standard operating procedures	Unlikely	Negligible	Low	N/A	N/A
Reduction in visual amenity Attraction of feral animals Highway user complaints from incorrect waste disposal	Unlikely	Negligible	All domestic or industrial waste is disposed of in accordance with relevant legislation and standard operating procedures	Unlikely	Negligible	Low	N/A	N/A

6.10.6 Evaluation of residual risk

The primary risk associated with waste disposal has been assessed as 'Low'. As a consequence, specific outcome and measurement criteria are not required. The standard operating procedures implemented as part of SIMEC Mining's AS/NZS ISO 14001 certified EMS are adequate to manage and control any potential impacts.

6.10.7 Outcome

No outcome is required for waste disposal because the primary risk is 'Low'.

6.11 Public Safety

6.11.1 Context

The SMR mine sites access is restricted to two entry points. The SMR main access route from 'Alternative Highway 1' that leads to visitor car parks is controlled through signage. Access beyond the SMR mine car park is controlled by a security card boom gate system. As the mine operates on a continuous basis, access by any individual not authorised to be on site will be identified and promptly dealt with by authorised mine site personnel.

Access to the Iron Knight and Iron Chieftain is either via the SMR main access route or via the rail access track from Sinclair's gap. This access route is controlled by two sets of locked gates, the first set is at the access point from the Kimba road and the second is approximately half way to Iron Knight.

6.11.2 Applicable legislation

The key pieces of legislation that apply are:

- *Mining Act 1971*
- *Work Health and Safety Act 2012*.

6.11.3 Stakeholders

The key stakeholders who have an interest in public safety include:

- DPC
- adjacent landholders
- general public.

6.11.4 Potential impacts

The potential impacts relating to public safety are summarised in Table 71.

Table 71 Impact event analysis – Public safety

Source	Pathway	Barrier	Environmental receptor	Consequences
Unauthorised site access – Exploration area	Site security failures	Existing site security Fences, gates, signage, vigilance	Member of the public	Injury or fatality to member of the public
Unauthorised site access – mining, operations and WRD areas	Site security failures	Existing site security Traffic management Fences, gates, signage, vigilance	Member of the public	Injury or fatality to member of the public

6.11.5 Control and management strategies

SIMEC Mining will implement a number of control measures to reduce the potential events associated with public safety. Where the primary risk is greater than 'Low', controls and management measures will be implemented to reduce the risk, including any changes to design and/or access protocols.

Outcomes and measurement criteria have been developed where the primary risk is higher than low, and where controls and management measures are required to reduce the residual risk.

Table 72 provides details for the risk assessment, any control and management strategies to be implemented, and the associated outcomes and measurement criteria for public safety.

6.11.6 Evaluation of residual risks

The primary risk to public safety was assessed as 'Very High' due to the potential for harm to people should an event occur.

With the implementation of due diligence, standard industry practices and specific controls and management measures, the residual risk has been determined to remain 'High'; although the likelihood an event occurring has been reduced to rare, the consequence still has the potential to be extreme.

Table 72 Risk assessment – Public safety

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Injury or death to members of the public as a result of exploration activities	Unlikely	Extreme	Adopt practices to protect personnel, land users, the public and animals from dangers to health and safety arising from exploration activities During drilling activities signage and barricades will be erected in work areas to notify unauthorised personnel of no-go zones Comply with all relevant fire restrictions and safeguards in the conduct of exploration activities Access to the drill sites will be limited to the drilling crew, geologists, field assistants and in-house safety and environmental personnel. Site work will usually involve a single entry and exit per day by the drilling crew, and up to three entries and exits per day by geologists, field assistants and other personnel. The service truck and water truck for the drill rig are the only other normal traffic	Rare	Extreme	High	No accidents involving the public as a result of exploration and mining activities that could have been reasonably prevented by SIMEC Mining	Records show that an independent investigation of recorded injuries from unauthorised access to the site, demonstrates that an incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Injury or death to members of the public as a result of mining activities	Possible	Extreme	Adopt practices to protect personnel, land users, the public and animals from dangers to health and safety arising from mining activities Maintain site fencing and signage. Maintain the implementation of site induction, visitor sign in and site access protocols Control entry and exit points	Rare	Extreme	High	No accidents involving the public as a result of exploration and mining activities that could have been reasonably prevented by SIMEC Mining	Records show that an independent investigation of recorded injuries from unauthorised access to the site, demonstrates that an incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator

6.11.7 Outcome

Since unauthorised access is considered to be a 'High' risk to the successful operation of the mine, the following outcome has been developed.

The outcome and measurement criteria for public safety is presented in Table 73.

Table 73 Outcomes – Public safety

Outcome	Measurement criteria	Monitoring programs
No accidents involving the public as a result of exploration and mining activities that could have been reasonably prevented by SIMEC Mining	Records show that an independent investigation of recorded injuries from unauthorised access to the site, demonstrates that an incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	Daily shift reports Mines Inspection record Monthly safety incident report KPIs Regulatory compliance audits conducted by the SIMEC Mining Environment Assurance department as per the audit schedule

6.12 Adjacent Land Use and Third Party Property

6.12.1 Context

Mining operations have the potential to affect third party property as a consequence of unintended and unexpected aspects of the operation.

Land adjacent to the SMR mining activities consists of a variety of land uses that include private and public conservation, pastoral grazing and nearby cereal crop farming. SIMEC Mining is actively rehabilitating the Uplands property through revegetation, erosion control, rabbit warren destruction, weed control, feral goat control and fox baiting.

The Ironstone Conservation Park borders the entire western SMR boundary. The Middleback Alliance, a partnership of significant landholders in the region, SIMEC Mining, DEWNR and Ecological Horizons, contributes to the management objectives of the park through land management and feral animal control programmes.

Broadview Station is situated immediately to the north of the proposed Iron Chieftain pit extension and associated WRD. Although the adjacent paddock has not been used for grazing in recent years, recent changes to land ownership will enable the owner to graze livestock in that area.

Moonabie Station, a merino sheep grazing property, borders much of the SMR operations on the eastern side.

There are no owners of services close enough to SMR to be affected by the operations.

Specific impacts to adjacent land vegetation are covered in Section 6.2. Specific impacts to adjacent land related to stormwater are covered in Section 6.5. Specific impacts related to adjacent residence amenity and human health are covered in Section 6.7. Specific impacts related visual amenity, noise and light are covered in Section 6.8. Specific impacts to adjacent land related to blasting and vibration are covered in Section 6.9.

6.12.2 Applicable legislation

The key pieces of legislation that apply are:

- *Mining Act 1971*
- *Work Health and Safety Act 2012*
- *Native Vegetation Act 1992*
- *Natural Resources Management Act 2004*.

6.12.3 Stakeholders

The key stakeholders who have an interest in adjacent land use and third party property include:

- neighbouring landholders
- DPC
- NVC
- SAAL NRM Board.

6.12.4 Potential impacts

The potential impacts relating to adjacent land use and third party property are summarised in Table 74.

Table 74 Impact event analysis – Adjacent land use and third party property

Source	Pathway	Barrier	Environmental receptor	Consequences
Mining operation activities adjacent to third party property	Airborne dust Vibration Uncontrolled land clearance Fire	SIMEC Mining procedures and protocols	Adjacent landholders	Claims of damage to third party, natural resources, livelihood, enjoyment or infrastructure Damage to property Breach of regulations Potential for law suit and prosecution

6.12.5 Control and management strategies

Table 75 provides details of the risk assessment for adjacent land use and third party property, any control and management strategies to be implemented, and the associated outcomes and measurement criteria.

6.12.6 Evaluation of residual risks

The primary risk associated with adjacent land use and third party property was assessed as 'Moderate' given the close proximity of private third party property adjacent to the proposed operations.

With ongoing consultation with stakeholders, and by implementing standard SIMEC Mining operating procedures and ensuring compliance with tenement conditions and agreed outcomes, the residual risk is 'Low'.

Table 75 Risk assessment – Adjacent land use and third party property

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Claims of damage to third party property natural resources, livelihood, enjoyment or infrastructure by mining operations including by dust, over clearance, stormwater, blasting, inundation and fire	Possible	Minor	Site operations are contained within the fenced boundary SIMEC Mining procedures are in place to minimise the impact on adjacent land (dust and clearance) Any complaints received will be investigated and actions put in place to achieve an agreed (by SIMEC Mining and complainant) resolution within one month of the complaint. Details will be communicated to DPC	Unlikely	Minor	Low	No unauthorised damage to adjacent property or infrastructure from mining operations	Records demonstrate that complaints of unauthorised damage are responded to within 24 hours, are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the impacted party or the Regulator

6.12.7 Outcome

The outcome and measurement criteria for adjacent land use and third party property are presented in Table 76.

Table 76 Outcomes – Adjacent land use and third party property

Outcome	Measurement criteria	Monitoring programs
No unauthorised damage to adjacent property or infrastructure from mining operations	Records demonstrate that complaints of unauthorised damage are responded to within 24 hours, are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the affected party or the Regulator	Complaints register records Incident/corrective action reports and associated reports and correspondence

6.13 Heritage

6.13.1 Context

Aboriginal heritage reviews and negotiations have culminated in the following key agreements and authorisations in support of mining operations in the SMR:

- the tripartite agreement between OneSteel, Barngarla and Kokatha Mula people, entitled OneSteel ILUA and Section 23 AHA Agreement, dated 7 June 2012 (confidential)
- the Barngarla OneSteel Indigenous Land Use Agreement (ILUA) dated 10 May 2103 (confidential) and registered on 22 November 2013 (NNTT reference SI2-13/002).

The ILUA sets out clear heritage clearance protocols for both parties and was registered in DSD's Mining Register on 4 December 2013.

Native Title and ILUA

In April 1996, the Barngarla Native Title Claimants lodged a native title claim (reference SC1996/004), covering all SIMEC Mining operations in the Middleback Ranges. The Federal Court is currently processing this claim and a ruling is expected during 2014.

An ILUA between OneSteel (SIMEC Mining) and the Barngarla Native Title Claimants was executed on 10 May 2013, and subsequently registered on 22 November 2013 (NNTT reference SI2-13/002). The ILUA sets out clear heritage clearance protocols for both parties.

The ILUA was registered in DSD's Mining Register on 4 December 2013.

The Iron Chieftain area was subject to a heritage clearance survey in August 2013 (Cane and Baird 2013). This survey provided an update on previous surveys conducted in the area.

SIMEC Mining's original concept for the extended WRD layout was to extend east. However, Aboriginal Elders identified this area contains sites of cultural significance (Cane and Baird 2013) and as a consequence, SIMEC Mining now propose to extend the WRD facility to the north.

6.13.2 Applicable legislation

The key pieces of legislation that apply are:

- *Mining Act 1971*
- *Aboriginal Heritage Act 1988*
- *Environment Protection Act 1993*
- *Native Title (South Australia) Act 1994*
- *Heritage Places Act 1993*.

6.13.3 Stakeholders

The key stakeholders who have an interest in heritage include:

- Barngarla Native Title Claimants (representing Barngarla)
- WAHC
- DPC
- South Australian Native Title Service (SANTS)
- Aboriginal Affairs and Reconciliation Division
- NNTT.

6.13.4 Potential impacts

The potential impacts relating to heritage are summarised in Table 77.

Table 77 Impact event analysis – Heritage

Source	Pathway	Barrier	Environmental receptor	Consequences
Disturbance from excavation activities (including exploration drilling)	Exploration drilling and mining uncovering sites/artefacts	Existing site survey and database search	Aboriginal heritage European heritage	Disturbance to Aboriginal or European heritage
Disturbance from project construction activities	Mine services construction uncovering sites/artefacts or disturbing existing heritage sites	Existing site survey, heritage area delineation and database search	Aboriginal heritage European heritage	Disturbance to Aboriginal or European heritage

Source	Pathway	Barrier	Environmental receptor	Consequences
Disturbance from pit development	Pit development uncovering sites/artefacts	Existing site survey and database search	Aboriginal heritage European heritage	Disturbance to Aboriginal or European heritage

6.13.5 Control and management strategies

Table 78 provides details for the risk assessment for heritage, any control and management strategies to be implemented, and the associated outcomes and measurement criteria.

6.13.6 Evaluation of residual risks

The primary risks associated with heritage were identified as ‘Moderate’ to ‘High’.

By undertaking heritage clearance surveys for the SMR area, liaising with the authorised Aboriginal representatives, and implementing due diligence, standard industry practices and specific controls and management measures, the residual risk has been determined to be ‘Moderate’; the likelihood of an impact event occurring is reduced to ‘Rare’ but the consequences remain as ‘Medium’.

Table 78 Risk assessment – Heritage

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Disturbance to (unforeseen) Aboriginal and European heritage during exploration activities	Possible	Medium	Exploration activities to be carried out with minimal disturbance and areas reinstated to current condition if further exploration/mining activity does not eventuate Exploration will be conducted in accordance with the ILUA protocols, and heritage clearance surveys Compliance with regulatory requirements in the event of a discovery In the event of discovery of a potential Aboriginal or European heritage artefact all works will stop in the immediate vicinity, the area clearly marked and isolated from other work and relevant authorities will be notified. Work recommenced only after authorisation has been received	Rare	Medium	Moderate	No disturbance to Aboriginal artefacts, sites of significance or European heritage unless prior approval under the relevant legislation is obtained	Records demonstrate that discoveries of suspected Aboriginal or European artefacts or remains were left without further disturbance, reported to the authorities and investigated and that work recommenced only after being authorised by the appropriate authority

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Disturbance to (unforeseen) Aboriginal and European heritage during construction and mining activities	Unlikely	Medium	Site developments will be conducted in accordance with the ILUA protocols, which includes a heritage clearance protocol Compliance with regulatory requirements in the event of a discovery In the event of discovery of a potential Aboriginal or European heritage artefact all works will stop in the immediate vicinity, the area clearly marked and isolated from other work and relevant authorities will be notified	Rare	Medium	Moderate	No disturbance to Aboriginal artefacts, sites of significance or European heritage unless prior approval under the relevant legislation is obtained	Records demonstrate that discoveries of suspected Aboriginal or European artefacts or remains were left without further disturbance, reported to the authorities and investigated and that work recommenced only after being authorised by the appropriate authority

6.13.7 Outcome

The outcome and measurement criteria for heritage are presented in Table 79.

Table 79 Outcomes – Heritage

Outcome	Measurement criteria	Monitoring programs
No disturbance to Aboriginal artefacts, sites of significance or European heritage unless prior approval under the relevant legislation is obtained	Records demonstrate that discoveries of suspected Aboriginal or European artefacts or remains were left without further disturbance, reported to the authorities and investigated and that work recommenced only after being authorised by the appropriate authority	Incident and corrective action records

6.14 Traffic

6.14.1 Context

There is not expected to be any increase in traffic as all vehicles will continue to be required to access the site via the SMR access routes. Increase in mining activity in the Iron Chieftain mine area will be offset by a decrease in mining activity in the Iron Knight and Iron Duke South mine pits.

6.14.2 Applicable legislation

The key pieces of legislation that apply are:

- *Mining Act 1971*
- *Road Traffic Act 1961*.

6.14.3 Stakeholders

The key stakeholders who have an interest in traffic include:

- neighbouring landholders
- DPC
- Whyalla community
- Lincoln highway users
- DPTI.

Consultations with the regulators for the transport corridors and road networks will continue to ensure compliance with all laws and regulations. Adjacent landowners, the local community and other relevant stakeholders are involved in regular meetings as part of SIMEC Mining's ongoing Community

Engagement Plan (see Section 5). Other stakeholders include workers, travellers, regional visitors and road commuters.

6.14.4 Potential impacts

The potential impacts relating to traffic are summarised in Table 80.

Table 80 Impact event analysis – Traffic

Source	Pathway	Barrier	Environmental receptor	Consequences
Road vehicle movements	Port Lincoln – Whyalla Road	Driver awareness, South Australian road rules	General public Road users	Injury or fatality to member of the public due to increased road use Injury or fatality to member of the public due to existing road use

6.14.5 Control and management strategies

Table 81 provides details for the risk assessment for traffic, any control and management strategies to be implemented, and the associated outcomes and measurement criteria.

6.14.6 Evaluation of residual risks

The primary risks associated with increased traffic were identified to be ‘Rare’ because there would be no increase in road use.

With the implementation of due diligence, standard industry practices and specific controls and management measures, the residual risk associated with existing traffic remains ‘High’. However if a rare occurrence impact event did occur, the consequences could be ‘Extreme’ given the potential for harm to humans.

Table 81 Risk assessment – Traffic

Aspect and impact	Level of risk (primary) LHD/CON		Controls/ Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Injury or fatality to member of the public due to increased road use	Rare	Extreme	Driver awareness and training South Australian Road Safety Rules	Rare	Extreme	High	No incidents or accidents resulting from road accidents associated with the SMR operational or access traffic that could have been reasonably prevented	Records of independent investigation of all recorded incidents and accidents involving SMR operational traffic, or SMR access road/public road interface traffic demonstrates that the incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator
Injury or fatality to member of the public due to existing road use	Possible	Extreme	Driver awareness and training South Australian Road Safety Rules	Rare	Extreme	High	No incidents or accidents resulting from road accidents associated with the SMR operational or access traffic that could have been reasonably prevented	Records of independent investigation of all recorded incidents and accidents involving SMR operational traffic, or SMR access road/public road interface traffic demonstrates that the incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator

6.14.7 Outcome – Traffic

The outcome and measurement criteria for traffic are presented in Table 82.

Table 82 Outcomes – Traffic

Outcome	Measurement criteria	Monitoring programs
No incidents or accidents resulting from road accidents associated with the SMR operational or access traffic that could have been reasonably prevented	Records of independent investigation of all recorded incidents and accidents involving SMR operational traffic, or SMR access road/public road interface traffic demonstrates that the incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	Incident reports Independent investigations of incidents

6.15 Post-Closure

6.15.1 Context

The key objectives of the SMR Closure Plan are to ensure:

- the area is left in a safe and stable condition that supports a resilient, self-sustaining natural ecosystem suitable for the post-mining land use identified in consultation with closure stakeholders
- risks to public health and safety and to fauna are as low as reasonably practical
- the final visual amenity of the site is harmonious with the local surrounding area.

The rehabilitation and closure strategies for the SMR operations include:

- arriving at designs that minimise impact footprint and achieve best overall final profile
- final landform profiles that will blend in over time with the natural topography and vegetation of the area
- ensuring adequate harvesting of topsoil and subsoil prior to dump and pad builds, and stockpiling management to enable the progressive rehabilitation program
- grading and dressing the faces of new WRDs to minimise surface water runoff beyond the WRD perimeter and minimising the risk of surface erosion
- progressively rehabilitating the faces of the new WRDs

- placing soil directly on the new, lower final dump slopes to progressively integrate the rehabilitated WRDs into the local topography
- seeding if required with species identified during vegetation assessments to complement the existing local vegetation communities.

See Section 8 for details of the final general landform at completion.

Table 83, Table 84 and Table 85 provide an outline of the broad aspects and potential impact events post-closure.

Table 83 Natural environment impacts – Post-closure

Aspects (Impact events)	Impact receptors	Consequences
Dust	Vegetation	Long term effects on vegetation due to dust deposition
Weeds	Vegetation Soil	Ongoing incursion of declared weed species
Stormwater flows	Drainage systems Vegetation Soil	Reduction of stormwater flows through natural drainage systems to dependent ecosystems
Open pits Water accumulating pit	Flora Fauna	Difficult to rehabilitate Potential for fauna to fall
WRD slopes	Soil	Erosion issues
Haul roads	Soil Surface water	Erosion issues Drainage issues

Table 84 Social impacts – Post-closure

Aspects (Impact events)	Impact receptors	Consequences
Mining / Topography Open pits	General public Visual amenity	Deterioration in visual amenity – permanent scarring of the landscape Hazardous pits – risk of falls
Disturbance to heritage areas by mining operations	Indigenous communities	Depletion of Aboriginal affinity for the area
Change in land use	Local community Regional community Visitors	Restricted access – fenced-off pit areas

Table 85 Economic impacts – Post-closure

Aspects (Impact events)	Impact receptors	Consequences
Change in land use	Local community	Less commercial activity/employment

Aspects (Impact events)	Impact receptors	Consequences
	Business community	

The development of post-mine land uses will be undertaken in consultation with key stakeholders. The selected option will ensure the site is restored to support a self-sustaining ecosystem suitable for the agreed post-mine land use.

The areas of disturbance that will be revegetated within the scope of activities covered by the SMR operations are shown on Figure 82. The vegetation to be replanted in those areas will complement the existing local vegetation communities. Species lists will be taken from the vegetation assessment (Bebbington 2014).

The final landforms and amenity are described as follows:

- pits will be made secure with closed accesses, stock fences, locked gates and signage, and remain as pits
- the existing Iron Chieftain WRD will be rehabilitated, which includes revegetation and the return to a self-sustaining ecosystem
- the extended Iron Chieftain WRD will be rehabilitated to a self-sustaining ecosystem
- the Iron Knight WRDs will be rehabilitated, which includes revegetation and the return to a self-sustaining ecosystem
- the DW03 and DW04 WRDs will be rehabilitated, which includes revegetation and the return to a self-sustaining ecosystem
- the Duke/Duchess western WRDs will be accessed to determine an appropriate final landform with consideration to blending with natural west face landforms, regional stakeholder priorities and tenement constraints
- peripheral aspects will blend into surrounding topography
- all infrastructure, facilities, buildings, and equipment will be decommissioned and removed from site, and the areas will be remediated to a suitable state for site rehabilitation and closure
- haul roads and open areas will be scarified sheeted with available topsoil and seeded with local native species
- any concrete footings will be covered with one metre of fill and soil
- all waste materials will be removed from site.

Section 8 provides further details in relation to mine closure and rehabilitation.

6.15.2 Applicable legislation

The key pieces of legislation and policies that apply are:

- *Mining Act 1971*
- *Work Health and Safety Act 2012*

- *Environment Protection Act 1993*
- Environment Protection (Air Quality) Policy 2016
- *Environment Protection and Biodiversity Conservation Act 1999*
- *Native Vegetation Act 1991*
- *Natural Resources Management Act 2004*.

6.15.3 Stakeholders

The key stakeholders that have an interest in post-closure include:

- neighbouring landholders
- DPC
- Whyalla community
- NVC
- DEWNR
- SAAL NRM Board
- WAHC
- Barngarla Native Title Claimants
- EPA.

The list of stakeholders will be reviewed as operations progress and as closure plans are refined towards the end of mine life.

6.15.4 Potential impacts

The potential impacts relating to post-closure are summarised in Table 86. These impacts will be reviewed as operations progress and as closure plans are refined towards the end of mine life.

Table 86 Impact event analysis – Mine closure

Source	Pathway	Barrier	Environmental receptor	Consequences
Industrial or general waste materials left on site post-closure	Amenity, soil or groundwater	Mine Site Closure and Rehabilitation Plan	Amenity Soil Groundwater	Potential site contamination Legacy of industrial waste left on site, reducing amenity
Dust generation from mine closure and rehabilitation activities	Atmosphere	Dust management SIMEC Mining procedures and protocols	Adjacent landholders Air quality	Reduction in visual amenity Increase in particulate matter in air

Source	Pathway	Barrier	Environmental receptor	Consequences
				Nuisance impacts to adjacent Landowners
WRD final remediated landform and function	Unacceptable rehabilitation completion criteria	Ongoing consultation Rehabilitation design as per Mine Plan Agreed rehabilitation completion criteria DMITRE guidelines	Adjacent landholders Highway users and visitors Community Land function Ecosystem function	Reduction in visual amenity
Final landform instability	Interference with sites/artefacts	Existing site survey, ongoing consultation SIMEC Mining protocols and procedures	Aboriginal heritage	Long term depletion of Aboriginal affinity to area
Increased pest animals, weed species and pathogens during post-closure works	Soil disturbance Inadequate pest control efforts	Sound rehabilitation plans	Native vegetation Fauna	Not meeting closure criteria Breach of the NRM Act 2004
Climate impacts Final landform	Earthworks Dust generation Stormwater flows	Mine Site Closure Plan	Flora Fauna	Revegetation failure Erosion and changes in drainage
Land clearance during rehabilitation	Earthworks Stormwater flows	Mine Site Closure Plan	Stormwater Soil quantity	Increased sedimentation Loss of topsoil
Mine closure and rehabilitation	Earthworks Stormwater flows	Mine Site Closure Plan Stormwater management	Flora Fauna	Reduction of flows to stormwater dependent ecosystems
Open pit Water accumulation in open pit	Earthworks Stormwater/ groundwater inflow	Site fencing and security	Fauna Member of the public	Injury or death to fauna or public as a result of landform of mine at closure Injury or death to fauna as a result of water accumulating in open pit at closure

Source	Pathway	Barrier	Environmental receptor	Consequences
Mine pit voids Drill holes	Earthworks	SIMEC Mining procedures Site fencing and security	Fauna	Injury or death to fauna due to trapping

6.15.5 Control and management strategies

Table 87 provides details of the risk assessment, any control and management strategies to be implemented, and the associated outcomes and measurement criteria for post-closure. The controls and management strategies will be reviewed as operations progress and as closure plans are refined towards the end of mine life.

6.15.6 Evaluation of residual risks

The primary risks associated with post-closure were identified as 'Low' to 'Very High' (see Table 87). The risk assessment will be reviewed as operations progress and as closure plans are refined towards the end of mine life.

With implementation of due diligence, standard industry practices and specific controls and management measures, the residual risk has been determined to be 'Moderate', given that it is considered that should an impact event occur, (which would be a rare occurrence) of the consequence would be of 'Extreme' due to the presence of external factors and the high level of human involvement in any risk.

Table 87 Risk assessment – Post-closure

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Rehabilitation of WRDs, haul roads and mine services areas resulting in increased sediment load in surface water	Possible	Minor	Reduce the area of exposed soil that could be eroded by stormwater by maintaining vegetative cover for as long as possible Rehabilitation plans to include industry standards of landform, vegetative cover and controls that will reduce erosion and sedimentation risks	Unlikely	Minor	Low	Integrate and harmonise final landforms and vegetation with surrounding landscape	Annual Progressive Rehabilitation Compliance Audit and final landform profile and revegetation audit demonstrates WRDs are constructed and remediated to integrate and harmonise the final landform and vegetation with the surrounding landscape as each lift is completed in accordance with the design, closure and rehabilitation strategy described in Section 8 Final landform profile and revegetation audit via ground and flora survey demonstrates that all constructed haul roads and open areas are remediated in accordance with design, closure and rehabilitation strategy described in Section 8

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Reduced visual amenity in project area (local and regional) associated with final waste rock dump landform and infrastructure areas	Possible	Minor	Remediate and revegetate mined out areas and waste rock dumps as soon as possible after they become inactive Minimise vegetation clearance Design of final mine landform to maximise revegetation and enhance visual amenity Progressive rehabilitation undertaken in accordance with staged design and rehabilitation plans Stakeholder consultation on development of final landform designs	Unlikely	Negligible	Low	Integrate and harmonise final landforms and vegetation with surrounding landscape	Annual Progressive Rehabilitation Compliance Audit and final landform profile and flora survey demonstrates the WRDs are constructed and remediated to integrate and harmonise the final landform and vegetation with the surrounding landscape as each lift is completed in accordance with the design, closure and rehabilitation strategy described in Section 8 Final landform profile and revegetation audit via ground and flora survey demonstrates that all constructed haul roads and the pit is remediated in accordance with design, closure and rehabilitation strategy described in Section 8 Records indicate that stakeholders are consulted on for WRD design
Land clearance during site closure and rehabilitation works leading to loss of topsoil and erosion	Unlikely	Negligible	Land clearance and topsoil management were undertaken during the operations and construction phases	Unlikely	Negligible	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Rehabilitation failure due to unacceptable revegetation outcomes	Possible	Medium	Closure outcomes criteria consistent with current rehabilitated WRDs in the Middleback Ranges. Procedures and method statements to identify rehabilitation and closure criteria Design, closure and rehabilitation strategy as described in Section 8	Unlikely	Medium	Moderate	Re-establishment of mine site ecosystem and landscape function	Annual assessment by internal specialist or external consultant and a final report from a suitably qualified person confirms that Landscape Function Analysis (LFA) indicates that LFA curve has moved above, or is likely to move above the critical threshold of sustainability, which, depending on specific site variables are within the following ranges (stability index; 45-55%, Infiltration index; 30-33%, Nutrient cycling index, 23-28%), on remediated WRDs, haul roads and operational and fixed plant areas. This criteria to remain open until the target is met
Dust generated from site closure and rehabilitation smothering native vegetation	Unlikely	Negligible	Rehabilitation works will restore land to a stable condition that will facilitate land use consistent with that established prior to implementing the program of work Dust suppression using water and/or agents will be undertaken during earthworks and in WRDs	Unlikely	Negligible	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Dust generated from site closure and rehabilitation causing reduction of palatability of vegetation for stock feed on neighbouring land	Unlikely	Negligible	Site dust monitoring and controls as per QP50_68	Unlikely	Negligible	Low	N/A	N/A
Contamination of soil, groundwater and surface water from wastes generated during mine closure	Unlikely	Negligible	Hydrocarbon spills will be contained immediately, collected, bagged and disposed of off-site in accordance with EPA requirements Waste rock dumps will be rehabilitated to minimise erosion and sedimentation of any surface water runoff All foreign materials brought on to site during mine closure are removed from site and disposed of appropriately	Unlikely	Negligible	Low	N/A	N/A
Adverse reaction to long-term depletion of Aboriginal affinity to the area	Unlikely	Minor	Ongoing consultation and engagement with the Barngarla Nation	Rare	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Injury or death to members of the public due to landform of pit at closure	Unlikely	Extreme	Fences, gates and signage to be maintained post-closure	Rare	Minor	Low	Risk to health and safety of the public and fauna are as low as reasonably practical	The completion safety audit demonstrates that WRDs, quarry pit and operational areas are constructed and remediated and that the safety bunds are 10 m outside of the potentially unstable pit edge zone, and that fencing and signage are in place in accordance with the design, closure and rehabilitation strategy described in Section 8.2.1 Fencing and signage will be maintained by SIMEC Mining until such time that it is agreed between SIMEC Mining and DPC that SIMEC Mining is no longer responsible for the maintenance
Lack of flows to stormwater dependent ecosystems	Unlikely	Negligible	Civil design of mining infrastructure during life of mine Restoration of natural drainage channels after mine closure Post-closure landform design allows drainage to align with existing natural drainage channels	Unlikely	Negligible	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Injury or death to fauna as a result of landform of mine at closure	Unlikely	Minor	Closure outcomes criteria consistent with Mine Plan, procedures and method statements to identify rehabilitation and closure requirements Site security to be maintained and open pit to be fenced to prevent access by fauna	Rare	Minor	Low	N/A	N/A
Final landform instability	Possible	Minor	Design, closure and rehabilitation strategy as described in the Mine Plan	Unlikely	Minor	Low	The site is physically stable	Annual and final landform profile compliance audits demonstrates WRDs, Iron Chieftain pits and infrastructure areas are constructed and remediated in accordance with design, closure and rehabilitation strategy set out in Section 8
Unacceptable final land use	Possible	Minor	Rehabilitation to be undertaken in alignment with the Mine Plan Final land use considers community engagement outcomes	Unlikely	Minor	Low	The site will be rehabilitated to a stable condition that supports a resilient, self-sustaining natural ecosystem suitable for the post mining land use that will be determined in consultation with relevant stakeholders	Site audit at mine closure by an independent professional to demonstrate that the site is rehabilitated as per the closure domain objectives (see Section 8)
Infrastructure removal not completed	Possible	Minor	Design, closure and rehabilitation strategy as described in the Mine Plan	Unlikely	Minor	Low	All infrastructure is removed from the site prior to mine completion	Final closure and divestment audit report demonstrates that all fixed mine infrastructure is demolished disposed of or removed from site within two years of mine closure

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Equipment not fully removed from site	Possible	Minor	Design, closure and rehabilitation strategy as described in the Mine Plan	Unlikely	Minor	Low	All equipment is removed from site prior to mine closure	Final closure and divestment audit report demonstrates that all mobile machinery and equipment is removed from site within 12 months (or as otherwise agreed with DPC) of completion of rehabilitation of all WRDs, haul roads and impacted areas
Waste disposal	Possible	Minor	All industrial and domestic waste disposed of in accordance with the South Australian *Environment Protection Act 1993* All waste disposal to comply WI50.43 Waste Management	Unlikely	Minor	Low	All mine waste materials left on site are chemically and physically stable	At mine closure records demonstrate all industrial and domestic wastes are disposed of in accordance with the *Environment Protection Act 1993*, and that all waste mine materials left on site are chemically and physically stable as determined by a site contamination audit conducted by an independent and qualified auditor
Soil topography	Unlikely	Minor	Design, closure and rehabilitation strategy as described in the Mine Plan	Unlikely	Minor	Low	N/A	N/A

Aspect and impact	Level of risk (primary) LHD/CON		Controls/Management strategies	Level of risk (residual) LHD/CON/RRL			Outcome	Measurement criteria
Increase in pests and weeds post-closure	Possible	Negligible	Vehicles will be clean and free of plant and mud material prior to entering tenement during rehabilitation works Revegetation with local native flora species Continuing site maintenance and weed monitoring post mine closure	Unlikely	Negligible	Low	N/A	N/A

6.15.7 Outcome

The outcome and measurement criteria for post-closure are presented in Table 88. These will be reviewed as operations progress and as closure plans are refined towards the end of mine life. These outcomes are to assist in meeting final land use requirements endorsed by the community and stakeholders, and are subject to change with ongoing engagement and consultation.

Table 88 Risk assessment – Post-closure

Outcome	Measurement criteria	Monitoring programs
Integrate and harmonise final landforms and vegetation with surrounding landscape	Annual Progressive Rehabilitation Compliance Audit and final landform profile and revegetation audit demonstrates WRDs are constructed and remediated to integrate and harmonise the final landform and vegetation with the surrounding landscape as each lift is completed in accordance with the design, closure and rehabilitation strategy described in Section 8 Final landform profile and revegetation audit via ground and flora survey demonstrates that all constructed haul roads and open areas are remediated in accordance with design, closure and rehabilitation strategy described in Section 8	Annual compliance audit schedule Final landform and revegetation audit
Re-establishment of mine site ecosystem and landscape function	Annual assessment by internal specialist or external consultant and a final report from a suitably qualified person confirms that Landscape Function Analysis (LFA) indicates that LFA curve has moved above, or is likely to move above the critical threshold of sustainability, which, depending on specific site variables are within the following ranges (stability index; 45-55%, Infiltration index; 30-33%, Nutrient cycling index, 23-28%), on remediated WRDs, haul roads and operational and fixed plant areas. This criteria to remain open until the target is met	Annual LFA assessment Final rehabilitation and LFA assessment report
Risk to health and safety of the public and fauna are as low as reasonably practical	The completion safety audit demonstrates that WRDs, quarry pit and operational areas are constructed and remediated and that the safety bunds are 10 m outside of the potentially unstable pit edge zone, and that fencing and signage are in place in accordance with the design, closure and rehabilitation strategy described in Section 8.2.1 Fencing and signage will be maintained by SIMEC Mining until such time that it is agreed between SIMEC Mining and DPC that SIMEC Mining is no longer responsible for the maintenance	Final landform and rehabilitation audit
The site is physically stable	Annual and final landform profile compliance audits demonstrates WRDs, pits and infrastructure areas are constructed and remediated in accordance with design, closure and rehabilitation strategy set out in Section 8	Annual compliance audit schedule

Outcome	Measurement criteria	Monitoring programs
The site will be rehabilitated to a stable condition that supports a resilient, self-sustaining natural ecosystem suitable for the post-mining land use that will be determined in consultation with relevant stakeholders	Site audit at mine closure by an independent professional to demonstrate that the site is rehabilitated as per the closure domain objectives (see Section 8)	Final landform and revegetation audit
All infrastructure is removed from the site prior to mine completion	Final closure and divestment audit report demonstrates that all fixed mine infrastructure is demolished disposed of or removed from site within two years of mine closure	Final closure and divestment audit
All equipment is removed from site prior to mine closure	Final closure and divestment audit report demonstrates that all mobile machinery and equipment is removed from site within 12 months (or as otherwise agreed with DPC) of completion of rehabilitation of all WRDs, haul roads and impacted areas	Final closure and divestment audit
All mine waste materials left on site are chemically and physically stable	At mine closure records demonstrate all industrial and domestic wastes are disposed of in accordance with the *Environment Protection Act 1993*, and that all waste mine materials left on site are chemically and physically stable as determined by a site contamination audit conducted by an independent and qualified auditor	Final closure and divestment audit

6.16 Outcomes, Measurement Criteria and Monitoring

Table 89 provides a summary of outcomes and measurement criteria and an outline of associated monitoring requirements that will be programmed and implemented by SIMEC Mining for the operational aspects of the SMR mining operations.

Similarly, Table 90 provides a summary of outcomes and measurement criteria and an outline of associated monitoring requirements for closure.

Table 89 Operational outcomes, measurement criteria and monitoring program for the SMR

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Flora	No permanent loss of abundance or diversity to native vegetation through clearance, dust/contaminant deposition, fire or other damage caused by mining operations on or off the tenements, unless prior approval under legislation is obtained	Annual aerial and/or ground surveys of operational areas demonstrates that the total area cleared does not exceed the approved area as per Table 31 (see Section 4.3) when compared to the September 2013 aerial image (see Figure 84).Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring pastoral properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (for Iron Chieftain and Iron Knight domains) and an impact score of 1 (for South SMR domains) (see Table 45) outside of approved clearance areas, from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC Mining dust management strategies were in place	Area of vegetation clearance by aerial photography and visual inspections	All clearance of native vegetation to comply with approved clearance area in Table 31 (see Section 4.3) under the *Native Vegetation Act 1991*	Biennial flora monitoring program undertaken by external consultants Biannual internal flora monitoring program by SIMEC Mining Environment Assurance Annual aerial and ground survey Construction and operational process audits ongoing throughout operations and closure Regulatory compliance audits and ISO 14001 EMS audits conducted by SIMEC Mining Environment Assurance as per audit schedule	SMR mining area	Inspection records Flora survey	Annual compliance reporting to DPC	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Flora	No vegetation health impacts to neighbouring properties from dust generated by mining activities	**Iron Chieftain** Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC Mining dust management strategies are applied in accordance with the Mines FDR Procedure QP50-68	Impacts to vegetation from dust deposition	Impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9)	Quarterly vegetation dust impact assessment Annual aerial and ground survey	As per the locations shown on Appendix A-9	Inspection records Flora survey	Annual compliance reporting to DPC	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
		<u>Iron Knight</u> Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9) Mine records demonstrate that SIMEC Mining dust management strategies are applied in accordance with the Mines FDR Procedure QP50-68	Impacts to vegetation from dust deposition	Impact assessment scores do not exceed an impact score of 2 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9)	Quarterly vegetation dust assessment Annual aerial and ground survey	As per the locations shown on Appendix A-9	Inspection records Flora survey	Annual compliance reporting to DPC	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
		South SMR Quarterly internal assessment and annual vegetation dust impact assessment by external consultant at the vegetation monitoring quadrats on neighbouring properties (see Appendix A-9), demonstrate that impact assessment scores do not exceed an impact score of 1 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9)the replicate control sites Mine records demonstrate that SIMEC Mining dust management strategies are applied in accordance with the Mines FDR Procedure QP50-68	Impacts to vegetation from dust deposition	Impact assessment scores do not exceed an impact score of 1 (see Table 45), from mine derived dust*, factoring in regional rangelands floristic health as measured at the control sites (see Appendix A-9)	Quarterly vegetation dust impact assessment Annual aerial and ground survey	As per the locations shown on Appendix A-9	Inspection records Flora survey	Annual compliance reporting to DPC	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Fauna	That there is no permanent loss of native fauna abundance caused by mining operations	Records demonstrate that incidents of drill collars not being capped immediately following exploration activities are logged and investigated and all corrective actions are closed out within 24 hours of receiving notification of the incident Annual aerial and/or ground surveys at operational areas demonstrates that the total area cleared does not exceed the approved area as listed in Table 31 (see Section 4.3) when compared to the September 2013 aerial image (see Figure 84).			Construction and operational process audits ongoing throughout operations and closure Regulatory compliance audits and ISO 14001 EMS audits conducted by SIMEC Mining Environment Assurance as per audit schedule	SMR Mining area		Annual compliance reporting to DPC	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Weeds pests and pathogens	No introduction of new species of weeds, nor a sustained increase in abundance of existing weed species in the Licence area, compared to adjoining land	Biannual weed inspections reports and continuous weed mapping demonstrate that new weeds and existing weeds are managed by control measures as per the SIMEC Mining Pest Plant and Animal Control Strategy QP50_62 within six months of documenting the presence of new weed incursions or increase in abundance of existing weeds in the licence area compared to baseline flora and fauna surveys (Bebbington 2009 and 2014)	Compliance with NRM Act 2004 New weed and pest incursions and abundance of existing weeds and pests compared to the continually updated weed map and that control measures are implemented and closed out as per QP50_62 b scheduled internal environmental audits	No introduction of new declared weeds, plant pathogens or pest (including feral animals), species nor a sustained increase in abundance of existing weed or pest species and pest plants within the tenements	Biannual weed and pest survey as per audit schedule Annual EMS/Regulatory compliance audits	SMR mining area	Flora and fauna survey reports Weed map (weeds mapped as they are found/ managed)	Annual compliance monitoring to DPC	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Soil	Topsoil quality and quantity is maintained	Six-monthly inspection audits demonstrate that topsoil has been stripped, stockpiled (see Figure 65) and maintained in accordance with SIMEC Mining's Soil Management Plan (QP50_66) and that all corrective actions from audits logged and closed out within 60 days or as otherwise agreed with the Regulator	Topsoil is stripped, stockpiled and maintained in accordance with SIMEC Mining's Soil Management Plan (QP50_66) at topsoil stockpile areas and all corrective actions from audits logged out and closed out within 60 days or as otherwise agreed with the Regulator That the soil quality parameters of no disturbance or compaction, no sheet or gully erosion, weeds controlled, stockpile heights are correct and good regeneration of native plants species has occurred	Zero outstanding action items after 60 days from audits	Six monthly	topsoil stockpile locations	Stockpile records Annual aerial survey results	Annual compliance reporting to DPC	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Stormwater	No water contaminated as a result of mining operations leaves the tenement areas or results in loss of, or contamination of, soil on, or off, the tenement/s	Records demonstrate that inspection audits of drainage silt traps (see location plan Appendix A-10) are carried out within five days of rainfall events that result in flows of stormwater, or every three months, whichever is the lesser, to determine that culverts are not blocked and that >500 mm of freeboard remains in silt traps and that spillways are not eroded or otherwise damaged, and that all corrective actions from inspections are logged and closed out within 30 days or as otherwise agreed with the Regulator	Drainage channels and silt traps in place as per design (see Appendix A-10) and that all corrective actions from inspections are logged and closed out within 30 days or as otherwise agreed with the Regulator	All drainage channels and silt traps installed as per Appendix A-10, and reactive maintenance and corrective actions closed out within 30 days of assignment	Within five days of rainfall events that result in flows of stormwater, or every three months, whichever is the lesser	Locations as indicated in Appendix A-10	Approved design	Annual compliance reporting to DPC	Principal Mining Contractor OHS&E Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Groundwater	No changes to groundwater levels that adversely impact vegetation due to Magnetite TSF operations	Records and reports demonstrate that SIMEC Mining is compliant with the Magnetite TSF Management Plan, and that the groundwater extraction wells are functioning (refer to Section 3.9.6) and that monthly groundwater level monitoring at location plan (see Figure 24), demonstrates a falling trend in groundwater levels to below the vegetation root zone, averaged over a twelve month period and taking into account rainfall events that may naturally raise groundwater levels temporarily. Biannual aerial and ground surveys demonstrate that the TSF vegetation impact area has not increased.	That groundwater extraction wells are in place and working effectively	All working effectively	Weekly	As per Appendix A-14	Iron Duke TSF EMP Tracking sheet	Monthly	Operations Manager – Ore Processing
			TSF management model upgrade is progressing as per sec 3.9.6	As per plan	Monthly	Magnetite TSF	Iron Duke TSF EMP Tracking sheet	Monthly	Manager Technology Development
			Groundwater levels	>1.5 m BGL	Monthly	As per sec 3.9.6	Groundwater Monitoring spreadsheet	Monthly	Environment Assurance Manager
			Vegetation impact area	Area of vegetation impact from sustained inundation no greater than indicated in Appendix A-14	Six-monthly	As per Appendix A-14	TSF vegetation monitoring reports	Annually	Environment Assurance Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
	No changes to groundwater levels that adversely impact vegetation due to Iron Duchess water storage operations	Monthly groundwater monitoring records demonstrate that the groundwater level does not exceed 160 m AHD at DMW03 (see Figure 24) Annual aerial and/or ground surveys demonstrate that the total area of vegetation cleared does not exceed the approved area as per Table 31 (see Section 4.3) when compared to the September 2013 aerial image (Figure 84).	Groundwater levels Vegetation impact area	No greater than 160 m AHD at monitoring well DMW03 No unapproved vegetation clearances, as per Table 31	Monthly Six-monthly/ continuous	As per Figure 24 Vegetated areas down slope of the Iron Duchess pit	Groundwater monitoring spreadsheet Vegetation monitoring reports	Monthly Six-monthly	Environment Assurance Manager Environment Assurance Manager
Air quality	No nuisance impacts to local residents and the general public from air emissions, dust and odour generated from mining operations	Records demonstrate that complaints of emissions, dust or odour are responded to within 24 hours, are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the affected party or the Regulator	Compliance with the FDR Procedure QP50_68 Compliance with WI50_004 (Complaints Management Protocol) and WI50_008 (Stakeholder Engagement and Communications Management)	No non-compliance against the FDR Procedure QP50_68 All complaints responded to as per WI50_004 (Complaints Management Protocol)	As required to respond to complaints	As required to respond to complaints	Business Support System (BSS) Environment Complaints management database and Landholder issues register	Annual compliance reporting to DPC	SMR Operations Manager Manager Stakeholder Engagement

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Visual amenity	The contrasting and reflective aspects of WRDs and infrastructure are visually softened to blend in with the surrounding landscape	Annual audits against the staged rehabilitation strategy, with the use of annual aerial and ground surveys of the landform development and biennial flora monitoring surveys demonstrate progressive rehabilitation undertaken in accordance with staged rehabilitation strategy for the SMR Mining Area (see Section 8)	Progressive rehabilitation actions are in accordance with each phase of WRD development, via an assessment against the Mine Plan closure and rehabilitation (see Section 8 for full details of the Mine Plan)	Timing and rehabilitation outcomes are achieved in accordance with the Mine Plan closure and rehabilitation (see Section 8 for full details of the Mine Plan)	Annual	WRDs	Previously rehabilitated areas	Annual compliance reporting to DPC	SMR Operations Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Blasting and vibration	No public health, safety and nuisance impacts from air blast overpressure, vibrations, fumes, dust or fly rock caused by blasting undertaken on site	Records show that an independent investigation of recorded incidents related to blasting activities on site, demonstrates that an incident could not have been prevented through implementation and use of reasonable preventative measures and that all incidents as a result of blasting, including fly rock occurrences outside of the blast management zone, or complaints related to blasting are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	That all incidents as a result of blasting, including fly rock found outside of the blast management zone, or complaints related to blasting are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	No public health, safety and nuisance impacts as a result of blasting that could have been reasonably prevented b SIMEC Mining Fly rock found outside of blast manageme nt zone	When or if an incident occurs	SMR mining area	Incident reports Independent investigations of incidents	Annual compliance reporting to DPC Monthly safety incident report, KPIs, daily shift reports, mines inspection record	SMR Operations Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Public safety	No accidents involving the public as a result of exploration and mining activities that could have been reasonably prevented by SIMEC Mining	Records show that an independent investigation of recorded injuries from unauthorised access to the site, demonstrates that an incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	That all incidents of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	No public injuries or deaths as a result of unauthorised entry to site that could have been reasonably prevented by SIMEC Mining	When or if an incident occurs	SMR mining area	Incident reports Independent investigations of accidents	Annual compliance reporting to DPC Monthly safety incident report, KPIs, daily shift reports, mines inspection record	SMR Operations Manager General Manager Mining (accountable)
Adjacent land use and third party property	No unauthorised damage to adjacent property or infrastructure from mining operations	Records demonstrate that complaints of unauthorised damage are responded to within 24 hours, are logged and investigated and all corrective actions are closed out within 30 days of receiving a complaint, or as otherwise agreed with the affected party or the Regulator	That complaints are recorded on the complaints register, responded to, investigated and that all corrective actions are closed out within 30 days of receiving the complaint, or as otherwise agreed with the impacted party or the Regulator	No confirmed damage to adjacent property or infrastructure	When or if a complaint is received	SMR mining area	Incident reporting register Complaints register	Annual compliance reporting to DPC	Manager Stakeholder Engagement

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Heritage	No disturbance to Aboriginal artefacts, sites of significance or European heritage unless prior approval under the relevant legislation is obtained	Records demonstrate that discoveries of suspected Aboriginal or European artefacts or remains were left without further disturbance, reported to the authorities and investigated and that work recommenced only after being authorised by the appropriate authority	That discovery of suspected Aboriginal or European artefacts or remains are recorded, reported, investigated and that work has ceased until authorised to recommence	All suspected discoveries of Aboriginal or European artefacts are left without further disturbance, reported to the authorities and investigated with work recommenced only after authorisation from the appropriate authority	On discoveries of suspected Aboriginal or European artefacts or remains or sites of significance	SMR mining area	Incident records relating to discovery of artefacts	Annual compliance reporting to DPC	SMR Operations Manager

Aspect	Outcome	Measurement criteria	Monitoring Program						
			What will be measured	Target value	Monitoring frequency	Measurement location	Baseline/ Control data	Reporting frequency	Responsibility
Traffic	No incidents or accidents resulting from road accidents associated with the SMR operational or access traffic that could have been reasonably prevented	Records of independent investigation of all recorded incidents and accidents involving SMR operational traffic, or SMR access road/public road interface traffic demonstrates that the incident could not have been prevented through implementation of reasonable preventative measures and that 100% of incidences of unauthorised access are investigated and corrective actions closed out within 30 days or as otherwise agreed with the Regulator	That all incidents involving SMR operational traffic or SMR road/rail traffic are investigated and that all corrective actions are closed out within 30 days or as otherwise agreed by the Regulator	No incidents or accidents resulting from SMR operational traffic or SMR road/rail traffic that could have been reasonably prevented by SIMEC Mining	When or if an incident occurs	SMR mining area Site access roads Railway access	Incident reports Independent investigations of incidents	Annual compliance reporting to DPC Monthly safety incident report, KPIs, daily shift reports, mines inspection record	SMR Operations Manager

Table 90 Closure outcomes, measurement criteria and monitoring program

Aspect	Outcome	Outcome measurement criteria	Monitoring program				
			What will be measured and method of measurement	Locations	Target value	Frequency	Responsibility
Visual amenity	Integrate and harmonise final landforms and vegetation with surrounding landscape	Annual Progressive Rehabilitation Compliance Audit and final landform profile and revegetation audit demonstrates WRDs are constructed and remediated to integrate and harmonise the final landform and vegetation with the surrounding landscape as each lift is completed in accordance with the design, closure and rehabilitation strategy described in Section 8	Final landform profile and revegetation audit via ground and flora survey against the design, closure and rehabilitation strategy described in Section 8	WRDs	Design, closure and rehabilitation strategy as described in Section 8	Annual and final at completion of rehabilitation	SMR Operations Manager
Visual amenity	Integrate and harmonise final landforms and vegetation with surrounding landscape	Final landform profile and revegetation audit via ground and flora survey demonstrates that all constructed haul roads and open areas are remediated in accordance the design, closure and rehabilitation strategy described in Section 8	Final landform profile and revegetation audit via ground and flora survey against the design, closure and rehabilitation strategy described in Section 8	Haul roads and open areas	Final landform profile and revegetation of all constructed haul roads and open areas are remediated in accordance with design, closure and rehabilitation strategy described in Section 8	At completion of rehabilitation	SMR Operations Manager

Aspect	Outcome	Outcome measurement criteria	Monitoring program				
			What will be measured and method of measurement	Locations	Target value	Frequency	Responsibility
Re-establishment of existing ecosystem and landscape function	Re-establishment of mine site ecosystem and landscape function	Annual assessment by internal specialist or external consultant and a final report from a suitably qualified person confirms that Landscape Function Analysis (LFA) indicates that LFA curve has moved above, or is likely to move above the critical threshold of sustainability, which, depending on specific site variables are within the following ranges (stability index; 45-55%, Infiltration index; 30-33%, Nutrient cycling index, 23-28%), on remediated WRDs, haul roads and operational and fixed plant areas. This criteria to remain open until the target is met	The LFA curve from remediated WRDs towards the target against the control analogue as determined by qualified external consultant	WRDs Pits Infrastructure areas	Achievement of Sustainable LFA curve has moved above, or is likely to move above the critical threshold of sustainability as determined by qualified external consultant	Annually by internal resources after final rehabilitation works are completed until the target is met. The final closure report is to be provided by a qualified external consultant	Environment Assurance Manager

Aspect	Outcome	Outcome measurement criteria	Monitoring program				
			What will be measured and method of measurement	Locations	Target value	Frequency	Responsibility
Public safety	Risk to health and safety of the public and fauna are as low as reasonably practical	The completion safety audit demonstrates that WRDs, quarry pit and operational areas are constructed and remediated and that the safety bunds are 10 m outside of the potentially unstable pit edge zone (see Figure 97, Figure 102, Figure 111 and Figure 112), and that, fencing and signage are in place in accordance with the design, closure and rehabilitation strategy described in Section 8.2.1 Fencing and signage will be maintained by SIMEC Mining until such time that it is agreed between SIMEC Mining and DPC that SIMEC Mining is no longer responsible for the maintenance	Final landform profile and revegetation via the final landform profile and revegetation audit Ongoing inspections of fence integrity and signage after mine closure	WRDs Pits Infrastructure areas	Design, closure and rehabilitation strategy as described in Section 8	Annual post-closure Ongoing regular inspection of fence and signage	SMR Operations Manager
Landform stability	The site is physically stable	Annual and final landform profile compliance audits demonstrates WRDs, pits, and infrastructure areas are constructed and remediated in accordance with design, closure and rehabilitation strategy set out in Section 8	Final landform profile compliance audit via ground audit Provision of Mine Completion report 3 months prior to relinquishment of licence or expiry	WRDs Pits Infrastructure areas	Design, closure and rehabilitation strategy as described in Section 8	Annually and final at completion of rehabilitation	SMR Operations Manager

Aspect	Outcome	Outcome measurement criteria	Monitoring program				
			What will be measured and method of measurement	Locations	Target value	Frequency	Responsibility
Land use	The site will be rehabilitated to a stable condition that supports a resilient, self-sustaining natural ecosystem suitable for the post-mining land use that will be determined in consultation with relevant stakeholders	Site audit at mine closure by an independent professional to demonstrate that the site is rehabilitated as per the closure domain objectives (see Section 8)	The LFA curve from remediated WRDs towards the target against the control analogue as determined by qualified external consultant Records show that the relevant stakeholders were involved in consultations and accept the planned final land use	SMR mining area	Rehabilitation strategy as described in Section 8 Relevant stakeholders accept final land use	At completion of rehabilitation	Environment Assurance Manager
Infrastructure removal	All infrastructure is removed from the site prior to mine completion	Final closure and divestment audit report demonstrates that all fixed mine infrastructure is demolished disposed of or removed from site within two years of mine closure	Demolition and removal of all mine infrastructure via a final closure audit	Mine facilities pad Amenities building Explosive stores and magazines	Design, closure and rehabilitation strategy as described in Section 8	Within 2 years of cessation of mining operations	SMR Operations Manager

Aspect	Outcome	Outcome measurement criteria	Monitoring program				
			What will be measured and method of measurement	Locations	Target value	Frequency	Responsibility
Equipment removal	All equipment is removed from site prior to mine closure	Final closure and divestment audit report demonstrates that all mobile machinery and equipment is removed from site within 12 months (or as otherwise agreed with DPC) of completion of rehabilitation of all WRDs, haul roads and impacted areas	Removal of all mobile machinery and equipment is confirmed by the final closure audit report	SMR mining area	Design, closure and rehabilitation strategy as described in Section 8	Within 12 months of completion of rehabilitation of all WRDs, haul roads and impacted areas	SMR Operations Manager
Waste disposal	All mine waste materials left on site are chemically and physically stable	At mine closure records demonstrate all industrial and domestic wastes are disposed of in accordance with the Environment Protection Act 1993, and that all waste mine materials left on site are chemically and physically stable as determined by a site contamination audit conducted by an independent and qualified auditor	Compliance with EPA regulations via compliance audits of disposal records	Mine facilities pad Magazine Crushing and screening plant	All industrial and domestic waste disposed of in accordance with the *Environment Protection Act 1993*	On cessation of mining	SMR Operations Manager

6.17 Forward Work Plan

This section summarises uncertainties and assumptions identified throughout the PEPR. A Forward Work Plan (FWP) has been developed which describes the current and future works to address uncertainties and assumptions (see Table 91).

Table 91 Forward work plan

PEPR review requirements	Forward work plan	Reference	Indicative date for submission to DPC
Review of environmental outcomes due to future changes in operations beyond Duchess B -1	Describe changes of the environment (if any) Describe changes to operations Provide assessment of new environmental impacts Review environmental outcomes and measurement criteria	MG2b 2.12 (ii) MD005	FY20
Geochemistry and Geohazards	Geochemical assessment of all rock types Mineralogical assessment to quantify sulphur species and acid neutralising capacity Chemical assessment of sulphur species Paste pH and pH NAG testing Leach testing	MD005 sec 10.5 and sec 11. WPC180, SMR PEPR rev 5, section 6.6	FY20
Geochemistry and Geohazards	Establish new chemistry trigger values using background groundwater chemistry data once a sufficient dataset of monitoring data is collected from CPMW01	WPC180, SMR PEPR rev 5, section 6.6	FY20
Hydrogeology	Conduct permeability testing and assessment of WRD materials and cover materials during operations to inform a seepage model assessment.	WPC180, SMR PEPR rev 5, section 6.6	FY20
Hydrology	Review hydrology impact due to updated WRD designs beyond Duchess B -1	MG2b 2.12 (ii) MD005 10.7	FY20
Vegetation	Provide information on future vegetation clearance requirements, update vegetation management plan and provision of SEB offset.	MG2b 2.12 (ii) MD005 sec. 11	FY20

7 COMPLIANCE MONITORING

7.1 Operator Compliance Monitoring

Monitoring programs will be implemented to measure compliance with the measurement criteria summarised in Section 6.16.

The monitoring programs will measure the achievement of each outcome and the effectiveness of strategies implemented to reduce the identified risk associated with potential impact events. SIMEC Mining is responsible for achieving the outcomes, implementing the monitoring program, maintaining appropriate records and reporting performance in relation to achieving the outcomes of this PEPR.

All monitoring actions will be incorporated into existing site documentation and developed, reviewed and continuously improved via processes associated with the AS/NZS ISO 14001 Certified Environmental Management System (EMS), see Section 9.

7.2 Compliance Reporting

7.2.1 Internal reporting

Internal reporting as part of SIMEC Mining's quality, safety and environmental management systems will include compliance with the outcomes and measurement criteria approved in this PEPR. SIMEC Mining's Environmental Assurance Manager is responsible for the operational management and monitoring reporting in relation to this PEPR.

7.2.2 External reporting

The statement of compliance against approved outcomes will be included in the Compliance Report to DSD, in accordance with Section 8.12 of the Minerals Regulatory Guidelines, MG2, Guidelines for Miners: Preparation of a mining lease proposal or Mining and Rehabilitation Program (MARP) in South Australia (PIRSA 2011).

Other external reporting to be undertaken by SIMEC Mining in relation to the activities incorporated in this PEPR includes load-based license reporting to the SA EPA.

7.2.3 Retention of records

As required under Regulation 65 (12) of the Mining Regulations 2011 records associated with reporting the implementation of this PEPR will be retained for a minimum period of five years after formal surrender or final expiry of the associated tenement/s.

8 MINE CLOSURE AND REHABILITATION

8.1 Closure Objectives and Overall Strategy

The key objectives of the SMR Closure Plan are to ensure:

- the area is left in a safe and stable condition that supports a resilient, self-sustaining natural ecosystem suitable for the post-mining land use identified in consultation with closure stakeholders
- risks to public health and safety, and fauna are as low as reasonably practical
- the final visual amenity of the site is harmonious with the surrounding area.

The rehabilitation and closure strategies for the SMR operations include:

- utilising designs to minimise impact footprint and achieve best overall final profile
- achieving final landform profiles that will over time blend in with the natural topography and vegetation of the area
- ensuring adequate harvesting of topsoil and subsoil prior to dump and pad builds, and managing appropriate stockpiling to support the progressive rehabilitation program
- grading and dressing the faces of new WRDs to minimise surface water runoff beyond the WRD perimeter and minimising the risk of surface erosion
- progressively rehabilitating the faces of the new WRDs
- placing soil directly on the new, lower final dump slopes to progressively integrate the rehabilitated WRDs into the local topography
- investigate soil/waste rock mixtures to achieve a medium that will resist erosion and maximise water retention water penetration and nutrient cycling
- investigate options to achieve surface roughness through methodologies that minimise erosion and maximise water retention, water penetration and nutrient cycling
- revegetation with selected species identified during vegetation assessments to complement the existing local vegetation communities.

8.2 Description of Closure Domains

The closure domains are:

- pits
- WRDs
- ROM pads, haul roads and hardstand areas
- major assets (process plant, rail, main buildings, workshops, offices)
- miscellaneous infrastructure (site amenities, access roads, go-lines, lighting, water infrastructure)
- stockpiles
- TSFs.

Figure 92 shows the closure domains and associated landforms.

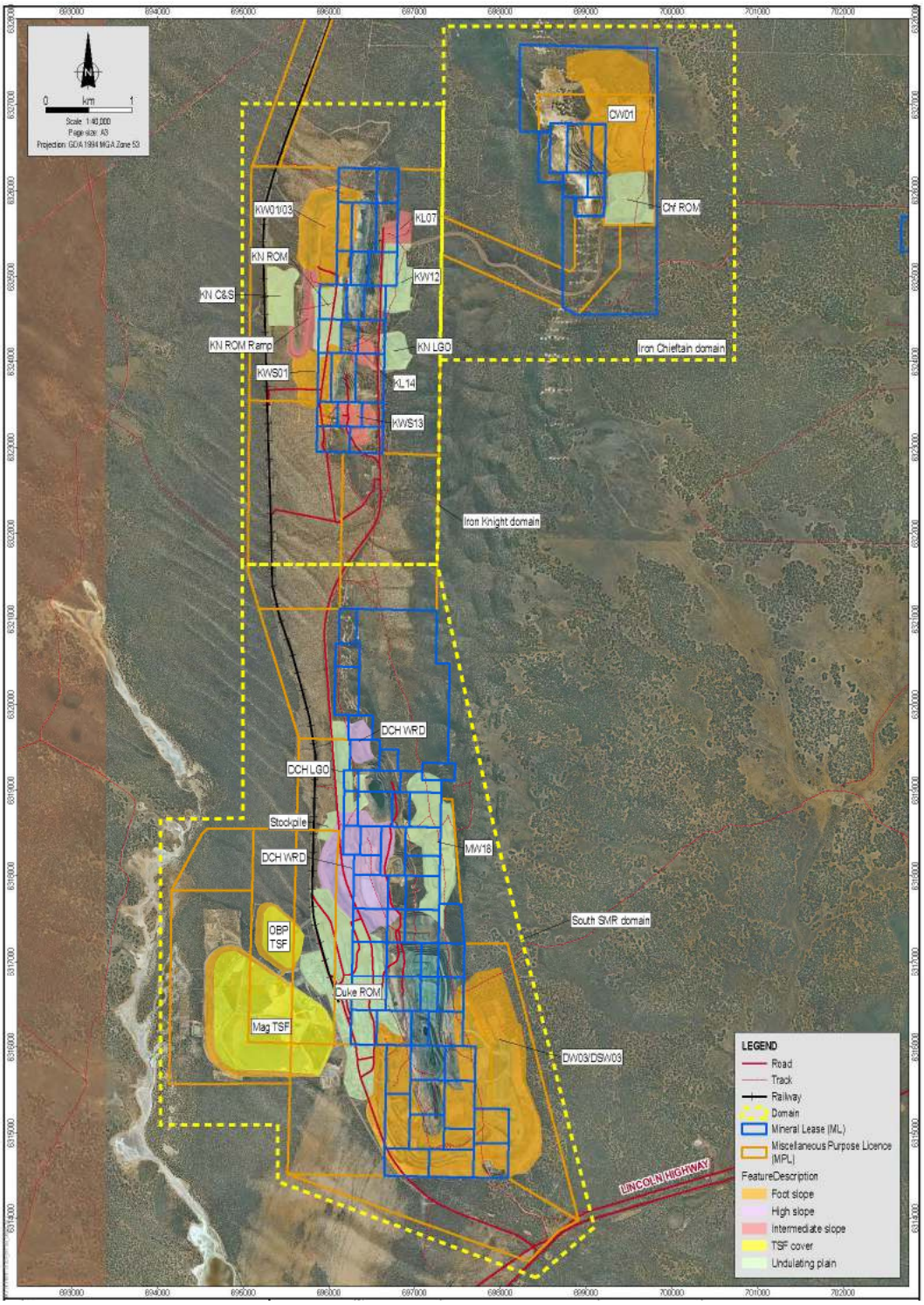


Figure 92 Closure domains and associated landforms

8.2.1 Pits

Final closure planning and risk assessments will determine the need and exact configuration of bunds and fencing required to ensure long-term public safety.

Activities to be undertaken for this domain include levelling of berms, rock raking, deep ripping and general tidying up of visual aspects, including revegetation work where reasonably practicable.

Suitable bunding will be established around the pit edge 10m from the potentially unstable pit edge zone. The potentially unstable pit zone is the area from the current pit edge to the point where a line dawn from the toe of the pit wall at 25^0 from the horizontal meets the pit shell. Similarly, fencing suitable for livestock and vehicle exclusion will be erected around the pits with safety signage warning the general public of the dangers of deep pits and unstable faces.

During operations the faces are scaled to remove any loose material and to make them as safe as practicable.

Drainage will be directed towards natural drainage channels where reasonably practicable.

Impacted areas around the pits will be suitably profiled, ripped and seeded for revegetation.

Indicative final landforms are presented in Section 8.3.

The pits at (and beyond) closure will generally accumulate water from surrounding catchment areas. Hydrology assessment and calculations predict that these accumulations will not be problematical in a 1-in-100 year flood event, with ample freeboard conditions prevailing.

8.2.2 WRDs

The overall design of the WRDs will result in a profile that will blend in with the surrounding landscape. Earthworks will include slope remediation to final landform and sheeting of lower slopes with suitable soil followed by revegetation with local native species. Refer to Table 93 for rehabilitation methodology and profiles for varying landforms.

The WRDs will be progressively developed, rehabilitated and re-profiled throughout mining operations, to blend with the surrounding landscape and arrive at an acceptable outcome in terms of visual amenity. Stockpiled topsoil and subsoil will be placed and spread over the affected area to promote regrowth of original species.

Timing of WRD rehabilitation is triggered by completion of each lift (see section 8.4) Rehabilitation of historic WRDs will occur once sequencing of mining allows buttressing and waste deposition to be completed. Final planning for historic WRD rehabilitation is under development, an example of this work can be seen on the southern end of Iron Duke.

Figure 93 and Figure 94 show the typical stylised construction of the initial and additional WRD terraces and the basic rehabilitation methodology. Note that in most cases topsoil actions will only occur on the lower slopes to blend with natural landscapes.

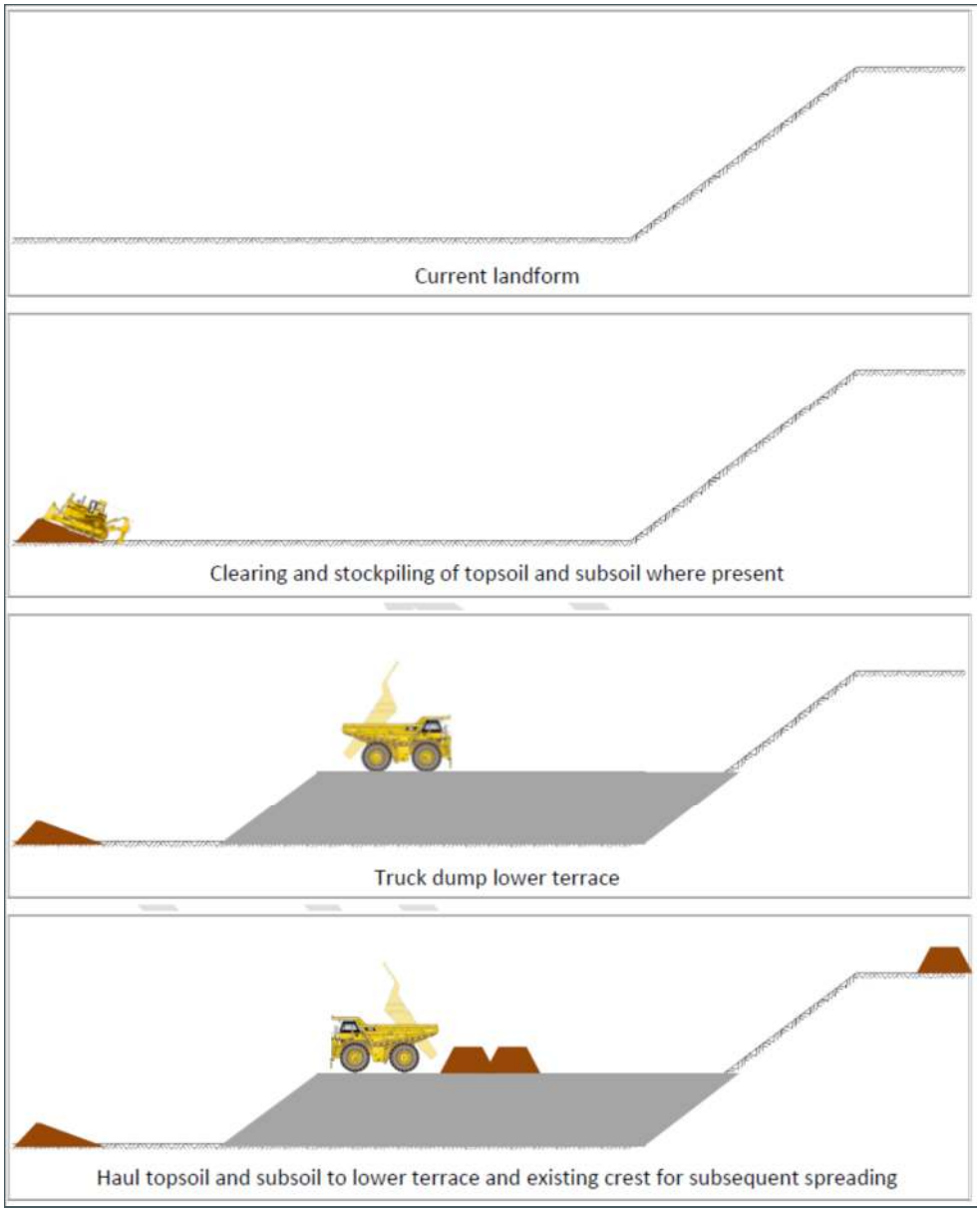


Figure 93 Initial WRD construction and rehabilitation methodology

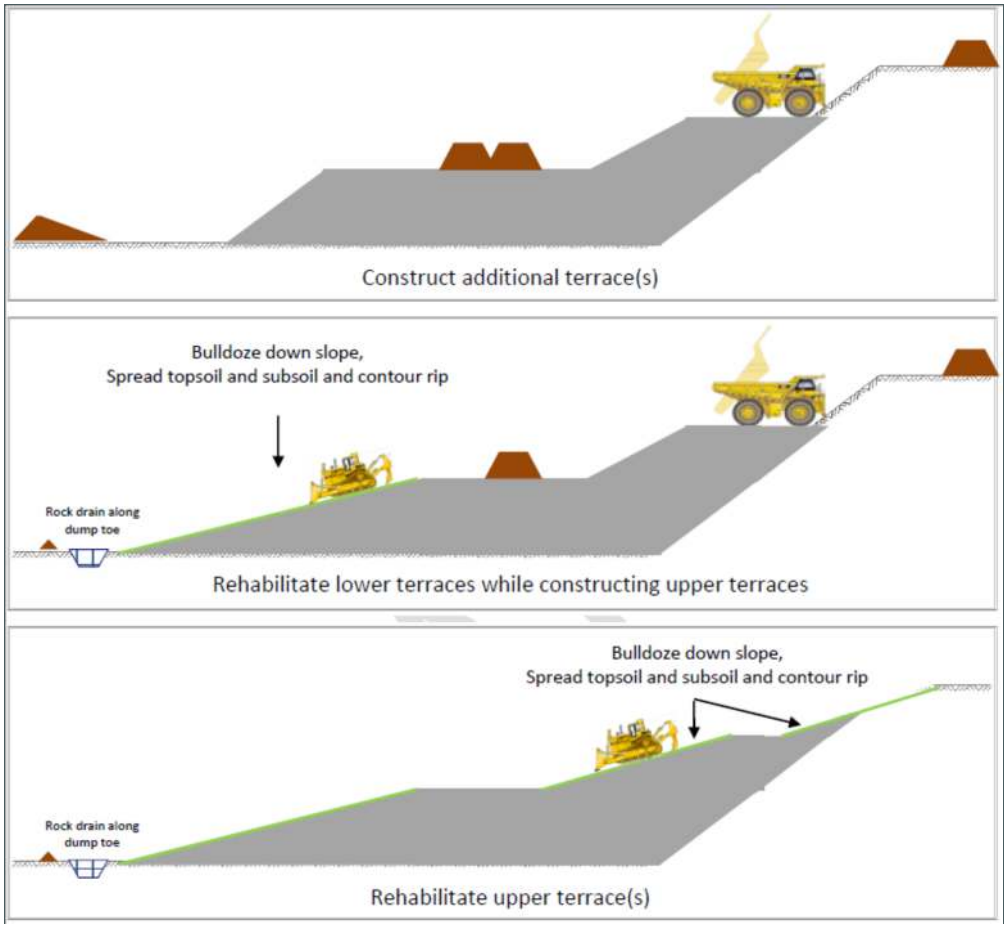


Figure 94 Final stages of WRD terrace construction and rehabilitation preparation

Table 92 provides the final design specifications for WRD landforms.

Table 92 WRD final design specifications

Mine area	WRD name	WRD lift (m RL)	Rehabilitation profile (degrees)
Iron Chieftain (SMR Zone 3)	WRD Stage A (CW01)	Surface-245	10
		245-260	15
		260-275	20
		275-290	20
		290-305	20
	WRD Stage C (CW01)	Surface-245	10
		245-260	15

Mine area	WRD name	WRD lift (m RL)	Rehabilitation profile (degrees)
		260-275	20
		275-290	20
		290-305	20
Iron Knight north (SMR Zone 2)	KNN WRD (KW03)	Surface-245	20
		245-260	20
	KNN WRD (KW01)	Surface-230	20
		230-245	20
		245-260	20
		260-275	20
	KNN WRD (KW12)	Surface-280	20
		280-295	20
	KNN LGO (KL07)	Surface-280	20
		280-295	20
Iron Knight south (SMR Zone 2)	KNS WRD (KL14)	Surface-275	20
		275-290	20
	KNS WRD (KWS13)	Surface-260	20
		260-275	20
		275-290	20
	KNS WRD (KWS01)	Surface-222	20
		222-237	20
		237-245	20
		245-260	20
	KNS Low Grade Stockpile (KL14)	Surface-270	20
		270-280	20
Iron Duchess south (SMR Zone 1)	Iron Duchess-Magnet WRD Completed (MW18)	Surface-290	20
		290-305	20
		305-320	20
	Iron Duchess-Magnet WRD Completed (MW18 – stage 6)	Surface-290	36
		290-305	20
		305-320	20
	Iron Duchess-Magnet WRD Completed (MW18 – stage 7)	Surface-290	36
		290-305	20
		305-320	20
Iron Duchess North Stage B Part 1		Surface-290	20
		290-305	20

Mine area	WRD name	WRD lift (m RL)	Rehabilitation profile (degrees)
(SMR Zone 1)	Iron Duchess-Magnet WRD north face (MW18 Duchess Stage B extension)	305-320	20
Iron Duke/Magnet	Iron Duke WRD (DSW03)	Surface-155	10
(SMR Zone 1)	Iron Duke WRD (DW03)	155-160	10
	Iron Magnet WRD (MW03)	160-175	15
		175-190	15
		190-205	20
		205-220	20
		220-235	20
Iron Magnet	Iron Magnet WRD (MW04)	Surface-245	20
(SMR Zone 1)		245-260	20

Strategies for progressively achieving final landform outcomes are described in Section 3.7.3 sub-heading **'WRD general build methodology',** and further in Section 3.7.3 sub-heading '**Progressive rehabilitation'.**

8.2.3 ROM pads, haul roads and hardstand areas

These domains will be among the last areas rehabilitated. A small access road for monitoring the site will be maintained, with the majority of haul roads and other internal site roads being ripped. These areas will be deep ripped and contoured to blend in with the surrounding topography as undulating plains. Stockpiled topsoil and subsoil will be spread over the surface and lightly ripped to promote regrowth of original species.

8.2.4 Major assets

This domain covers the decommissioning, removal and remediation of major assets at the SMR including:

- process plant
- rail
- main buildings
- workshops
- offices.

All facilities, buildings, and equipment will be decommissioned, and all infrastructure and equipment will be removed from site. All areas will be remediated to a suitable state for site rehabilitation and closure.

8.2.5 Miscellaneous infrastructure

This domain covers the decommissioning, removal and remediation of miscellaneous infrastructure including:

- site amenities
- access roads
- go-lines
- lighting
- water infrastructure.

All facilities, buildings, and equipment will be decommissioned and removed from site, and the areas will be remediated and setup for rehabilitation and closure.

Remediating these sites generally involves deep ripping and sheeting with topsoil to establish a suitably revegetated landscape that blends with the natural environment.

8.2.6 Stockpiles

Once stockpiles have been reclaimed the surface will be ripped and contoured to blend with the surrounding landscape. Stockpiled topsoil and subsoil will be placed and spread over the affected area to promote regrowth of original native vegetation species.

8.2.7 TSF Closures

Magnetite TSF closure concept

The TSF will be closed with a store-and-release cover placed over the tailings beach, grading to the east where an overflow spillway and channel will direct storm flow south of the TSF to the natural drainage system (Golder 2014g).

The surface of the TSF will be formed into sub-catchment areas for the storage and release of water. These sub-catchment areas will incorporate overflow channels and will step down to the east of the TSF. At the eastern edge of the TSF, a spillway will direct overflow water into a diversion channel situated on natural soils. This diversion channel will direct the water to the south of the TSF and into the natural drainage of the area (Golder 2014g).

The embankments will be shaped into unbroken concave slopes consistent with the surrounding landscape. Armouring and vegetation will be required to manage erosion (Golder 2014g).

OBP TSF closure concept

Tailings deposition into the OBP TSF ceased in July 2014 and it is expected that future OBP tailings will continue to be deposited as a combined OBP/Concentrator tailings stream into the Magnetite TSF.

Given the potential for removal and re-processing of OBP tailings, and the opportunities for re-use of the OBP TSF, there are a number of possible rehabilitation scenarios for the facility when it is finally decommissioned.

A pre-decommissioning review of the OBP TSF will be conducted to determine a suitable closure plan, although it is likely the ultimate rehabilitation of the OBP TSF will be similar to that described for the Magnetite TSF. A scenario where the OBP TSF is left to contain consolidated tailings would suit a store-and-release cover placed over the tailings beach with overflow channels and a spillway to direct storm flow to the natural drainage system west of the OBP TSF.

An alternative scenario for an empty OBP TSF with intact embankments may involve planting suitable vegetation cover and strategic armouring to minimise erosion along drainage channels. Any rainwater runoff collected within the TSF footprint and draining into the internal basin would evaporate or infiltrate naturally to groundwater storage as it would have prior to TSF construction.

Climate data for the Middleback Ranges has shown average evaporation exceeds average monthly rainfall regardless of season (Golder 2014g), therefore surface water ponding within the rehabilitated OBP TSF landform is likely to be intermittent and ephemeral in nature, and groundwater recharge would only be expected to occur during storm events where daily rainfall exceeds mean daily evaporation.

Progressive rehabilitation and cover system trials

The tailings beach area will be active for the operational life of the TSF. Progressive rehabilitation will be limited to portions of the embankment remote from the operational area. The available portions of the embankment will be used to trial the cover systems. The success of the cover systems is typically assessed over decades of monitoring. Trialling cover systems while the TSF is operational allows its performance to be monitored and adjustments to be made while operational resources are available. The longer a cover system performance can be monitored, the greater the confidence in the long-term performance and accuracy estimate of the closure costs. The following steps would be taken to progressively rehabilitate the TSF and trial cover systems:

- erosion modelling to identify slope dimensions (slope angle, shape, length etc.) and covers that might be stable in the long term
- detailed design of a cover trial (or series of trials) for portions of the embankment
- construction of trial(s) along portions of the embankment, shaping the embankment to the desired dimensions and placing the cover material on top. This would include trialling various seed mixtures in the cover.
- monitoring the trial(s) over the Master Plan period (see Section 3.9.6), to assess if the cover design is performing as expected (Golder July 2014g).

Early closure

An early termination of mining operations would lead to the need to close the TSF prematurely. The execution of closure trials early in the mine life and the progressive rehabilitation of the TSF slopes will allow early closure of the facilities to be implemented in a cost effective and sustainable manner.

In the event that it becomes necessary to decommission the TSF prior to achieving its full capacity the following steps would be implemented:

- a pre-decommissioning review of the TSF would be conducted and a specific closure plan developed in consideration of the stage of development of the TSF the exposed tailings surfaces would be covered with material identified from the cover design trials. If possible this will be shaped to direct water to the east, and away from the embankments, and onto the natural soils
- the remaining infrastructure would be removed, including pipes, pond liners etc., and the area rehabilitated including respreading topsoil and seeding (Golder 2014g).

8.3 Final Landform and Stability

The final landform design delivers a stable, safe and visually acceptable amenity beyond closure. Revegetation will be undertaken in accordance with species found in the flora surveys of the mining areas.

Depending on vegetation size and type, vegetation is either cleared immediately prior to topsoil harvesting and stockpiled separately, or cleared during topsoil harvesting and stockpiled with topsoil. Cleared vegetation is a very important source of seed and organocarbon that will aid revegetation as described in Section 6.2, following the establishment of the final landform and placement of topsoil. Table 93 describes the rehabilitation strategy for the landform types.

Figure 95 shows the proposed closure design layout for the Iron Chieftain mining area, and Figure 96 shows the location of the final landforms cross-sections, with the cross-sections showing the original, existing and final rehabilitated surfaces provided as Figure 97 and Figure 98.

Figure 99 shows proposed closure design layout for the Iron Knight mining area, and Figure 100 shows the location of the final landforms cross-sections, with the cross-sections showing the original, existing and final rehabilitated surfaces provided as Figure 101 to Figure 105.

Figure 106 shows the proposed closure design layout for the South SMR mining area, and Figure 107 shows the location of the final landforms cross-sections, with the cross-sections showing the original, existing and final rehabilitated surfaces provided as Figure 108 to Figure 113. Figure 114 shows the location of the final landform cross-section for Iron Duchess North Stage B Part 1, with the cross-section showing the original, existing and final rehabilitated surfaces provided as Figure 115.

Iron Duchess WRD final landform to be ‘Undulating Plains’, the northern slope dozed to 20 degrees and sheeted with topsoil from the top soil stockpile shown in Figure 114. The top plain scarified and sheeted with topsoil stockpiled during operations as shown in Figure 114 and on the plain itself.

Table 93 Rehabilitation strategy by landform

Landform	Rehabilitation strategy
Foot slopes	• Doze concave profile – 10, 15, 20 degree slope (bottom to top) • Sheet 10 and 15 degree slopes with topsoil (up to 200 mm deep) • Scarify plateaus • Seed-box or contour rip 10 and 15 degree slopes • Broadcast selected seed species if required
Intermediate slopes	• Doze continuous 20 degree slope • Seed-box slope • Scarify plateau • Doze windrows
High slopes	• Varied dozing on upper crests to provide landform relief • Push topsoil over top edge where possible to do so
Undulating plains	• Remove all infrastructure • Doze piled material to 20 degrees • Scarify open areas • Spread topsoil over areas that are not underlain with sand, clay or calcareous soils
TSF cover	• Sheet with minimum of 200 mm of topsoil when compressive strength of tails surface enables safe access by SME

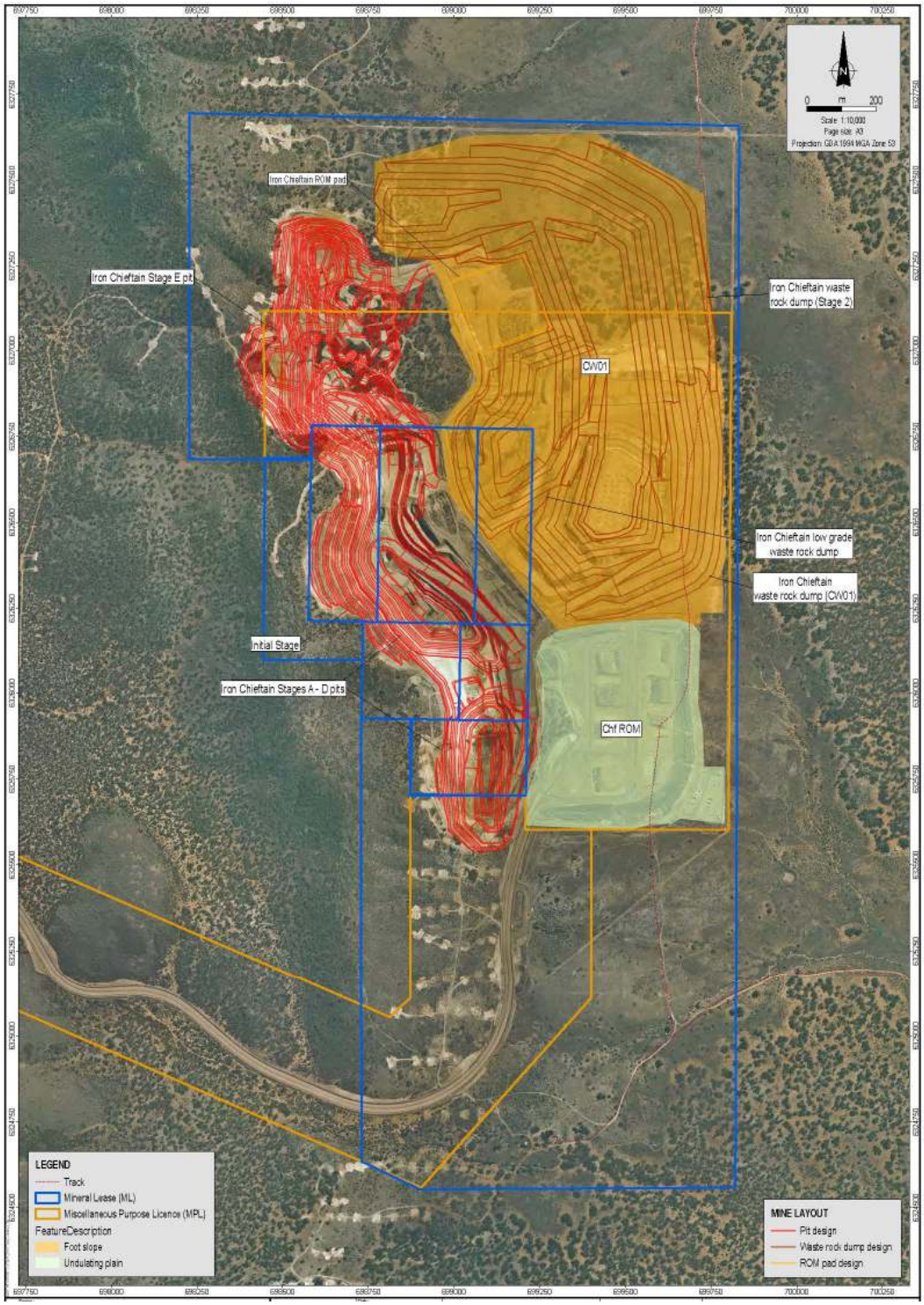


Figure 95 Iron Chieftain (SMR Zone 3) final landform

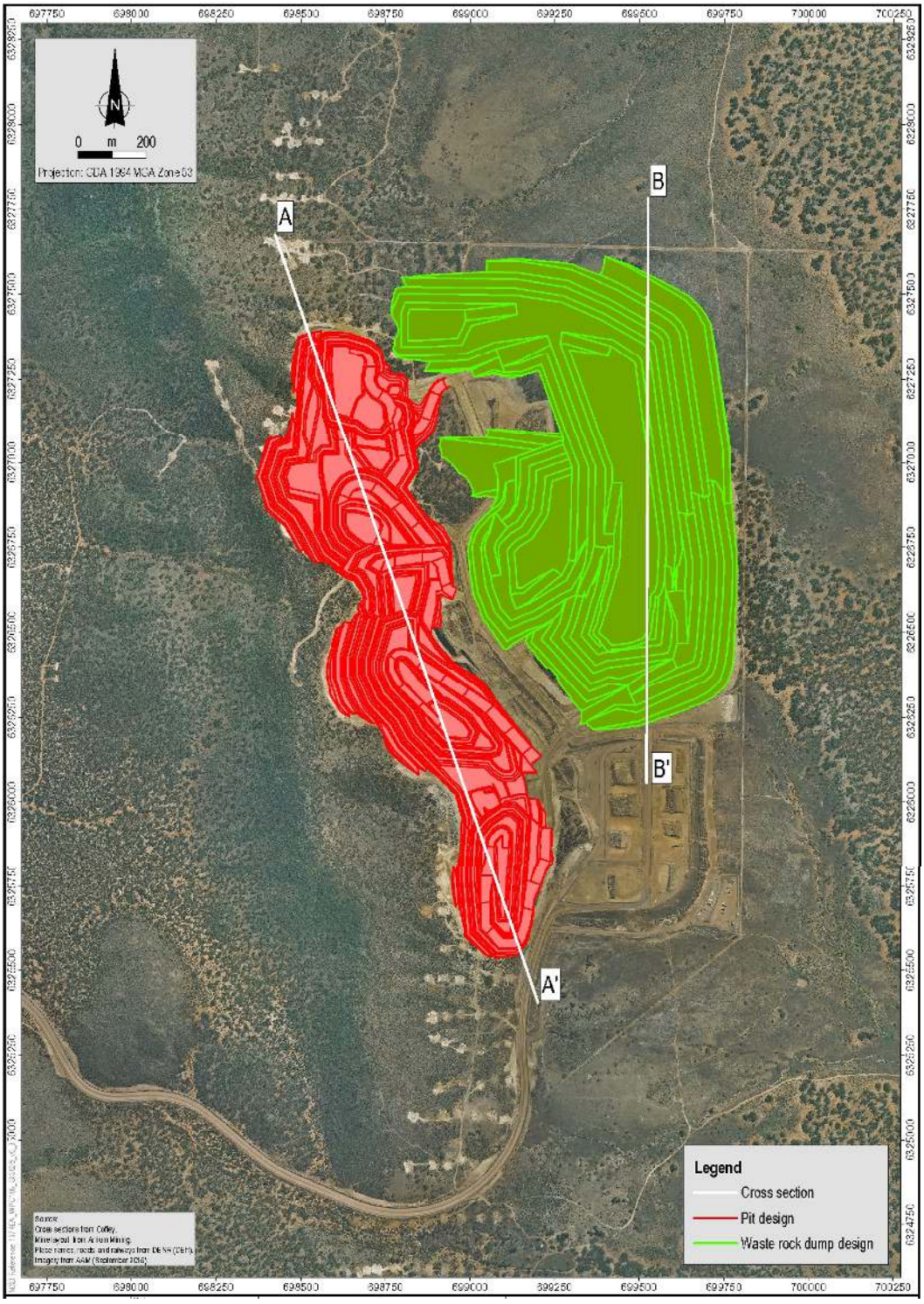


Figure 96 Iron Chieftain domain final landform cross sections

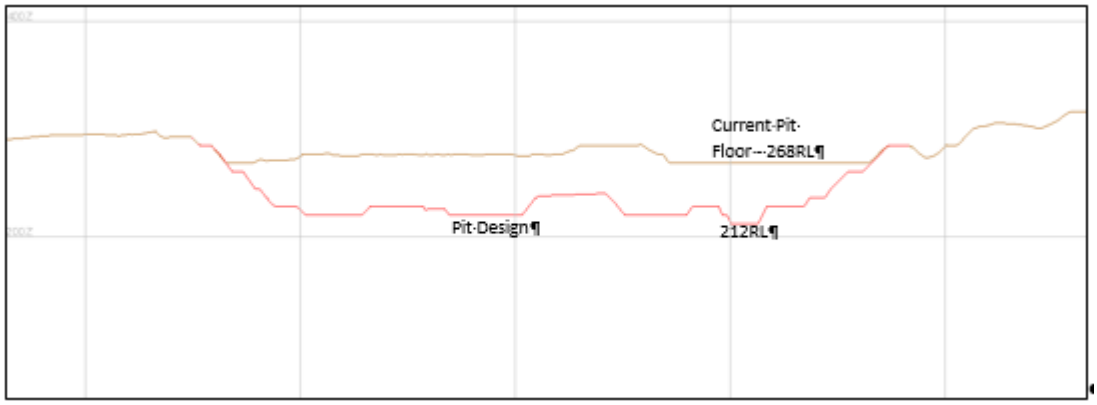


Figure 97 Iron Chieftain pit – Cross-section A-A' (looking west)

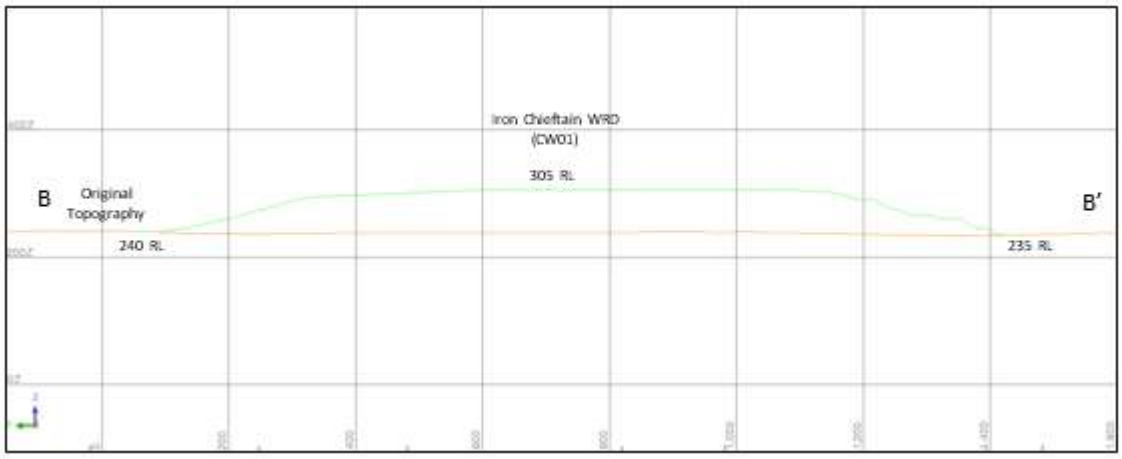


Figure 98 Iron Chieftain WRD – Cross-section B-B' (looking west)

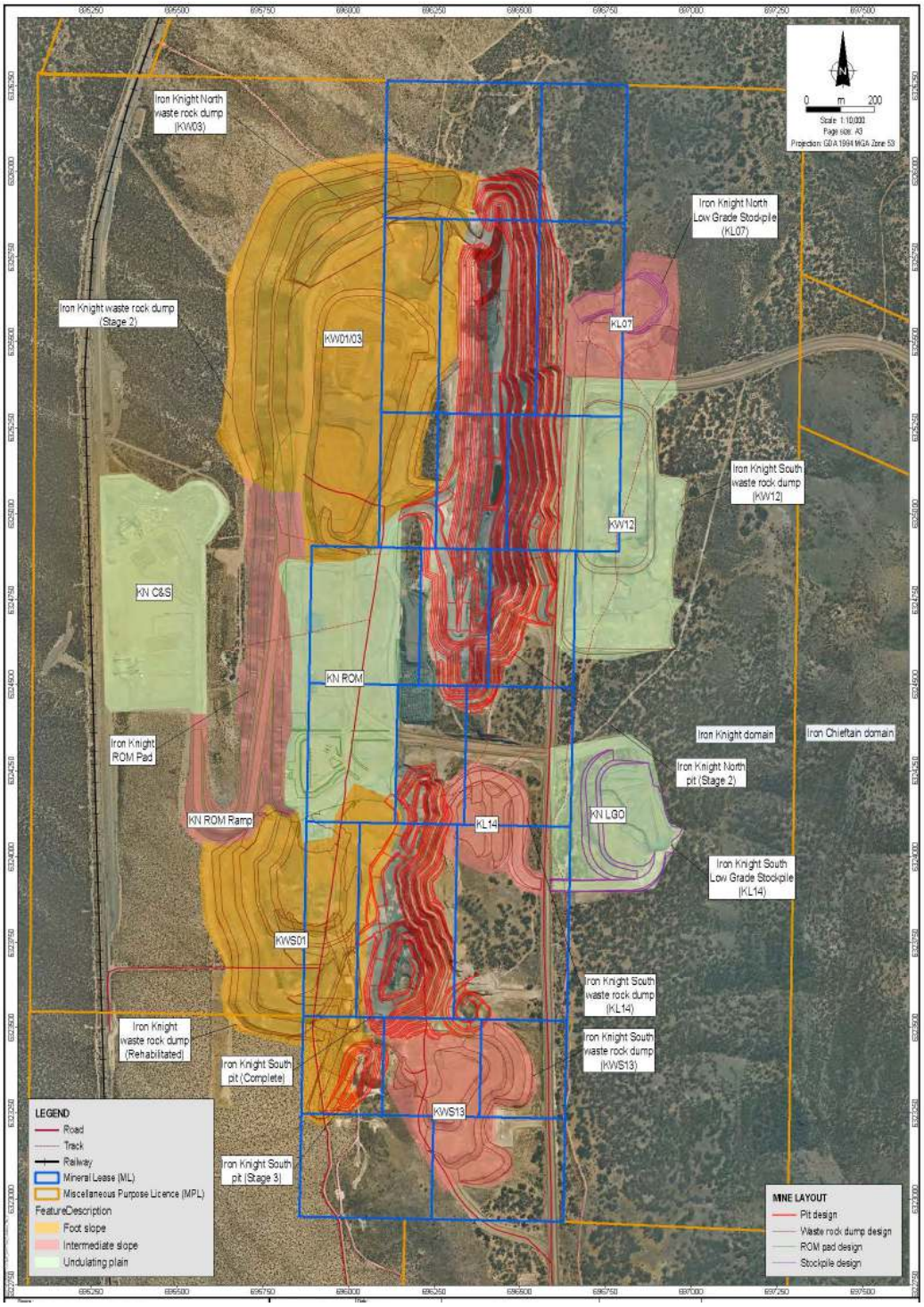


Figure 99 Iron Knight (SMR Zone 2) final landform



Figure 100 Iron Knight domain final landform cross sections

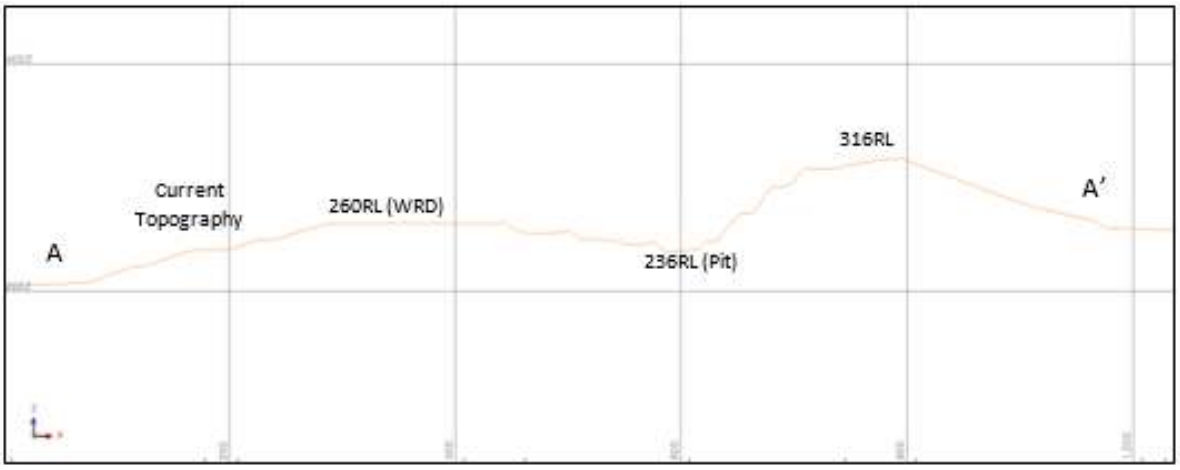


Figure 101 Iron Knight WRD – Cross-section A-A' (looking north)

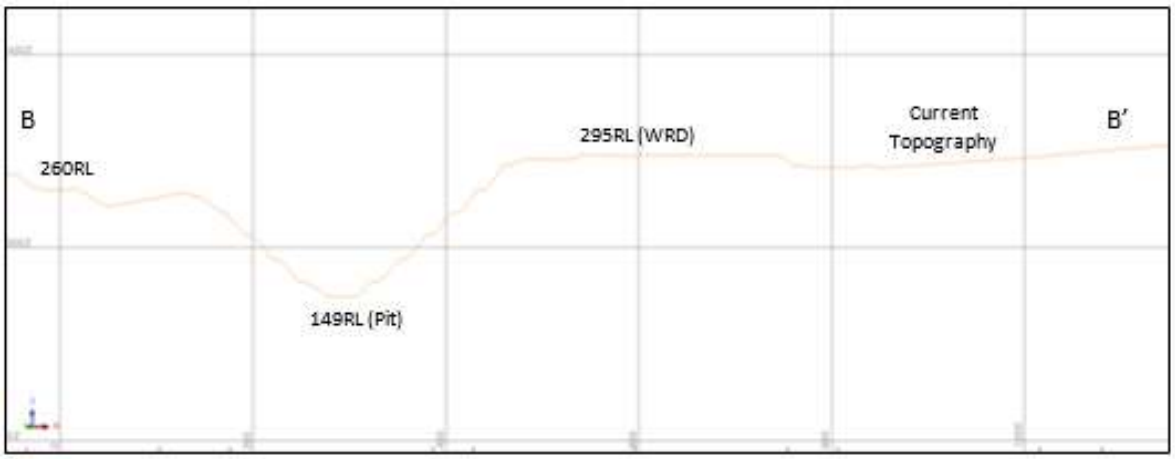


Figure 102 Iron Knight North pit and WRD – Cross-section B-B' (looking north)

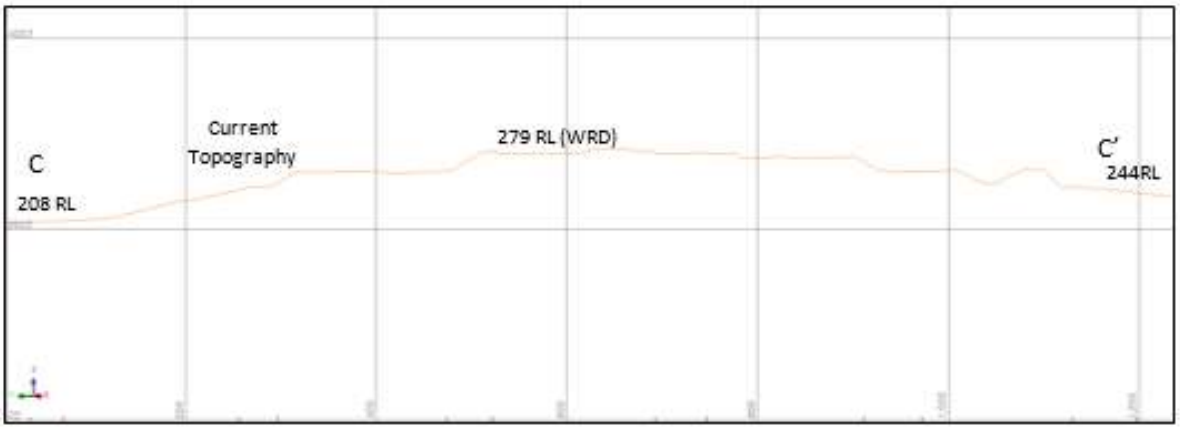


Figure 103 Iron Knight WRD – Cross-section C-C' (looking northeast)

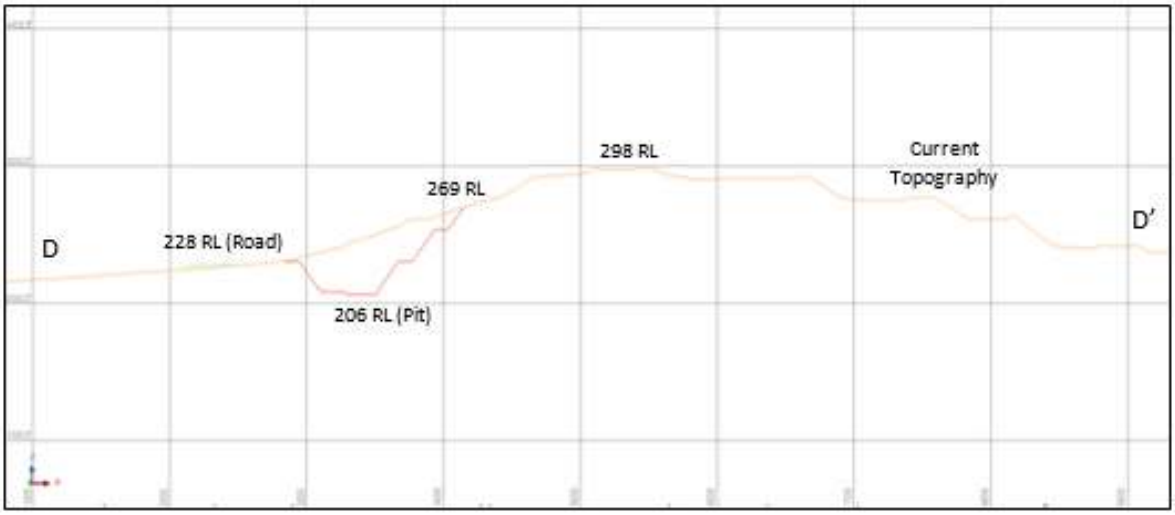


Figure 104 Iron Knight South pit – Cross section D-D' (looking north)

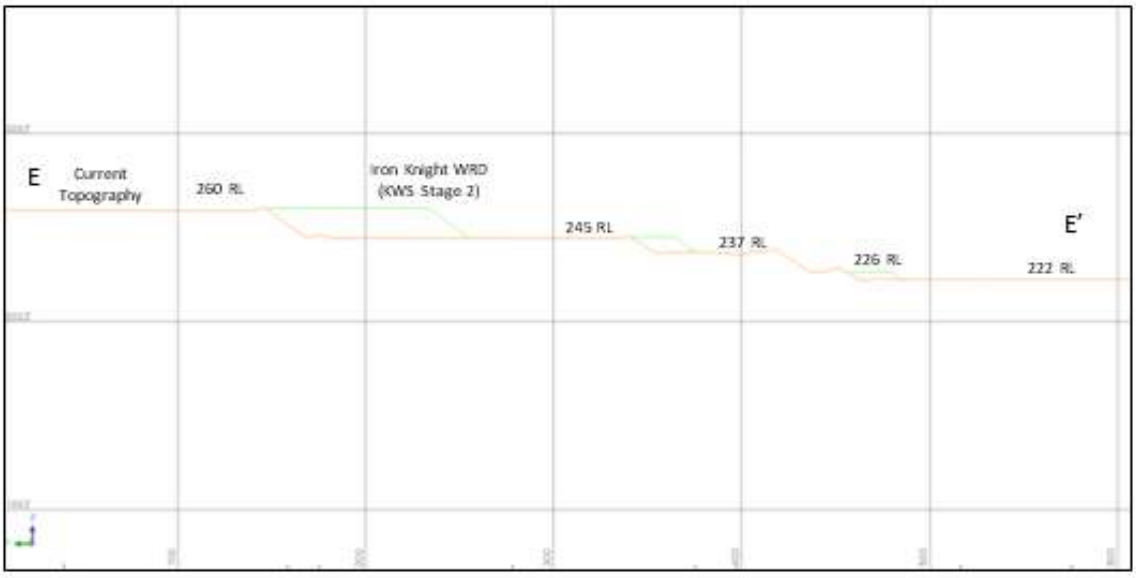


Figure 105 Iron Knight South WRD – Cross section E-E' looking East

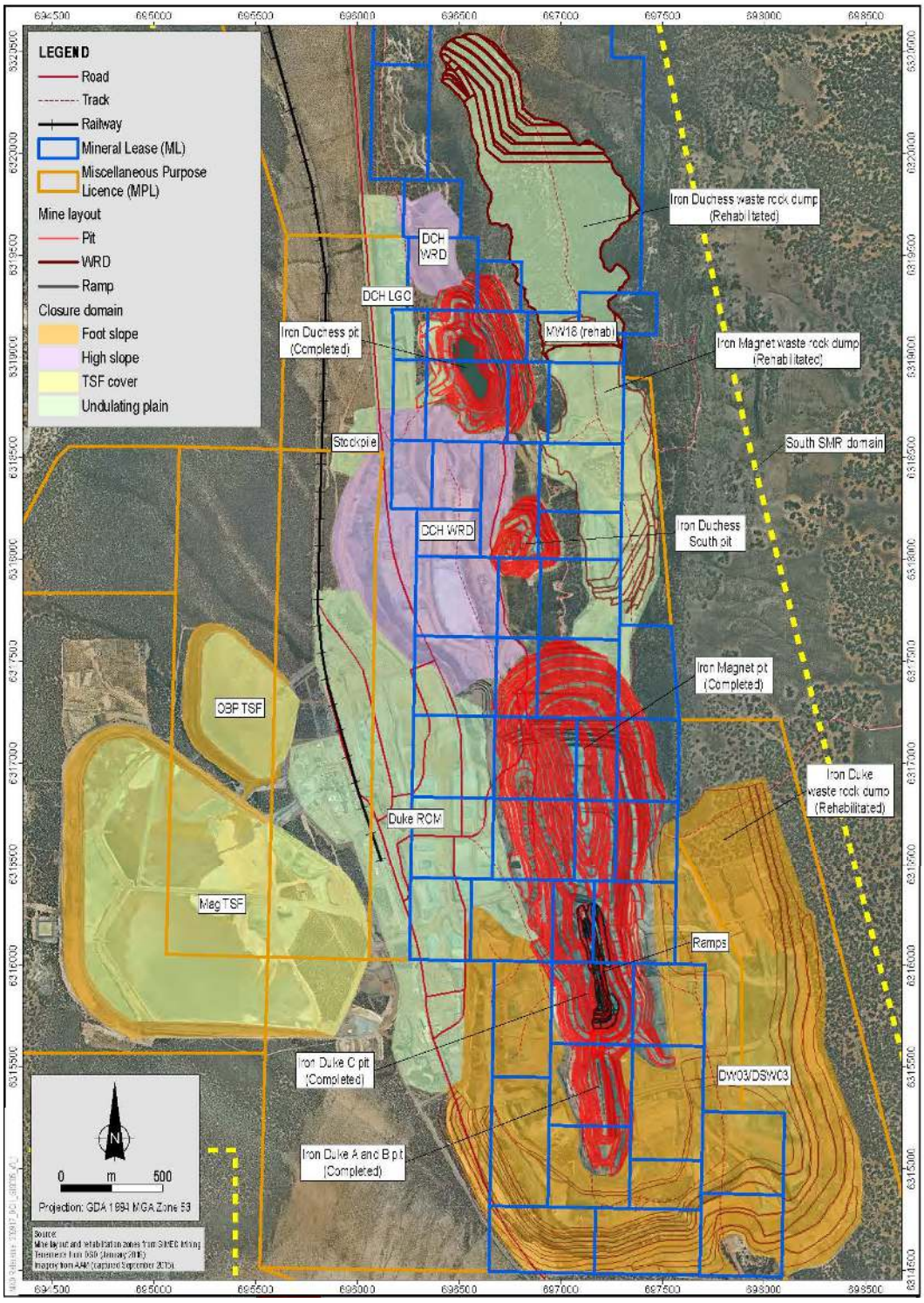


Figure 106 South SMR (SMR Zone 1) final landform

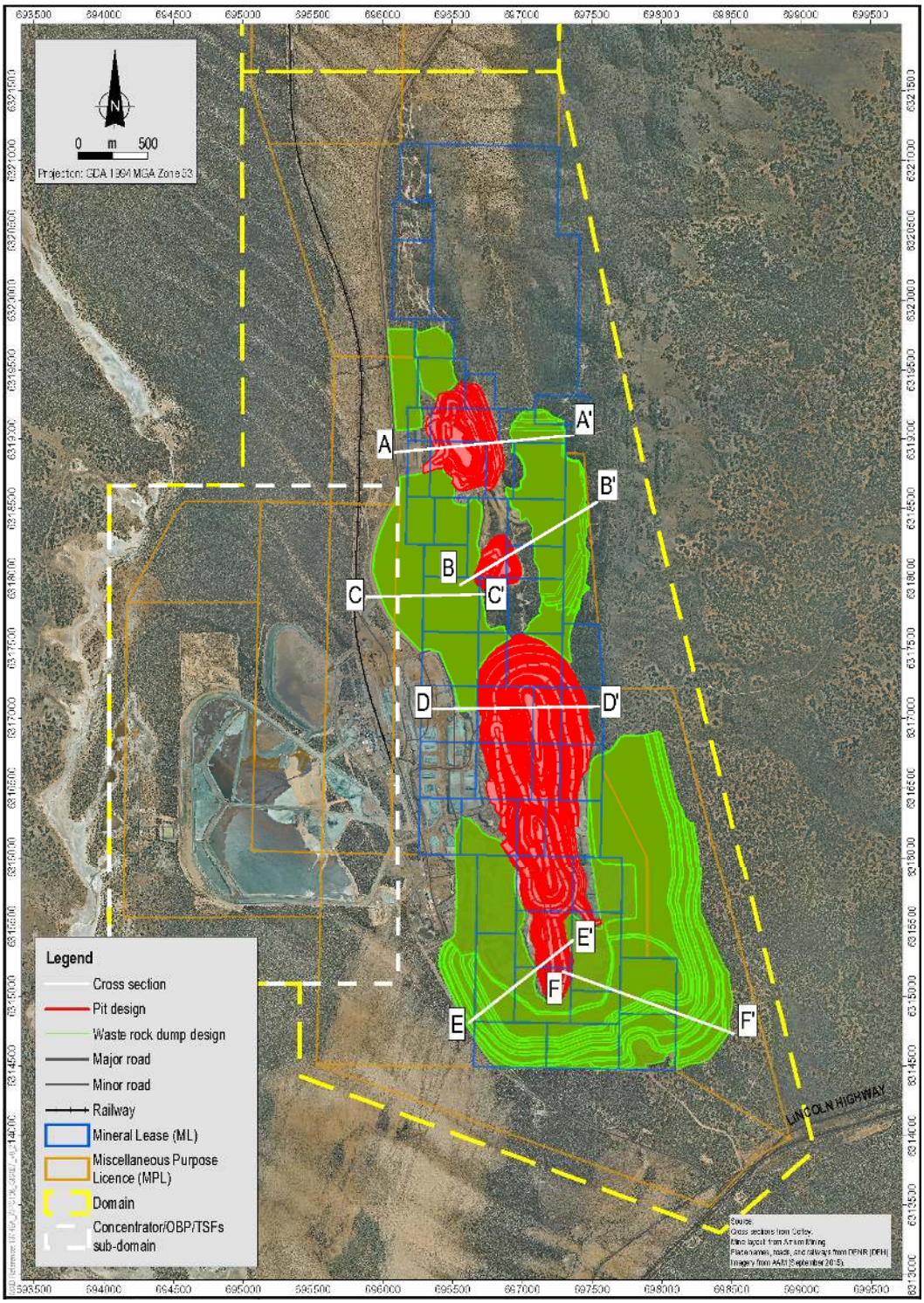


Figure 107 South SMR domain final landform cross sections

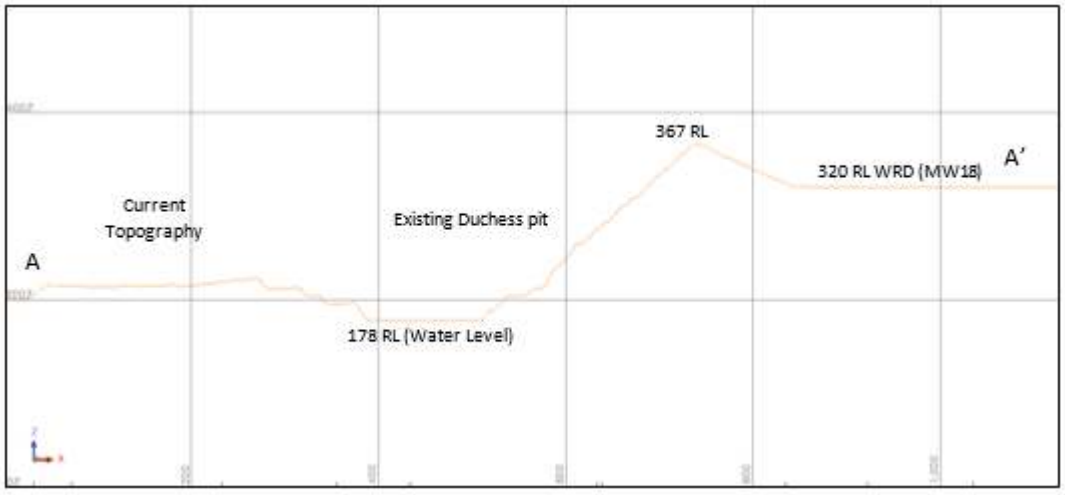


Figure 108 Iron Duchess pit - Cross section AA' looking North

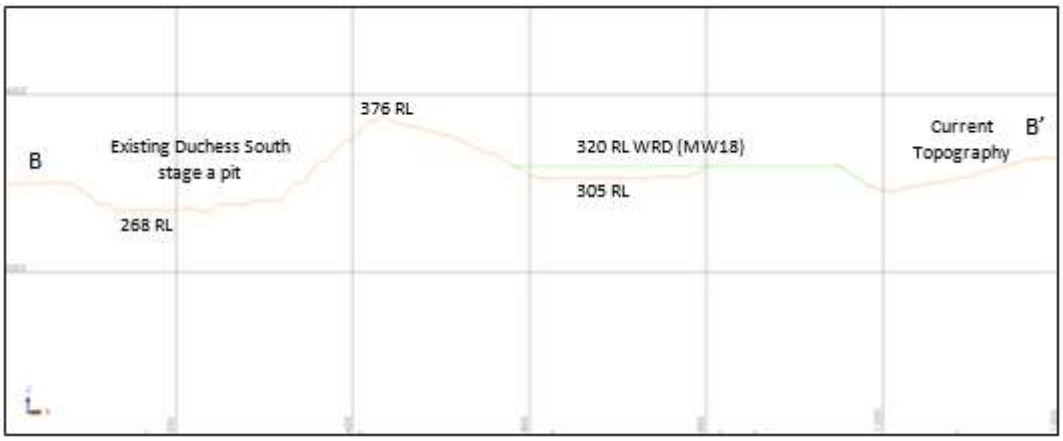


Figure 109 Iron Duchess South pit - Cross section BB' looking North

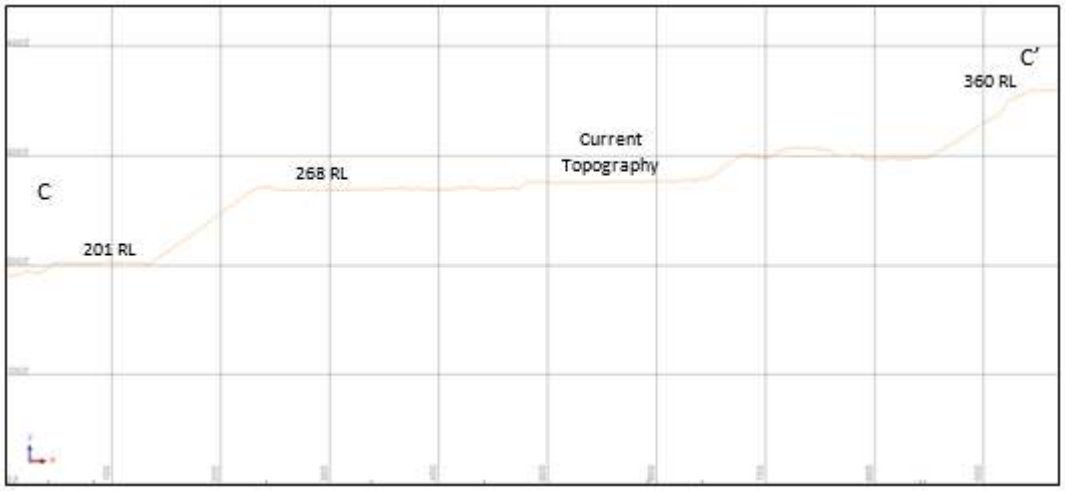


Figure 110 Iron Duchess WRD - Cross section CC' looking North

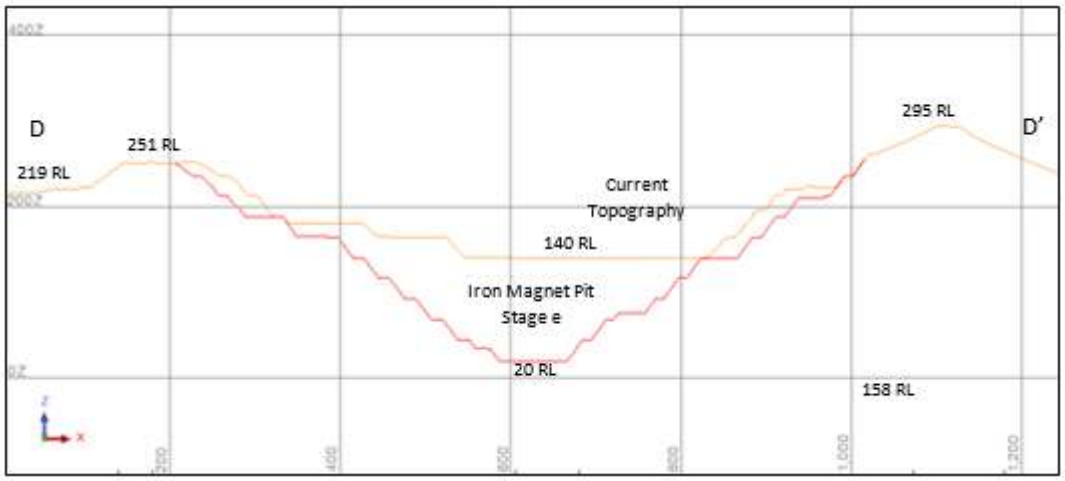


Figure 111 Iron Magnet pit - Cross section DD' looking North

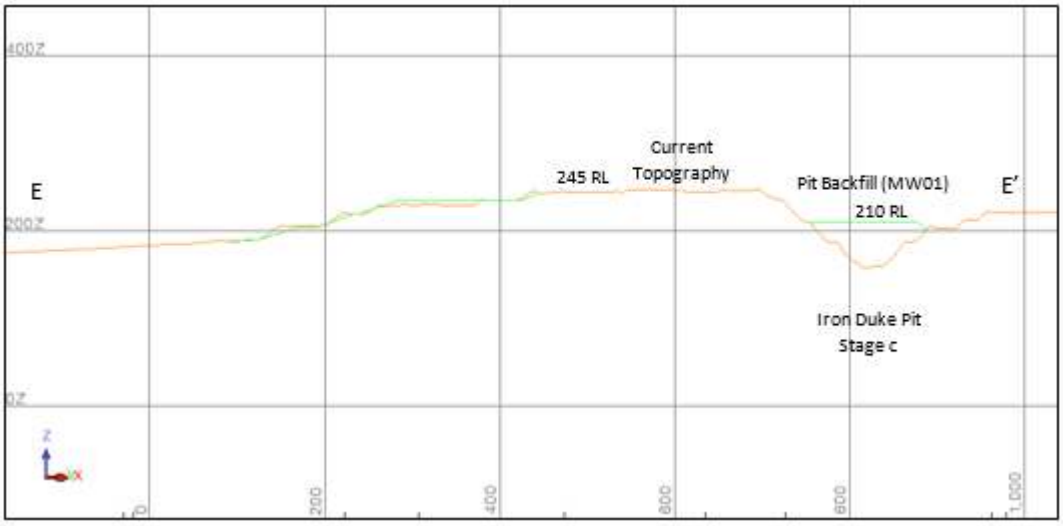


Figure 112 Iron Duke stage c pit - Cross section EE' looking North-west



Figure 113 Iron Magnet WRD - Cross section FF' looking North-east

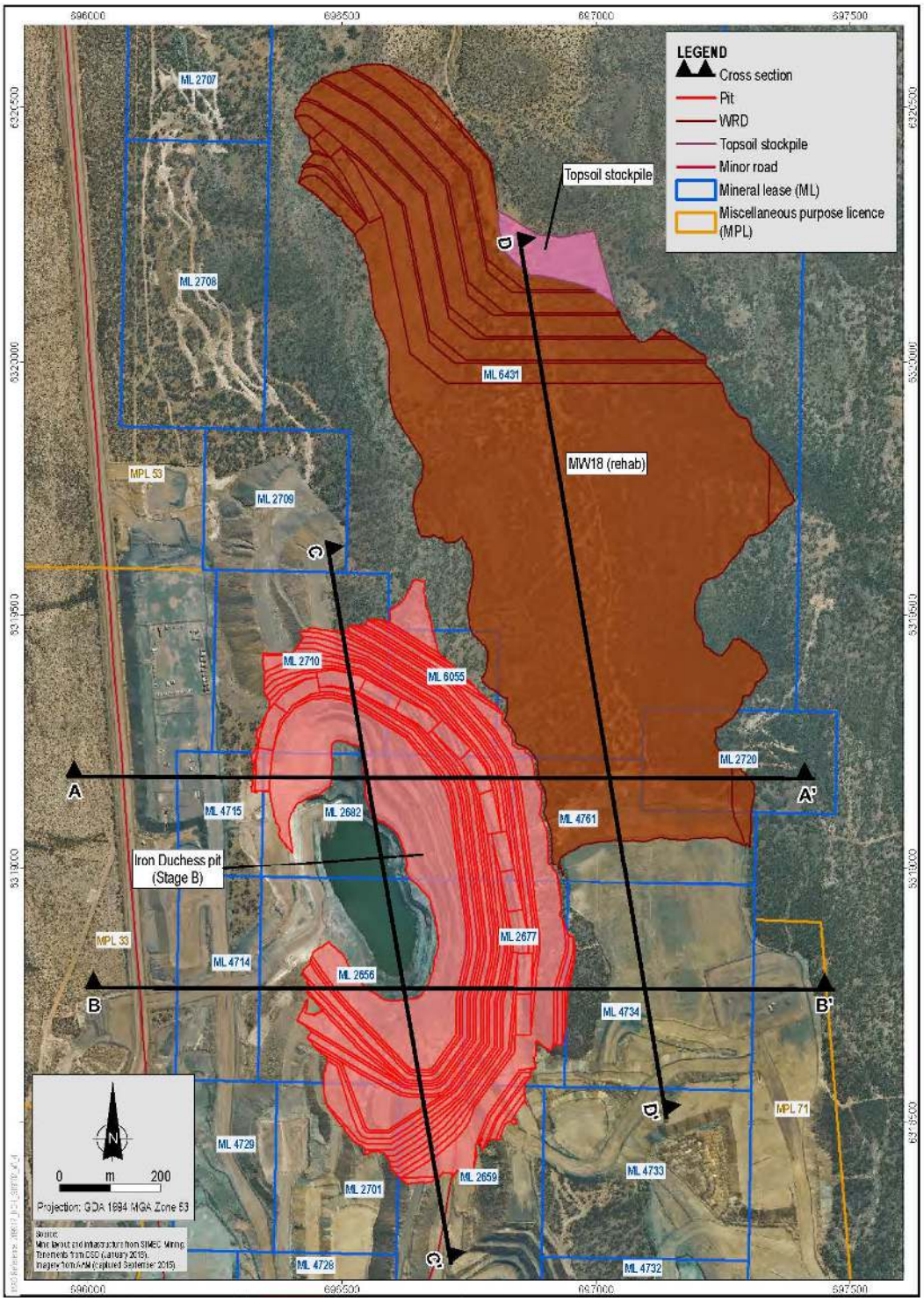


Figure 114 Iron Duchess North final landform cross sections

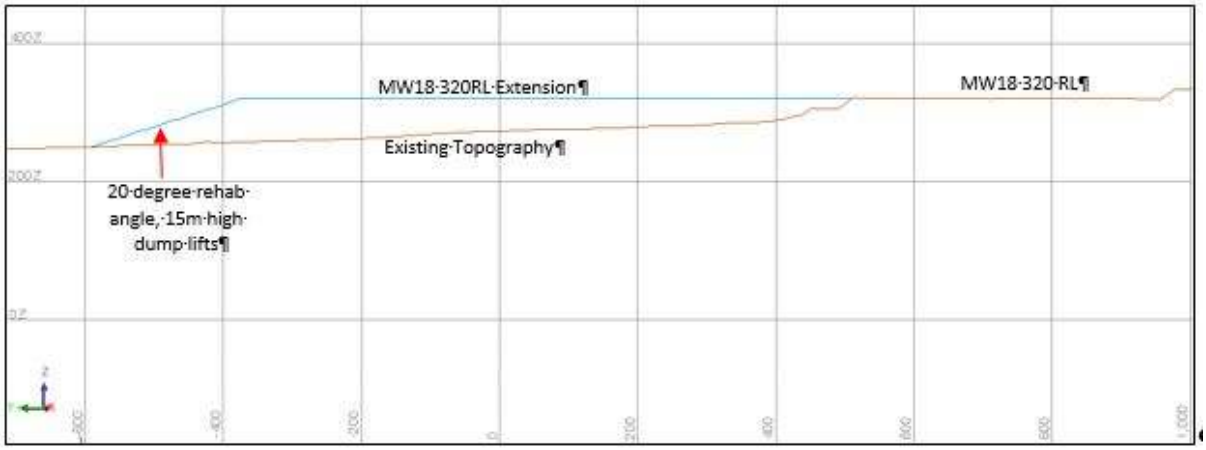


Figure 115 Iron Duchess North WRD - Cross section DD' looking East

8.4 Timing of Closure

The timing of closure is approximated due to the variability in the LOM schedule, particularly beyond the five-year term. There is also variability within this term due to ongoing exploration and mine optimisation processes to suit market conditions.

Once a pit is completed, a process of 'sterilisation' occurs prior to final closure actions. This process is generally completed within one year of completion of mining. The processing of ore stockpiles may continue for up to five years beyond pit closure.

Once a WRD lift is complete, the slope is pushed down to the final landform profile and sheeted with soil as necessary. This is required to occur prior to the next lift being tipped to the tip limit. Funding to complete rehabilitation is built into the mining contractors load and haul rates and therefore not subject to financial year budgetary constraints.

Based upon the current information available from the LOM, the estimated closure dates for each of the closure domains for the SMR mining areas is provided in Table 94.

Table 94 SMR estimated closure dates

SMR domain	Approximate date	Comments
Iron Chieftain pit	2020	
Iron Chieftain WRD	2021	
Iron Chieftain ROM	2021	
Iron Chieftain stockpiles	2038	Removal of stockpiles for rehabilitation will depend on blending requirements of the OBP plant, but potentially may occur earlier than this date
Iron Chieftain access road	2038	Rehabilitation can occur once stockpiles are removed

SMR domain	Approximate date	Comments
Iron Knight pit	2016	
Iron Knight WRD	2017	
Iron Knight stockpiles	2038	Removal of stockpiles for rehabilitation will depend on blending requirements of the OBP plant, but potentially may occur earlier than this date
Iron Knight access road	2038	Rehabilitation can occur once Iron Chieftain and Iron Knight stockpiles are depleted
Iron Duchess South pit	2016	
Iron Duchess North pit	2021	
Iron Duchess WRD (MW18 north)	2021	
Iron Duchess WRD (DW03, DWS03)	2018	
Iron Duke pit	2030	The Iron Duke pit will continue to be considered 'open' whilst the Iron Magnet pit operation at the northern end continues
Iron Duke WRD (DW03, DWS03)	2017	
Iron Magnet pit	2030	
Iron Magnet WRD (MW03, MWS03)	2017	
Iron Magnet WRD (MW18 south)	2019	
Iron Duke ROM, crushers, OBP plant	2040	
Iron Duke OBP TSF	2042	Allowance of 2–3 years for tails to dry sufficiently for coverage
Iron Duke magnetite plant	2032	
Iron Duke magnetite TSF	2034	Allowance of 2–3 years for tails to dry sufficiently for coverage
Administration, workshops and main access roads	2043	

8.5 Water Catchment

8.5.1 Catchment areas

A high-level surface water hydrology review (Mining Plus Pty Ltd 2014a) considered the catchment areas affected by the remaining SMR mine structures post closure (excluding the OBP and Magnetite TSFs). Figures A-15 and A-16 (see Appendix A) show the catchments at each of the main SMR mining areas. Four sub-catchment types were defined:

- In-pit – disturbed areas bounded by final LOM pit crests
- Ex-pit Divertible In-pit – ex-pit disturbed and undisturbed surface areas that currently or will report in-pit, or with a 'reasonable' amount of work, e.g. re-grading, revised dumping strategy, diversion drains and bunds etc. could be directed in-pit

- Ex-pit Impacted – ex-pit undisturbed surface areas which are trapped, i.e. cut-off with no obvious outlet, otherwise impacted due to the development of the mine facilities
- Ex-pit Off-site – ex-pit disturbed surface areas that cannot 'practically' be diverted in-pit. As a result, runoff from these areas will ultimately report off site.

Undisturbed catchment areas in the vicinity of the SMR site that will not be affected by the facilities at closure have not been delineated.

Additional calculations for the Iron Duchess Stage B Part 1 development were conducted internally by SIMEC (see Section 3.8.8 for more information). A comprehensive independent hydrology review will be provided in the full PEPR update to be completed by 2020.

The areas of the catchments affected post closure are shown in Table 95.

Table 95 SMR closure catchment areas

Catchment name and sub-catchment type	Area (m^2)
Iron Chieftain	
In-pit	526,600
Ex-pit divertible in-pit	1,083,200
Ex-pit trapped	694,200
Ex-pit offsite	817,050
Sub-total	**3,121,100**
Iron Knight	
In-pit	644,900
Ex-pit divertible in-pit	1,061,000
Ex-pit trapped	1,294,300
Ex-pit offsite	1,333,500
Sub-total	4,333,700
Iron Duke	
In-pit	1,352,400
Ex-pit divertible in-pit	1,677,000
Ex-pit trapped	549,000
Ex-pit offsite	4,353,900
Sub-total	7,932,300
Iron Duchess	
In-pit	483,900
Ex-pit divertible in-pit	482,500
Ex-pit trapped	incl. with Iron Duke
Ex-pit offsite	incl. with Iron Duke
Sub-total	966,400

A total undisturbed catchment area of approximately 2.5 km^2 (0.69 km^2 at Iron Chieftain, 1.29 km^2 at Iron Knight and 0.55 km^2 at Iron Duke/Duchess) has been identified as requiring closure preparations such diversion channels, culverts, rock-armoured outlets to address catchment areas that are 'trapped' by current infrastructure:

- Iron Chieftain – catchment areas 'trapped' by the Chieftain haul road
- Iron Knight – multiple catchment areas 'trapped' primarily by the Knight haul road and KD14 WRD area
- Iron Duke/Duchess – natural valley sides along both edges of the DU18 WRD.

Opportunities have also been identified to contour some ex-pit disturbed areas to maximise the volumes of runoff that will report to the various pit voids at closure.

8.5.2 Pit rainfall capture

As part of the hydrology assessment the capacity of the pits post closure to contain runoff from a 1-in-100-year rainfall event (based on a local rainfall figure of 130 mm over a period of 72 hours) was assessed (Mining Plus 2014b).

Consideration was taken into account of natural landforms, WRDs and any man made features that could direct water to the pits. A runoff coefficient was considered for landforms and the pits (0.80 and 0.95 respectively). Volumes of surface runoff from surrounding landforms and running directly off pit walls were conservatively (+15%) considered. Figure 116 and Figure 117 show the typical catchment areas for the Iron Chieftain and Iron Duke/Magnet pits.

Table 96 shows that the pit areas have ample holding capacity to cope with such a large rainfall event, both in terms of the percentage of pit area consumed by water, and the RL of water within the pit.

Table 96 Percentage of pit holding water following a 1-in-100-year rainfall event of 130 mm

Pit	Water in the pit (%)	RL of water in the pit
Chieftain	3.81	188
Knight North	1.02	148
Knight South	2.47	204
Duke/Magnet	0.50	20
Duchess North	6.54	172
Duchess South	2.69	252

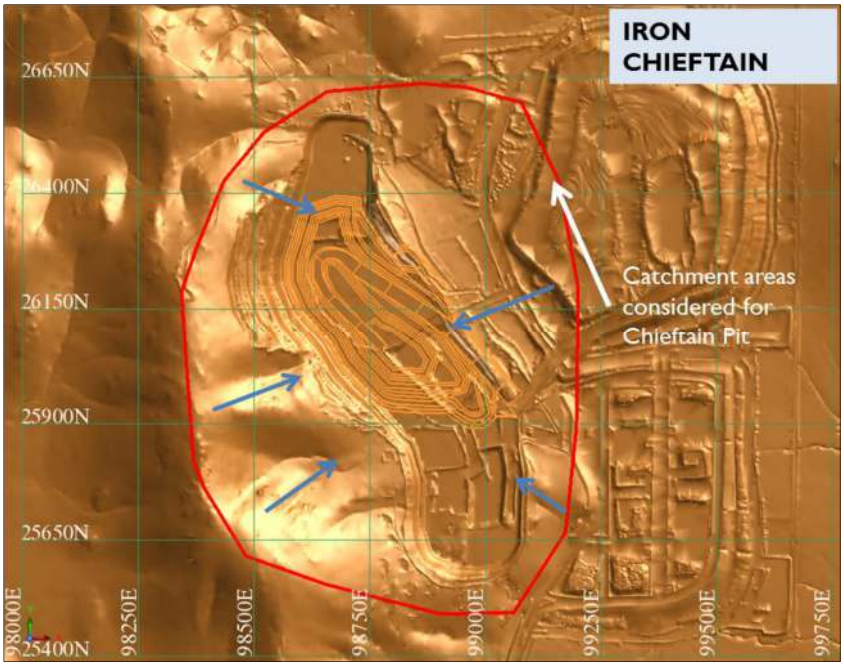


Figure 116 Typical catchment area for Chieftain pit

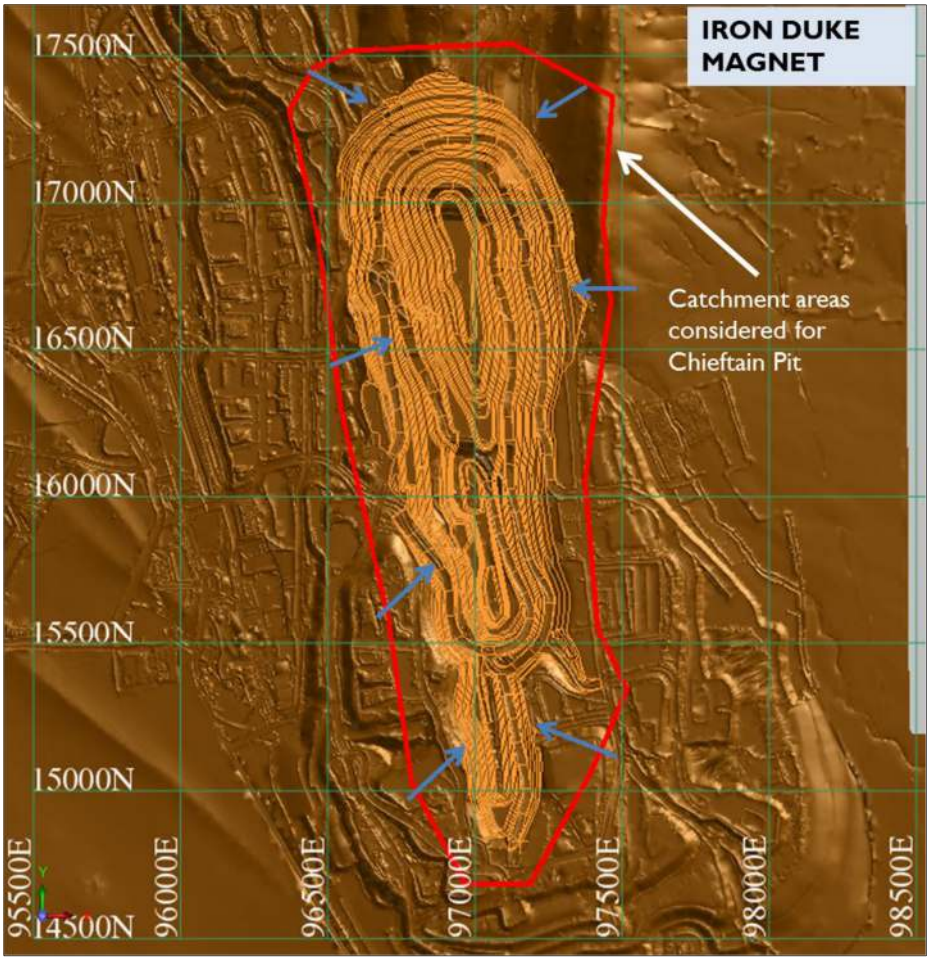


Figure 117 Typical catchment area for Duke/Magnet pit

The final profile sections provided in Section 8.3 show the potential pit water levels as calculated in the hydrology review.

8.5.3 Surface water management strategies

Surface water management at closure will include consideration of the following:

- construction of diversion channels along both sides of the final DU18 WRD to direct runoff from the undisturbed valley sides off-site towards the south-east (see Figure 118). These channels (in the order of 2 km long) would be cut into the natural hillside immediately above the 'contact' with the WRD top. Given that the upper valley sides are undisturbed, runoff from this catchment will be of high quality and would not be mixed with impacted runoff prior to discharge off site.
- diversion channels, culverts and drive-through flood ways with rock-armoured outlets will be provided to enable 'trapped' areas to drain

- all practical steps will be taken to maximise the draining of disturbed catchment towards the pit voids at closure
- opportunities to optimise WRD rehabilitation practices will be reviewed and considered to enhance the early uptake of vegetation to improve water runoff management, and ensure water that reports off site is not ‘contaminated’ by mining silt and residues.

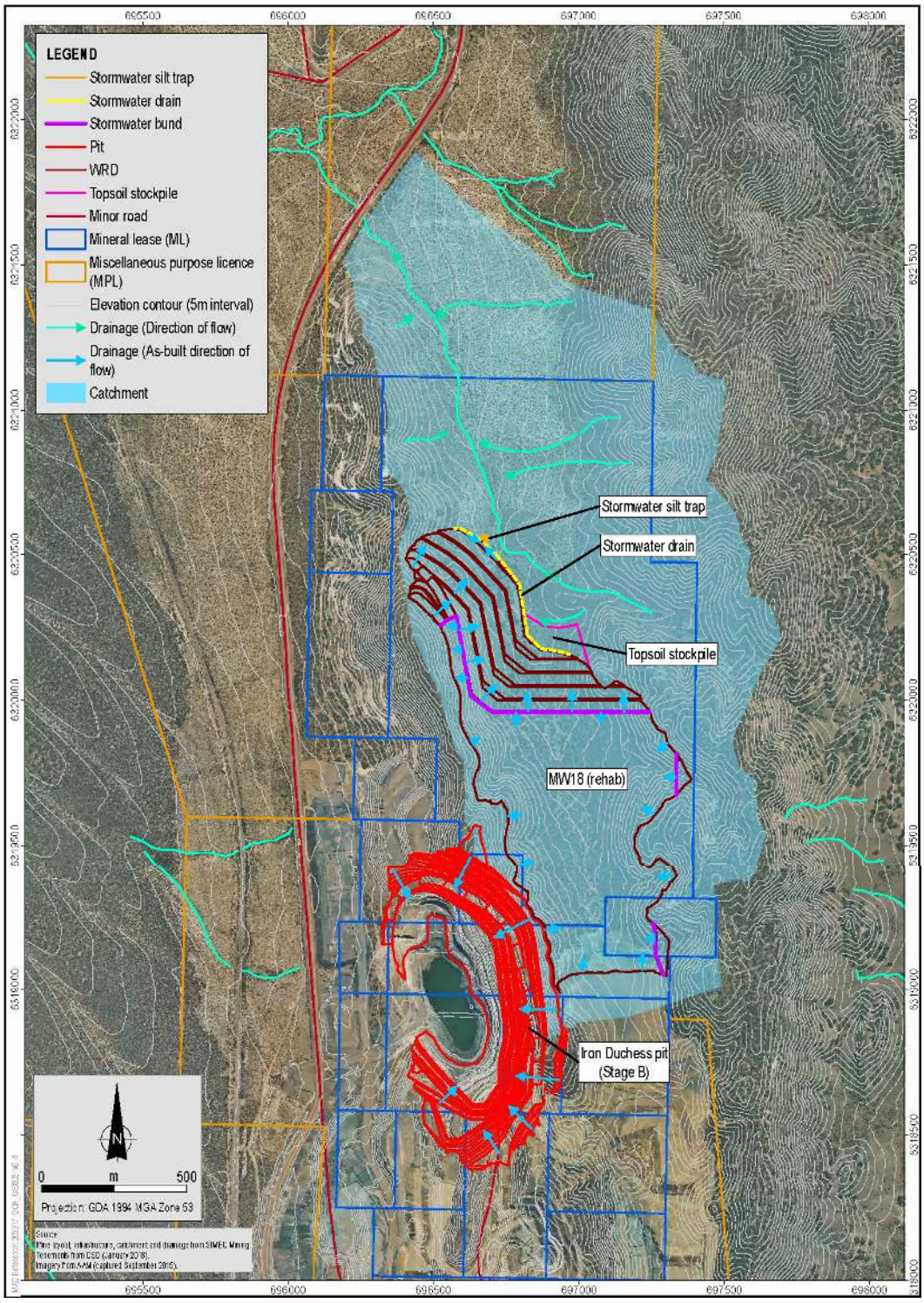


Figure 118 Iron Duchess North surface water drainage channels and silt traps (indicative)

8.6 Post-Closure Monitoring

The post-closure monitoring scope, methodology, programs and costs will be finalised in close liaison with DPC and the community, as the closure period approaches.

An allowance for project management will be included to cover any costs incurred by SIMEC Mining for project staff and any consulting/specialist fees that may arise in order to complete the final stages of rehabilitation of the site. The contingency of 10% is standard industry practice to cover any unforeseen eventualities in completing a project of this magnitude.

SIMEC Mining will make provision for post-closure maintenance of safety signs and fences.

8.7 Post-Closure Land Use

The following land uses may be adopted once SMR rehabilitation and closure has been established:

- pits will generally be useful reference sites for geology students, but otherwise it is expected these sites will be closed to the general public
- the west side will naturally merge with the Ironstone Hill Conservation Park
- the north-east side (Uplands Station) is planned to remain a conservation reserve, and could be formerly converted to a Conservation Park in the future
- the south-east side (Moonabie Station), could return to extensive grazing use once rehabilitation is established.

8.8 Closure Cost Estimate

Cost estimates for closure and rehabilitation of the SMR domains have been derived from a series of separate external and internal cost estimates that have been calculated in depth to cover all of SIMEC Mining's Rehabilitation obligations.

Key consultants that were involved in the detailed assessments included Hatch and Golder Associates Pty. Closure costs were calculated for both the Middleback ranges and SMR TSFs

The rehabilitation and closure cost estimate for the updated SMR Program of Work is set out in Table 97.

An updated closure cost estimate will be provided in the full PEPR update to be completed by 2020.

Table 97 SMR closure cost estimates

Domain	Security deposit cost ($)
Domain 1: Infrastructure areas (SMR)	10,079,133.34
Domain 2: Tailings Emplacements (SMR)	12,520,000.00
Domain 3: Overburden and Waste Dumps (SMR)	10,015,349.08
Domain 4: Active mine and voids (SMR)	1,484,911.83
Domain 5: Other	231,000.00

Domain	Security deposit cost ($)
Duchess B-1 Abandonment bunds	146,608.00
Duchess B-1 WRD	139,130.00
Duchess B-1 Monitoring, Maintenance, Management & Contingency	124,292.00
Contingency (11%)	3,893,132.14
Third Party Project Management (13%)	4,600,927.14
Total security deposit for the mining project (excl. of GST)	**43,234,483.53**

Notes: Costing done using NSW- Resources and Energy: ESB26: DPI-MR Rehabilitation Cost Calculation Tool.

All waste dumps footprints, waste dump face lengths and perimeters of open pits were measured in Surpac based on September 2013 RGFs and current WRD and pit designs dated Feb/March 2014.

Infrastructure domain from Hatch report (Hatch 2016).

Tails dam domain from Golder report (Golder 2015b).

Explosives storage domain from previous MP work (2012).

Duchess B-1 Government of SA Mine Rehabilitation Liability Calculator Tool

9 OPERATOR CAPABILITY

SIMEC Mining's AS/NZS ISO 14001:2004 certified Environmental Management System (EMS) provides a framework of procedures, such as quality procedures (QP) and work instructions (WI), and processes to consistently undertake operations whilst ensuring continuous improvement and compliance against legal and other requirements.

9.1 Environmental Management System

SIMEC Mining's EMS covers both the OneSteel Whyalla Steelworks and SIMEC Mining's operations (including the Whyalla Port, the Whyalla Pelletising Plant and the Ardrossan Dolomite Quarry).

The EMS was first certified to AS/NZS ISO 14001:2004 standards in November 2001. Audits occur annually by third party accredited auditors. As part of SIMEC Mining's internal audit program, trained and qualified SIMEC Mining personnel also conduct more frequent audits. A triennial re-certification audit was conducted in September 2013 without a single non-conformance finding. Recertification was granted in November 2013 for a further three years.

Maintenance of an EMS certified to AS/NZS ISO 14001 standard requires SIMEC Mining's management systems to demonstrate and provide assurance that safeguards for the environment are put in place and consistent with the standard and ensure compliance with legal and other requirements, including those associated with tenement conditions, PEPR outcomes and measurement criteria.

SIMEC Mining ensures that regulatory approval has been obtained before starting mining activities and that regulatory requirements are met for the life of the operation. SIMEC Mining's contractors operating mining and construction sites adhere to all approved PEPR conditions and operational licenses as part of the commercial contract agreements.

The principal mining contractor and all domiciled contractors are contractually required to maintain an EMS compliant with the AS/NZS ISO 14001:2004 standard and to implement an Environmental Management Plan (EMP), approved by SIMEC Mining. These EMPs must consider relevant tenement conditions and PEPR outcomes and measurement criteria, in accordance with QP 41.05 SIMEC Whyalla Mine Development and Operational PEPR Compliance Management Plan (CMP).

9.2 Compliance to Mining Regulations 2011

This section deals with the requirements of Regulation 89 pertaining to Mining Regulations 2011 under the *Mining Act 1971:*

Operational policies

Operational policies that address the achievement of regulatory requirements and environmental outcomes under the Mining Act are embedded in the SIMEC Mining corporate environment policy, which sets the foundation for all environmental objectives and subsequent strategic planning. The policy includes, as a minimum, the overarching objectives to:

- comply with all laws, regulations and standards
- set environmental objectives
- measure, monitor and continually improve environmental performance
- use resources (land, water, energy) efficiently
- control and manage risks
- educate and communicate with the workforce, the community and stakeholders.

Achieving compliance to environmental outcomes

Compliance with legislation and approved PEPR outcomes is achieved at site level by ensuring EMPs are developed and implemented in accordance with QP 41.05, and aligning them with PEPR approvals, and all other regulatory requirements. Site EMPs therefore capture all PEPR outcomes and measurement criteria and assign controls, implementation, monitoring, measurement and reporting responsibilities to operational and/or management positions for that particular site. Specific responsibilities are documented in the responsible person's position description.

QPs are developed to manage issues that are deemed to be of 'critical control' such as dust, topsoil, hazardous materials storage and spills response and vegetation clearance.

The principal mining contractor is also required to develop a site EMP supported by procedures. These procedures must align with the SIMEC Mining procedures as a minimum standard. The SIMEC Mining QP must be complied with in the absence of contractor procedures.

The principal mining contractor's EMP must be approved by SIMEC Mining and is subject to compliance auditing by SIMEC Mining.

Operations risk management system

SIMEC Mining maintains a comprehensive aspects and impacts Risk Register for every operational activity. The Risk Register rates inherent and residual risks, and lists controls, legal and other requirements.

The principal mining contractor must also maintain an aspects and impacts Risk Register as part of their ISO 14001 certified EMS.

Systems to monitor, evaluate and audit

All SIMEC Mining operations and domiciled contracting firms are audited internally by the SIMEC Mining Environment Assurance Department for compliance to the AS/NZS ISO 14001 EMS standard and for compliance to all PEPR commitments, licences, works approvals, current legislation and

SIMEC Mining's internal standards in accordance with its internal auditing schedule. External accredited auditors review the internal audit schedule, the results of internal audits and the closing out of any issues raised during internal audits.

Systems to identify and report non-compliances

SIMEC Mining maintains an environmental incident reporting system. The definitions of an environmental incident are documented in QP29_06 (incident reporting and investigation).

Once entered into the reporting system, key personnel are automatically alerted and provided with a report detailing the incident. The Manager Environment and Sustainability and the Mines Environment Assurance Manager review the reports and decide if any non-compliance issues have occurred and if the incident needs to be reported to an authority.

Compliance Reports for the SMR mining area are submitted to DSD annually. With approval of this PEPR, a single report will be provided commencing the 2014 reporting year (due 2015). Previously, compliance reporting has been done as two separate reports for S-SMR and N-SMR.

9.3 PEPR Compliance Management Plan

The SIMEC Mining QP 41.05, SIMEC Whyalla Mine Development and Operational PEPR Compliance Management Plan (CMP) applies to all mining activities approved by DSD, and contractors operating for, or on behalf of, SIMEC Mining's development and operational sites in the Middleback Ranges.

The purpose of the CMP is to provide the framework and guidance to employees and contractors in relation to documents, procedures, processes and activities, which are to be adopted and implemented to achieve compliance with approved PEPRs. The CMP is reviewed annually or as a new outcome, measurement criteria or PEPR is approved.

The CMP outlines the specific outcomes, management strategies and monitoring and measurement criteria required to ensure compliance with approved PEPRs. The CMP also identifies the primary and support responsible person/s lists, the relevant QPs and/or work instructions (WIs), and monitoring requirements for:

- general project management
- flora
- fauna
- weeds and pests
- soil
- stormwater
- groundwater
- air quality
- visual amenity, nuisance noise/vibration/light

- waste
- public safety and traffic
- third party property damage
- cultural heritage
- closure and rehabilitation.

The CMP also provides:

- measurement criteria, and associated target values, lead indicators, monitoring frequency and reporting responsibility, frequency of reporting and report distribution requirements
- requirements associated with SIMEC Mining's AS/NZS ISO 14001:2004 EMS, which must be incorporated into EMPs for:
  - environmental governance
  - environmental training, awareness and competence
  - audits and inspections
  - emergency preparedness, incidents and response
  - monitoring, measurement and evaluation
  - management review
  - documentation and records.

9.4 PEPR Development and Change Management

9.4.1 PEPR development

The flow diagram provided in Figure 119 provides an overview of the inputs into the development and lodgement of the PEPR by SIMEC Mining and the process that leads up to its approval by DSD. Although it is intended that the PEPR incorporates provisions for all planned activities in a particular mining area, from time to time minor variations to these activities do occur.

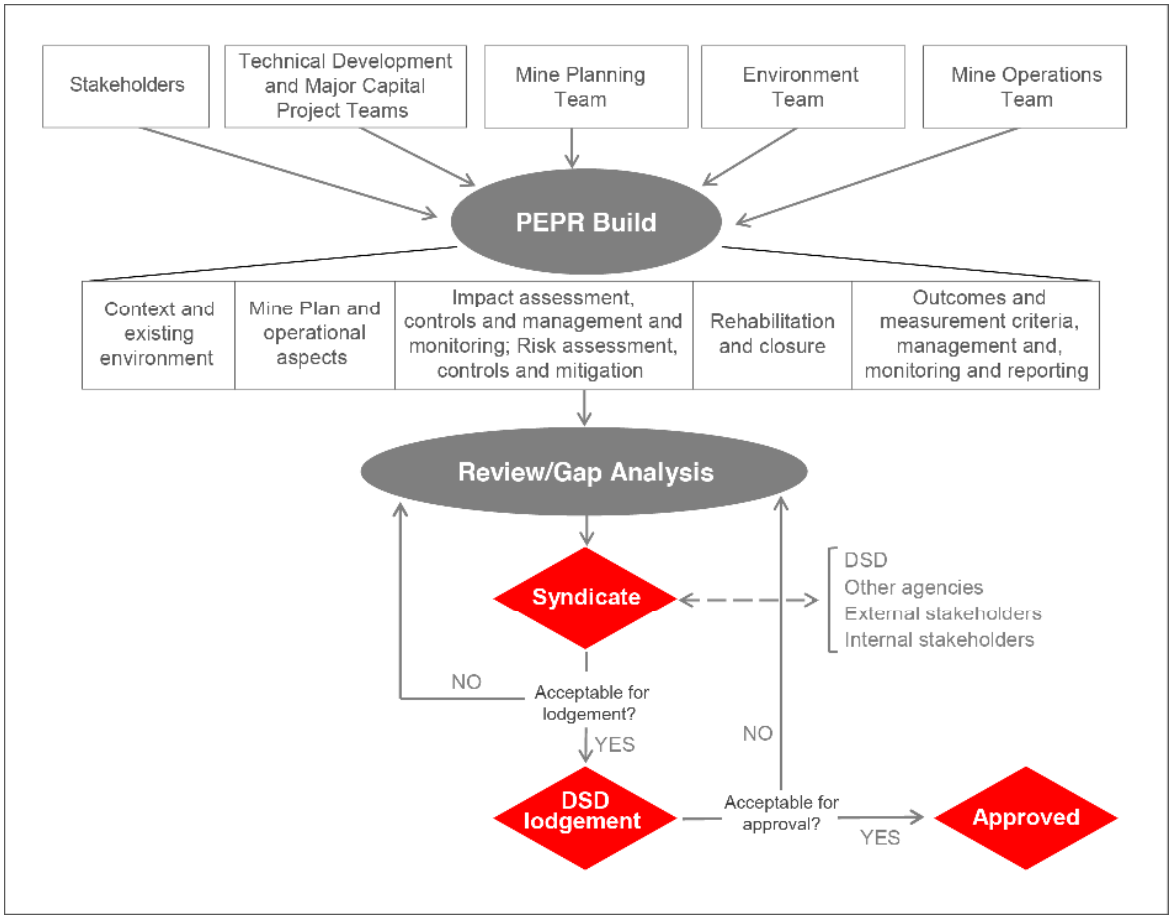


Figure 119 PEPR development process

9.4.2 Changes to existing and planned activities

Where a change to existing or planned operations or circumstances is required, SIMEC Mining will undertake assessment of the proposed change and determine if the change is in or out of the scope of the approved PEPR or the originally granted lease (in accordance with Appendix 2, Assessment of changes to existing operations, Mineral Regulatory Guidelines MG3, V 3.0, January 2014).

A change is considered significant (Level 1, 2 or 3) if it:

- is significantly outside the scope of that originally assessed when the lease was granted
- impacts the lease or licence conditions
- results in any additional risks or increase in the existing risk profile
- requires any modification to the approved outcomes or measurement criteria.

Significance Level 1 change (Tenement review)

For a PEPR review that requires a change which is not within scope of the existing lease or licence conditions, such as a new or significant increase in risk level, or is outside of the scope of proposed operations that was assessed as part of the original tenement grant, requires submission of a mining proposal, including proposed changes to existing lease or licence conditions which results in a new round of public consultation. Confirmation of whether the bond, required under the *Mining Act 1971,* needs to be recalculated for the mining area.

Significance Level 2 or 3 change (PEPR review)

A PEPR review, which only requires minor alterations to existing outcomes and/or measurement criteria and is still covered by pre-existing lease conditions, will result in a review and update of the PEPR, incorporating the changes, for submission to DSD for approval.

Significance Level 4 change (minor change)

SIMEC Mining will notify DSD of proposed operational changes that have been justified as within scope of the existing PEPR. The notification will include a description of the change and confirmation that the change will not contravene lease or licence conditions, increase environmental risks or require any modification to approved outcomes or measurement criteria.

A notification will be submitted to DSD with the following components:

- demonstration that the proposed change is within the scope of the original circulated mining proposal document
- the lease/licence condition(s) that apply to the proposed change
- the outcome(s) that apply to the proposed change
- the current risk rating for the related outcome(s) and a statement describing any increase in the existing risk profile
- the measurement criterion that applies to the proposed change
- the minor change to the operation that can be conducted within approved measurement criteria
- any supporting information or update of information already presented to DSD.

9.5 Communication of the Approved PEPR

Information, strategies, plans and commitments contained within the PEPR are familiar to the SIMEC Mining team/s that contribute to developing the PEPR for submission to DSD for assessment and ultimate approval (see Figure 119). The same SIMEC Mining team/s are also involved in the identification, review and assessment of planned activities that may vary from those presented in the approved PEPR, and in the subsequent impact and risk assessments for the preparation of Minor Change Notifications for submission to DSD (see Section 9.4).

Communication of the approved PEPR, and any subsequent changes or updates within SIMEC Mining and across the operations, involves all levels of the workforce – both employed and contracted. Communications occur in the form of:

- special presentations and workshops
- via the procurement process as contracts include relevant requirements of the PEPR
- operational communications such as toolbox meetings, regulator notices (emailed, pinned on noticeboards), monthly management and lead team reporting, and contractor performance and project progress meetings
- SIMEC Mining's EMS and associated operational procedures (see Section 9.1) and specifically via the implementation of QP41.05, ensuring outcomes and management criteria are met operationally (see Section 9.3).

The current approved PEPR is maintained electronically at SIMEC Mining and a hardcopy is available and kept on-site at the mining operation.

10 LEASE / LICENCE CONDITIONS

Table 98 provides the conditions that apply to SIMEC Mining's SMR MLs and MPLs and the relevant section of the SMR PEPR where these conditions are addressed.

Table 98 Mining Lease conditions

Lease condition	PEPR reference
MPL 2652, ML2648–ML2651, ML2653–ML2654, ML2656–ML2659, ML 2668–ML2669, ML2677, ML2682–ML2683, ML2701, ML2704–ML2712, ML2714–ML2716, ML2718–ML2720	
1. The Lessee will during the said term pay or cause to be paid to the Minister of Mines (hereinafter referred to as 'the Minister") at the office of the Department of Mines in the City of Adelaide on behalf of the Governor the rent and other sum hereby reserved at the times and in the manner hereinbefore appointed for payment thereof free and clear of all rates taxes impositions outgoings and deductions whatsoever.	Acknowledged: however not specifically addressed in this PEPR
2. That the Lessee will pay and discharge all rates taxes assessments impositions and outgoings which during the said term shall become payable in respect of the said land and premises.	Acknowledged: however not specifically addressed in this PEPR
3. That the lessee will maintain in position during the said term the posts and trenches or piles of stone required by the said regulations to be erected or put on the said land when the same was pegged out as a claim and in addition thereto will paint legibly on such posts the number of this lease.	Acknowledged: however not specifically addressed in this PEPR
4. That the lessee will during the said term make construct and work all mines and so and perform all things authorised by this lease in a fair orderly, skilful and workmanlike manner.	Acknowledged: however not specifically addressed in this PEPR
5. That the lessee will during the said term employ and keep constantly employed not less than one man for every ten acres of portion of ten acres except as provided by Regulation No. 125 in mining or prospecting for all metals and mineral except gold in or upon the said land and will whenever thereunto requires by the Minister furnish him with satisfactory evidence that such number of men have been and are so employed due allowance being made by the Minister for machinery or horses employed at the rate of two men for each horse or horsepower of machinery.	Acknowledged: however not specifically addressed in this PEPR
6. The Lessee will make such provision for the disposal of silt sludge dirt waste or refuse which may be brought out by the said mines and premises so that the same will not flow or find its way into any stream brook river or water channel or so as to injure or interfere with any land set apart for water supply purposes.	Section 6.5
7. That the lessee will build and keep in proper repair a sufficient and substantial stone wall or other fence around all the pits and shafts which may at any time during the said term be open in any part of the said land and premises for the purpose of this lease so as effectually to prevent all access thereto by all kinds of cattle.	Section 8
8. That the lessee will whenever lawfully required do to so at the lessee's own cost and in manner required by any regulations for the time being in force in that behalf cause to be made a survey of the said land and cause to be forwarded to the said Department of Mines a map or plan of such survey.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
9. That the lessee will at all times during the said term keep and preserve the said mines and premises in good order repair and condition and in such good order repair and condition at the end or other sooner determination of the said term deliver peaceable possession thereof and of all and singular the premises hereby leased unto the Governor or the Minister or to some officer authorised by him or them to receive possession thereof.	Acknowledged: however not specifically addressed in this PEPR
10. (a) That the lessee will half-yearly in the months of January and July furnish to the Warden of the mining district in which the said land is situated a full and true return showing in respect of the preceding half-year the quantity of stone or ore treated the quantity of metals and mineral taken from the said land and the working expenses incurred in and the gross proceeds and net profits received from the occupation and working of the said land and the sale of all metals and minerals.	Acknowledged: however not specifically addressed in this PEPR
11. That the lessee will permit the pastoral lessee (if any) of the said land at all times to have free access and user for domestic purposes and for the purposes of watering stock to and of any surface water on the said land which shall not have been provided or stored by artificial means by the lessee.	Acknowledged: however not specifically addressed in this PEPR
12. That the lessee will report to a Warden when payable gold is struck or metals precious stones minerals coal shale oil salt or gypsum are found in payable quantities in or upon the said land.	Acknowledged: however not specifically addressed in this PEPR
13. The lessee will not during the continuance of the said term without the written consent of the Minister first had and obtained use or occupy or permit to be used or occupied the said land and premises other than for the purpose of exercising the rights and liberties hereinbefore granted.	Acknowledged: however not specifically addressed in this PEPR
14. The lessee will not prevent any person who holds a right privilege or authority under the said Acts and regulations or any amendment thereof from exercising the same.	Acknowledged: however not specifically addressed in this PEPR
15. The lessee will not during the said term transfer assign sublet or otherwise dispose of or part with the possession of or mortgage charge or encumber the said land and premises or any part thereof or do not permit to suffer to be done any act matter or thing whereby the said land and premises or any part thereof shall or may be transferred assigned sublet or otherwise disposed of or the possession thereof parted with or mortgaged charged or encumbered to any person or persons for the whole or any part of the said term without the consent in writing of the Minister first hand and obtained for every such purpose.	Acknowledged: however not specifically addressed in this PEPR
16. It shall be lawful for the Governor or the Minister or any person authorised by him or them at all proper and reasonable times during the said term without any interruption from the lessee or the lessee's agents servants or workmen to enter into and upon the said land and premises and into and upon any mines or works that may be found therein to view and examine the condition thereof and whether the same be worked in a proper skilful and workmanlike manner and for such purpose to make use of any of the railroad or other roads or ways machinery and work belonging to the said mines and premises and to examine and take extracts from all books accounts vouchers and documents relating thereto	Acknowledged: however not specifically addressed in this PEPR
17. That so far as applicable the provisions of the said Acts and all regulations made thereunder or any amendment of the said Acts are embodied and incorporated herein and the lessee hereby covenants to observe fulfil and perform the same.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
18. The lessee shall on due performance and observance of the covenants conditions and provisos herein contained be entitled to a renewal from time to time of this lease for any period at each renewal not exceeding twenty one years from the expiration of this lease or any renewal thereof at the rent for the time being chargeable by law in respect of leases of the same class as this lease and shall be subject to the covenants conditions and provisions prescribed by any Act or regulations for the time being in force relating to leases of the same class as this lease.	Acknowledged: however not specifically addressed in this PEPR
19. If the said rent be not paid on or before the day hereinbefore appointed for payment thereof a penalty of five pounds per centum shall be added to the said rent and if the said rent and penalty not be paid within one calendar month after the said day a further penalty of ten pounds per centum shall be added and if the said rent and penalties be not paid within one calendar month after the said first month the same shall be recoverable by the Minister by action in any court or competent jurisdiction.	Acknowledged: however not specifically addressed in this PEPR
20. If the lessee shall during the said term commit any breach of or shall fail to comply with any covenant condition or proviso herein contained this lease shall be liable to forfeiture in manner hereinafter provided.	Acknowledged: however not specifically addressed in this PEPR
21. If the said rent shall be in arrear and unpaid for more than three calendar months after the day at which the same is payable under this lease it shall be lawful for the Governor to cancel this lease and the Minister may thereupon insert a notice in the *Government Gazette* declaring this lease to be forfeited.	Acknowledged: however not specifically addressed in this PEPR
22. If the Minister has reason to believe that there has been a breach of or non-compliance with any of the covenants conditions or provisos herein contained other than a breach of the covenant for payment of the said rent or non-compliance with the labour conditions of this lease, the Minister shall give written notice to the lessee specifying the covenants conditions or provisos which he has reason to believe are not being complied with and notifying the lessee that this lease will be liable to forfeiture at the expiration of one month from the date of such notice unless in the meantime such covenants condition or provisos are duly complies with and if at the expiration of such notice such covenants conditions or provisos are still not being complied with by the lessee the Governor may cancel this lease notwithstanding that the rent payable under this lease for the period during which such breach is committed may have been paid and notwithstanding any implied waiver of such breach by the Governor and the Minister shall thereupon insert a notice in the *Government Gazette* declaring this lease to be forfeited. In case of a breach of the covenant for payment of the said rent or the non-compliance with the said labour conditions the Governor may exercise the power of cancellation without giving the written notice hereinbefore mentioned.	Acknowledged: however not specifically addressed in this PEPR
23. A notice of forfeiture as hereinbefore mentioned in the last two preceding provisos so published in the *Government Gazette* shall be taken to be conclusive evidence that this lease has been legally cancelled and forfeited.	Acknowledged: however not specifically addressed in this PEPR
24. In case this lease shall become liable to forfeiture the Minister may (except as to any case coming under the operation of section 70 of the said Acts) extend the period during which the lessee may perform the covenants conditions and provisos of this lease for such time and subject to such terms and conditions as the Minister may think fit and the terms and conditions so imposed by the Minister shall bind the lessee and all transferees mortgagees assignees and other persons claiming through or under him and this lease shall thereafter be constructed as if the said terms and conditions were inserted therein.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
25. The lessee shall be at liberty to surrender this lease by giving to the Minister three calendar months' notice in writing of the lessee's desire or intention so to do and upon payment of all arrears or rent up to the date or surrender.	Acknowledged: however not specifically addressed in this PEPR
26. The lessee shall be at liberty to remove from the said land at any time within- (a) three months of the date of forfeiture or surrender of this lease any plant machinery engines or tools (b) six months from the date of forfeiture or surrender of this lease any ore or other substance mined by virtue of this lease and stacked upon the said land But shall not remove or interfere with any timber in any mine upon said land.	Section 8
ML4714–ML4720, ML4722–ML4741, ML4743, ML4744, ML4746, ML4747, ML4761, ML4771–ML4775	
1. The Lessee will during the said term pay or cause to be paid to the Minister of Mines (hereinafter referred to as 'the Minister") at the office of the Department of Mines in the City of Adelaide on behalf of the Governor the rent and further sums hereby reserved at the times and in the manner hereinbefore appointed for payment thereof free and clear of all rates taxes impositions outgoings and deductions whatsoever.	Acknowledged: however not specifically addressed in this PEPR
2. That the Lessee will pay and discharge all rates taxes assessments impositions and outgoings which during the said term shall become payable in respect of the said land.	Acknowledged: however not specifically addressed in this PEPR
3. That the lessee will maintain in position during the said term the posts and trenches or piles of stone required by the said regulations to be erected or cut on the said land when the same was pegged out as a claim and in addition thereto will paint legibly on such posts the number of this lease.	Acknowledged: however not specifically addressed in this PEPR
4. That the lessee will during the said term make construct and work all mines and do and perform all things authorised by this lease in a fair orderly, skilful and workmanlike manner.	Acknowledged: however not specifically addressed in this PEPR
5. The lessee will during the said term employ and keep constantly employed not less than one man for every ten acres in mining or prospecting for all metals and minerals except gold in or upon the said land and will whenever thereunto required by the Minister furnish him with satisfactory evidence that such number of men have been and are so employed, due allowance being made by the Minister for machinery or horses employed at the rate of two men for each horse or horsepower of machinery and provided that if the number of men horsepower and horses employed by the lessee on any one or more of the mineral leases held by the lessee is not less than the total number of men horsepower and horses required to be employed by the lessee on all the mineral leases held by the lessee the lessee shall be deemed to have complied with this covenant.	Acknowledged: however not specifically addressed in this PEPR
6. The Lessee will make such provision for the disposal of silt sludge dirt waste or refuse which may be brought out by the said mines and premises so that the same will not flow or find its way into any stream brook river or water channel or so as to injure or interfere with any land set apart for water supply purposes.	Section 6.5
7. That the lessee will build and keep in proper repair a sufficient and substantial stone wall or other fence around all the pits and shafts which may at any time during the said term be open in any part of the said land and premises for the purpose of this lease so as effectually to prevent all access thereto by all kinds of cattle.	Section 8

Lease condition	PEPR reference
8. That the lessee will whenever lawfully required do to so at the lessee's own cost and in manner required by any regulations for the time being in force in that behalf cause to be made a survey of the said land and cause to be forwarded to the said Department of Mines a map or plan of such survey.	Acknowledged: however not specifically addressed in this PEPR
9. That the lessee will at all times during the said term keep and preserve the said mines in good order repair and condition and in such good order repair and condition at the end or other sooner determination of the said term deliver peaceable possession thereof and of the land hereby leased unto the Governor or the Minister or to some officer authorised by him or them to receive possession thereof.	Acknowledged: however not specifically addressed in this PEPR
10. That the lessee will permit the pastoral lessee (if any) of the said land at all times to have free access and user for domestic purposes and for the purposes of watering stock to and of any surface water on the said land which shall not have been provided or stored by artificial means by the lessee.	Acknowledged: however not specifically addressed in this PEPR
11. That the lessee will report to a Warden when gold precious stones coals shale oil gypsum or other minerals other than iron ore or iron bearing substances are found in payable quantities in or upon the said land.	Acknowledged: however not specifically addressed in this PEPR
12. The lessee will not during the continuance of the said term without the written consent of the Minister first had and obtained use or occupy or permit to be used or occupied the said land and premises other than for the purpose of exercising the rights and liberties hereinbefore granted.	Acknowledged: however not specifically addressed in this PEPR
13. The lessee will not prevent any person who holds a right privilege or authority under the said Acts and regulations or any amendment thereof from exercising the same.	Acknowledged: however not specifically addressed in this PEPR
14. It shall be lawful for the Governor or the Minister or any person authorised by him or them at all proper and reasonable times during the said term without any interruption from the lessee or the lessee's agents servants or workmen to enter into and upon the said land and into and upon any mines or works that may be found therein to view and examine the condition thereof and whether the same be worked in a proper skilful and workmanlike manner and for such purpose to make use of any of the railroad or other roads or ways machinery and work belonging to the said mines and premises and to examine and take extracts from all books accounts vouchers and documents relating thereto	Acknowledged: however not specifically addressed in this PEPR
15. If the said rent be not paid on or before the day hereinbefore appointed for payment thereof a penalty of five pounds per centum shall be added to the said rent and if the said rent and penalty not be paid within one calendar month after the said day a further penalty of ten pounds per centum shall be added and if the said rent and penalties be not paid within one calendar month after the said first month the same shall be recoverable by the Minister by action in any court or competent jurisdiction.	Acknowledged: however not specifically addressed in this PEPR
16. If the lessee shall during the said term commit any breach of or shall fail to comply with any covenant condition or proviso herein contained this lease shall be liable to forfeiture in manner hereinafter provided.	Acknowledged: however not specifically addressed in this PEPR
17. If the Minister has reason to believe that there has been a breach of or non-compliance with any of the covenants conditions or provisos herein contained the Minister shall give written notice to the lessee specifying the covenants conditions or provisos which he has reason to believe are not being complied with and notifying the lessee that this lease will be liable to forfeiture at the expiration of one month from the date of such notice unless in	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
the meantime such covenants condition or provisos are duly complied with and if at the expiration of such notice such covenants conditions or provisos are still not being complied with by the lessee the Governor may cancel this lease notwithstanding that the rent payable under this lease for the period during which such breach is committed may have been paid and notwithstanding any implied waiver of such breach by the Governor and the Minister shall thereupon insert a notice in the *Government Gazette* declaring this lease to be forfeited..	
18. A notice of forfeiture so published in the *Government Gazette* shall be taken to be conclusive evidence that this lease has been legally cancelled and forfeited.	Acknowledged: however not specifically addressed in this PEPR
19. In case this lease shall become liable to forfeiture the Minister may extend the period during which the lessee may perform the covenants conditions and provisos of this lease for such time and subject during such period of extension to such terms and conditions as the Minister may think fit.	Acknowledged: however not specifically addressed in this PEPR
20. The lessee shall be at liberty to surrender this lease by giving to the Minister three calendar months' notice in writing of the lessee's desire or intention so to do and upon payment of all arrears or rent up to the date or surrender.	Acknowledged: however not specifically addressed in this PEPR
ML6055	
First Schedule	
1. Quarrying operations may be conducted for the recovery of iron ore from the area of the lease.	Acknowledged: however not specifically addressed in this PEPR
2. The lessee must ensure that quarrying operations on the land are carried out in an orderly and skilful manner in accordance with a program for mining and rehabilitation of the land approved, from time to time, by the minister.	Acknowledged: however not specifically addressed in this PEPR
3. The lessee must submit to the Director, from time to time, at the Director's request, a current plan or survey of the land in the form requested by the director.	Acknowledged: however not specifically addressed in this PEPR
4. The lessee shall ensure that land disturbed by quarrying operations is rehabilitated to achieve a regular landform, to minimise erosion, to establish native vegetation indigenous to the area, and return the land to a grazing after use.	Section 8
Second Schedule	
1. The lessee shall ensure that as operations progress to appropriate stages, land disturbed by mining is progressively rehabilitated to facilitate regeneration of native vegetation.	Section 3.7 and Section 8
2. The lessee shall ensure that rare or endangered species of native flora and fauna are identified and a program implemented to ensure their survival and return to the area after operations are complete.	Section 4 and Section 6.2
3. The lessee shall ensure that an Environmental Management Plan is prepared, generally, in accordance with the recommendations of the University of South Australia's Centre for Environmental and Recreational Management report "A Biological Study of BHP Mining Leases in the South Middleback Ranges, SA" June 1997, Clark I. The Environmental Management Plan is to be implemented to the satisfaction of the Chief inspector of Mines.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
4. The lessee shall ensure that all employees and contractors are made aware of the requirements to operate in a manner that will minimise environmental impact.	Acknowledged: however not specifically addressed in this PEPR
5. The lessee shall consult with the landowner and shall ensure the provision of grazing rights and the protection of stock by appropriate fencing or provide other compensation as may be agreed or determined in accordance with section 61 of the Mining Act, 1971.	Section 5 and Section 6.12
6. The lessee shall ensure that waste dumps are contoured in harmony with the local topography and are constructed in a manner to prevent erosion and retain soil moisture in order to facilitate revegetation.	Section 3.7 and Section 8
7. The lessee shall ensure that upon completion of quarrying operations, all plan, equipment, materials and structures are removed from the site and the land is rehabilitated to the satisfaction of the Chief Inspector of Mines.	Section 8
ML6361, 6362	
First Schedule	
1. Mining operations authorised by this Lease must only be for the recovery of Iron Ore.	Acknowledged: however not specifically addressed in this PEPR
2. The Lessee must not commence or undertake any mining operations on the land until a Mining and Rehabilitation Program (MARP) has been approved by the Minister and a bond has been paid in accordance with Section 62 of the *Mining Act 1971.*	Acknowledged: however not specifically addressed in this PEPR
3. The Lessee must prepare a MARP that complies with the requirements of guidelines approved by the Director of Mines and include environmental outcomes and criteria that are developed in consultation with relevant stakeholders.	Section 6
4. The criteria included in the MARP must demonstrate clear and unambiguous achievement of the environmental and mine closure outcomes specified in the Second Schedule by: • Including the specific parameters to be measured and monitored by the Lessee • Specifying the locations that the parameters will be measured, or how these locations will be determined • Clearly stating the acceptable values for demonstrating achievement of the outcome, with consideration of any inherent errors of measurement • Specifying the frequency of monitoring by the Lessee • Identifying what background or control data are to be used or specifying how it will be acquired (if necessary)	Section 6
5. The Lessee must implement and comply with the approved MARP.	Acknowledged: however not specifically addressed in this PEPR
6. The Lessee must review the MARP on request of the Director of Mines within a time specified in the request and submit the revised MARP for approval to the Director of Mines	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
7. The Lessee agrees to the approved MARP being made available for public inspection.	Acknowledged: however not specifically addressed in this PEPR
8. The Lessee must provide information as requested by and to the satisfaction of the Director of Mines, on the Lessee's capability and competence to comply with the requirements of the Mining Act 1971, the conditions of this Lease, and the MARP in accordance with approved guidelines or as otherwise specified by the Director of Mines.	Acknowledged: however not specifically addressed in this PEPR
9. The Lessee must prove to the Director of Mines a Mining and Rehabilitation Compliance Report (MARCR) on operations carries out on the Lease and compliance with the approved MARP. The MARCR must be submitted every year, within 2 months after the anniversary of the date the Lease was granted, or at some other time agreed with the Director of Mines in accordance with guidelines approved by the Director of Mines. The lessee agrees to the MARCR being made available for public inspection.	Section 7
10. The Lessee must if requested by the Director of Mines, undertake an independent audit of achievement of the environmental outcomes in the MARP, by an independent expert approved by the Director of Mines and submit the audit to the Director of Mines. The lessee agrees to the audit being made available for public inspection.	Acknowledged: however not specifically addressed in this PEPR
11. At least 3 months prior to Lease relinquishment or expiry, the Lessee must provide to the Minister a Mine Completion Report prepared in consultation with the landowner and in accordance with guidelines approved by the Director of Mines, which demonstrates achievement of the closure criteria as specified in the current MARP.	Acknowledged: however not specifically addressed in this PEPR
12. The Lessee must prior to commencing operations under this Lease and for the duration of the lease maintain public liability insurance to cover all operations under the Lease (including sudden and accidental pollution) in the name of the Lessee for a sum not less than $20 million or such greater sum as specified by the Director of Mines, and make such amendments to the terms and conditions of the insurance as the Director of Mines may require. A copy of the cover note of certificate of currency for the insurance must be provided to the Director of Mines upon request. If requested by the Director of Mines, the Lessee must engage an independent and reputable risk assessor to prepare a risk assessment report detailing the public liability risks arising out of the conduct of operations on the Lease, and recommending the level of amount of public liability cover (in respect of any one occurrence) that should be effected and maintained by the Lessee. In preparing the risk assessment report, the assessor must consult with the landowner and the Director of Mines. In specifying the level of insurance required, the Director of Mines accepts no liability for the completeness, adequacy of the sum insured the limit of liability, the scoped coverage, the conditions or exclusions of the insurance in respect of how the Lessee may or may not respond to any loss, damage or liability.	Acknowledged: however not specifically addressed in this PEPR
13. The Lessee must report any non-compliance with these conditions and approved MARP to the Director of Mines. A verbal notification must be provided within 24 hours, after the Lessee becomes aware of the non-compliance. A written report must be provided within 3 calendar days or such time period as approved by the Director of Mines.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
14. In requesting a review of the bond required under the Mining Act 1971 the Minister may request that written quotes from an independent third parted approved by the Minister are obtained by the Lessee for the cost of rehabilitating the site to the requirements specified in the approved MARP. The Lessee must meet all the charges and costs in obtaining and maintaining the Bond.	Acknowledged: however not specifically addressed in this PEPR
Second Schedule	
Visual Amenity 1. The Lessee must in constructing and operating the Lease ensure that contrasting and reflective aspects of waste rock dumps are visually softened to blend in with the surrounding landscape.	Section 6.8 and Section 8
Unauthorised Access 2. The Lessee must in constructing and operating the Lease ensure that there are no public injuries or deaths resulting from unauthorised entry to the site that could have been reasonable prevented.	Section 6.11
Aboriginal and European Heritage 3. The Lessee must in constructing and operating the Lease, ensure that there is no disturbance to Aboriginal or European artefacts or sites of significance unless prior approval under the relevant legislation is obtained.	Section 6.13
Native Fauna 4. The Lessee must in constructing and operating the Lease ensure that there are no net adverse impacts from the site operations (including fire) on native fauna abundance or diversity in the lease area and in adjacent areas.	Section 6.2
Native Vegetation 5. The Lessee must, in constructing and operating the Lease ensure no permanent loss of abundance or diversity on or off the lease to native vegetation through: • clearance • dust/contaminant deposition • fire, or • other damage Unless prior approval under the relevant legislation is obtained.	Section 6.2
Weeds and Pests (feral animals) 6. The Lessee must in constructing and operating the Lease ensure no introduction of new species of weeds, plant pathogens or pests (including feral animals), nor increase in abundance of existing weed or pest species in the area compared to adjoining land. Weeds are defined in this condition as any invasive plant that threatened native vegetation in the local area or any species recognised as invasive in SA.	Section 6.3
Soil 7. The Lessee must in constructing and operating the Lease ensure that the existing soil quality and quantity is maintained.	Section 6.4

Lease condition	PEPR reference
Groundwater and Hydrology 8. The Lessee must in constructing and operating the Lease ensure that there is no adverse impact to the quality and quantity of ground and or surface water caused by mining operations to existing users and water dependent ecosystems.	Section 6.6
Flooding/runoff 9. The Lessee must, in constructing and operating the Lease ensure no water runoff from the Lease results in flooding of adjacent areas, to an extent greater than that that could reasonably be expected to occur prior to mining operations being established on the Lease.	Section 6.5
Waste disposal and hazardous substances 10. The Lessee must, in constructing and operating the Lease ensure that all domestic or industrial waste is disposed of in accordance with relevant legislation.	Section 6.10
Mine Closure 11. The Lessee must demonstrate to the satisfaction of the Director of Mines that the following mine closure outcomes (in so far as they may be affected by mining operations) are expected to be achieved and sustained after mine closure: • Integrate and harmonise final landforms and vegetation with the surrounding landscape. • The risks to the health and safety of the public and fauna are as low as reasonably practical • Where practical, re-establishment of the pre-mining ecosystem and landscape function • The site is physically stable • No compromise of the quality and quantity of ground and or surface water to existing users and water dependent ecosystems • All mine waste materials left onsite are chemically and physically stable • No industrial or domestic waste left onsite • Where practical, pre mining land use is re-established	Section 6.15 and Section 8
Backfilling of voids 12. The Lessee must dispose as much as possible of waste rock into mine voids to the extent it is technically feasible.	Section 8
13. The above environmental outcomes do not derogate from the operation of any other Acts that may be applicable to this operation including (but not limited to): • *Aboriginal Heritage act 1988* • *Environment Protection Act 1993*	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
ML6441	
Description of the Land The Mining tenement is granted over an area of 340.62 hectares and is located approximately 60 km south-west of Whyalla	Section 3, Figure 3
Rental The Tenement Holder shall pay, by way of rental, such sums as may be prescribed and in accordance with section 40 of the Act and regulation 42 of the Regulations	Acknowledged: however not specifically addressed in this PEPR
Compensation The Minister may, at any time, require the Tenement Holder to pay to any person an amount of compensation stipulated by the Minister, to which that person is, in the opinion of the Minister, entitled in consequence of mining operations in pursuance of the rights granted and the obligations imposed by the grant of the Mining Tenement	Acknowledged: however not specifically addressed in this PEPR
Suspension and Cancellation: Stipulation of Process Pursuant to subsection 41(1) of the act, the Minister may suspend or cancel the Mining Tenement if the Tenement Holder contravenes or fails to comply with a term or condition of this Tenement Document or a provision of the Act (which includes the Regulations)	Acknowledged: however not specifically addressed in this PEPR
Environmental outcomes specified pursuant to Regulation 65 of the Regulations The Sixth Schedule of this Tenement Document sets out outcomes contemplated in regulation 65(2) of the Regulations that the Tenement Holder is required to address in any program submitted in accordance with Part 10A of the Act.	Section 6
Restatement of rights conferred on Tenement Holder Restatement of selected provisions from the Act: Explanation of Restatements All of the restatements in this portion of this Tenement Document are included for guidance only and do not replace the substantive provisions of the Act or the Regulations If any restatement is inconsistent with the substantive provisions of the Act or the Regulations, the restatement will be invalid and the substantive provision of the Act of the Regulations will prevail and the Tenement Holder is required to comply with the substantive provision of the Act or the Regulations. The Tenement Holder is still required to comply with any provision of the Act or Regulations that is not restated in this Mineral Lease.	Acknowledged: however not specifically addressed in this PEPR
Restatement of rights conferred on Tenement Holder The grant of the Mining Tenement confers an exclusive right upon the Tenement Holder including officers, employee(s), contractor(s) or duly authorized agent(s) of the Tenement Holder, to conduct mining operations on the Land, for the Mineral(s), subject to the provisions of the act and the Regulations, and the terms and conditions of this Tenement Document.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
The grant of the Mining Tenement authorizes the Tenement Holder, including officers, employee(s), contractor(s) or duly authorized agent(s) of the Tenement Holder, to sell, or dispose of, the Mineral(s) recovered in the course of mining operations conducted in pursuance of the grant or to utilise any such mineral(s) for any commercial or industrial purpose, subject to the payment of a royalty.	Acknowledged: however not specifically addressed in this PEPR
Restatement of rights and powers not conferred on the Tenement Holder The grant of the Mining Tenement does not confer any right on the Tenement Holder: • To use the Land for any purpose other than the authorised mining operations • To confer any rights on any other person in relation to the Mining Tenement	Acknowledged: however not specifically addressed in this PEPR
Restatement of obligations imposed on Tenement Holder: Program for environment protection and rehabilitation The Tenement Holder must not carry out mining operations unless there is an approved program for environment protection and rehabilitation (an APPROVED PEPR).	Acknowledged: however not specifically addressed in this PEPR
A PROPOSED PEPR will only be approved with it complies with the requirements of Part 10A of the Act and the Regulations	Acknowledged: however not specifically addressed in this PEPR
To comply with Part 10A of the Act, the PROPOSED PEPR must: • Contain the information specified in section 70B(2) of the Act and regulation 65(2), (5), (6) of the Regulations and determinations made by the Minister under regulation 65(7) of the Regulations (if any) • Comply with any applicable conditions specified in this Tenement Document (if any) • Address any relevant environmental outcomes listed in the Sixth Schedule of this Tenement Document	Acknowledged: however not specifically addressed in this PEPR
In accordance with regulation 65(10) of the regulations, the Tenement Holder must submit to the Department of State Development for Ministerial approval a PROPOSED PEPR that fully complies with the Act and Regulations within twelve (12) months after the grant of the Mining Tenement unless the Tenement Holder has been granted an extension of time for such submission	Acknowledged: however not specifically addressed in this PEPR
Restatement of obligations imposed on Tenement Holder: Working conditions In accordance with regulation 35 of the Regulations, unless otherwise determined or agreed by the Minister, the Tenement Holder must: • Commence mining operations in accordance with the APPROVED PEPR within twelve months (12) after its approval • Thereafter continue mining operations in accordance with the requirements of the program in the APPROVED PEPR	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
Restatement of obligations imposed on Tenement Holder: Other In addition to obligations about the conduct of mining operations and rehabilitation, the Act and Regulations impose other obligations on the Tenement Holder including obligations to: • Comply with Part 3 of the Act (royalties) • Comply with the applicable provisions of the Part 9 of the Act (entry onto land and use of declared equipment) • Comply with the applicable provisions of Part9B of the Act (native title) • Comply with the provision of section 76 of the Act mining returns) to the extent relevant to a mineral lease • Comply with section 77 of the Act (records and geological samples) and regulation 84 of the Regulations • Comply, as necessary, with section 83 of the Act (ministerial consent for dealings in relation to the Tenement) and regulations 44 and 70 of the Regulations • Comply, insofar as applicable to a mineral lease, with regulation 86 of the Regulations (compliance reports) • Comply with the requirement in regulation 43 of the Regulations to maintain all posts, boundary indicator markers and notices in the positions required by the Regulations as applicable • Permit the pastoral lessee (if any) of the Land to have free access and use at all times for domestic purposes, and for the purposes of water stock from any surface water on the land which shall not have been provided or stored by artificial means by the Tenement Holder	Acknowledged: however not specifically addressed in this PEPR
Restatement of Exempt Land In accordance with section 9 of the Act, the grant of the Mining Tenement does not authorize prospecting, exploring or mining upon any exempt land unless or until the benefit of the exemption is waived under section 9AA.	Acknowledged: however not specifically addressed in this PEPR
Restatement of Bond In accordance with section 62 of the Act, the Minister may be written notice require the Tenement Holder to pay a bond in such sum and subject to such terms and conditions as ensure, in the opinion of the Minister, that the following will be satisfied: Any civil or statutory liability likely to be incurred by the Tenement Holder in the course of carrying out mining operations The present and future obligations of the Tenement Holder in relation to the rehabilitation of land disturbed by mining operations	Acknowledged: however not specifically addressed in this PEPR
Restatement of Fees The Tenement Holder shall pay all fees imposed by the act and Regulations from time to time	Acknowledged: however not specifically addressed in this PEPR
Restatement of Renewal *This Mineral Lease shall be renewed in accordance with the Act*	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
Restatement of Surrender The Tenement Holder may apply to surrender the Mining Tenement during its term in accordance with the Act and Regulations	Acknowledged: however not specifically addressed in this PEPR
Restatement of Forfeiture The Mining Tenement is subject to the forfeiture provisions of the Act being sections 70 and 85	Acknowledged: however not specifically addressed in this PEPR
Restatement of Notices Notices under the Act will be served in accordance with regulation 106 of the Regulations	Acknowledged: however not specifically addressed in this PEPR
Restatement of Mining Register Section 15A of the Act requires the Mining Registrar to keep a register of, amongst other things, mineral leases. Upon payment of the prescribed fee, the public may inspect the Mining Register	Acknowledged: however not specifically addressed in this PEPR
Restatement of Mining Operations As defined by section 6 of the Act "mining operations" means: • Operations carried out in the course of prospecting, exploring or mining for minerals; or • Without limiting paragraph 35.1, any operations by which minerals are recovered from any place or situation, including by recovering minerals from the sea or a natural water supply; or • On-site operations undertaken to make minerals recovered from the site a commercially viable product, other operations involving such minerals, or other operations involving minerals brought on to the site of a mine for processing; or • Operations for the rehabilitation of land on account of the impact of any operations under a preceding paragraph; or • Operations that are directly related to any operations under a preceding paragraph But does not include – • An investigation or survey under section 15 of the Act; or • Fossicking; or • The surface removal of loose rock material disturbed by agricultural operations This definition applies to operations that occur during all phases of the mine's life	Acknowledged: however not specifically addressed in this PEPR
Restatement of Declaration of Insolvency Comply with regulation 98(1)(c), which concerns bankruptcy, insolvency and liquidation	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
FIRST SCHEDULE **Authorised Mining Operations** The grant of the Mining Tenement authorizes mining operations (only) for the recovery of the Hematite Iron Ore on the Lease; and The grant of the Mining Tenement authorizes mining operations (only) that are consistent with the mining operations described in the Mining Lease Proposal document dated 27 June 2014	Acknowledged: however not specifically addressed in this PEPR
SECOND SCHEDULE – ADDITIONAL CONDITIONS	
Transparency The Tenement Holder agrees to the Approved PEPR and any compliance reports and reportable incident reports, submitted in accordance with the Regulations, being made available for public inspection	Acknowledged: however not specifically addressed in this PEPR
Complaints Register The Tenement Holder must establish and maintain a public complaints register. The public complaints register must, as a minimum, record the following detail in relation to each complaint received in which it is alleged that environmental harm (including an environmental nuisance) has been caused by the mining operations: • The time at which the complaint was received • All personal details of the complainant which were provided by the complainant or, if no such details were provided, a note to that effect • The subject matter of the complaint • The action taken by the tenement holder in relation to the complaint, including any follow-up contact with the complainant; and • If no action was taken by the tenement holder, the reasons why no action was taken	Section 5
All records in respect of the public complaints must be maintained for a period of at least 7 years	Acknowledged: however not specifically addressed in this PEPR
The Tenement Holder must make the public complaints register publically available except for the name and contact details of each complainant	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
Other Legislation The Tenement Holder must comply with all State and Commonwealth legislation and regulations applicable to the activities undertaken pursuant to this lease including (but not limited to): • *Aboriginal Heritage Act 1988* • *Environment Protection Act 1993* • *Environment Protection and Biodiversity Conservation Act 1999* • *Development Act 1993* • *Explosives Act 1936* • *Natural Resources Management Act 2004* • *Public and Environmental Health Act 1987* • *Aboriginal Heritage Act 1988* • *Heritage Places Act 1993* • *Work Health and Safety Act 2012* • *Environment Protection Act 1993* • *Native Vegetation Act 1991* • *Mines and Works Inspection Act 1920* • *Road Traffic Act 1961*	Section 6
THIRD SCHEDULE- MAP Map will be provided after lease is entered in the Mining Register	Acknowledged: however not specifically addressed in this PEPR
THIRD SCHEDULE – DESCRIPTION OF AREAS Description will be provided after Lease is entered in the Mining Register	Acknowledged: however not specifically addressed in this PEPR
FOURTH SCHEDULE – PROCESS FOR SUSPENSION **Issuance of Suspension Show Cause Notice** Where the Minister is of the view that there may be grounds to consider whether to suspend the grant of the Mining Tenement, the Minister shall give written notice to the Tenement Holder, which shall: Specify the provision of the Act or the Regulations, or the term or condition of the grant of the Mining Tenement, that the Minister believes the Tenement Holder has contravened or failed to comply with; and Give the Tenement Holder thirty (30) Business Days from the date of the written notice to show cause why the grant of the Mining Tenement should not be suspended (“the Suspension Show Cause Notice”)	Acknowledged: however not specifically addressed in this PEPR
Minister’s action if Tenement Holder does not respond If the Tenement Holder does not respond to the Suspension Show Cause Notice within thirty (3) Business Days, the Minister may suspend the grant of the Mining Tenement without further notice (in accordance with the process outlined below)	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
Minister's action if Tenement Holder does respond If the Tenement Holder responds to the Suspension Show Cause Notice within thirty (30) Business Days, the Minister will consider the Tenement Holder's submission and decide whether to suspend the grant of the Mining Tenement (in accordance with the process outlined below)	Acknowledged: however not specifically addressed in this PEPR
Written Notice of Minister's decision The Minister shall give written notice to the Tenement Holder of the Minister's decision If the decision is to suspend the grant of the Mining Tenement, the written notice shall be called "Notice of Decision: Suspended" If the decision is to not suspend the grant of the Mining Tenement, the written notice shall be called: "Notice of Decision: Not Suspended" A Notice of Decision: Not Suspended, may contain any information that the Minister considers relevant	Acknowledged: however not specifically addressed in this PEPR
A Notice of Decision: Suspended, shall: • Specify the reason for the suspension • Specify the period of suspension • Specify the action (if any) the Tenement Holder may be required to take for the Minister to consider revoking the suspension, and the time frame for taking that action • Inform the Tenement Holder of their right of appeal to the Environment, Resources and Development Court in accordance with subsection 41(3) of the Act	Acknowledged: however not specifically addressed in this PEPR
The Mining Register Notice of Decision: Suspended, shall be placed on the Mining Register	Acknowledged: however not specifically addressed in this PEPR
Minister's action if Tenement Holder takes action as specified in Notice of Decision If the Tenement Holder takes the action specified by the Minister under paragraph 4.4.3, the Minister will consider revoking the suspension	Acknowledged: however not specifically addressed in this PEPR
If the Minister revokes the suspension, the Minister will, within a reasonable time: Write to the Tenement Holder informing the Tenement Holder of the revocation Cause the revocation to be placed on the Mining Register	Acknowledged: however not specifically addressed in this PEPR
Minister's action if the Tenement Holder appeals If the Tenement Holder appeals to the Environment, Resources and Development Court the Minister will consider exercising the discretion under section 41(4) of the Act, to stay the operation of the suspension until the appeal is finally disposed of	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
If the Environment, Resources and Development Court is satisfied that there is no proper ground for the suspension, and so orders, the Minister will: • Cause the Court's order to be placed on the Mining Register; and • Reinstate the grant of the Mining Tenement in accordance with section 41(5) of the Act	Acknowledged: however not specifically addressed in this PEPR
FIFTH SCHEDULE- PROCESS FOR CANCELLATION Issuance of Cancellation Show Cause Notice Where the Minister is of the view that there may be grounds to consider whether to cancel the grant of the Mining Tenement, the Minister shall give written notice to the Tenement Holder, which shall: • Specify the provision of the Act or the Regulations, or the term or condition of the grant of the Mining Tenement, that the Minister believes the Tenement Holder has contravened or failed to comply with; and • Give the Tenement Holder sixty (60) Business Days from the date of written notice to show cause why the grant of the Mining Tenement should not be cancelled ("the Cancellation Show Cause Notice")	Acknowledged: however not specifically addressed in this PEPR
Minister's action if the Tenement Holder does not respond If the Tenement Holder does not respond to the Cancellation Show Cause Notice within sixty (60) Business Days, the Minister may cancel the grant of the Mining Tenement without further notice (in accordance with the process outlined below)	Acknowledged: however not specifically addressed in this PEPR
Minister's action if the Tenement Holder does respond If the Tenement Holder responds to the Cancellation Show Cause Notice within sixty (60) Business Days, the Minister will consider the Tenement Holder's submission and decide whether to cancel the grant of the Mining Tenement (in accordance with the process outlined below)	Acknowledged: however not specifically addressed in this PEPR
Written notice of Minister's decision The Minister shall give written notice to the Tenement Holder of the decision. If the decision is not to cancel the grant of the Mining Tenement, the written notice shall be called "the Notice of Decision: Not Cancelled"	Acknowledged: however not specifically addressed in this PEPR
• If the decision is to cancel the grant of the Mining Tenement, the written notice shall be called "the Notice of Decision: Cancelled" • A Notice of Decision: Not Cancelled may contain any information that the Minister considers relevant	Acknowledged: however not specifically addressed in this PEPR
• A Notice of Decision: Cancelled shall: • Specify the reason for cancellation • Specify the date form which cancellation is effective • Inform the Tenement Holder of their right of appeal tro the Environment, Resources and Development Court in accordance with subsection 41(3) of the Act	Acknowledged: however not specifically addressed in this PEPR
The Mining Register Notice of Decision: Cancelled, shall be placed on the Mining Register	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
Minister's action if Tenement Holder appeals If the Tenement Holder appeals to the Environment, Resources and Development Court the Minister will consider exercising his discretion under section 41(4) of the Act, to stay the operation of the cancellation until the appeal is finally disposed of	Acknowledged: however not specifically addressed in this PEPR
If the Environment, Resources and Development Court is satisfied that there is no proper ground for cancellation, and so orders, the Minister will: • Cause the Court's order to be placed on the Mining Register; and • Reinstate the grant of the Mining Tenement in accordance with section 41(5) of the Act	Acknowledged: however not specifically addressed in this PEPR
SIXTH SCHEDULE- ENVIRONMENTAL OUTCOMES AND ASSOCIATED CRITERIA AND STRATEGIES PURSUANT TO REGULATION 65 OF THE MINING REGULATIONS 2011	
1. Native Vegetation The Tenement Holder must, in constructing and operating the Lease ensure no clearance or damage of native vegetation occurs as a result of mining operations unless prior approval under the relevant legislation is obtained.	Section 6.2
2. Weeds, pests, pathogens The Tenement Holder must, in constructing and operating the Lease ensure no introduction of new species of weeds, plant pathogens or pests (including feral animals), nor sustained increase in abundance of existing weed or pest species in the Lease area compared to adjoining land.	Section 6.3
3. Soil Quality The Tenement Holder must, in constructing and operating the Lease ensure that all available topsoil is removed and managed to ensure adequate reinstatement of pre mining land use at mine closure. *4. Soil (quantity and quality) Protection Strategies* The Tenement Holder is required to address the following matters for the purposes of Regulation 65(2)(c) of the Regulations in relation to Sixth Schedule Clause 3; 4.1 Strategies to achieve recovery of topsoil and subsoil from areas to be disturbed by mining operations. 4.2 Strategies for maintaining the quality and quantity of stockpiled soil/s until such time that it is used for rehabilitation purposes.	Section 6.4
5. Air quality The Tenement Holder must, in constructing and operating the Lease ensure that there are no public health and/or nuisance impacts to local residents from air emissions, dust and odour generated by mining operations. *6. Air quality criteria* The Tenement Holder is required to address the following matters for the purposes of Regulation 65(2)(d) of the Regulations in relation to the outcome in Sixth Schedule Clause 1; 6.1 Measure TDD using monitoring methodology, equipment and instruments that are recognised by a relelvant International or Australain Standard. 6.2 DDD is to be measured using monitoring equipment and instruments that are recognised by a relelvant International or Australain Standard.	Section 6.7

Lease condition	PEPR reference
7. Visual amenity The Tenement Holder must, in constructing and operating the Lease, ensure that the form and contrasting and reflective aspects of waste dumps and pit high walls are visually softened to blend in with the surrounding landscape.	Section 6.8
8. Traffic The Tenement Holder must, in constructing and operating the Lease, ensure that there are no traffic accidents involving the public atmine access points that could have been reasonably prevented by the Tenement Holder.	Section 6.14
9. Adjacent land use The Tenement Holder must, in constructing and operating the Lease, ensure that there are no adverse impacts to adjacent land use.	Section 6.12
10. Aboriginal and European heritage The Tenement Holder must, in constructing and operating the Lease, ensure that there is no disturbance to Aboriginal or European sites, objects or remains unless prior approval under the relevant legislation is obtained.	Section 6.13
11. Mine completion The Tenement Holder must demonstrate to the satisfaction of the Director of Mines that the following mine closure outcomes (in so far as they may be affected by mining operations) are expected to be achieved and sustained after mine closure: 11.1 Integrate and harmonise final landforms and vegetation with the surrounding landscape. 11.2 The risks to the health and safety of the public, native fauna and livestock are as low as reasonably practical. 11.3 Where practical, re-establishment of the pre-mining ecosystem and landscape function. 11.4 The site is physically stable. 11.5 No compromise of the quality and quantity of ground and or surface water to existing users and water dependent ecosystems. 11.6 All mine waste materials left onsite are chemically and physically stable. 11.7 No industrial or commercial waste left onsite. 11.8 Where practical, pre mining land use is re-established.	Section 8
MPL135	
Terms and conditions required by the Act to be specified in the MPL	
Term Commencement and Expiration The Miscellaneous Purposes License (MPL) is granted for the term of seventeen (17) years and 314 days. The Term of this MPL commenced on 1 September 2011, and, unless it is earlier renewed, surrendered or cancelled, this MPL will cease on 11 July 2029.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
Rental The Tenement Holder shall pay, by way of rental, such sums as may be prescribed and in accordance with subsection 52 (6) of the Act and regulation 54 of the Regulations.	Acknowledged: however not specifically addressed in this PEPR
Suspension and Cancellation: Stipulation of Process Pursuant to subsection 56(1) of the Act, the Minister may suspend or cancel this MPL if the Tenement Holder contravenes of fails to comply with a term or condition of this MPL or a provision of the Act (which includes the Regulations). Pursuant to subsection 56(2) of the Act, the Minister may stipulate in the MPL a process for suspension or cancellation that must be followed before the powers in subsection 56(1) may be exercised. (a) The process for suspension of this MPL shall be as stipulated in the Third Schedule of this MPL. The process for cancellation of this MPL shall be as stipulated in the Fourth Schedule of this MPL.	Acknowledged: however not specifically addressed in this PEPR
First Schedule	
1. The MPL is granted for the purpose of a waste rock dump directly related to the mining operation known as (South SMR Mining Area) authorised under mining tenement(s) ML4472, ML2715, ML2653, ML2682, ML2781, ML2729, ML4716, ML4724, ML4739, ML4741, ML4746, ML4774, ML4735, ML4770, ML4723, ML2704, ML2707, ML4719, ML2656, ML2658, ML2663, ML2677, ML4727, ML4734, ML4738, ML4747, ML6167, ML2720, ML4715, ML4717, ML4721, ML2659, ML2683, ML4722, ML4736, ML2706, ML4728, ML4744, ML2651, ML2654, ML2701, ML2710, ML4729, ML4771, ML6055, ML4733, ML4740, ML2717, ML4720, ML2668, ML2652, ML2669, ML2709, ML2711, ML4730, ML4761, ML4775, ML2730, ML2712, ML2650, ML2714, ML4726, ML4732, ML4745, ML4773, ML2708, ML4725, ML2649, ML2657, ML2648, ML4743, ML2705, ML2660, ML4737, ML4742, ML4714, ML2662, ML2716, ML2719, ML4718, ML4731 in accordance with the MPL proposal document dated May 2011 (WPC-060 Rev C).	Section 3.1
2. In accordance with Regulation 86(1)(a) the Licensee must provide a Compliance report every year, within 2 months after the anniversary date the License was granted, or at some other time agreed with the Minister.	Section 7
3. In accordance with Regulation 90(1) the Licensee must, prior to commencing operations under this Licence and for the duration of the Licence maintain public liability insurance to cover all operations under the Licence (including sudden and accidental pollution) in the name of the Licensee for a sum not less than $50 million or such greater sum as specified by the Minister, and make such amendments to the terms and conditions of the insurance as the Minister may require.	Acknowledged: however not specifically addressed in this PEPR
4. In requesting a review of the bond required under the *Mining Act 1971* the Minister may request that written quotes from an independent third party approved by the Minister are obtained by the Licensee for the cost of rehabilitating the site to the requirements specified in the approved Program under Regulation 65(2)	Acknowledged: however not specifically addressed in this PEPR
5. The Licensee must meet all the charged and costs in obtaining and maintaining the bond.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
Second Schedule- Environmental Outcomes	
Visual Amenity 1. The Licensee must, in constructing and operating the Licence ensure that the form and contrasting and reflective aspects of waste rock dumps are visually softened to blend in with surrounding landscape.	Section 6.8
Unauthorised Access 2. The Licensee must, in constructing and operating the Licence ensure that there are no public injuries and or deaths resulting from unauthorised entry to the site that could have been reasonable prevented.	Section 6.11
Adjacent land use 3. The Licensee must, in constructing and operating the Licence, ensure that there are no adverse impacts to the adjacent land use.	Section 6.12
Protection of third party property 4. The Licensee must, in constructing and operating the Licence, ensure that there is no unauthorised damage (including that caused by fire) to adjacent public or private property and infrastructure.	Section 6.12
Aboriginal and European Heritage 5. The Licensee must, in constructing and operating the Licence, ensure that there is no disturbance to Aboriginal or European artefacts or site of significance unless prior approval under the relevant legislation is obtained.	Section 6.13
Native Vegetation 6. The Licensee must, in constructing and operating the Licence ensure no loss of abundance or diversity of native vegetation on or off the Licence through: a. clearance b. dust/contaminant deposition c. fire, or d. other damage Unless prior approval under the relevant legislation is obtained.	Section 6.2
Weeds and Pests (feral animals) 7. The Licensee must, in constructing and operating the Licence ensure no introduction of new species of weeds, plant pathogens or pests (including feral animals), nor sustained increase in abundance of existing weed or pest species in the Licence area compared to adjoining land. *Weeds are defined in this condition as any invasive plan that threatens native vegetation in the local area or any species recognised as invasive in South Australia*	Section 6.3
Soil 8. The Licensee must, in constructing and operating the Licence, ensure that the existing soil quality and quantity is maintained.	Section 6.4
Stormwater 9. The Licensee must, in constructing and operating the Licence ensure no water contaminated as a result of mining operations leaves the Licence area or results in loss of or contamination of soil on or off the Licence.	Section 6.5

Lease condition	PEPR reference
Acid Mine Drainage (AMD) 10. The Licensee must, in constructing and operating the Licence ensure that no contamination of natural water drainage systems, stream and rivers, groundwater, land and soils occurs either on or off site resulting from permanent disposal or temporary storage of mine or waste material.	Section 6.5 and Section 6.6
Mine Closure 11. The Licensee must demonstrate to the satisfaction of the Director of Mines that the following mine closure outcomes (in so far as they may be affected by mining operations) are expected to be achieved and sustained after mine closure: • Integrate and harmonise final landforms and vegetation with the surrounding landscape. • The risks to the health and safety of the public and fauna are as low as reasonably practical. • Where practical, re-establishment of the pre-mining ecosystem and landscape function. • The site is physically stable. • No compromise of the quality and quantity of ground and or surface water to existing users and water dependent ecosystems. • All mine waste minerals left onsite are chemically and physically stable. • No industrial or domestic waste left onsite.	Section 6.15 and Section 8
Second Schedule- Other Environmental Conditions	
Public Complaints 12. The Licensee will be responsible for recording and addressing in manner and form (to the satisfaction of the Director of Mines) any complaints received from the public.	Section 5
Landholder Liaison 13. The Licensee must ensure that the occupier of the land is fully advised of their program of activities, particularly in regard to the impact of operations on the land and rehabilitation progress.	Section 5
Progressive Rehabilitation 14. The Licensee must undertake rehabilitation of mining operations in accordance with an integrated mining and rehabilitation plan as approved in the PEPR.	Section 3.7 and Section 8
Other Legislation 15. The above environmental outcomes do not derogate from the operation of any other Acts that may be applicable to this operation including (but not limited to): • *Aboriginal Heritage Act 1988* • *Environmental Protection Act 1993*	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
MLP67	
First Schedule	
1. This authorisation is subject to and does not derogate from the need to comply with any other relevant Commonwealth or State statutory legislation.	Acknowledged: however not specifically addressed in this PEPR
2. The licensee shall ensure that low-grade Beneficiation Plant and Tailings Storage Facility operations on the land are carried out in an orderly and skilful manner in accordance with a program for the plant construction, operation and rehabilitation of the land, approved, from time to time, by the Minister which shall incorporate the proposal as generally outlined within: a. *Mining Program Submission South Middleback Ranges (Iron Duke/Iron Duchess/Iron Knight August 2003 and amendments;* and b. Native Vegetation Councils requirements for land clearance.	Section 3.9, Section 4 and Section 8
3. The lessee must submit to the Director, from time to time, at the Director's request, a current plan or survey of the land in the form requested by the Director.	Acknowledged: however not specifically addressed in this PEPR
Second Schedule	
1. The licensee shall lodge a Rehabilitation Bond before constructing and processing operations commence, to ensure land disturbed by construction and Tailings Storage Facility activities and the low-grade Beneficiation Plant will be rehabilitated, vegetation established and infrastructure removed to the satisfaction of the Minister.	Acknowledged: however not specifically addressed in this PEPR
2. The licensee shall ensure that all activities on the land are designed, constructed and operated in a manner to minimise the footprint of disturbance associated with such activities.	Section 3.7
3. The licensee shall manage stormwater run-off from the land in a manner to minimise erosion of the land and to minimise interference with the natural drainage patterns of the land.	Section 6.5
4. The licensee shall ensure that as part of the site preparation prior to construction and advancing waste dumps, all available topsoils shall be stripped from the land to be occupied. The soil is to be stockpiled for later use in the rehabilitation of land disturbed by ancillary activities, or may be utilized to temporarily landscape the site.	Section 3.8.11 and Section 8
5. The lessee shall ensure that all employees and contractors on-site are fully aware of the significance of Aboriginal heritage and culture and are to take due care to preserve all Aboriginal Sites and Objects as defined by the *Aboriginal Heritage Act, 1988.*	Section 6.13
6. The licensee shall construct the outer perimeter of the Tailings Storage Facility at a slope of no greater than 1 vertical to 3 horizontal, and shall be spread with topsoil and sown to native vegetation.	Section 3.9.6
7. The licensee shall not exceed a maximum height of 181 m Australian Height Datum (AHD) for the construction of the Tailings Storage Facility.	Section 3.9.6
8. The licensee shall ensure that all faces of waste dumps shall be covered with dark coloured waste rock.	Section 8

Lease condition	PEPR reference
9. The licensee shall ensure that fuel and liquid chemical storage is adequately bunded to capture spillage and to prevent the migration of any spillage or leakage to the surrounding environment in conformance with the EPA Guidelines.	Section 3.10
10. The licensee shall ensure that land disturbed by the low-grade Beneficiation Plant, Tailings Storage Facility, railway and loading facility, crushing plant and other facilities relating to operations and Explosive Magazine Storage area is rehabilitated, with native vegetation re-established, to achieve a stable land-formation and to return the area to a post-operational land use as approved by the Minister.	Section 8
MPL70	
First Schedule	
1. The development and operation of a service corridor to contain a power line and buried pipelines to transport concentrate and return water are operations ancillary to mining and may be carried out on the area of the licence.	Acknowledged: however not specifically addressed in this PEPR
2. The licencee must ensure that activities ancillary to mining operations are carried out in an orderly and skilful manner in accordance with a program for mining and rehabilitation of the land approved, from time to time, by the minister.	Acknowledged: however not specifically addressed in this PEPR
3. The licencee must ensure that land disturbed by activity ancillary to mining is rehabilitated to achieve a safe and stable landform consistent with the surrounding environment, to minimise erosion and to re-establish native vegetation, indigenous to the area.	Acknowledged: however not specifically addressed in this PEPR
Second Schedule	
1. The licencee must ensure that as operations progress to appropriate stages, land disturbed by operations ancillary to mining is progressively rehabilitated to facilitate regeneration of native vegetation.	Section 3.7 and Section 8
2. At least two weeks prior to the commencement of operations ancillary to mining, the licencee must submit to the Minister a report detailing compliance with all the relevant regulatory approvals that apply to the proposed operations.	Acknowledged: however not specifically addressed in this PEPR
3. The licencee must ensure that all available topsoil is progressively stripped ahead of land disturbance and appropriately managed for use in the rehabilitation of land disturbed by operations ancillary to mining.	Section 3.8.11
4. The licencee must ensure that all employees and contractors on-site are fully aware of the requirement to operate in a manner that will minimise environmental impact.	Acknowledged: however not specifically addressed in this PEPR
5. The licencee must abide by the provisions of the *Aboriginal Heritage Act, 1988.*	Acknowledged: however not specifically addressed in this PEPR
MPL72	
1. The construction and operation of a waste rock dump are operations ancillary to mining and may be carried out on the area of the licence.	Acknowledged: however not specifically addressed in this PEPR
2. The licencee must ensure that activities ancillary to mining operations are carried out in an orderly and skilful manner in accordance with a program for mining and rehabilitation of the land approved, from time to time, by the Minister.	Acknowledged: however not specifically addressed in this PEPR

Lease condition	PEPR reference
3. The licencee must ensure that land disturbed by activity ancillary to mining is rehabilitated to achieve a safe and stable landform consistent with the surrounding environment, to minimise erosion and to establish native vegetation, indigenous to the area.	Section 8
Second Schedule	
1. The lessee must ensure that as operations progress to appropriate stages, land disturbed by mining is progressively rehabilitated to facilitate regeneration of native vegetation.	Section 3.7 and Section 8
2. At least two weeks prior to the commencement of construction or mining the lessee must submit to the Minister a report detailing compliance with all the relevant regulatory approvals that apply to the proposed operations.	Acknowledged: however not specifically addressed in this PEPR
3. The licencee mist ensure that all available topsoil is progressively stripped ahead of land disturbance and must be temporarily stockpiled, for use in the rehabilitation of land disturbed by operations ancillary to mining.	Section 3.8.11
4. The licencee must ensure that rare or endangered species of native flora and fauna are identified and a program implemented to ensure their survival and return to the area after operations are complete.	Section 4 and Section 6.2
5. The lessee must ensure that all employees and contractors on-site are fully aware of the requirement to operate in a manner that will minimise environmental impact.	Acknowledged: however not specifically addressed in this PEPR
6. The licencee must abide by the provisions of the *Aboriginal Heritage Act, 1988.*	Acknowledged: however not specifically addressed in this PEPR
MPL73	
First Schedule	
1. The construction and operation of a tailings storage facility are operations ancillary to mining and may be carried out on the area of the licence.	Acknowledged: however not specifically addressed in this PEPR
2. The licencee must ensure that activities ancillary to mining operations are carried out in an orderly and skilful manner in accordance with a program for mining and rehabilitation of the land approved, from time to time, by the Minister.	Acknowledged: however not specifically addressed in this PEPR
3. The licencee must ensure that land disturbed by activity ancillary to mining is rehabilitated to achieve a safe and stable landform consistent with the surrounding environment, to minimise erosion and to establish native vegetation, indigenous to the area.	Section 8
Second Schedule	
1. The licencee must ensure that as operations progress to appropriate stages, land disturbed by operations ancillary to mining is progressively rehabilitated to facilitate regeneration of native vegetation.	Section 3.7 and Section 8
2. At least two weeks prior to the commencement of operations ancillary to mining, the licencee must submit to the Minister a report detailing compliance with all the relevant regulatory approvals that apply to the proposed operations.	Acknowledged: however not specifically addressed in this PEPR
3. The licencee must ensure that all available topsoil is progressively stripped ahead of land disturbance and must be temporarily stockpiled, for use in the rehabilitation of land disturbed by operations ancillary to mining.	Section 3.8.11

Lease condition	PEPR reference
4. The licencee must ensure that rare or endangered species of native flora and fauna are identified and a program implemented to ensure their survival and return to the area after operations are complete.	Section 4 and Section 6.2
5. The licencee must ensure that all employees and contractors on-site are fully aware of the requirement to operate in a manner that will minimise environmental impact.	Acknowledged: however not specifically addressed in this PEPR
6. The licencee must abide by the provisions of the *Aboriginal Heritage Act, 1988.*	Acknowledged: however not specifically addressed in this PEPR
MPL74	
First Schedule	
1. The construction and operation of a tailings storage facility are operations ancillary to mining and may be carried out on the area of the licence.	Acknowledged: however not specifically addressed in this PEPR
2. The licencee must ensure that activities ancillary to mining operations are carried out in an orderly and skilful manner in accordance with a program for mining and rehabilitation of the land approved, from time to time, by the Minister.	Acknowledged: however not specifically addressed in this PEPR
3. The licencee must ensure that land disturbed by activity ancillary to mining is rehabilitated to achieve a safe and stable landform consistent with the surrounding environment, to minimise erosion and to establish native vegetation, indigenous to the area.	Section 8
Second Schedule	
1. The licencee must ensure that as operations progress to appropriate stages, land disturbed by operations ancillary to mining is progressively rehabilitated to facilitate regeneration of native vegetation.	Section 3.7 and Section 8
2. At least two weeks prior to the commencement of operations ancillary to mining, the licencee must submit to the Minister a report detailing compliance with all the relevant regulatory approvals that apply to the proposed operations.	Acknowledged: however not specifically addressed in this PEPR
3. The licencee must ensure that all available topsoil is progressively stripped ahead of land disturbance and must be temporarily stockpiled, for use in the rehabilitation of land disturbed by operations ancillary to mining.	Section 3.8.11
4. The licencee must ensure that rare or endangered species of native flora and fauna are identified and a program implemented to ensure their survival and return to the area after operations are complete.	Section 4 and Section 6.2
5. The licencee must ensure that all employees and contractors on-site are fully aware of the requirement to operate in a manner that will minimise environmental impact.	Acknowledged: however not specifically addressed in this PEPR
6. The licencee must abide by the provisions of the *Aboriginal Heritage Act, 1988.*	Acknowledged: however not specifically addressed in this PEPR

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12 GLOSSARY

Term	Definition
alluvial	describing soil deposited by river or flood water
arid	an area with an average annual rainfall of less than 250 mm
artefact	an object, such as a tool, weapon or ornament, of archaeological or historical interest
bank cubic metre	a measure of volume representing a cubic metre of *in situ* rock or material before it is drilled and blasted
bench	a landform consisting of a strip of level land in an otherwise sloped area
biannual	occurring twice a year
biennial	happening every two years
biodiversity	the range of genetic, species and ecosystem diversity present in a given ecological community or system
blasting	detonation of explosive charge in a mine or elsewhere to assist in the breaking up of hard rock
bore	a hole drilled into the ground to intersect an aquifer and from which water may be pumped
bund	an earth, rock or concrete wall constructed to prevent the inflow or outflow of liquids used as a secondary containment for tanks or other storage vessels
catchment	the entire land area from which water (e.g. rainfall) drains to a specific water course or water body
chenopod	a member of a family of plants, mainly shrubs of saline and semi-arid regions including bluebushes, saltbushes and samphires
compaction	the process of close packing of individual grains in a soil or sediment as a response to pressure
conglomerate	a coarse grained clastic rock composed of rounded fragments (derived from pre-existing rocks or mineral that have been mechanically transported) held together by either a mineral cement or in a fine-grained matrix
crusher	that part of an ore-processing plant where the ore is mechanically crushed into smaller pieces
deposition	laying down of particulate material (e.g. sediment in a lake or tailing solids in a tailings storage facility)
ecosystem	the biotic (living) and abiotic (non-living) environment within a specified location in space and time
emission	a discharge of a substance (e.g. dust) into the environment
Environmental Management System	a set of policies, procedures and practices detailing the approach required to protect and enhance environmental values at a site
ephemeral	not permanent, for example a stream that flows only seasonally or after rainfall, or a lake that periodically dries out

Term	Definition
erosion	wearing away and transforming Earth's crust by water (rain, sea, ice) and other atmospheric agents (wind)
fault	a fracture of the Earth's crust caused by the relative movement of rock masses
fauna	the animal life of a region or geological period
flora	the plants of a particular region, geological period, or environment
fly rock	airborne rock generated during blasting activities
footprint	the land area taken up by a development
geotechnical	a term employed to cover the fields of soil mechanics, rock mechanics and engineering geology
gilgai	the micro relief of soils produced by expansion and contraction with changes in soil moisture, found in high-clay soils. It is characterised by an undulating surface with mounds and depressions
goethitic	pertaining to an iron bearing oxide material
grade	the concentration of metal (e.g. copper) either in an individual rock sample or averaged over a specified volume of rock
gradient	rate of change of a given variable (such as temperature or elevation) with distance
grubbed	digging out stumps and root systems of shrubs and trees
habitat	a specific place or natural conditions in which a plant or animal lives
hardstand	a hard surfaced area
hazard	a source of potential harm, or a situation with a potential to cause loss or adverse effect
hydrocarbon	pertaining to oil or natural gas
hydrogeology	the study of groundwater with particular reference to geology and including its origin, occurrence, movement and quality
indicated resource	economic mineral occurrences that have been sampled (from locations such as outcrops, trenches, pits and drill holes) to a point where an estimate has been made, at a reasonable level of confidence, of their contained metal, grade, tonnage, shape, densities and physical characteristics
inferred resource	that part of a mineral resource for which tonnage, grade and mineral content can be estimated with a low level of confidence
landform	a specific feature of a landscape (such as a hill) or the general shape of the land
lift	each separate layer placed in the construction of an embankment or waste rock emplacement
measured resource	are indicated resources that have undergone enough further sampling that a competent person (e.g. a geologist) has declared them to be an acceptable estimate, at a high degree of confidence, of the grade, tonnage, shape, densities, physical characteristics and mineral content of the mineral occurrence
mining tenement	means a claim, lease or licence under the *Mining Act 1971*

Term	Definition
mitigation measure/strategy	action taken to minimise or lessen the impact of activity on the environment or surrounding communities
modelling	the process of creating and using a model
native title	a concept in the law of Australia that recognises the continued ownership of land by local Indigenous Australian
offsets	actions taken outside the development area to 'compensate' for environmental impacts created within the development area that relate directly to the conservation values affected by the development
operations	mining and ore processing activities
ore	a mineral or mixture of minerals containing a metal in sufficient amounts for its extraction to be profitable
ore body	a solid mass of ore (both high and low grade) that is geologically distinct from the rock that surrounds it; the portion of a mineral deposit that can be mined profitably
ore reserve	the part of a mineral resource which can be mined and forms valuable or useful minerals that can be recovered economically
overburden	material that is located above a deposit of ore (e.g. soil, rock or vegetation) which must be removed for the ore to be mined
palaeochannel	Old or ancient river channels often infilled with course fluvial deposits which can store and transmit appreciable quantities of water. Where below the water table, these geomorphological features are often targeted for water supply
particulate	also referred to as particulate matter (PM), aerosols or fine particles. Particulates are tiny particles of solid (smoke) or liquid (aerosol) suspended in a gas. They range in size from less than 10 nanometres to more than 100 micrometres in diameter
probable resource	that part of the indicated resources that can be mined in an economically viable fashion, and in some circumstances, a measured mineral resource. It includes diluting material and allowances for losses which may occur when the material is mined. It has a lower level of confidence than a proved ore resource but is of sufficient quality to serve as the basis for decision on the development of deposit.
process water	water used during the processing of ore
proved resource	that part of the measured resources that can be mined in an economically viable fashion. It includes diluting materials and allowances for losses which occur when the material is mined. It represents the highest confidence category of reserve estimate.
receptor	a designated place at which an impact (e.g. pollution) may occur
rehabilitation	the process of restoring land to its previous natural state or to another use (e.g. industrial or recreational) after mining has been completed
reserve	in the context of a mineral reserve, it is the economically mineable part of a measured or indicated mineral resource
Richter scale	a logarithmic scale of 0 to 10 for representing the strength of an earthquake

Term	Definition
risk assessment	the process of measuring risk, including both the likelihood and consequences of a risk (also known as risk analysis and risk evaluation)
risk management	the process of measuring, or assessing, risk and developing strategies to manage it. The culture, processes and structures that are directed towards effective management of potential opportunities and adverse effects
runoff	that portion of precipitation (rain, hail and snow) that flows from a specific area as water
run of mine	the raw ore as it is delivered by conveyors or skips, before treatment of any sort
sedimentation	the deposition of particles (e.g. soil or organic matter) from a state of suspension in water or air
silt	granular material made up of fragments of soil or rock between 3.9 and 62.5 µm, smaller than a sand grain and larger than coarse clay
topography	the study of Earth's surface features. It is concerned with local detail in general, including not only relief but also vegetative and human-made features
understorey	the vegetative cover beneath taller trees and shrubs
visual amenity	the visual attractiveness of an area
water table	the surface of the groundwater, below which soil and rock are saturated
windrow	a linear heap of material. It may be on the edge of earthworks, roads or at a tip-head to provide a safety barrier
watercourse	a natural channel conveying water, such as a creek or river
waste rock dump (WRD)	a structure designed for the long-term storage of non-mineralised rock and non-economic ore

Appendix A

Reference Maps and Plans

A-1: SIMEC mining areas in the Middleback Ranges

A-2: SMR mining tenements

A-3: SMR mining area domains

A-4: SMR existing surface contours

A-5: SMR key infrastructure locations

A-6: SMR mining area Adjacent landholders

A-7: SMR mining area Regional Landholders

A-8: SMR mining areas Homesteads proximity

A-9: SMR dust monitoring locations

A-10: SMR surface water drainage channels and silt traps

A-11: Iron Duchess North surface water drainage channels and silt traps

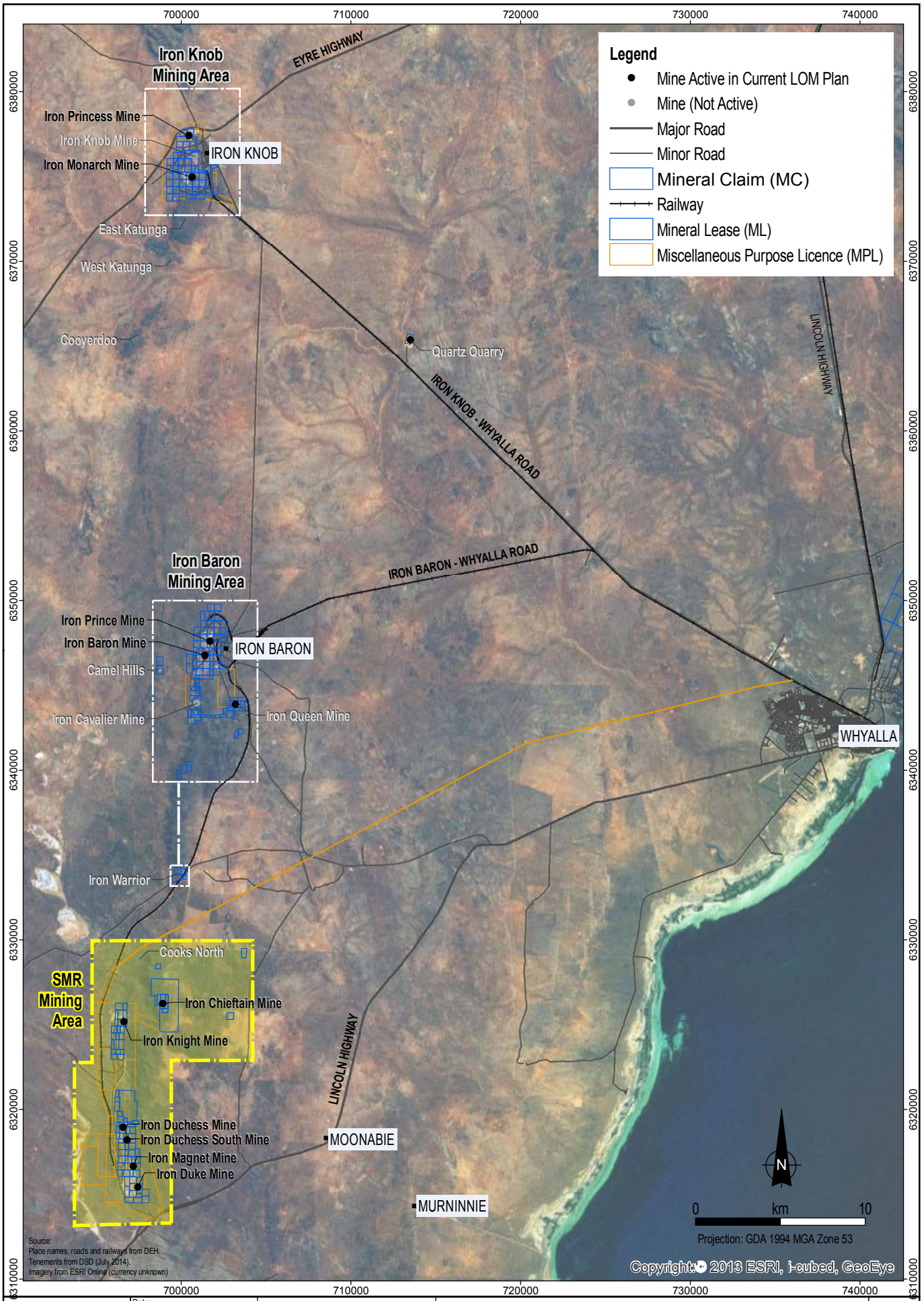
A-12: SMR topsoil and subsoil stockpiles

A-13: SMR vegetation SEB ratios reference map

A-14: TSF Vegetation impact monitoring

A-15: SMR closure catchments – Knight and Chieftain

A-16: SMR closure catchments – Duke and Duchess



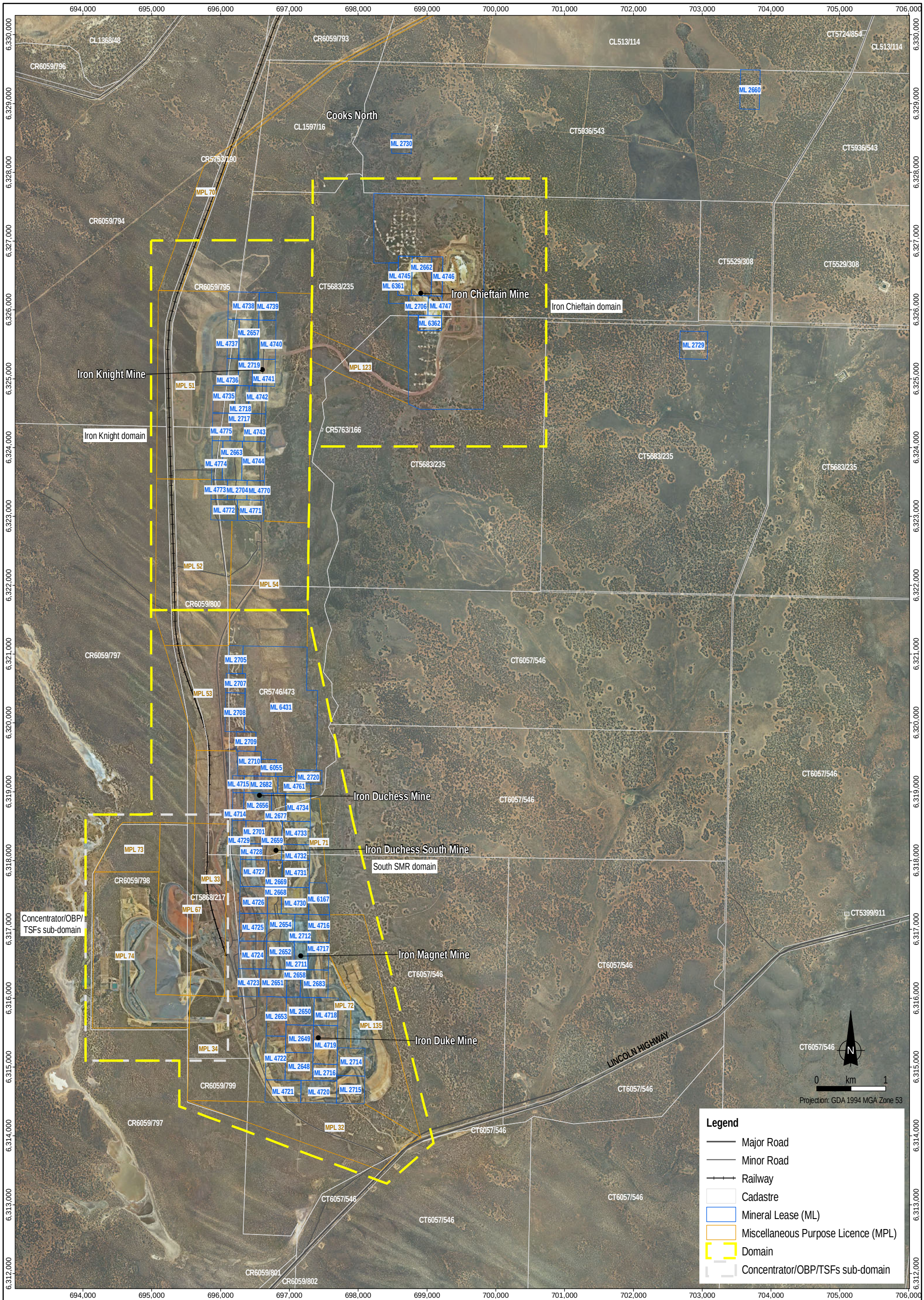
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South Middleback Ranges (SMR) mining areas

Figure No: A-1



Source:
Place names, roads and railways from DEH.
Tenements from DSD (July 2014).
Cadastre from DMITRE (Jan 2013).
Imagery from AAM (captured September 2013).

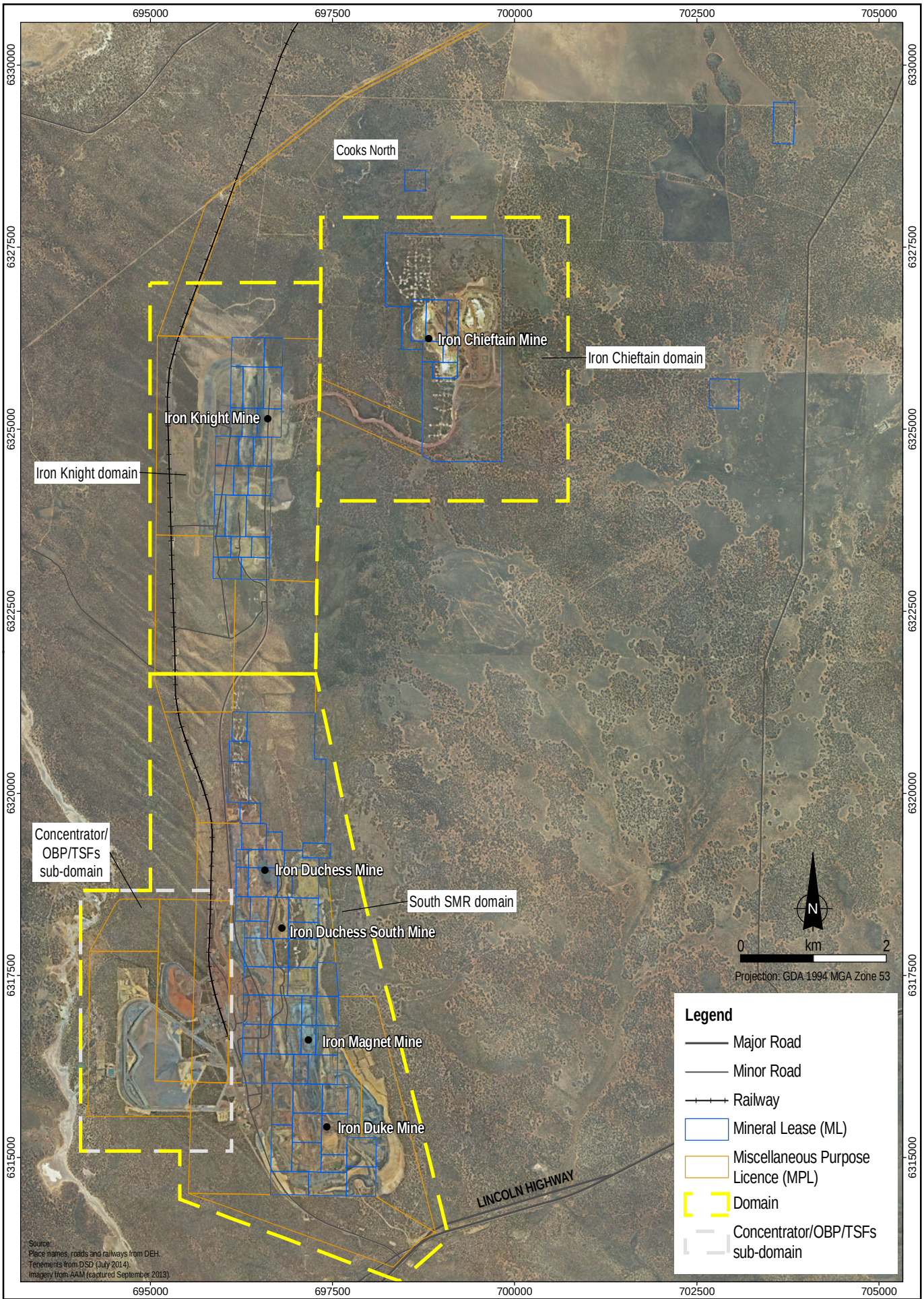
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South Middleback Ranges (SMR) mining area tenements and cadastre boundaries

Figure No: A-2



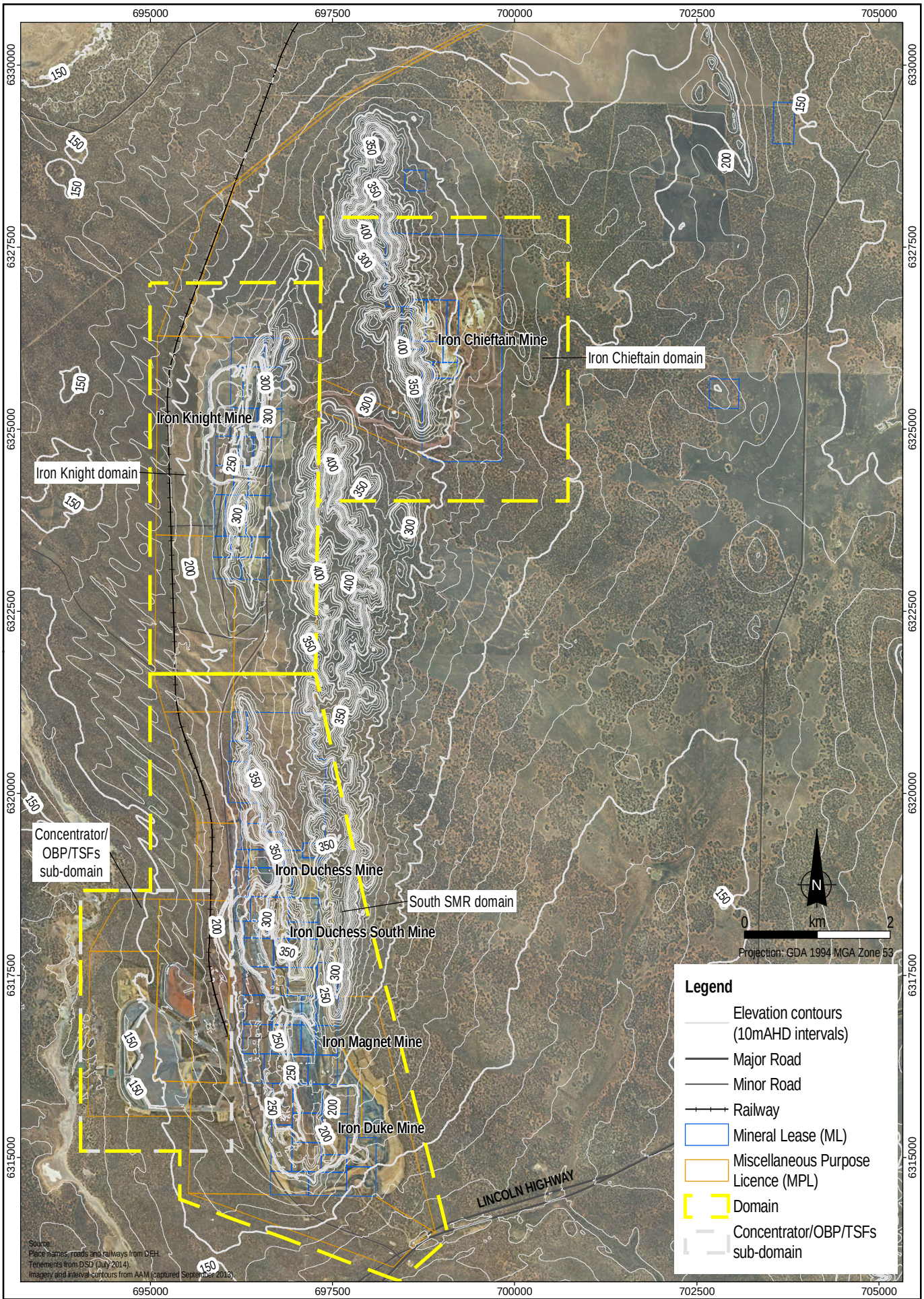
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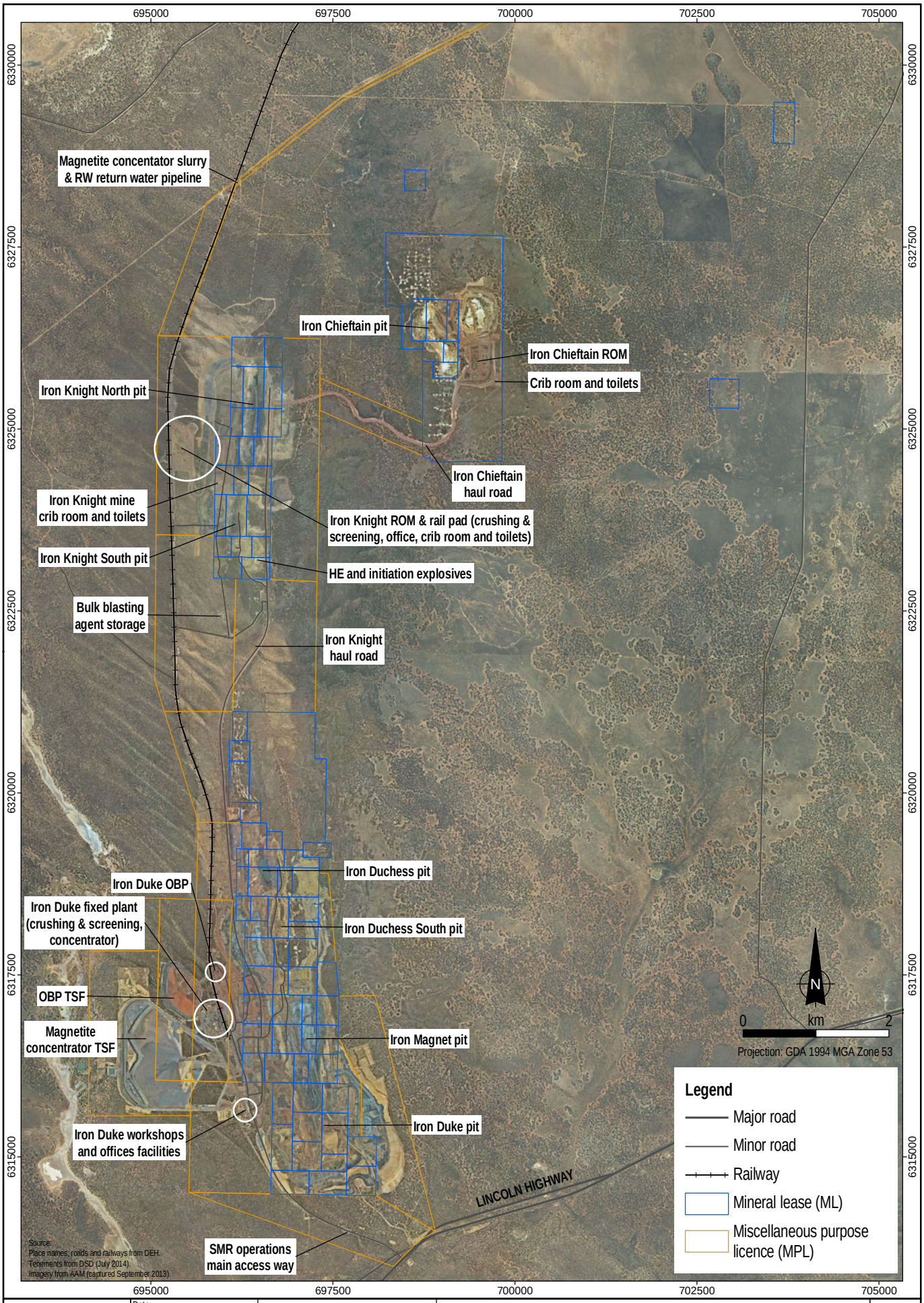
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South Middleback Ranges (SMR) mining area - domains

Figure No: A-3



coffey	Date: 23.09.2014 MXT: 1374BE_WPC108_GIS043_v0_1 File Name: 1374BE_WPC108_F043_GIS	arrium MINING	**South Middleback Ranges (SMR) mining area elevation contours**	Figure No: A-4



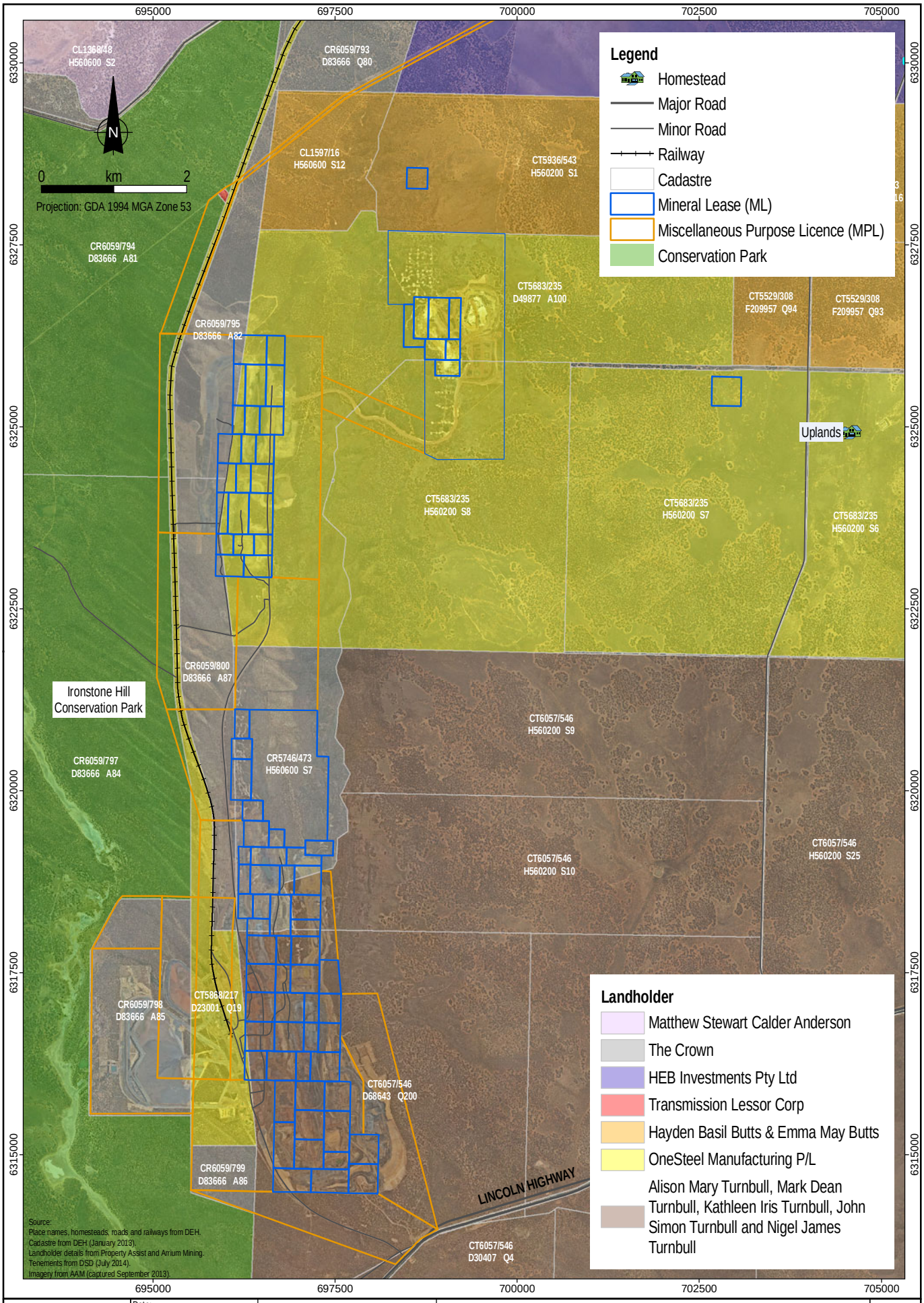
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South Middleback Ranges (SMR) mining area key infrastructure locations map

Figure No: A-5



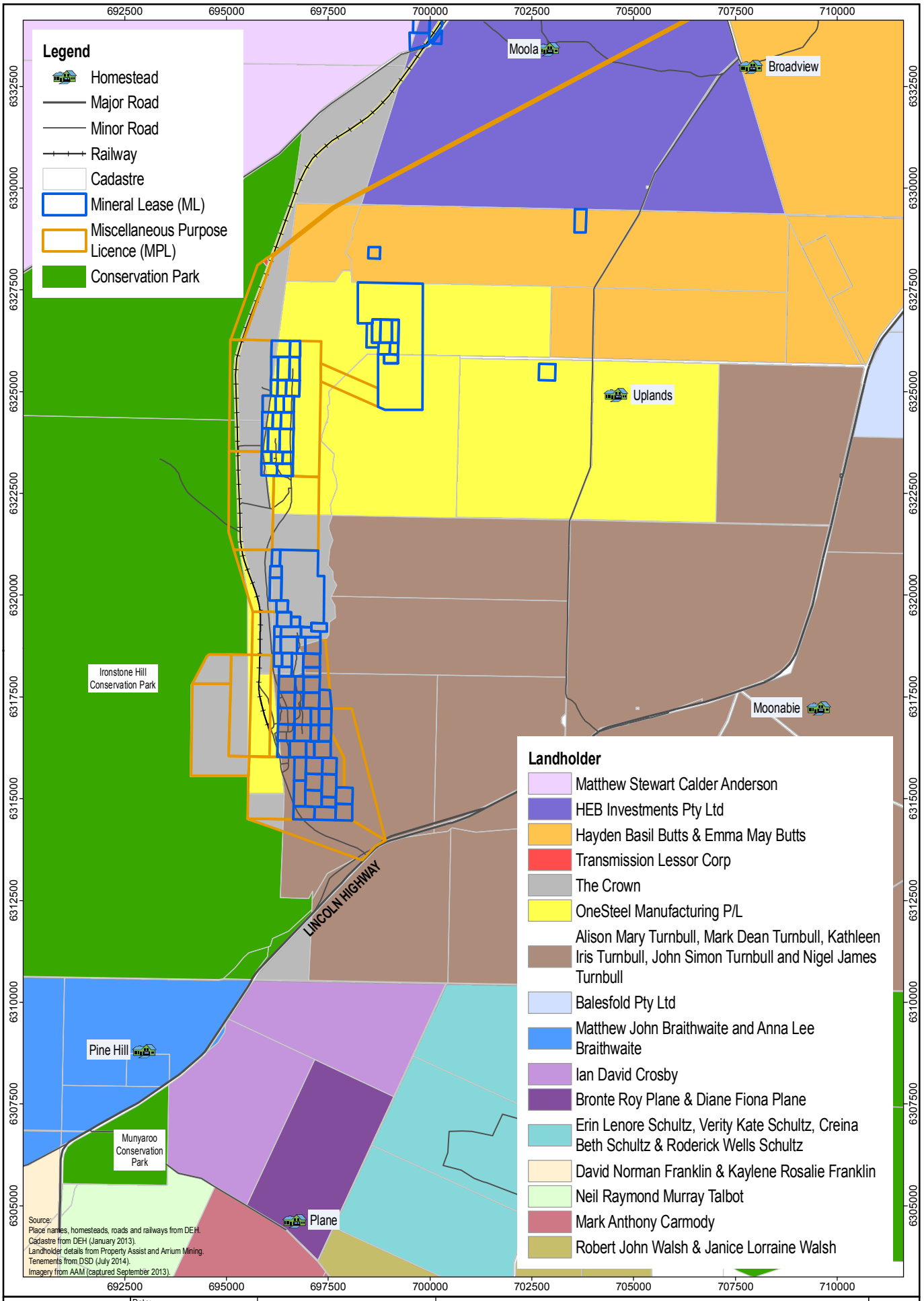
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South Middleback Ranges (SMR) mining area adjacent landholders

Figure No: A-6



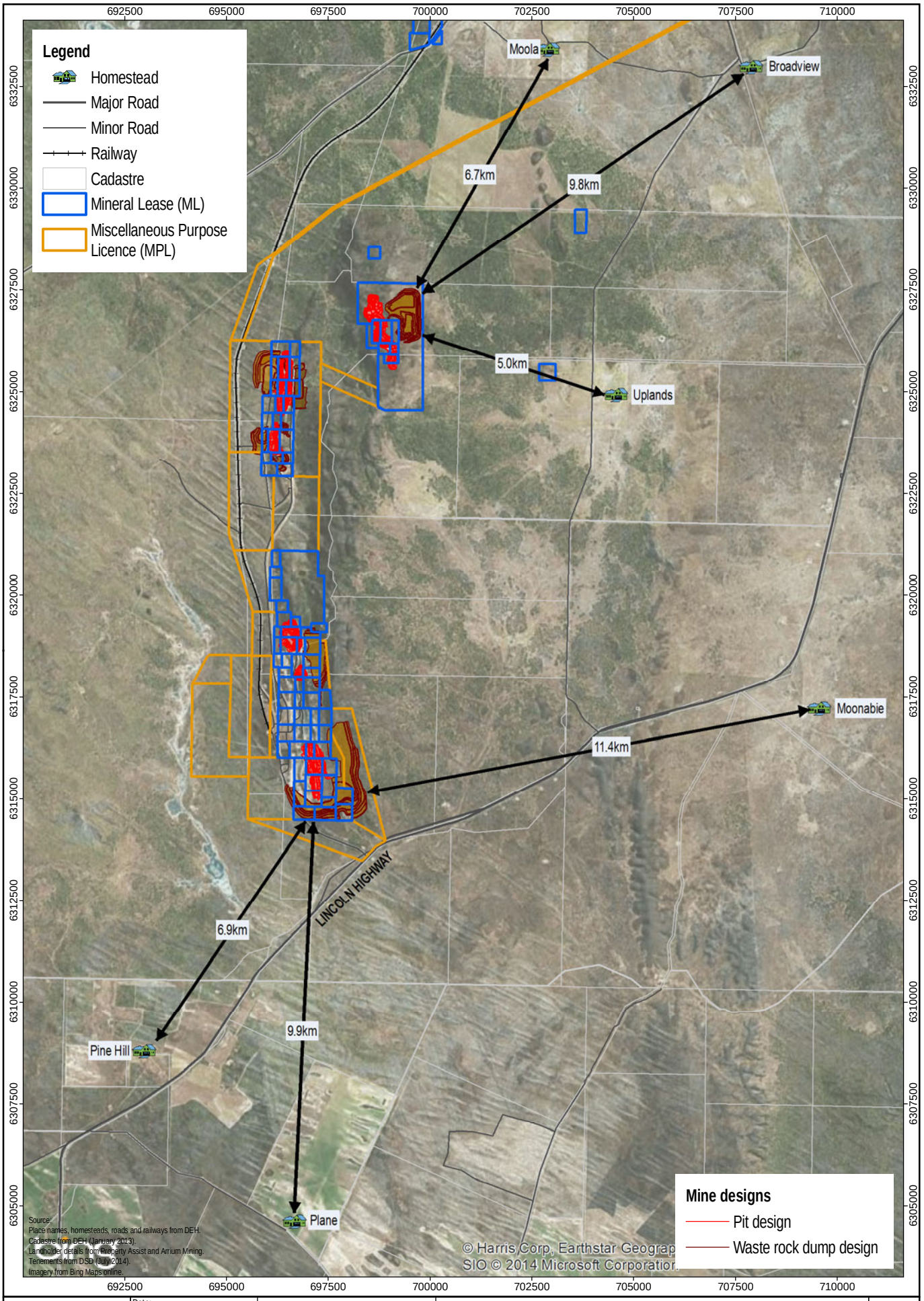
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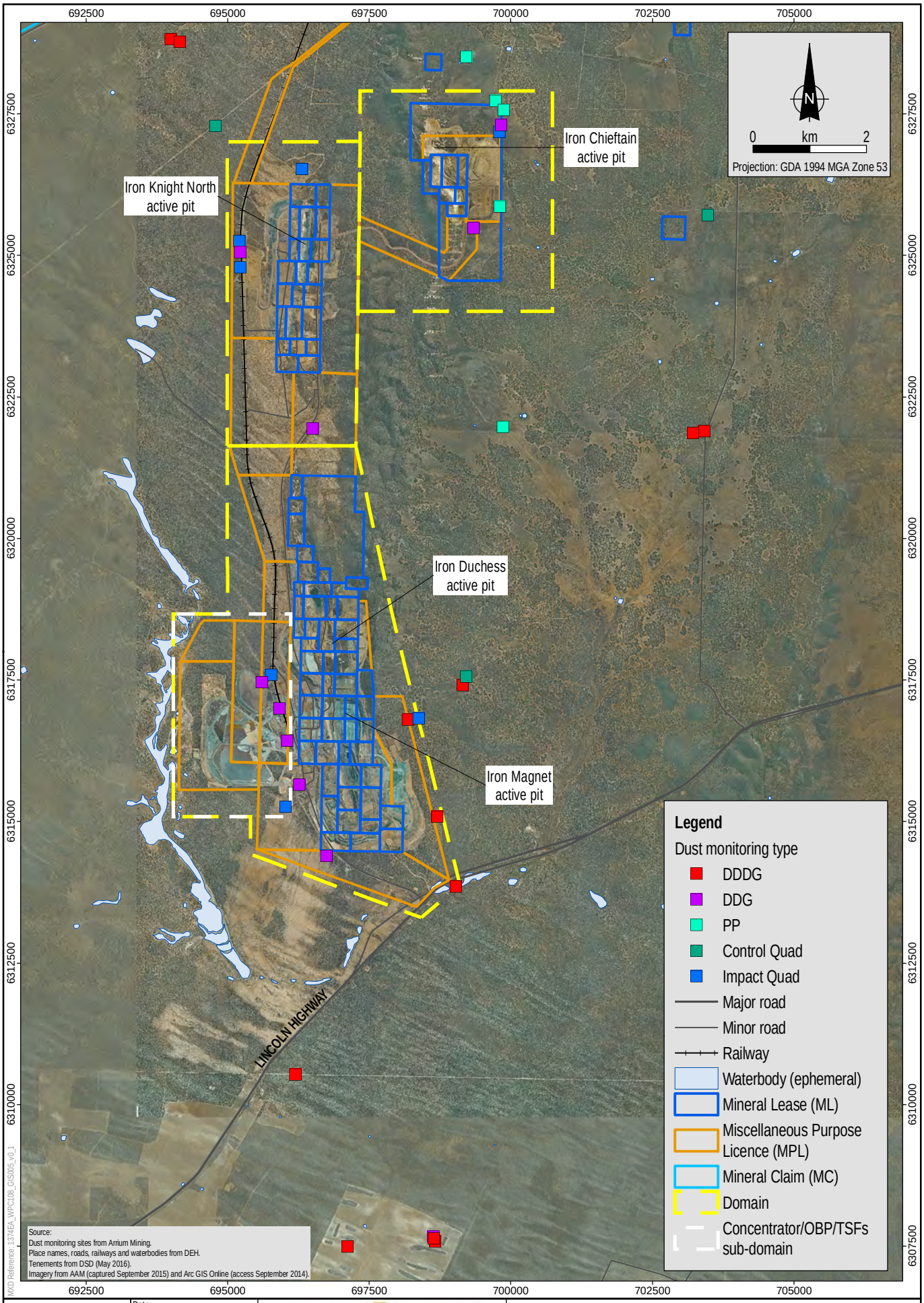
arrium MINING

South Middleback Ranges (SMR) mining area regional land holders

Figure No: A-7



coffey	Date: 27.08.2014 MXT: 1374BE_WPC108_GIS031_v0_1 File Name: 1374BE_WPC108_F030_GIS	arrium MINING	South Middleback Ranges (SMR) mining area homesteads proximity	Figure No: A-8



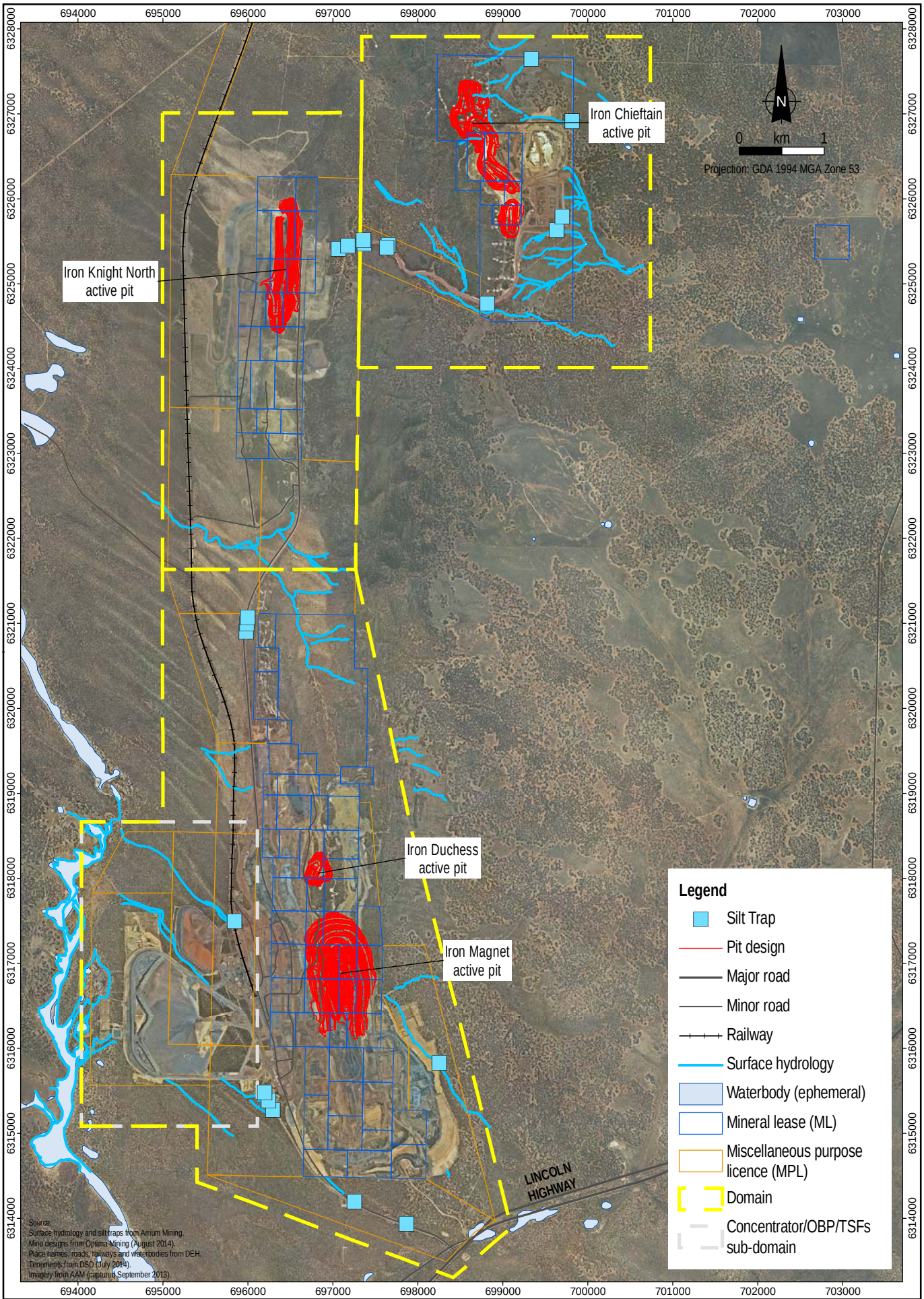
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A TETRA TECH COMPANY

Date: 24.11.2016
Project: ENAUABTF01374EA
File Name: 1374EA_WPC173_F005_GIS

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South Middleback Ranges (SMR) mining area dust monitoring

A-9



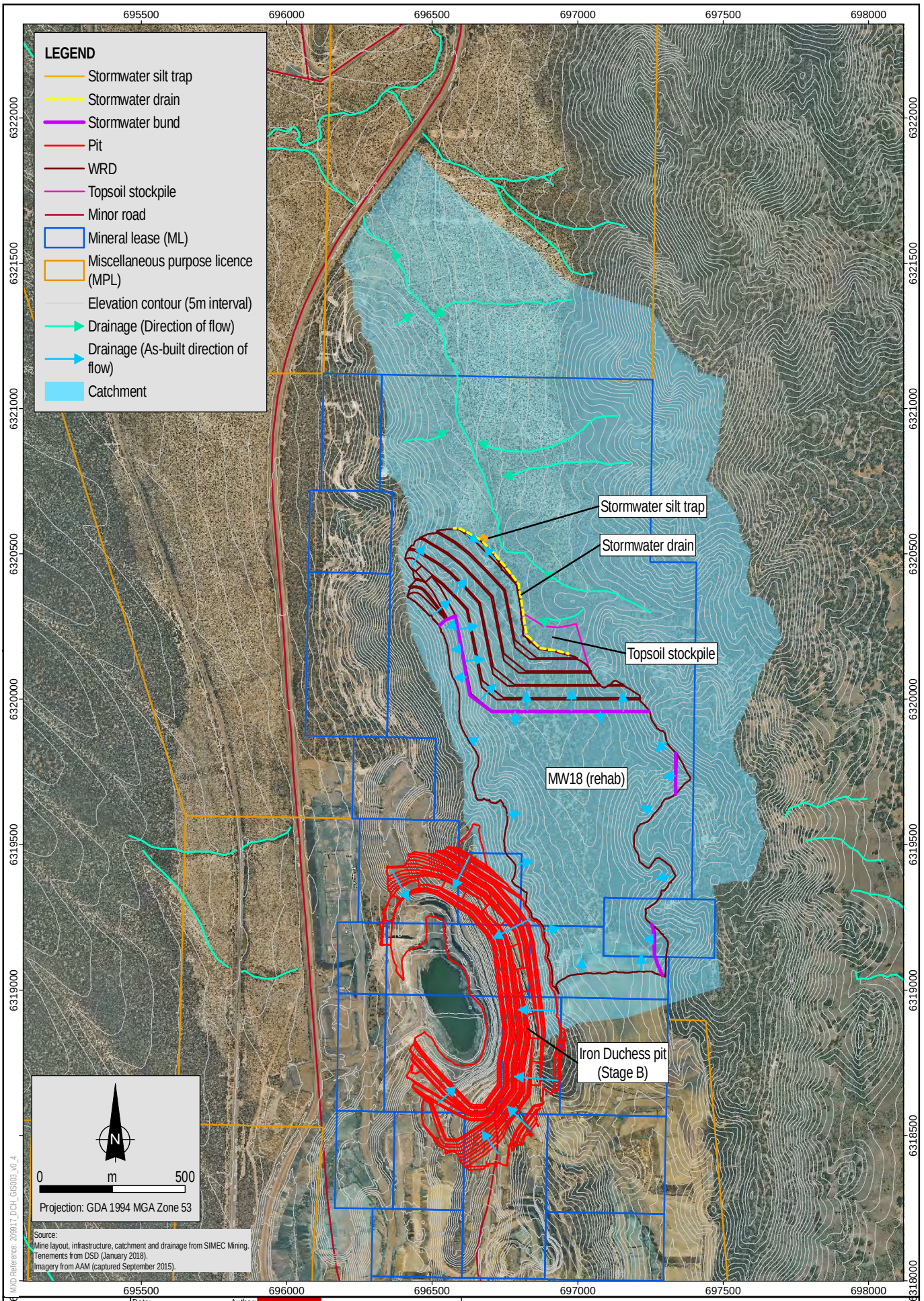
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Date: 12.09.2014
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File Name: 1374BE_WPC108_F038_GIS

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South Middleback Ranges (SMR) mining area - surface hydrology

Figure No: A-10



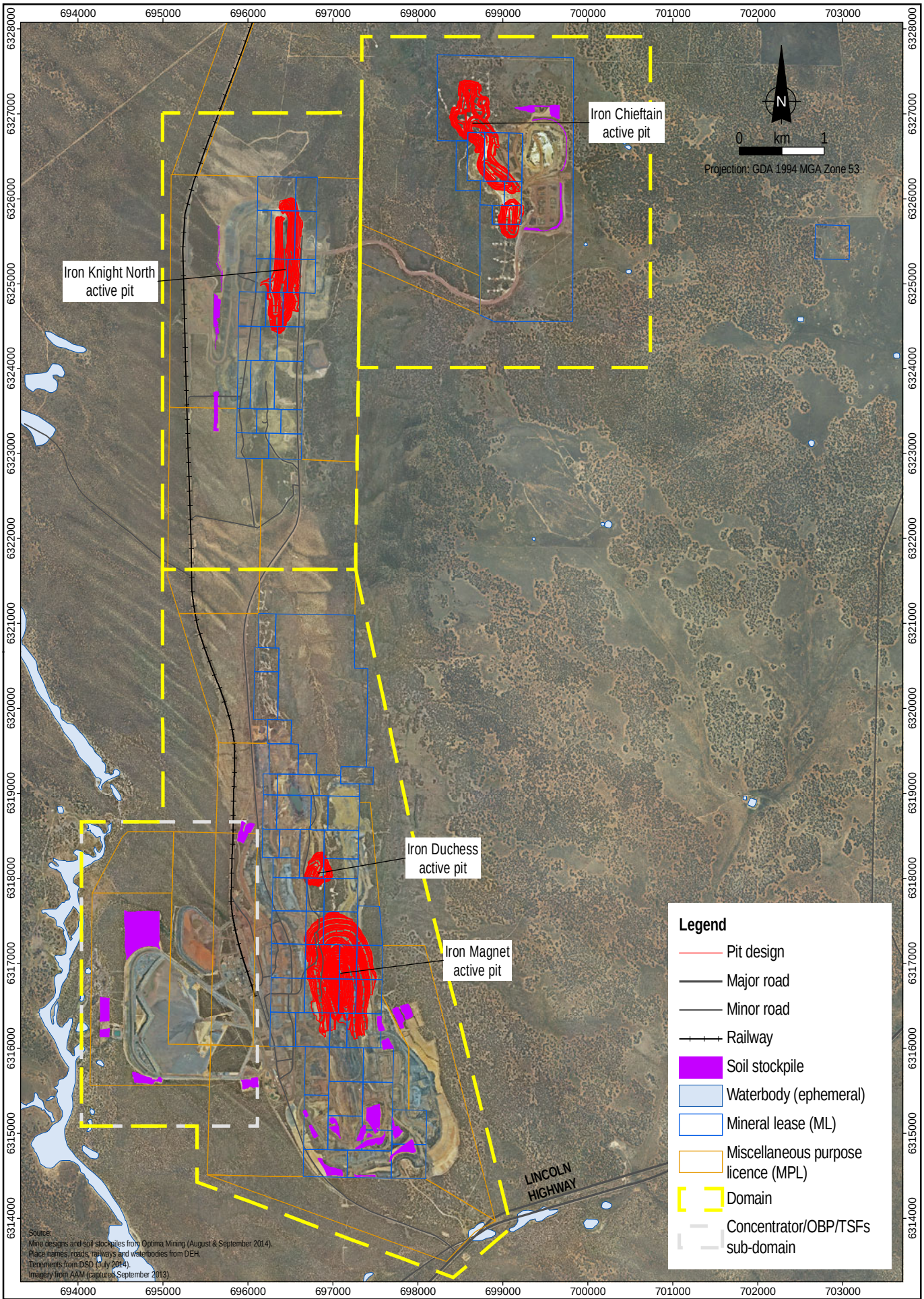
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A TETRA TECH COMPANY

Date: 26.04.2018
Author: H. Unkovich
Project: 754-MELEN209917
File Name: 209917_DCH_F003_GIS

SIMEC MINING

Iron Duchess hydrology

A-11



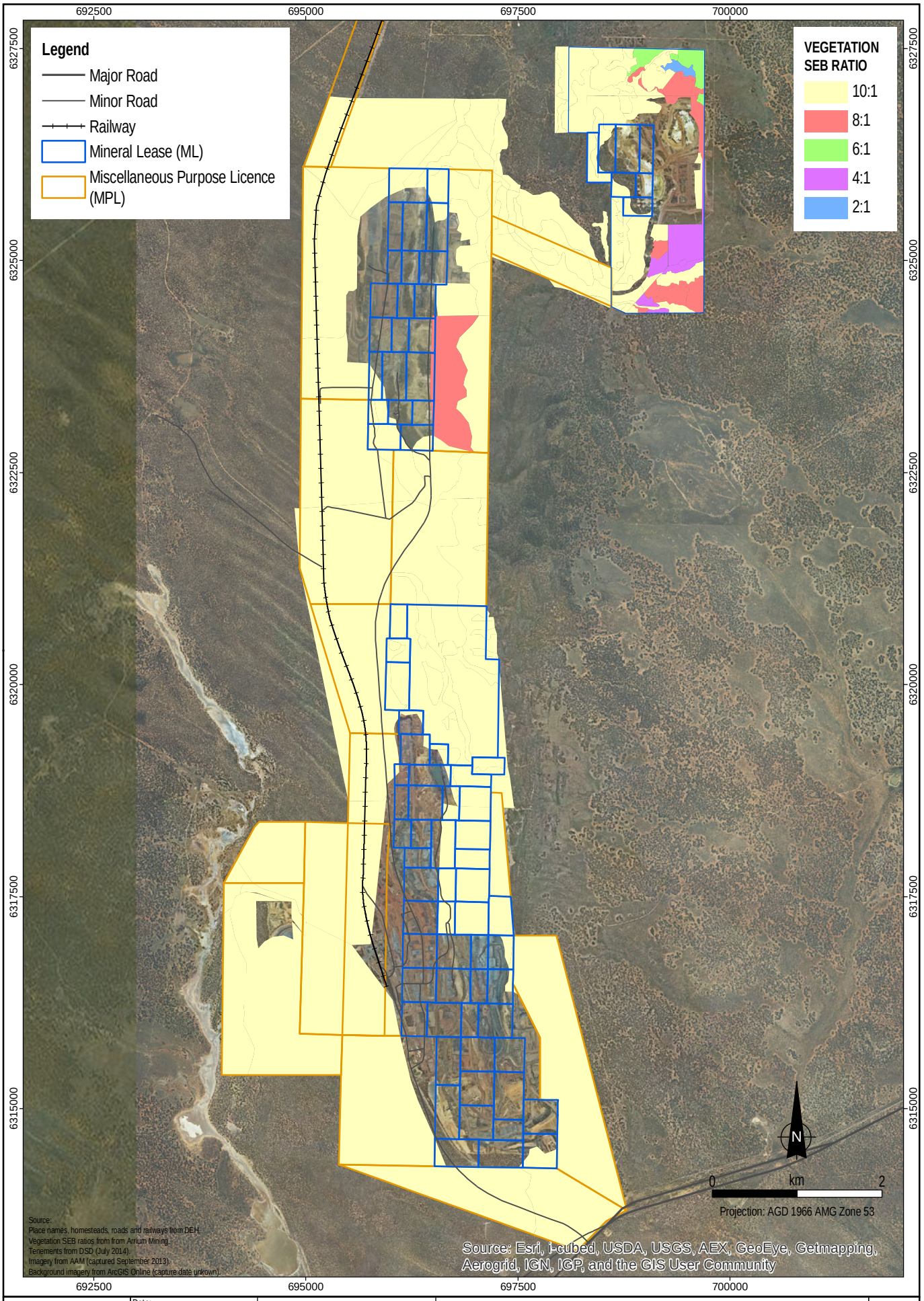
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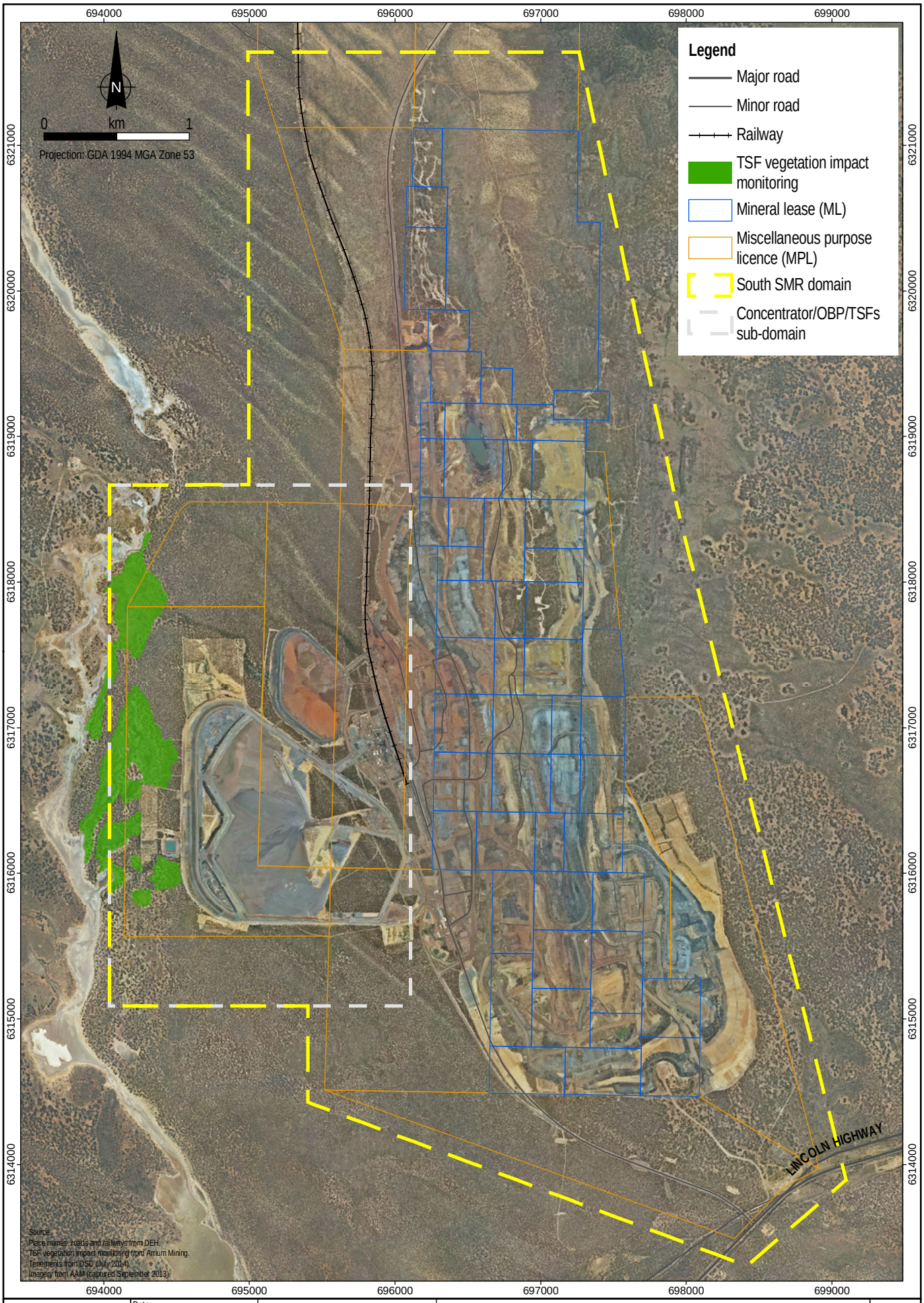
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South Middleback Ranges (SMR) mining area - soil stockpiles

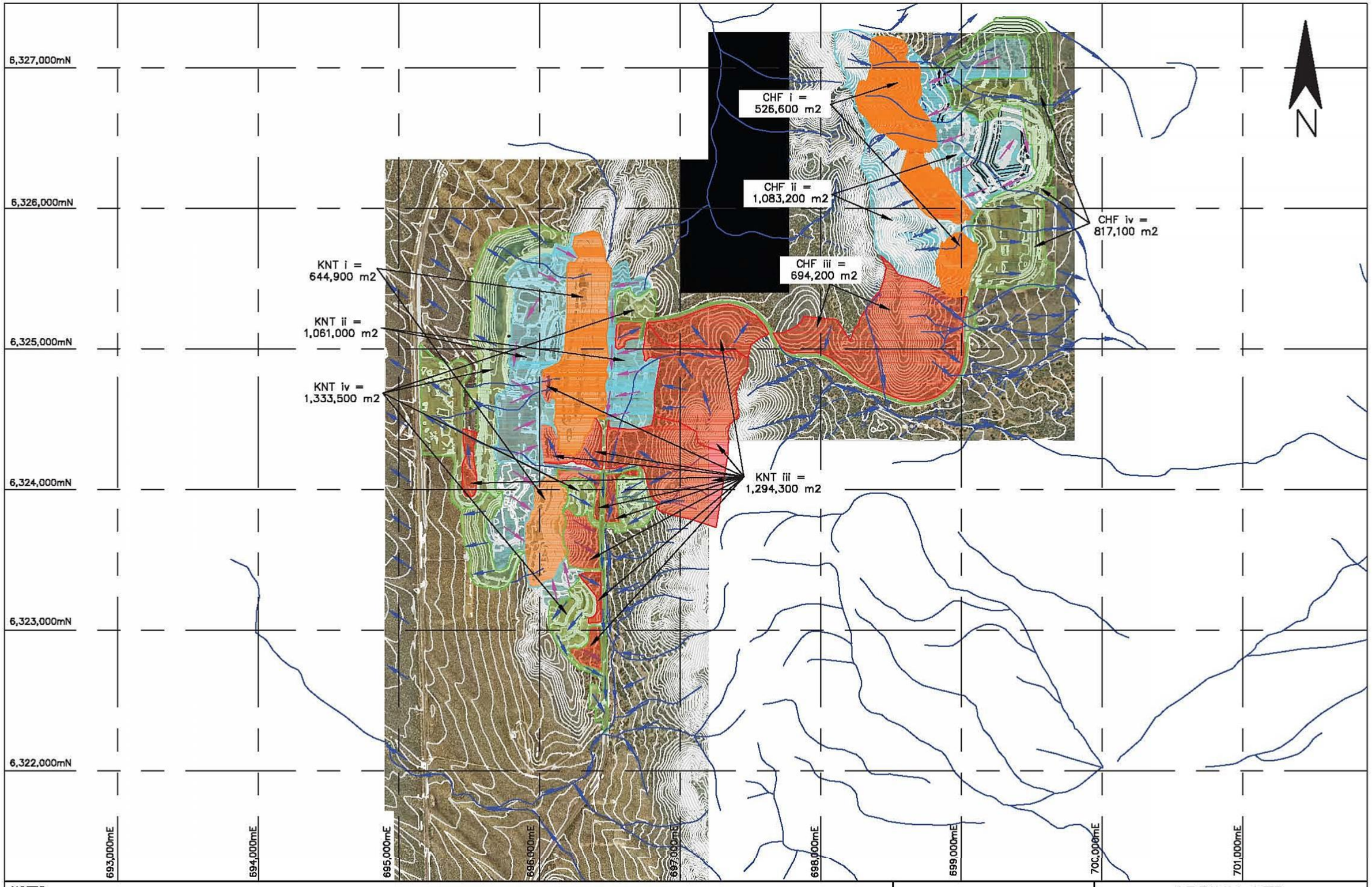
Figure No: A-12



coffey	Date: 12.09.2014 MXT: 1374BE_WPC108_GIS042_v0_1 File Name: 1374BE_WPC108_F042_GIS	arrium MINING	South Middleback Ranges (SMR) mining area vegetation SEB ratios	Figure No: A-13



coffey	Date: 11.09.2014 MXT: 1374BE_WPC108_GIS039_v0_1 File Name: 1374BE_WPC108_F039_GIS	arrium MINING	TSF vegetation impact monitoring	Figure No: A-14



NOTES:
1. COORDINATES TO AMG66/Z53.
2. ELEVATIONS TO AHD.
3. ALL MAPPING DATA & AERIAL IMAGERY PROVIDED BY ARRIUM.
4. CONTOUR INTERVAL IS 10m.
5. FIGURE SCALE 1:25,000 @A3.

FIGURE A-15

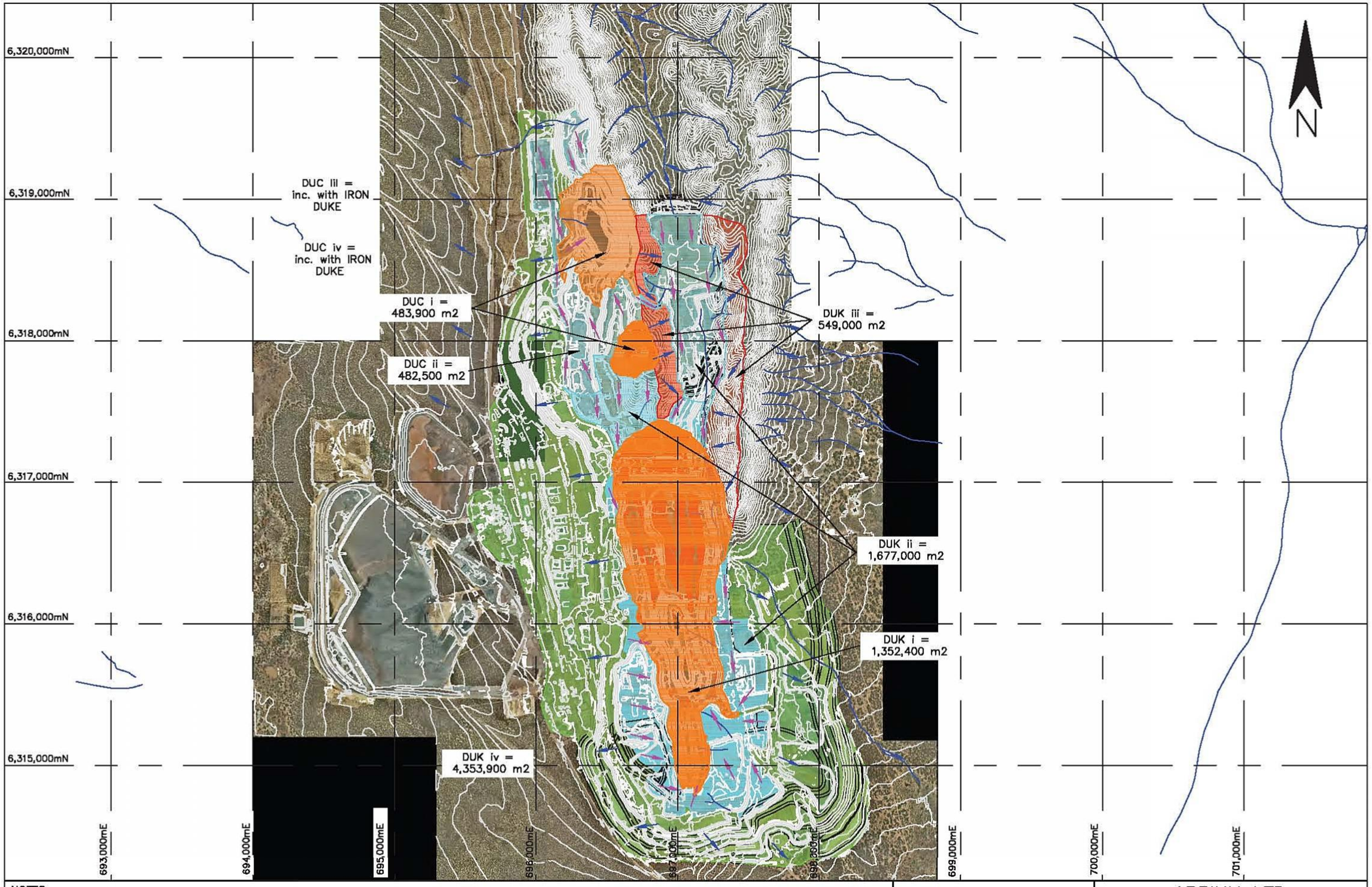
ARRIUM LTD.

SOUTH MIDDLEBACK RANGES MINESITE

IRON KNIGHT & IRON CHIEFTAIN CATCHMENT DELINEATION

ARL	MAY'14	MCARRW55	FIGURE No. 5

A3



NOTES:
1. COORDINATES TO AMG66/Z53.
2. ELEVATIONS TO AHD.
3. ALL MAPPING DATA & AERIAL IMAGERY PROVIDED BY ARRIUM.
4. CONTOUR INTERVAL IS 10m.
5. FIGURE SCALE 1:25,000 @A3.

FIGURE A-16

ARRIUM LTD.

SOUTH MIDDLEBACK RANGES MINESITE

IRON DUKE & IRON DUCHESS CATCHMENT DELINEATION

ARL	MAY'14	MCARRW55	FIGURE No. 4

Appendix B

Regulatory Correspondence

B-1: Letter from DMITRE – 5 June 2013

B-2: Letter to DMITRE – 3 July 2013

B-3: Letter from DSD – 19 December 2014

B-4: Letter from DPC – 31 August 2017

Government of South Australia
Department for Manufacturing,
Innovation, Trade, Resources and Energy

Reference No.: MO6331.001; A1669243

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5 June 2013

Don Gartsky
Arrium – OneSteel Whyalla
PO Box 21
WHYALLA SA 5600

Dear Mr Gartsky

RE: Review and Integration of N-SMR and S-SMR PEPRs - Southern Middleback Ranges Operations (including Early Delivery Dust Measurement Criteria)

It is a requirement under Section 70B of the *Mining Act 1971* (the Act), that the recovery of minerals be conducted in accordance with a Program for Environmental Protection and Rehabilitation (PEPR) approved by the Minister.

The S-SMR PEPR was approved in October 2007 and has been the subject of numerous updates and Addendums as a result of minor changes to operations. The N-SMR PEPR was approved in April 2010 and is adjacent to (and in some cases overlapping) the S-SMR PEPR.

In light of the changing operations and the similarities between the two mining areas, there is an opportunity to integrate the two PEPRs. Pursuant to Section 70C(2) of the Act, Arrium are instructed to **review the N-SMR and S-SMR PEPRs** and submit a final version (prepared in accordance with Regulation 65 of the *Mining Regulations 2011*) of the integrated document **within 12 months** of the date of this letter.

The review is to incorporate a full risk assessment and the commensurate generation of Outcomes and Measurement Criteria (in accordance with Ministerial Determination #5, refer attached) that guide environmental performance for the Southern Middleback Ranges. It is expected that all new risks will be adequately addressed, including (but not limited to):

- dust impacts on vegetation, and
- operation of the TSF and subsequent interactions with groundwater.

Arrium are required to present a schedule for the completion of this project (PEPR review and integration) **by 21 June 2013.**

Dust
Arrium are required to submit the revised **Outcomes and Dust Measurement Criteria** ahead of the final review (the deadline clearly indicated in the above mentioned schedule). The revised outcome and measurement criteria must

demonstrate consideration of all receptors in addition to heath and native vegetation. The dust specific items will be implemented under exclusive approval (addendum) ahead of the full PEPR submission.

If you require a longer time to prepare your PEPR, please respond in writing indicating the reason and the estimated submission date, so that an extension may be considered.

Please note that in accordance with this Agency's consultation process your draft PEPR may be circulated to relevant stakeholders for comment, and this should be considered when preparing your PEPR.

If you have any enquiries or require assistance, please contact Nicole Edkins (Principal Mining Regulator), Email: Nicole.Edkins@sa.gov.au, Ph: 08 8463 3108.

Yours sincerely

Greg Marshall
DIRECTOR MINING REGULATION

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3 July 2013

Mr Greg Marshall
Director Mining Regulation
Department for Manufacturing, Innovation, Trade, Resources and Energy
Mining Regulation
GPO Box 1264
Adelaide, SA, 5001

Dear Mr Marshall

RE: Review and Integration of N-SMR and S-SMR PEPRs – Southern Middleback Ranges Operations (including Early Delivery of Dust Measurement Criteria)

We refer to your letter of 5 June on the above matter and provide below the response you requested by 21 June 2013, (which was extended by agreement to 3 July 2013).

1. Revised Outcomes and Dust Measurement Criteria
Arrium Mining (Arrium) understands the requirement from DMITRE to develop and submit revised **Outcomes and Dust Measurement Criteria** for the SMR region, and that the revised outcome and measurement criteria are to be derived from a comprehensive risk assessment review in accordance with the standard practice. We also understand that a critical element of this process is that Arrium undertakes appropriate engagement to obtain input from stakeholders who may potentially be impacted by dust arising from mining operations.

Arrium proposes to undertake the above with the target of submitting an addendum by 14 Jan 2014 for review and approval by DMITRE. Subject to DMITRE's acceptance of this timeline, Arrium envisages undertaking the following high level steps:

STEP		**Complete by:**
1.	Identification of potentially impacted stakeholders.	12 July 2013
2.	Initial engagement of potentially impacted stakeholders to obtain input. *(Subject to stakeholder availability and willingness to engage.)*	7 Aug. 2013
3.	Undertake a comprehensive risk assessment and develop draft outcome and measurement criteria (taking account of stakeholder feedback and expert consultant input).	21 Oct. 2013
4.	Review draft outcome and measurement criteria with key stakeholders.	21 Nov. 2013
5.	Finalise proposed outcome and measurement criteria and syndicate with DMITRE.	14 Dec. 2013
6.	Finalise and submit addendum to DMITRE.	14 Jan. 2014

2. Review and Integration of N-SMR and S-SMR PEPRs

Arrium accepts the DMITRE requirement for the N-SMR and S-SMR PEPRs to be reviewed, and whilst Arrium does not see any major advantages in doing so, understands that DMITRE has a preference for these two PEPRs to be integrated into one new PEPR.

Further, Arrium considers the proposed joint progress reviews with DMITRE during the development of the outcomes and measurement criteria in the revised PEPR as a positive step which will provide confidence to both parties that the final PEPR will precede through the assessment and approval process in a timely and efficient manner.

In consideration of an appropriate process and timeline for achieving a revised and integrated SMR PEPR, Arrium has considered the following:-

1. Operational changes, development activities and improvement initiatives which must be accommodated and facilitated during the review period. These include:-

    - The Chieftain North extension. (This will require new tenements and there is a business imperative to provide extra waste rock dump capacity to support existing Chieftain mining operations beyond approximately May 2014.)
    - The potential Chieftain South extension. (This may require new tenements, and is subject to further exploration drilling and resource definition.)
    - The magnetite concentrator throughput improvement project.
    - The magnetite TSF operational improvement initiatives (consistent with Arrium's approved Management Plan submitted on 30 April 2013 in response to DMITRE's Environmental Direction).
    - The review and update of mine closure and rehabilitation plans.

2. The forecast timing of the registration by the National Native Title Tribunal of the recently executed ILUA covering the Middleback Ranges, which becomes a trigger for the offer of a Mineral Lease related to MC4290

3. Resource requirements to achieve the PEPR review, recognising that Arrium and consultant resources involved are also engaged in progressing regulatory matters associated with other Arrium projects

In consideration of the above, and following internal review and discussion, it is Arrium's view that the review and integration of the PEPR within DMITRE's preferred timing of 12 months is unlikely to be achievable. Consequently, Arrium proposes what it believes to be a practical and achievable timeframe for PEPR review and integration by a submission target date of 30 September 2014.

A high level schedule for completion of the PEPR review and integration by 30 September 2014 is set out below.

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STEP		Complete by:
1.	Develop integrated PEPR structure and approach, and syndicate with DMITRE.	19 July 2013
2.	Review and update SMR LOM (Life of Mine Schedule) designs and closure plans.	Mid Jan 2014
3.	Review and update risk assessments and update outcomes and measurement criteria	End Feb 2014
4.	Undertake stakeholder engagement (where required) and refine closure plans and outcome management where appropriate.	Mid May 2014
5.	Syndicate proposed outcome and measurement criteria with DMITRE.	Mid June 2014
6.	Prepare integrated SMR PEPR proposal draft.	End Aug. 2014
7.	Complete internal review and sign off then submit integrated SMR PEPR proposal to DMITRE.	End Sep. 2014

In proposing the above schedule, Arrium notes the following key points:-

(i) Two matters specifically identified by DMITRE as priorities for early attention are being addressed well within the PEPR review timeframe. These are:-
   a. Implementation of the approved Management Plan to address identified magnetite TSF issues; and
   b. Development and implementation of revised outcomes and dust measurement criteria within the timeframe proposed in section 1 of this letter

(ii) Further assessment of the proposed PEPR review and integration schedule is continuing with the objective of bringing forward the completion date and at the same time integrating the new tenements and mine plan associated with the Chieftain North extension, (which is the subject of a business imperative as indicated above).

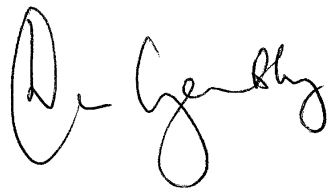
(iii) That in the event that the further assessment discussed in item (ii) above does not identify a means of bringing forward the integrated PPER to align with the Chieftain North business imperative, Arrium will discuss alternative options with DMITRE with the objective of identifying and agreeing a course of action which ensures continuity of mining operations at the Chieftain whilst the PEPR review is completed.

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We would be happy to discuss the above further at your convenience, and would be please if you could confirm the acceptably of Arrium's proposal in due course.

Should you require any further information, do not hesitate to contact me, Email: gartskyd@arrium.com, Ph: 0419 518 133.

Yours sincerely



Don Gartsky
Manager Regulatory Approvals

Government of South Australia
Department of State Development

Ref: MO 6331.001 V6
Doc No: A2236270

19 December 2014

Gavin Hobart
General Manager Development
Arrium Mining
Level 2 169 Fullarton Rd
DULWICH SA
5065

Dear Mr Hobart

***Mining Act 1971* – Notification of approved Program for Environmental Protection and Rehabilitation (PEPR) for South Middleback Range (SMR) Mining Operations**

The program for the SMR Mining Operations, WPC-108 Rev2 as submitted 18 December 2014 has been approved as PEPR No. MPEPR2014/109 in accordance with Section 70B(5) of the *Mining Act 1971*.

You are reminded that in accordance with Section 70D (3), you must at all times implement and comply with this approved PEPR.

Any significant proposed changes to mining operations stated in this PEPR will require a review of the PEPR in accordance with Section 70C of the *Mining Act 1971*.

The PEPR also includes a native vegetation management plan for the clearance of 276.2ha of vegetation on the SMR mining area. The Significant Environmental Benefit (SEB) for the removal of this vegetation has been assessed by the Department of State Development in accordance with the delegation from the Native Vegetation Council as requiring an offset of 2521.4ha.

You have indicated your preferred option is to provide this offset by way of the Shirrocoe Block (Ironstone Conservation Park) and this is also formally approved by the Department of State Development in accordance with the delegation from the Native Vegetation Council.

This approval does not constitute endorsement of the systems that you have in place to manage the mining operations in compliance with the *Mining Act 1971*. Whilst the

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SOUTH AUSTRALIA

PEPR you have provided and your capability to undertake this activity have been considered in making the approval under Section 70B of the *Mining Act 1971,* the responsibility for compliance with the *Mining Act 1971*, *Mining Regulations 2011* and tenement conditions, remains at all times with the tenement holder.

Please note that as a part of undertaking mining operations:

- a copy of the certificate of insurance must be provided
- A bond may be requested (Mining Act 1971 S62). This bond may be formally requested under separate cover.

Under *Mines and Works Inspection Regulation 18, you* are exempted from the operation of *Mines and Works Inspection Regulations* 12(4) and or 14. The Chief Inspector of Mines is satisfied that the alternative procedures and actions contained in this PEPR will achieve the protections to the environment provided by these Regulations.

In accordance with Mining Regulation 86 and Ministerial Determination 009, you are required to provide the Department of State Development with an annual Compliance Report as per existing operational reporting arrangements.

Matters Subsequent to this Approval:

In accordance with Section 70B of the *Mining Act 1971*, I require OneSteel Manufacturing Pty Ltd (Arrium Mining) to review the PEPR, now approved, to address the following matters:

1.1 Inclusion of baseline environmental information associated with the Iron Duchess water storage and consequent update of outcome measurement criterion
   a. Information on water levels, water quality, hydrostatic pressure and geology subsequent to drilling of monitoring bores to the west of the Iron Duchess water storage;
   b. Cross sectional information illustrating surface features, geology and geological structures between the Iron Duchess water storage and down gradient sensitive receivers;
   c. Hydrogeological impact assessment, utilising updated environmental information, of the likelihood and consequence of environmental impacts that the Iron Duchess water storage may have on sensitive receivers in downstream environment;
   d. Update outcomes and measurement criteria to reflect additional baseline information.

1.2 Provide final design specifications for waste rock dump landforms and the strategies for progressively achieving final landform outcomes.

2. Update the SMR PEPR with emphasis on rehabilitation, closure and completion of mining operations in order to demonstrate capacity and capability to successfully achieve closure and completion outcomes of the SMR mines.
   a. Update closure risk assessment utilising updated information;

b. Provide environmental information, focussing on post closure liabilities to support management and planning for rehabilitation and closure including but not limited to:
    i. Post completion landform stability (erosion and geotechnical);
    ii. Analysis of geochemical risk (if any) associated with tailings, waste rock and exposed rock faces;
    iii. Hydrogeological processes.
c. Review closure and completion outcomes, measurement criteria and strategies to achieve these;

The revised PEPR, addressing items 1.1 and 1.2 (above) is to be submitted within 3 months of the date of this approval.

The revised PEPR, addressing item 2 (above) is to be submitted within 2 years of the date of this approval.

Should you require any further assistance, please contact Alistair Walsh, Principal Mining Regulator, Ph: 8463 3108 Mobile: 0477 743 836.

Yours sincerely

Greg Marshall
DIRECTOR MINING REGULATION
DELEGATE OF THE DIRECTOR OF MINES, CHIEF INSPECTOR OF MINES

Government of South Australia
Department of the Premier and Cabinet

Ref: MO6331.001 V6
ID No: 2017D038421

31 August 2107

Gavin Hobart
General Manager Development
OneSteel Manufacturing
Arrium Mining
Level 2 169 Fullarton Rd
DULWICH SA

Dear Mr Hobart

Program for Environment Protection and Rehabilitation (PEPR) Submission for South Middleback Range (SMR) Mining Operations - Request for Review

Thankyou for submitting the draft PEPR for the SMR (18 December 2016), addressing the "Matters Subsequent to Approval" specified in the 19 December 2014 PEPR approval notification. (Attachment 1)

The draft PEPR submitted has been reviewed by a Mining Assessment Officer from the Department of the Premier and Cabinet.

Parts 1.1, 1.2 and 2 of the matters to be addressed detailed in the attached approval letter have been adequately addressed by the draft PEPR submission.

New information in Section 2.2.2. of the draft PEPR submission introduces the potential for leaching of trace elements from the OBP and magnetite TSFs. This new information states the leaching could be at levels that could potentially exceed water quality guidelines. The trace elements present include boron, chromium, aluminium, copper, uranium and zinc. Aluminium, copper and zinc exceeded water quality guidelines and baseline groundwater quality whilst boron and chromium exceeded guidelines but not baseline.

The updated draft PEPR does not contain analysis of potential new risks and impacts to the environment presented by TSF leachates described in section 2.2.2. The requirements in Ministerial Determination MD005 and Guidelines MG2b provide detail on the treatment of new information or new potential environmental impacts in a PEPR.

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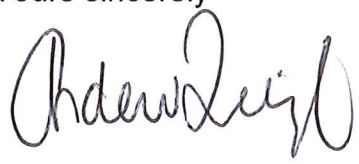
SOUTH AUSTRALIA

You are still required to submit a PEPR in accordance with Section 70C of the *Mining Act 1971* as requested in the letter dated 19 December 2014. In this PEPR you must address the additional matter raised in this letter to ensure your PEPR meets the requirements set out in MD005.

In accordance with Mining Regulation 68, I require that you submit your revised PEPR within 3 months of the date of this letter. If you require a longer period to review your PEPR, please respond in writing indicating the reason and the estimated submission date.

Should you require any further assistance, please contact Alistair Walsh, Principal Mining Regulator, Ph. 8463 3108, Mobile: 0477 743 836.

Yours sincerely



Andrew Querzoli
Deputy Director Mining Assessment

Attachment: Notification of approved program for Environment Protection and Rehabilitation 19 Dec 2014
Cc Geoff Mills
Wilna Haarhoff

Appendix C

Hydrogeological Review of WRDs

Golder Associates 2016, *Hydrogeological Processes, Potential Acid Formation and Geotechnical Stability, Review of Southern Middleback Ranges Waste Rock Dumps,* Golder Report reference 1666199-001-R-Rev0, December 2016

December 2016

HYDROGEOLOGICAL PROCESSES, POTENTIAL ACID FORMATION AND GEOTECHNICAL STABILITY

Review of Southern Middleback Ranges Waste Rock Dumps and Tailings Storage Facilities

Submitted to:
Arrium Mining Ltd
PO Box 21
WHYALLA SA 5600

REPORT

Report Number. 1666199-001-R-Rev0

Distribution:

Arrium: 1 electronic copy
Golder: 1 electronic copy

Golder Associates

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Important Information

1.0 INTRODUCTION

Arrium Mining Limited (Arrium) owns and operates the Southern Middleback Ranges (SMR) operations in South Australia. The operations produce iron ore for export and supply to the OneSteel Whyalla steelworks. The regulator, the Department of State Development (DSD), regulates these operations.

The DSD is currently seeking additional information relating to Arrium's closure and rehabilitation plans, in the form of an updated Program for Environmental Protection and Rehabilitation (PEPR). Specifically, the DSD requires further assessment related to the geotechnical stability, geochemical and seepage potential and weathering/erosion potential of SMR's waste rock dumps (WRDs) and tailings storage facilities (TSFs).

Golder Associates Pty Ltd (Golder) was commissioned by Arrium to assist with the compilation of available information, and where possible, provide additional interpretations to support this further assessment. A significant number of investigations and assessments have been undertaken for Arrium's WRDs and TSFs, particularly at the Iron Duke Mine site, including geotechnical assessments and reviews of geochemistry and local and regional hydrogeology. In addition, geochemical analyses have been undertaken of waste rock at SMR's operations.

Investigations have been undertaken and documented over a significant period – a list of key reports is contained in Appendix A.

2.0 REGULATOR REQUIREMENTS

Arrium is required by the DSD to undertake, amongst other things, a geotechnical and seepage assessment of SMR's WRDs and their final landforms. Specifically, the following is required:

a) Review of the related reports, geological, geotechnical and hydrogeological information available

b) A geochemical and geotechnical assessment of the waste rock and tailings based on the geochemical and geotechnical properties determined from the analysis of the representative sampling of all waste rock types and tailings to be disposed

c) A review of the geochemical assessment of all rock types that are to be disturbed based on representative sampling and analysis that includes the identification and quantification of, but not limited to, sulphide minerals that have the potential to generate acid or mobilise metals into the environment

d) An assessment on the weathering and erosive potential of waste rock to be disposed

e) Where relevant, a description of the placement and encapsulation of waste material deemed to be hazardous including potentially acid forming material (PAF)

f) A geotechnical stability assessment and a factor of safety analysis

g) An assessment of seepage of liquids through the waste rock and tailings storage facilities

h) Strategies for the containment of any seepage that has the potential to impact the environment (if applicable)

i) An assessment of the post completion chemical and physical stability of the structure following rehabilitation, including the expected extent of erosion

j) An assessment of the source, pathway and ultimate fate of any potential mobile contaminants (if applicable)

k) Arrium's impact assessment methodology and terminology must be used for alignment with PEPR impact assessment statements

l) Assessment of limitations of the waste dump and tailings facility assessment based on information available and recommendations for future investigations/assessment.

3.0 RESPONSE TO DSD ITEM A: REVIEW OF RELATED REPORTS, GEOLOGICAL, GEOTECHNICAL AND HYDROGEOLOGICAL INFORMATION

Golder has reviewed the list of reports contained in Appendix A, and where necessary, utilised relevant information contained within them to support this assessment.

4.0 RESPONSE TO DSD ITEM B: GEOCHEMICAL AND GEOTECHNICAL ASSESSMENT OF THE WASTE ROCK AND TAILINGS

4.1 Geotechnical assessment of tailings

Samples of tailings were assessed in August 2015 following the implementation of the Magnetite Expansion Project (MEP) 2.4 (Golder, 2015a). The geotechnical parameters adopted in design of the Mag TSF were predominantly referenced in Golder (2014a) and Golder (2014b).

Two samples of tailings were tested in August 2015 programme, described below.

1) A sample of 'combined tailings' was prepared by mixing OBP tailings and magnetite fine tailings at a ratio of 5:41 of dry solids (representing 50 tonnes per hour (tph) of OBP tailings and 410 tph of Magnetite tailings). The polymer provided by Arrium was diluted to 0.2% mass concentration using process water from the Concentrator, and then added to the tailings mixture at a rate of 400 grams of polymer per tonne of tailings solids. The polymer-treated combined tailings is referred to as 'combined tailings'.

2) A sample of 'coarse tailings', referring to the coarse fraction of the magnetite tailings generated at the Concentrator.

For each parameter assessed, a comparison has been made to the historical value adopted and whether there would be any effect on the design of the Mag TSF.

4.1.1 Specific gravity (G_s) of solids

The G_s for the combined tailings solids was measured as 3.13. This compares to a range of 2.94 to 3.34 measured on previous samples of the magnetite tailings alone, and 3.07 measured on a sample of combined tailings that was prepared at a different mix ratio of 3.2:1 (Mag:OBP). Note this ratio considered that reprocessing of the OBP TSF was going ahead, which was not feasible and did not progress.

The G_s of the coarse tailings was measured as 3.21, consistent with the combined tailings as it from the same material source.

The changed tailings stream has had negligible effect on this parameter.

4.1.2 Particle size distribution

The PSD of the combined tailings and coarse tailings was measured as described below, and the results are plotted in Figure 1. The PSD of the:

- combined tailings was measured by Sedigraph™ by Microanalysis Australia.
- coarse tailings was measured by sieving by Golder.

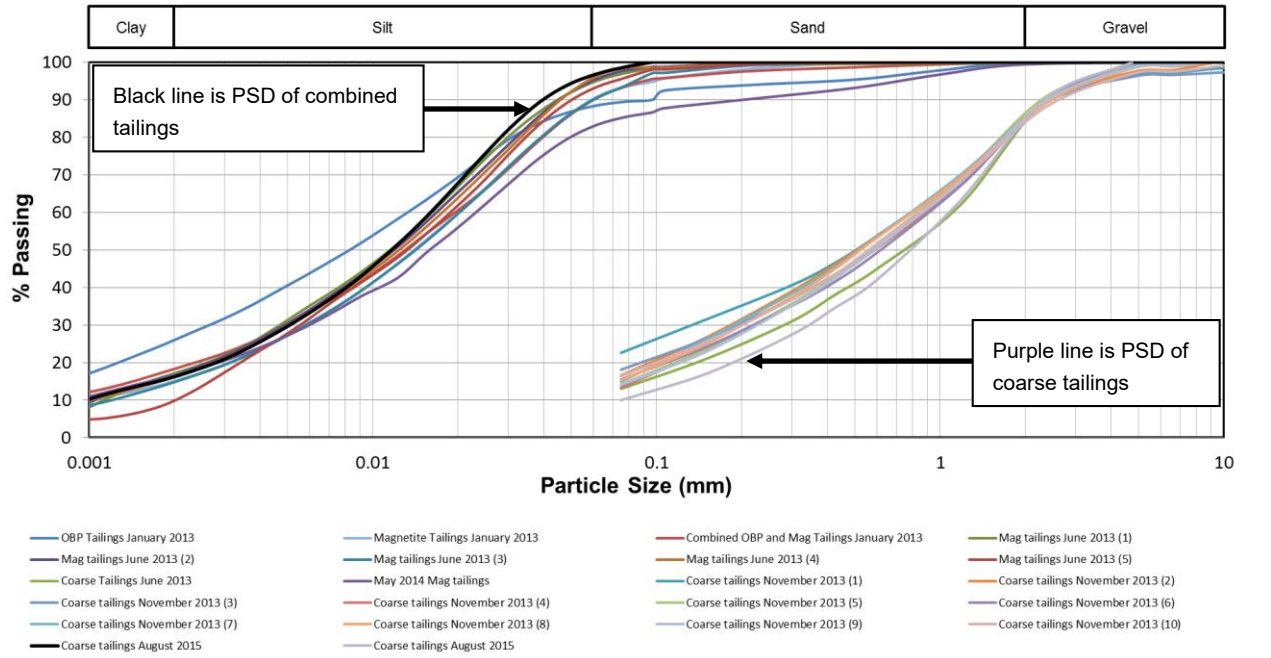


Figure 1: Comparison of tailings PSD results

The combined tailings is generally finer than the historical PSD of the magnetite tailings alone, as shown by the black line in Figure 1. This is inferred to be due to the contribution of OBP tailings (the finest PSD on Figure 1, blue line furthest to the left) as well as a finer magnetite tailings stream as a result of MEP2.4. The coarse tailings appears to be coarser than previous based on the testing undertaken by Golder, shown by the purple line in Figure 1. Overall, neither of these changes are considered to have a material effect on the design of the Mag TSF.

4.1.3 Atterberg limits

The Atterberg Limits of the tailings streams were assessed and the results are summarised in Table 1. The changed tailings stream has had negligible effect on this parameter.

Table 1: Comparison of plasticity test information

	Previous Range for Mag and Combined Tailings	August 2015 Programme for Combined Tailings	Previous Result for Coarse Tailings	August 2015 Programme for Coarse Tailings
Liquid Limit (%)	30-34	29	17	Non-plastic
Plastic Limit (%)	15-26	18	16	Non-plastic
Plasticity Index (%)	8-15	11	1	Non-plastic
Linear Shrinkage (%)	5.0-6.4	2.5	0.0	Non-plastic

4.1.4 Density

Compacted density of coarse tailings

The standard maximum dry density (SMDD) and standard optimum moisture content (SOMC) for the coarse tailings were measured. The result of this test is compared to range of results from samples tested by Golder in the past in Table 2.

Table 2: Comparison of compacted density of coarse tailings

Parameter	Previous Range	August 2015 Testing Programme
Standard maximum dry density (t/m^3)	2.39 to 2.49	2.35
Standard optimum moisture content (%)	6.8 to 9.4	6.5

The changed tailings stream has had only a small effect on the SMDD and SOMC, reducing both parameters slightly.

Shrinkage limit of combined tailings

A shrinkage limit test was undertaken on the combined tailings, and the results are shown in Figure 2. Two samples were measured to reduce uncertainty with respect to measurement of the sample, which is carried out using callipers.

The testing showed that the moisture content at shrinkage limit for the combined tailings is approximately 25%. This is a decrease from 30% measured for only the Mag tailings treated with polymer in our previous testing programme (Golder, 2014b). The guidance developed from our previous testing programme was for Arrium to target 25% moisture content on the tailings beach prior to construction of an embankment raise, which acknowledged variations in the tailings, polymer dosing and drying regime. Based on the results shown in Figure 2, Arrium should continue to follow this guidance.

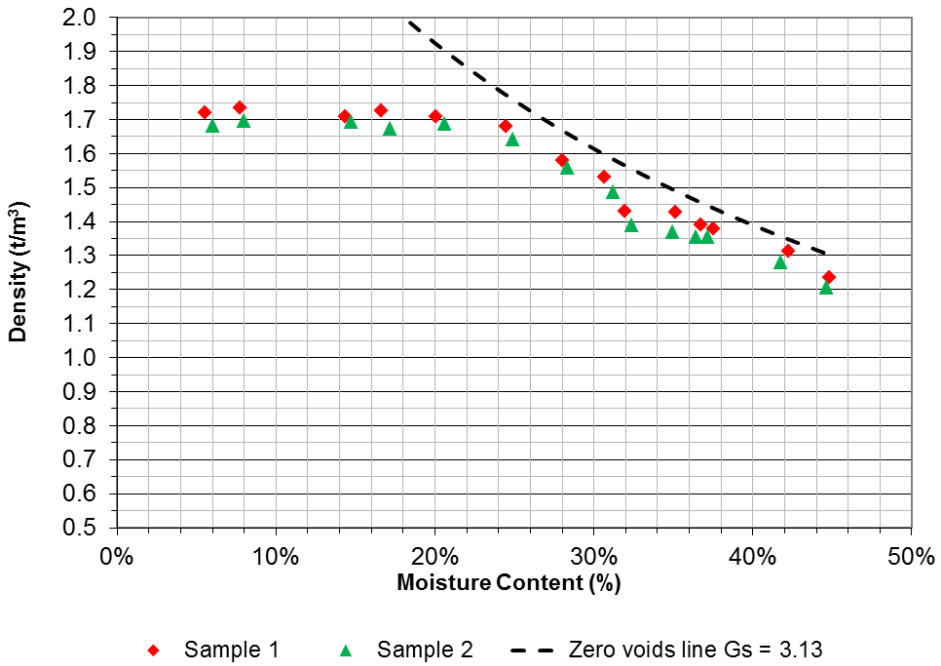


Figure 2: Shrinkage testing undertaken on combined tailings

Consolidated density of combined tailings

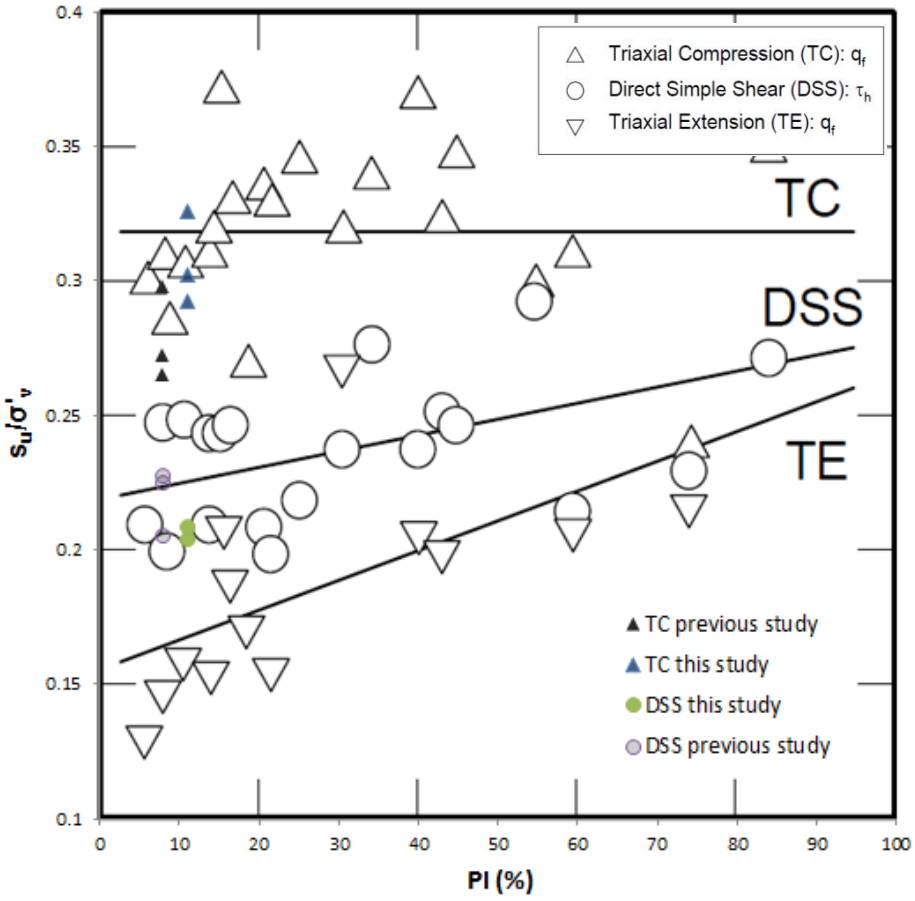
The consolidation testing undertaken as part of the strength testing showed densities of the combined tailings ranging between 1.4 t/m^3 and 1.6 t/m^3. These values correspond well to our previous testing programmes on the tailings and the design value for average stored dry density of combined tailings in the Mag TSF of 1.5 t/m^3.

4.1.5 Peak shear strength

Combined tailings

The peak shear strength of the combined tailings was assessed using triaxial compression tests and direct simple shear (DSS) tests. The triaxial testing was undertaken using the Ck_oU method, wherein samples are consolidated to vertical and effective stresses relevant to *in situ* conditions. This form of triaxial testing provides an estimate of both peak undrained strength, small-strain brittleness (where relevant), and effective friction angle. DSS testing was undertaken under monotonic conditions to estimate peak undrained shear strength. Samples were consolidated to a range of pressures to test over the range of pressures expected during the development of the Mag TSF. The combined tailings were subjected to initial vertical effective stresses of approximately 100 kPa, 400 kPa and 800 kPa and consolidated under k_o conditions. The samples for the DSS tests were consolidated under effective vertical stresses of 100 kPa.

The critical condition for the combined tailings is the undrained strength as the tailings are contractive and the Mag TSF is raised upstream (onto the tailings). The value of the undrained shear strength ratio varied from approximately 0.2 measured in simple shear testing (shown with the green circles in Figure 3) to 0.3 measured in triaxial compression testing (shown with the blue triangles in Figure 3). These values compare reasonably well to those previously measured for the Mag tailings treated with polymer.



Note: based on plot of Ladd (1991)

Figure 3: Undrained strength ratio from triaxial compression (TC) and direct simple shear (DSS) vs plasticity index (PI)

Typically the average between these two methods is adopted for use in stability analysis (Ladd, 1991). Previously Golder adopted an undrained shear strength ratio of 0.25 in the slope stability analyses undertaken for the Master Plan of the Mag TSF (Golder 2015b), and based on the testing from this programme, Golder considers this value should remain unchanged.

The results are also summarised in Table 3. Golder considers that the changed tailings stream has not had a significant effect on this parameter.

Table 3: Peak strength parameters for combined tailings

Parameter	Value used in Previous Designs (Tested only Mag Tailings with Polymer)	Value from August 2015 Testing Programme
Drained Friction angle (degrees)	30	32-35
Undrained shear strength ratio, s_u/σ'_v	0.25	0.25

Coarse tailings

The strength of the coarse tailings was assessed using consolidated, isotropic, undrained triaxial tests. Samples were prepared by remoulding the coarse tailings to 95% standard dry density ratio at standard optimum moisture content.

The results are summarised in Table 4. The coarse tailings have a higher peak effective friction angle compared to the previous testing programme, which will improve the factor of safety for stability of the embankments should Arrium continue to use this material for construction.

Table 4: Strength parameters for coarse tailings

Parameter	Value used in Previous Designs	Value from August 2015 Testing Programme
Drained Friction angle (degrees)	34	37
Cohesion (kPa)	0	0

4.1.6 Post-cyclic shear strength of combined tailings

Test method

Cyclic direct simple shear (CDSS) testing was undertaken by consolidating samples to the desired stress level and then cyclically shearing under constant volume conditions to a desired stress level (stress controlled test) and maximum peak to peak strain. The results of the testing are plotted in Figure 4.

Based on the outcomes of this study and acknowledging the limitations of a laboratory investigation that cannot accurately replicate all of the process that occur *in situ*, Golder considers a post cyclic peak undrained strength of the tailings of 0.11 to be a reasonable post cyclic undrained strength value to be used in post seismic limit equilibrium analysis. This is a slight reduction from the value of 0.12 adopted during the development of the Master Plan for the Mag TSF (Golder, 2015c).

Note that a value of 0.08 was adopted during development of the life of mine studies for the Mag TSF (Golder, 2014b). This value is sensitive to field conditions and should be regularly reviewed by field and laboratory testing as the Mag TSF increases in height.

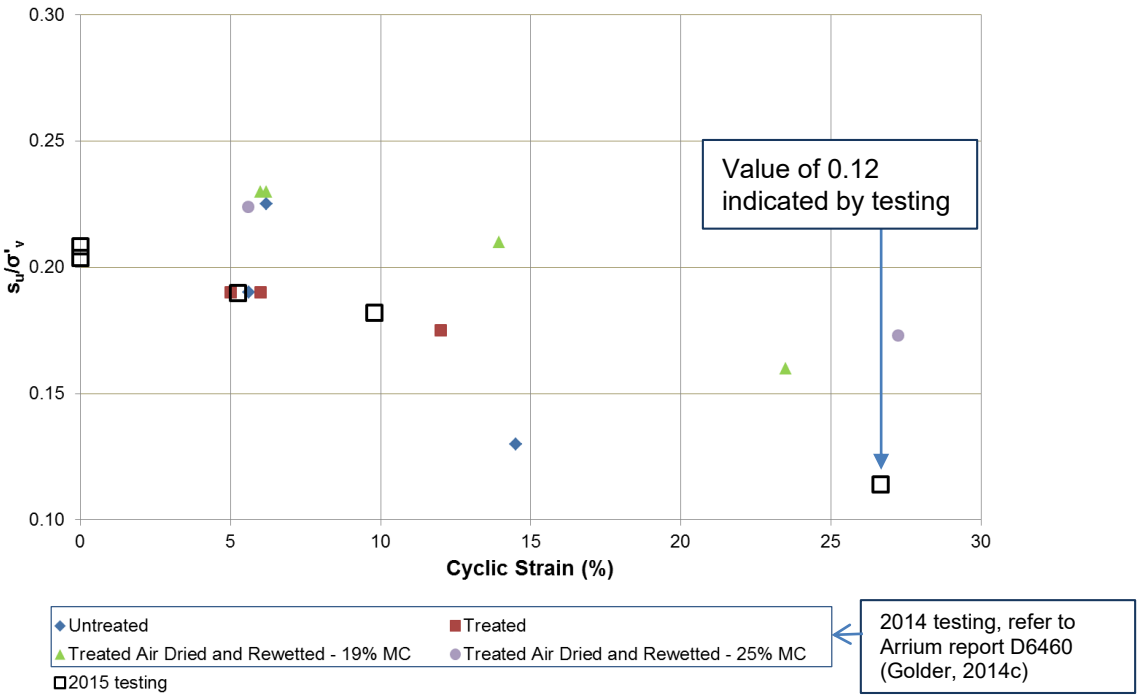


Figure 4: Effect of cyclic loading on undrained strength of tailings

4.2 Geotechnical assessment of waste rock

Geotechnical testing and assessment of the waste rock at SMR is limited owing to the impracticalities of testing large diameter cobbles and boulders. A typical photograph of waste rock is shown in Figure 5.



Iron Duke – View south over recent ripping of lower waste rock dump lower benches

(Mining Plus, 2014)

Figure 5: Typical waste rock at SMR

The natural rill angle of the waste rock dumps operated by Arrium has been identified as 37° (Mining Plus, 2012, referenced by Arrium Mining, 2015), which was based on a review of historical WRDs with 30 m to 40 m high faces at both Iron Knob and Iron Baron.

The waste rock is variable, owing to different lithology and weathering. The photograph shown in Figure 5 was taken by Golder in June 2013 during a geotechnical investigation at the Mag TSF (Golder, 2014a). Compared to the waste rock shown in Figure 6, it appears to have a much higher fines/clay content, which is inferred to be sourced from a more oxidised portion of the orebody.



Figure 6: Oxide mine waste forming safety windrow on Mag TSF perimeter embankment

The oxide mine waste was sampled in June 2013 using hand tools so particles larger than 150 mm were not sampled. Particles over this size can be seen in Figure 6 and therefore the PSD is not fully representative of the mine waste, although it provides a reasonable indication.

The results of the classification testing undertaken on the oxide mine waste are summarised in Table 5 (adapted from Golder, 2014a). Based on the results, the unified soil classification system (USCS) description for the oxide mine waste is:

Clayey Gravel, fine to coarse, brown grey, approximately 20% medium plasticity fines, with approximately 15% fine to coarse sand.

Table 5: Summary of geotechnical classification test results on borrow material samples

Test	Parameter	Oxide Mine Waste
Particle Size Distribution	% Passing 150 mm	100
	% passing 60 mm (upper limit of gravel fraction)	86
	% Passing 2.36 mm (upper limit of sand fraction)	35
	% Passing 75 µm (silt + clay fractions)	18
Atterberg Limits	Liquid Limit (%)	46
	Plastic Limit (%)	16
	Plasticity Index (%)	30
	Linear Shrinkage (%)	8.0
Emerson Class	Emerson Class Number	4
Moisture Content	Field moisture content (%)	17.9

The oxide mine waste was also tested for permeability using the constant head method in a flexible wall permeameter. One limitation of this test method and the apparatus used is that the test is undertaken only on material smaller than 6.7 mm, so it is an indication of the permeability of the fines. Another limitation is that each sample fraction finer than 6.7 mm was remoulded to 95% of the standard maximum dry density, but the compaction test is carried out on a much wider range of particle sizes. The permeability of the oxide mine waste fines was assessed to be 7.3×10^{-10} m/s.

The samples were remoulded to 95% of their standard maximum dry density to resemble their expected *in situ* states after being moisture conditioned and compacted to form an embankment. It is likely that the sample was remoulded to a higher dry density ratio owing to the difference in particle sizes for each of the tests. The measured permeability agrees well with Hazen's 1892 equation (Terzaghi *et al*, 1996) for permeability of granular soils (referenced in Golder, 2014a).

It is not possible to undertake meaningful shear strength testing on samples of waste rock. Golder adopted a friction angle of 38° in slope stability assessments undertaken for the Mag TSF, owing to the compaction of the mine waste during placement (Golder, 2014a).

4.3 Geochemical assessment of tailings

PB (2004 and 2007) and Golder (2014a) undertook geochemical testing on tailings materials, including materials on embankments, to assess the acid forming potential and potential for leaching of toxic elements from the TSFs. No other studies were carried out on tailings solid materials. Groundwater quality in the vicinity of the TSFs was reviewed in 2015 (Golder 2015e). The tailings tested by PB (2004 and 2007) were from magnetite ore processing, and tailings materials tested by Golder (2014a) were from the hematite ore beneficiation plant (OBP) and magnetite ore concentrator.

The findings of the tailings geochemical assessment include:

- The sulphur content of all tailings samples, including the OBP and magnetite tailings, was low <1%, ranging between 0.01% and 0.48% in tailings tested by PB (2004 and2007).
- Dolomite, a carbonate mineral with high neutralising capacity, was found to occur in both the OBP tailings (3%) and magnetite tailings (14%) samples.
- The tailings and embankment materials tested by PB (2004 and 2007) and Golder (2014a) were classified as non-acid forming.
- Tailings tested by PB (2004 and 2007) generated leachate that was characterised by near-neutral pH and low levels of trace elements.

- The OBP and magnetite tailings (Golder, 2014a) indicated potential for leaching of trace elements at levels that could potentially exceed water quality guidelines. These included boron, chromium, aluminium, copper, uranium and zinc. These elements were also found to be elevated in the tailings supernatant. Aluminium, copper and zinc exceeded water quality guidelines and baseline groundwater quality whilst boron, chromium and uranium[1] exceeded guidelines but not baseline. The pH of the leachates and supernatant were alkaline (7.9-9.1).

Based on available tailings geochemical data, the risk of ARD generation of tailings materials is low. However, there is potential for leaching of trace elements into groundwater from the tailings. There is also a potential for tailings seepage to leach major and trace elements from the embankments as the seepage is likely to be under-saturated with respect to metals found in abundance in the saline soils used in embankment construction.

4.4 Geochemical assessment of waste rock

Parsons Brinkerhoff (PB) undertook geochemical testing on selected rock samples, including waste rock and ore, in 2004 and 2007. The tests included assessing the acid forming potential and leaching potential of the different rock units that would be deposited on the WRDs or be exposed on pit faces. However, the tests were done on one sample of each rock unit (PB, 2007). No further geochemical tests have been done on waste rock units or rock units that are likely to be exposed on pit faces. The results of the acid forming tests by PB (2007) are presented in Table 6.

The following are the findings of the studies:

- The waste rock samples were characterised by low sulfur content (0.03%-0.14%), with the exception of sulfide breccia, which had a very high sulfur content (10.3%).
- Most of the ore rock units, which are likely to occur on exposed faces, had sulfur content ranging from <0.01% to 0.16%, with the exception of magnetite amphibole ore, which had a sulfur value of 0.45%.
- The pH of all samples was alkaline (9.3-9.7).
- The waste rock units were classified as acid consuming material (ACM), with the exception of sulfide breccia, which was potentially acid forming (PAF). It was, however, noted that the sulfide breccia represented a small fraction of waste rock materials.
- The ore rock units were classified as either non-acid forming (NAF) or acid consuming materials due to presence of calcium and magnesium carbonate.

[1] Uranium was not reported in groundwater

Table 6: Acid forming potential screening test results (taken from PB 2007)

Material Type	Description	S %	pH	NAG kg H_2SO_4/t	NAPP kg H_2SO_4/t	ANC kg H_2SO_4/t	Classification of Acid Forming Potential
Waste Rock/exposed faces	SBX Sulfide Breccia	10.3	9.6	29	246	70	Uncertain (PAF, other than pH)
	DOM Dolomite	0.14	9.3	<0.5	-716	720	Acid Consuming Material (ACM)
	AMP Amphibolite	0.03	9.7	<0..5	-217	220	Acid Consuming Material (ACM)
Ore/Exposed faces	MTA Magnetite Amphibole Ore	0.45	9.3	<0.5	-80	93	Non Acid Forming (NAF)
	MTC Magnetite Carbonate Ore	0.04	9.4	<0.5	-194	200	Acid Consuming Material (ACM)
	MTS Magnetite Silica Ore	0.03	9.7	<0.5	-139	140	Acid Consuming Material (ACM)
	Blind Duplicate (MTS)	0.16	9.8	<0.5	-129	130	Acid Consuming Material (ACM)
	MTO Massive Magnetite Ore	0.05	9.6	<0.5	-52	53	Acid Consuming Material (ACM)
	MTT Magnetite Talc Ore	0.14	9.6	<0.5	-47	51	Non Acid Forming (NAF)
	HMO Hematite Magnetite Ore	<0.01	9.4	<0.5	-149	150	Non Acid Forming (NAF)
	HEO Hematite Ore	0.04	9.7	<0.5	-100	100	Acid Consuming Material (ACM)
	MCH Magnetite Chlorite Ore	0.06	9.5	<0.5	-129	130	Non Acid Forming (NAF)
	HEC Hematite Carbonate Ore	<0.01	9.7	<0.5	-429	430	Acid Consuming Material (ACM)
	MHO Magnetite Hematite Ore	0.01	9.7	<0.5	-84	84	Non Acid Forming (NAF)

The results of the leach testing indicated that the leachate from the waste rock and ore samples were characterised by low TDS (19 mg/L-176 mg/L) and trace elements. It should however be noted that the trace element data was not available for review and could not be checked for completeness.

Based on available geochemical data, the geochemical risk associated with waste rock materials and exposed rock faces is considered to be generally low given that the volume of sulfide breccia, which has the sole potential of generating ARD, is low.

It is understood that the sulfide breccia will not be encountered until 2024 based on the current mine planning assumptions. The volume of breccia expected in Magnet E pit is 20 000 BCM, likely to be intersected on the western wall at approximately 100 RL (refer to Figure 7).

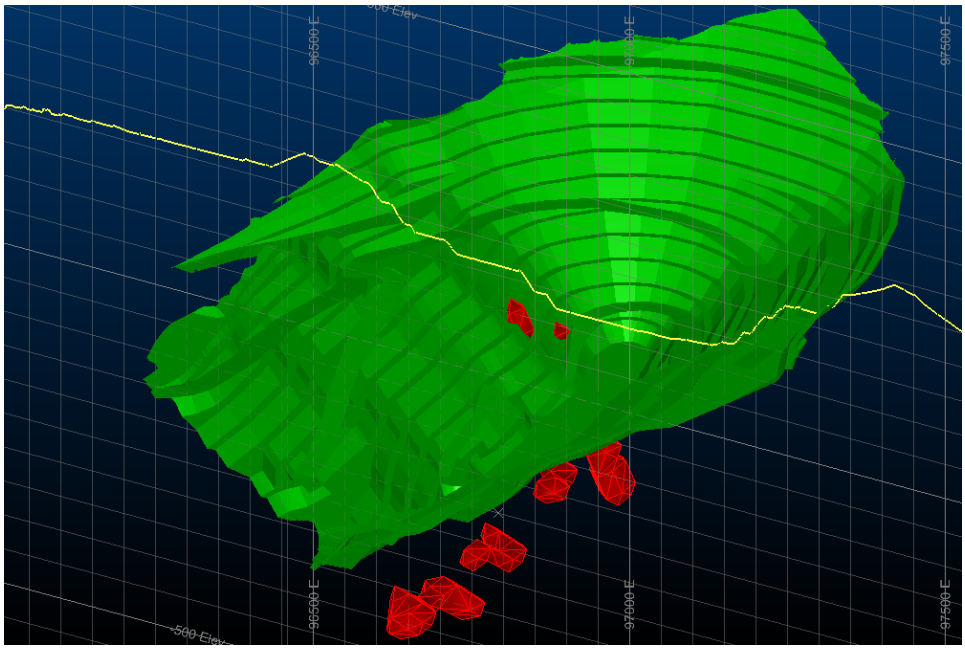


Figure 7: Estimated location of the sulfide breccia where Magnet E pit (green) sulfide breccia (red)

The sulfide breccia will be blended with high acid consuming materials, for example dolomite. The PB report recommended blending of three parts dolomite to one part sulfide breccia. The mixture could produce neutral or saline drainage.

Samples of the dolomite should be collected to verify the neutralising potential and their likely mined locations relative to the breccia.

The above approach needs to be validated against the current mine plan since it is based on information from the 2004 and 2007 studies.

5.0 RESPONSE TO DSD ITEM C: REVIEW OF THE GEOCHEMICAL ASSESSMENT OF ALL ROCK TYPES

Refer to information contained in Section 4.3.

6.0 RESPONSE TO DSD ITEM D: ASSESSMENT OF THE WEATHERING AND EROSIVE POTENTIAL OF WASTE ROCK

As summarised by Arrium (2015), WRD design profiles, features and finishes have been developed through a combination of engaging independent experts, making observations of historical WRDs previously established in these mining regions, and commissioning studies and trials on variations of regolith and armouring materials. Stable SMR WRD designs reference the following observations and learnings:

- A review of as-built WRD structures within Arrium's MBR was completed by Mining Plus in 2012. The review identified a high level of stability in historical dumps over 50 years old at the natural rill angle of 37°. These WRDs remain stable, even at substantially high 30 m to 40 m faces as evidenced in the historical WRD profiles in the Iron Knob and Iron Baron operations.
- An area of approximately 0.2 km^2 of the outer face of the WRD to the south-east of the Iron Duke pit was rehabilitated in early 2013, comprising flattening the outside slope to <20°, ripping in topsoil and broadcast seeding (Mining Plus, 2014). Arrium (2015) note this has improved the erosion resistance of the WRD.
- Investigation into the best cover material types carried out by LandLoch Pty Ltd indicated a mixture of coarser alluvial material mixed with finer sandy material recovered during topsoil stripping helps reduce both wind and water erosion of the finer materials. Arrium is trialling methodologies to mix fine dispersible soils with coarse waste rock prior to sheeting the slopes (Arrium, 2015).
- Progressive rehabilitation during operations allows for monitoring of final landform development and various trials of cover materials, top soil and vegetation placement and its success (Arrium, 2015).

There are no other studies about weathering and erosive potential of waste rock.

The leachability studies summarised in the previous PEPR (2014) indicate that the waste rock assessed in this study did not dissolve, thus from these limited data there is no indication that the geochemistry of the waste rock tested presents a risk to the stability of the current WRD.

7.0 RESPONSE TO DSD ITEM F: GEOTECHNICAL STABILITY ASSESSMENT AND A FACTOR OF SAFETY ANALYSIS

7.1 TSFs

7.1.1 Mag TSF

The original Mag TSF design (Coffey, 2006) assumed that deposition of tailings would take place from a central location with the TSF. Supernatant water from the tailings during the initial years of deposition was to be collected at the decant locations along the western wingwall. It was intended to increase the slurry solids concentration to a consistency where there would be little or no bleed water from the tailings (~64% by mass), whereupon it was planned for the decants to be decommissioned. It was expected that wingwall would be overtopped and the tailings would subsequently beach against the western embankment.

The tailings are delivered to the Mag TSF at a solids concentration with the range of approximately 43% to 48%, resulting in the delivery of significantly more water to the TSF than intended by the original design. Consequently, the design has been converted to a perimeter discharge facility and the decants have been retained, being progressively raised to their current height of approximately 20 m. Tailings will continue to be discharged from the perimeter embankments until the TSF is decommissioned.

The original design assumed that truck-hauled coarse tailings would form the perimeter embankments and the wingwall. The perimeter embankments were to be raised in an upstream direction. Due to the lower solids content of the slurry and larger than expected quantity of supernatant water, the decants have remained in operation, and the wingwall has been buttressed and raised in a downstream direction using a combination of mine waste rock, coarse magnetite tailings and clayey sand from within the footprint of the TSF.

The raises to the wingwall prevented tailings deposited in the main basin from beaching against the western embankment. The western embankment remained at its starter elevation until April 2013 when it was raised upstream by approximately 5 m. The combination of the raised wingwall/buttress and the western embankment resulted in three "voids" between the wingwall and western embankment. Deposition of slurry tailings commenced into the voids in early 2014 and the western embankment has been raised three times, by a total of approximately 9 m since that time, as follows:

- RL 154 m to RL 156 m by a top-hat raise
- RL 156 m to RL 159 m by the upstream raise method. This also included a step-in bench of about 5 m width (i.e. there is a bench at RL 156 m).
- RL 159 m to RL 163 m by the upstream raise method. The western embankment construction was completed to this elevation in October 2016.

Golder prepared the original design for the conversion of the Mag TSF from central discharge to perimeter discharge and undertook a geotechnical investigation and stability assessment as part of that design. The design was to increase the perimeter embankment elevation to RL 199 m, assuming that mining continued until 2034. The stability assessment considered both static, pseudo-static and post-liquefied conditions. For the pseudo-static conditions, a peak ground acceleration of 0.37g was applied, equivalent to the 1:10000 AEP earthquake event. At closure, a maximum credible earthquake of 1.22g (1:60000 AEP) was applied. Note that these values were factored down by 50% as is common practice in pseudo-static analysis (Fell, 2015). Under the conditions investigated by Golder, the minimum factor of safety is summarised in Table 7.

Table 7: Summary of stability analysis for Mag TSF showing minimum factor of safety

Failure Mode	Static Conditions (Target 1.5)	Maximum Design Earthquake (Target 1.0)	Maximum Credible Earthquake	Post-Liquefied Conditions (Target 1.0)
Effective stress (drained analysis)	2.03	-	0.51	-
Total stress (undrained analysis)	2.13	1.12	-	0.45

The stability of the Mag TSF will be governed by post-liquefied strength conditions, which will be affected by how tailings are deposited over the life of the TSF. Given a factor of safety less than unity under these conditions, a quantitative dam break risk assessment (QRA) was undertaken to consider the consequences of a flow failure of the Mag TSF. The QRA demonstrated that the estimated likelihood of a flow failure from the Mag TSF is approximately 1 in 16 000 per annum. Additionally, the probability of one or more fatalities or serious injuries arising from a flow failure of the Mag TSF has been estimated to be about 1 in 38 000 per annum. This risk of a flow failure plots well within the 'as low as reasonably practicable' (ALARP) region of ANCOLD's F-N diagram. These studies are documented in the design studies prepared by Golder (2014b) for the Mag TSF.

Additional stability assessments were undertaken as part of the detailed engineering for the embankment raises to RL 172 m (referred to as the Mag TSF Master Plan, Golder (2015c)). The results of the stability analyses indicate that the estimated minimum factor of safety against downstream failure, under static, pseudo-static and post liquefaction loading conditions, for the section analysed, are greater than the target values, as shown in Table 8. Note that these analyses were undertaken prior to design changes such as the top-hat raise from RL 154 m to RL 156 m, but it is not expected that these changes to embankment geometry would significantly impact the outcomes of the assessment.

Table 8: Summary of stability analyses for western embankment raised to RL 172 m

Failure Mode	Static Conditions (Target 1.5)	Maximum Design Earthquake (Target 1.0)	Post-Liquefied Conditions (Target 1.0)
Effective stress (drained analysis)	2.17	-	-
Total stress (undrained analysis)	2.02	1.12	1.39

A further geotechnical investigation was undertaken in October 2015 of the tailings in the voids (Golder, 2015d). The investigation indicated a lower post-liquefied strength than adopted in the stability analyses described above; an undrained strength ratio s_u/σ'_v of 0.05 instead of 0.08, although this does not significantly impact the probability of failure, indicated by the probabilistic analysis undertaken for the studies for the ultimate TSF at RL 199 m (Golder, 2014b and 2015c).

At current conditions, the only portion of the western embankment that is significantly raised upstream on the tailings is from approximately RL 156 m to RL 163 m, and the remainder of the tailings (i.e. from RL 156 m and below) are predominantly impounded by the original western embankment.

7.1.2 OBP TSF

The original design of the OBP TSF by GHD assumed that deposition of tailings would occur from the perimeter embankment, with supernatant water recovered from the facility via a centrally-located decant tower. However, due to limitations of the pumping system that delivers tailings to the OBP TSF, tailings could not be pumped around the entire perimeter of the TSF without significant dilution of the tailings slurry (Coffey, 2010). Arrium therefore adopted a single discharge point closer to the plant to enable the design slurry density to be maintained. Due to deposition from the north-east end of the facility, pumping from the central decant tower ceased. A decant trench and filter embankment were constructed in the southern end of the facility to recover supernatant water (Coffey, 2010).

Coffey prepared a revised design in 2009 and 2010 (Coffey, 2010) for perimeter discharge up to a maximum perimeter crest elevation of RL 188.5 m, with the embankment to be raised in a downstream direction. The design was subsequently implemented to an embankment crest elevation of RL 177 m and OBP tailings was deposition into the OBP TSF until July 2014 at which time it was redirected to the Mag TSF.

The stability assessment undertaken by Coffey (2010) considered both the north-west and south-west perimeter embankments, at RL 188.5 m and RL 183.7 m, respectively. The stability assessment considered both static and pseudo-static conditions. For the pseudo-static conditions, a peak ground acceleration of 0.15g was applied, which Coffey (2010) noted was equivalent to a 1:500 AEP earthquake event. Note that this value was not factored down by 50% as is common practice in pseudo-static analysis (Fell, 2015), so the analysis is more representative of an earthquake of 0.3g. As noted above, the embankments of the OBP TSF are ~6 m to ~10 m lower than the ultimate design height. Under the conditions investigated by Coffey (2010), the minimum factor of safety is summarised in Table 9.

Table 9: Summary of stability assessment undertaken for OBP TSF

Perimeter Embankment	Factor of Safety	Recommended Factor of Safety
North-west embankment, static conditions	2.31	1.50
North-west embankment, pseudo-static conditions	1.52	1.10
South-west embankment, static conditions	2.24	1.50
South-west embankment, pseudo-static conditions	1.44	1.10

7.2 WRDs

The SMR WRD operational strategy was developed by Mining Plus (2011c) that validated earlier conceptual design work (Mining Plus, 2011a and 2011b) and incorporated results of erosion assessments undertaken by LandLoch Pty Ltd (2011). The key design features of the WRDs, in terms of ensuring geotechnical stability, are:

- A target concave slope profile at closure of 10° on the lower slopes, 15° on mid-slope and 20° on upper slope, shown on the right hand side of Figure 8. As the natural rill angle of the waste rock is 37° (refer Section 4.1), this has been adopted as the operational 'tip' angle and the bench widths are varied between 10 m and 18 m wide (indicated on left hand side of Figure 8) to be cut and filled post-closure.
- At closure, the reshaped slope will be covered in predominantly non-dispersive materials sourced from within the footprint of the WRDs prior to placement of waste, i.e. stripped topsoil. Landloch identified some dispersive materials that would be susceptible to erosion at the closure slopes and then rock armouring is recommended on the final dump faces.

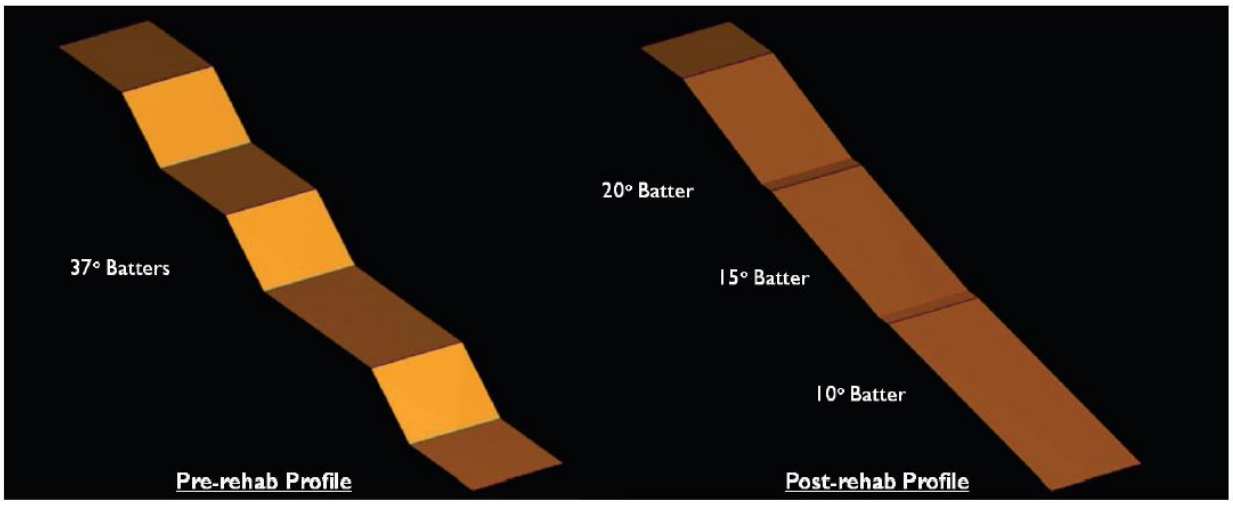


Figure 8: Slope profile of WRDs

The selection of the operational and post-closure WRD profiles have been supported by geotechnical stability analyses (Mining Plus, 2011b). The analyses considered different foundation conditions (weathered rock or sand) and different profiles and ultimate dump heights. The critical factor of safety from each analyses was summarised by Mining Plus (2011b) and the outcomes of this work are illustrated in Figure 9. The results indicate that the WRD profiles shown in Figure 8 are likely to be geotechnically stable.

WRD Material Type	Type 1 - Hard Waste		Type 2 - Hard Waste Mixture with Friable Material	
Basement Type	Weathered Rock Basement	Sandy Basement	Weathered Rock Basement	Sandy Basement
	Determined Factor of Safety (Phase2 FEM Analysis)			
Full Height Dump (No Berm)				
15m @ 37deg Slope Angle	3.27	1.74	3.09	1.69
30m @ 37deg Slope Angle	2.41	1.43	2.27	1.51
45m @ 37deg Slope Angle	1.85	1.12	1.71	1.08
60m @ 37deg Slope Angle	1.42	0.89	1.33	0.82
Conceptual Initial Shape (Varied Berm)				
15m @ 37deg Slope Angle	9.66	2.31	8.12	2.32
30m @ 37deg Slope Angle	4.68	2.16	4.36	2.09
45m @ 37deg Slope Angle	3.50	1.83	3.27	1.77
60m @ 37deg Slope Angle	2.93	1.62	2.72	1.5
Conceptual Final Shape (5m Berm)				
15m @ 10deg Slope Angle	14.67	3.34	14.27	3.27
30m @ 10/15 deg Slope Angle	5.63	2.19	5.23	2.17
45m @ 10/15/20 deg Slope Angle	3.95	1.92	3.63	1.64
60m @ 10/15/20/20 deg Slope Angle	2.87	1.65	2.68	1.54

(Table 6 from Mining Plus, 2011b)

Figure 9: Results of stability analyses on WRDs

8.0 RESPONSE TO DSD ITEM G: ASSESSMENT OF SEEPAGE OF LIQUIDS THROUGH THE WASTE ROCK AND TSFS

8.1 TSFs

Assessments of seepage have been undertaken on a number of occasions as part of slope stability analyses, water balance studies during the design phase and ongoing reviews of seepages observed to occur in near-surface areas (Golder, 2014).

8.2 WRDs

In order to assess potential rainfall infiltration into SMRs WRDs and seepage generation, climate data from the nearest Bureau of Meteorology weather station was assessed (Whyalla Aero, Station ID 18120, approximately 40 km north east of Iron Chieftain and Iron Knight). Daily average (Class A) pan evaporation data were used to estimate potential evapotranspiration, employing an assumed pan coefficient (K_{pan}) of 0.7 (Table 10), consistent with the approach taken in Golder (2015). These data were then used to calculate the number of days each year when daily rainfall was observed to exceed potential evapotranspiration over the period 1999 to 2015 (Table 11), leading to conditions during which infiltration into WRDs, and seepage to groundwater more generally, might occur.

Table 10: Average daily ("Class A") pan evaporation and estimated evapotranspiration 1993 to 2016 (Whyalla Aero, BOM Station 18120)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Daily Average Pan Evaporation (mm)	11.2	10	8.2	5.8	4	3	3.2	4.3	6.3	7.9	9.5	10.7
Estimated Potential Evapotranspiration (mm)[1]	7.8	7.0	5.7	4.1	2.8	2.1	2.2	3.0	4.4	5.5	6.7	7.5

Note: [1]Pan coefficient (K_{pan}) assumed to be 0.7, potential ET = Pan Evaporation x K_{pan}.

Table 11: Summary of rainfall and evapotranspiration 1999 to 2015 (Whyalla Aero, BOM Station ID 18120)

Year	Rainfall > Evapotranspiration (days)	Total Annual Rainfall Exceeding Daily Average Evapotranspiration(mm)	Total Annual Rainfall (mm)	Total Annual Rainfall Deficit (mm)
1999	19	89	254	-1622
2000	26	107	250	-1651
2001	26	176	363	-1601
2002	12	49	139	-1696
2003	21	112	266	-1633
2004	10	39	158	-1675
2005	21	118	278	-1627
2006	12	83	192	-1678
2007	19	178	327	-1638
2008	13	69	188	-1675
2009	22	106	258	-1635
2010	23	166	346	-1607
2011	27	186	392	-1580
2012	15	109	262	-1641
2013	16	130	229	-1688
2014	16	98	211	-1673
2015	18	171	295	-1663
Average	**19**	**117**	**259**	**-1646**

On average, only 19 days per year were found to present potential conditions for WRD infiltration or groundwater recharge, with daily observed rainfall exceeding estimated average daily evapotranspiration. These days over which rainfall was observed to exceed estimated daily evapotranspiration accounted for an annual average of 117 mm total rainfall in excess of estimated daily evapotranspiration. Daily rainfall deficit was calculated for days when observed rainfall did not exceed estimated daily evapotranspiration, resulting in an annual average rainfall deficit of approximately -1650 mm (Table 11).

The review of climate data from the Whyalla Aero station indicated that conditions leading to potential rainfall infiltration into SMR WRDs will likely be limited to a small number of days each year (19 days on average) and confirms that the area of SMR operations is likely to be in long term rainfall deficit. Thus the annual infiltration into SMR WRDs that could then lead to seepage to groundwater is anticipated to be very low.

Seepage monitoring is not considered necessary at this time due to the general inert nature of the waste materials and the very low risk of significant rates of rainfall infiltration into the WRDs and seepage to groundwater.

9.0 RESPONSE TO DSD ITEM H: STRATEGIES FOR THE CONTAINMENT OF ANY SEEPAGE THAT HAS THE POTENTIAL TO IMPACT THE ENVIRONMENT

9.1 TSFs

TSF seepage has primarily been managed by Arrium Mining through the installation and expansion of seepage interception sumps and pumping wells to the west of the SMR TSFs in November 2009 (four wells) and April to May 2012 (seven additional wells and a caisson) (WorleyParsons, 2010 and 2012b; referenced in Golder, 2015). The seepage interception pumping system (wells) was commissioned on 26 September 2013.

A review of the groundwater interception scheme performance over the period November 2013 to December 2014 established that the long term average extraction flow was 4 litres per second (L/s) over this period although this is likely an underestimation due to intermittent volume totaliser faults (Golder, 2015). It is noted that not all interception pumps were operational concurrently over the period November 2013 to December 2014, but if they had been the extraction flow rate could have been up to 5 L/s (Golder, 2015).

In addition to the downstream groundwater interception pumping wells, the Mag TSF was modified in late 2013 to convert the facility from a central discharge perimeter decant facility to a perimeter discharge central decant facility. This change in TSF operations is envisaged to result in reduced seepage to groundwater as the supernatant pond is moved away from the perimeter embankments, instead being located above low permeability tailings.

Revised stochastic water balance modelling has predicted the most likely long term future TSF seepage rates to groundwater will be between 1.9 to 2.1 L/s based a range of tailing permeabilities and two different tailings solids content scenarios (Golder, 2015). These predicted TSF seepage seepages rates are approximately half of average groundwater extraction from the interception pumping system to the west of the TSFs observed over the period November 2013 to December 2014.

If TSF seepage to groundwater continues at the predicted rates, and the groundwater interception scheme continues to operate at least at the capacity observed between November 2013 and December 2014, then groundwater levels should subside over time to the west of the SMR TSFs. Groundwater levels at some wells at a distance from pumping wells have not shown strong water level responses to pumping, considered likely on account of relatively low hydraulic conductivity of the sedimentary groundwater system (Golder, 2015). It is also noted that that subsidence of groundwater levels to the west of the SMR TSFs may be slowed by above average rainfall events and during deposition into the TSF voids as monitoring well groundwater levels and pumped volume from the groundwater interception scheme were both observed to increase with above average rainfall events (Golder, 2015).

Dewatering spears were also installed along the southern end of the Mag TSF western flank in February 2015. Golder understands that 15 spears were installed with combined total flows ranging from approximately 36 m^3/day to 60 m^3/day (0.4 L/s to 0.7 L/s). Groundwater level responses to pumping from spears indicate a positive contribution to reducing seepage impacts to the downstream environment but with a somewhat localised radial influence (300 to 400 m). It is considered unlikely that pumping from dewatering spears will have an effect on lowering the water table further west of the SMR TSFs in regions currently showing signs of vegetation stress (Golder, 2015).

9.2 WRDs

There are no data or information available that would indicate the need for the design and implementation of a seepage containment system.

10.0 RESPONSE TO DSD ITEM I: ASSESSMENT OF THE POST-COMPLETION CHEMICAL AND PHYSICAL STABILITY OF THE STRUCTURE FOLLOWING REHABILITATION

10.1 TSFs

The OBP and Mag TSFs store chemically inert tailings. There have been no studies undertaken on the post completion physical and chemical stability of the TSFs. The chemical stability is not considered to be an issue as the tailings are NAF. As discussed previously, the chemical testing demonstrated that the tailings (tested by PB (2004 and 2007)) generated leachate that was characterised by near-neutral pH and low levels of trace elements. However, to our knowledge, this has not been verified through post completion testing.

Chemical testing of the Mag and OBP tailings conducted by Golder 2014a, demonstrate that the tailings are NAF but that they hold the potential to leach elements over time. This will create a mass loss which could alter the physical properties of the material. No kinetic testing has been conducted on the materials and therefore this statement cannot be validated.

The physical stability of the Mag TSF under a 1:60,000 AEP earthquake was demonstrated to be less than unity for an ultimate landform height of RL 199 m (refer value of 0.51 in Table 6). The slope stability analysis considered the downstream slope of 3H:1V (the current slope) and has not considered changes to geometry of the slope as a result of reshaping and revegetation, nor any potential strength gain in the tailings as a result of consolidation. There are no slope stability analyses undertaken for the OBP TSF for post-closure.

The closure studies by Golder (2015a) reshaping outer slopes of the perimeter embankments to form concave slopes, and placement of topsoil, vegetation seeding and armouring with erosion protection materials. It also recommended covering of the upper surfaces of the TSFs with a layer of oxide mine waste rock and forming sub-catchments with hard rock armour. Hard rock would be sourced from the crushing and screening of fresh mine waste rock. Areas not covered with armour rock would be topsoiled and vegetated. Furthermore, armoured spillways would be constructed on both TSFs to pass extreme rainfall events post-closure. With all of these management measures, it is expected that the TSFs would be sufficiently resistant to erosion. However, there have been no detailed studies undertaken to support the closure design of the TSFs; i.e. the closure designs are conceptual (Golder, 2015a). Additional assessment will be undertaken when a more detailed closure design of the TSF becomes available, at an appropriate time in the future ahead of implementation of TSF closure. The additional studies required to support the design are described in Section 12.0.

Any hard rock used as a cover should be assessed for its leaching potential to demonstrate that it is chemically stable.

10.2 WRDs

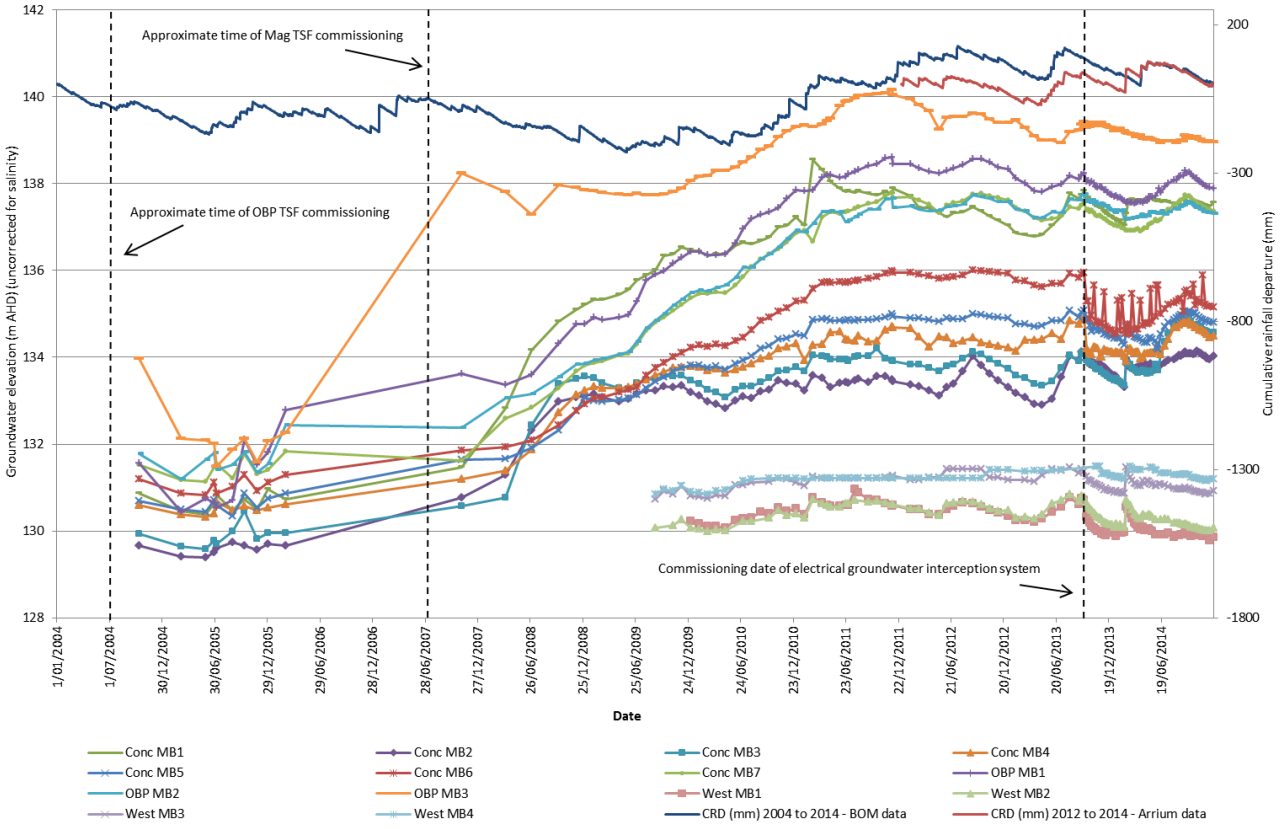
The physical stability of the WRDs has been demonstrated to be acceptable during post-closure by flattening the outside slope to a concave profile (Mining Plus, 2011) for WRD heights up to 60 m above ground. The measures described in Section 2.0 including flattening the outside slope to <20°, ripping in topsoil and broadcast seeding, as well as ongoing rehabilitation trials by Arrium will be used to inform the closure design as mining continues. The additional studies required to support the design are described in Section 12.0.

The physical stability of the WRD can inform the chemical stability of the materials within the current WRDs. If the WRD is physically stable it can be inferred that the material from which it is constructed is chemically stable enough to not affect the physical stability. There is limited chemical data to verify this statement. The only chemical testing of the waste rock was conducted in 2004.

11.0 RESPONSE TO DSD ITEM J: ASSESSMENT OF THE SOURCE, PATHWAY AND ULTIMATE FATE OF ANY POTENTIAL MOBILE CONTAMINANTS

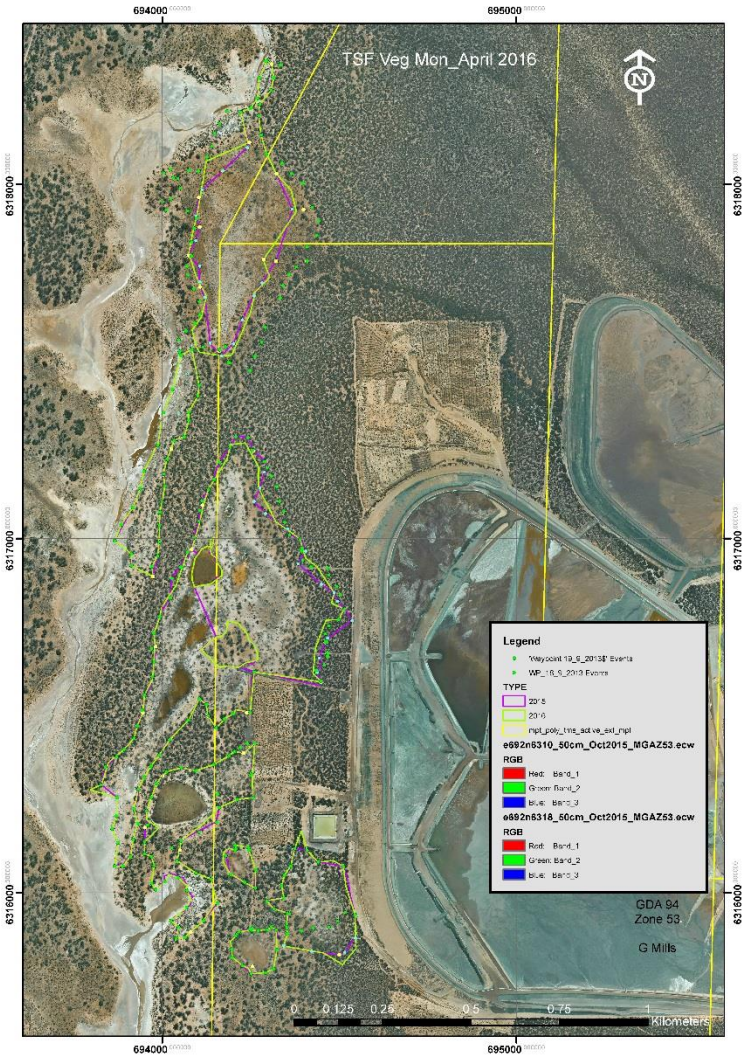
11.1 TSFs

Groundwater monitoring to the west of the Mag TSF and the Ore Benefaction Plant TSF (OBP TSF) since October 2004 has established substantial groundwater level rise in response to the commissioning of the Mag TSF (Figure 10). This rise in groundwater levels has resulted in vegetation stress to the west of the TSFs as the naturally saline and in some cases low pH (3.6 to 3.9 pH units in March 2005; Parsons Brinckerhoff (2007)) groundwater has risen and interacted with the root zone (Figure 11) (WorleyParsons, 2012).



Note: Wells titled "Conc MB" relate to Mag TSF monitoring wells.
Golder 2015

Figure 10: Cumulative rainfall departure (CRD) and groundwater levels from Mag TSF and OBP TSF monitoring wells



(Map provided by Arrium Mining, 25 November 2016)

Figure 11: Iron Duke TSF vegetation impact map 2015 and 2016

The local geological map of the area surrounding the TSFs, *Middleback* 1:100,000 Geological Map Sheet (DMITRE, 2012), identifies the sediments below the TSFs as Moornaba Sand, described as “white quartz sand of inland shelf dunes; grades down into yellow sand with carbonate pipes of Peebinga Soil”. Geotechnical investigations conducted by Golder in June 2013 at the Mag TSF identified generally consistent geological conditions with that of published information: clayey and gravelly sand was encountered in test pits to approximately 3 m depth and Piezo Cone Penetration Test (PCPT) test results were consistent with sandy silt or silty sand (as described by the Unified Soil Classification System, USCS) (Golder, 2015).

The monitoring well network to the west of the SMR TSFs is comprised of seven wells adjacent to the Mag TSF western boundary (BHMB1-BHMB7), three wells adjacent to the OBP TSF (OBPBMB1-OBPMB3) and four wells between the Mag TSF and salt creek (West 1-West 4).

Monitoring wells adjacent to the Mag TSF and OBP TSF are installed in the sedimentary sequence in the sedimentary sequence overlying basement rock aside from the southernmost Mag TSF monitoring well, BHMB1, completed in gneiss bedrock (Parson Brinckerhoff, 2012). Well construction details for wells West 1 to West 4 were not available for review (Golder, 2015).

A conceptual hydrogeological model for the area surrounding the SMR TSFs was developed by Worley Parsons (2012), and is summarised as:

- The region of the SMR TSFs is underlain by a sedimentary (porous medium) groundwater system, beneath which a fractured bedrock groundwater system occurs.
- The sedimentary and underlying bedrock groundwater systems may be hydraulically connected.
- The sedimentary groundwater system is broadly comprised of two units: a surficial unconfined sandy clay unit underlain by a semi-confined, predominantly sandy gravelly unit deposited in a palaeochannel. It is suggested that these two sedimentary groundwater system units are in hydraulic connection.
- Recharge to the groundwater system (both sedimentary and fractured rock elements) is predominantly due to TSF seepage as natural rainfall recharge is considered to be low as evidenced by naturally saline groundwater conditions.
- Discharge from the groundwater system is via evapotranspiration. Evapotranspiration from Salt creek will limit groundwater level rise downstream of the SMR TSFs.

Groundwater level response presented in Figure 10 is consistent with this conceptual model. Groundwater levels in both the sedimentary system and the bedrock system (well BHMB1) have risen in response to TSF seepage (Figure 10). An additional observation is that groundwater level rise has been observed in response to above average rainfall events at monitoring wells to the west of the TSFs with water table depth shallower than 6 m (Golder, 2015). This indicates that while natural recharge to the groundwater system from rainfall is likely to be low, above average rainfall event can lead to groundwater recharge.

Groundwater level responses, geological data and evident vegetation stress to the west of the SMR TSFs indicate that the sedimentary groundwater system is in hydraulic connection with TSF seepage and hence may be a potential pathway for mobile contaminants between the TSFs and downstream environmental receptors to the west of the TSFs.

No studies were reviewed that identified any mobile contaminants or potential mobile contaminants associated with TSF seepage. Vegetation stress associated with TSF seepage is understood to be a consequence of a rising, naturally saline water table as opposed to mobile contaminants from TSF seepage.

While a hydraulic pathway for mobile contaminants may be present in the sedimentary groundwater system between the TSFs and environmental receptors to the west, potential transport of mobile contaminants is also controlled by factors such as hydraulic conductivity (permeability), effective porosity, existing groundwater quality, water quality of TSF seepage, clay/oxide content of subsurface geology and contaminant specific behaviour (adsorption).

A number of the factors controlling potential mobile contaminant transport along groundwater pathways at the SMR site are poorly defined. This said, a review of groundwater drawdown induced by seepage interception pumping identified likely low hydraulic conductivity of the sedimentary groundwater system as evidenced by localise drawdown around pumping wells (Golder, 2015). This indicates that while the sedimentary groundwater system may be in hydraulic connection to TSF seepage, overall average groundwater flow velocity may be slow due to low permeability, potentially limiting transport of mobile contaminants. It is also noted that groundwater quality has been observed as having low pH at the majority of monitoring wells directly adjacent the TSFs (2.6 to 3.9 pH units in March 2006; Parson Brinckerhoff (2007).

The risks associated with potential mobile contaminant transport along groundwater pathways from the TSFs to downstream environmental receptors will be assessed by Arrium as part of ongoing groundwater quality data collection and reviews.

11.2 WRDs

SMR's operations span an approximate north south extent of 11.6 km across five mining domains from Iron Knight and Iron Chieftain to the north down to Iron Duke and Iron Magnet to the south. Each of the five main mining domains have a number of associated WRDs, summarised in Table 12.

Table 12: Summary of SMR WRDs

Mining Domain[1]	WRD Name[2]	Description	Arrium Mining (2015) Figure
Iron Chieftain	CW01	East of Iron Chieftain Pits A - D	Figure 31
Iron Knight	KW01 and KW03	West of Iron Knight North Pit	Figure 36
	KW12	East of Iron Knight North Pit	Figure 36
	KWS01	West of Iron Knight South Pit	Figure 36
	KWS13	South East of Iron Knight South Pit	Figure 36
	KL14	East of Iron Knight South Pit	Figure 36
Iron Duchess	Iron Duchess WRD	West of Iron Duchess South Pit	Figure 44, Figure 49, Figure 50
Iron Magnet	MW18	East of Iron Duchess North and South Pits; north east of Iron Magnet Pit.	Figure 42
	MW03	East of Iron Magnet Pit	Figure 43
	MW04	West of Iron Duke Stage B Pit	Figure 43
Iron Duke	DW03	South East of Iron Duke Stage B Pit	Figure 43
	DSW03	South and West of Iron Duke Stage B Pit	Figure 43

Notes: [1]From north to south; [2]Based on Arrium Mining (2015).

An existing wells search using the SA Department for Environment Water and Natural Resources (DEWNR) online database and correspondence with Arrium Mining confirmed that no monitoring wells are present surrounding the SMR WRDs, thus groundwater level and quality conditions are not known in these locations. General inferences about groundwater conditions surrounding the WRDs (in the absence of any seepage influences) can be made based on the regional hydrogeological setting:

- Groundwater can be expected to occur in surficial sediments in the vicinity of WRDs where they are present.
- Groundwater flow direction can be generally expected to follow surface topography. Land surface generally declines on either side of the SMR ridge along which most of the mining domains are located. Thus groundwater flow direction can generally be expected to be westwards for WRDs located to the west of mine pits and eastwards in the vicinity of WRDs to the east of Iron Chieftain and Iron Duke mine pits but not for WRDs to the east of Iron Duchess and Iron Knight pits as these WRDs are located west of the SMR ridgeline.
- Groundwater quality could be expected to be saline based on the semi-arid climate setting, groundwater recharge being a likely very low percentage of rainfall, and hydrogeological investigations to the west of the Iron Duke mine that identified saline groundwater conditions.

The surface geology on which the SMR WRDs are located was reviewed in order to assess the potential for WRD seepage to infiltrate to the groundwater table if such sufficient seepage were to occur at the base WRDs. Surface geology was reviewed using the 1:100,000 scale surface geology database available from the SA Department of State Development, Resources and Energy (DSDRE, 2012). A summary of the WRD surface geology review is presented as Table 13.

The review of surface geology beneath the SMR WRDs identified that the majority of WRDs are built over sedimentary units, with the exception being KWS13 (Iron Knight) which is mainly underlain by outcrop of Palaeoproterozoic rock. Sedimentary units beneath SMR WRDs include Tertiary sediments (ferruginous pebbly grit, conglomerate and sandstone) and undifferentiated Holocene age alluvial/fluvial sediments to east of the SMR ridge and Quaternary age Moornaba Sand to the south and west of the ridge. Holocene talus/scree deposits occur along both the eastern and western margins of the SMR ridge. WRDs on the eastern side of the SMR ridge are variously underlain by a combination of Palaeoproterozoic rock and sedimentary units due to the complexity of surficial geology (Table 13).

The review of surface geology beneath SMR WRDs identified that the majority are constructed over sedimentary units and thus the potential for WRD seepage to infiltrate to groundwater would exist, if seepage volume is sufficient and persistent. As indicated previously, annual infiltration to SMR WRDs is expected to be very low, thus the potential for groundwater infiltration of WRD seepage is also considered low.

Table 13: Summary of SMR WRDs and surface geology

Mining Domain	WRD Name	Description	Surface Geology
Iron Chieftain	CW01	East of Iron Chieftain Pits A-D	CW01 is underlain by two main geology types: Holocene tallus/scree and Tertiary sediments (Miocene to Pliocene ferruginous pebbly grit, conglomerate, fine sandstone). The boundary between these units runs approximately north-northwest from the central southern boundary of the CW01 WRD.
Iron Knight	KW01 and KW03	West of Iron Knight North Pit	Moornaba Sand (Quaternary)
	KW12	East of Iron Knight North Pit	Majority of KW12 is located on top of Undifferentiated Holocene alluvial/fluvial sediments, the northern portion overlies Cook Gap Schist (Palaeoproterozoic) and possibly a small portion of Lower Middleback Jaspilite (Palaeoproterozoic).
	KWS01	West of Iron Knight South Pit	Majority of KWS01 is located on Moornaba Sand (Quaternary) but eastern portion may be over Cook Gap Schist and Katunga Dolomite (Palaeoproterozoic)
	KWS13	South East of Iron Knight South Pit	Majority of KWS13 is located over Lower Middleback Jaspilite (Palaeoproterozoic), eastern portion may overly undifferentiated Holocene alluvial/fluvial sediments.
	KL14	East of Iron Knight South Pit	KL14 is underlain by both Lower Middleback Jaspilite and undifferentiated Holocene alluvial/fluvial sediments. The boundary between these units runs approximately north-south, centrally beneath the KL14 footprint.
Iron Duchess	Iron Duchess WRD	West of Iron Duchess South Pit	Iron Duchess WRD is located over Holocene talus/scree deposits and Moornaba Sand (Quaternary)
	MW18	East of Iron Duchess North and South Pits	MW18 is underlain by Cook Gap Schist and Lower Middleback Jaspilite. The northernmost end of MW18 may be adjacent to Undifferentiated alluvial/fluvial sediments.
Iron Magnet	MW03	East of Iron Magnet Pit	MW03 located over a range of geology including Cook Gap Schist (along eastern edge, Undifferentiated Holocene alluvial/fluvial sediments, and Holocene talus/scree deposits. Holocence sediments are generally located under the central and western MW03 footprint.
	MW04	West of Iron Duke Stage B Pit	MW04 located over Holocene talus/scree deposits and Moornaba Sand (Quaternary)

Mining Domain	WRD Name	Description	Surface Geology
Iron Duke	DW03	South East of Iron Duke Stage B Pit	Majority of the central DW03 footprint underlain by Pleistocene gravel, clay, silt and sand with soft carbonate, overlying nodular/tabular calcrete; some Warrow Quartzite (Palaeoproterozoic) present. Along the western boundary (closer to the Iron Duke Stage B Pit) DW03 is underlain by Lower Middleback Jaspilite and Cook Gap Schist.
	DSW03	South and West of Iron Duke Stage B Pit	The portion of the DSW03 directly south of the Iron Duke Stage 2 Pit is underlain by Lower Middleback Jaspilite while the remaining WRD footprint to the west is underlain by Moornaba Sand (Quaternary).

Assessment of downstream environmental receptors for SMR WRDs was limited to review of aerial imagery and the Geoscience Australia 1:250,000 scale Surface Hydrology WM MapServer. From this review, the following is noted:

- Salt Creek is likely to be an environmental receptor for potential WRD seepage from WRDs located to the south and west of Iron Duke and west of Iron Duchess. This said, both of these locations have potential seepage sources that may mask any WRD seepage; these being the SMR TSFs at Iron Duke and water storage within the Iron Duchess North Pit.
- Geoscience Australia surface hydrology data indicates the presence of minor, non-perennial watercourses to the west of western Iron Duke, Iron Duchess and Iron Chieftain WRDs, which may be environmental receptors for potential WRD seepage.
- An existing well is located approximately 800 m east of the Iron Chieftain WRD (Unit No. 6331-28). This well is listed as being of operational status on the DEWNR online database but its current status is unknown.
- Two existing wells are located approximately 1.5 km to the west of the Iron Knight South WRD (Unit No. 6331-44 and 6331-45). Both wells were drilled in 1957 and although they are listed as operational on the DEWNR online database their current status in unknown.

12.0 RESPONSE TO DSD ITEM L: LIMITATIONS AND KNOWLEDGE GAPS

Key limitations and knowledge gaps are as follows:

TSFs

- The risks of groundwater levels rising to within the root zone of trees/grasses.
- Erosion susceptibility and resistance of the tailings to wind and water erosion.
- Long-term stability of the TSFs.

WRDs

- Baseline groundwater quality data in the regions of the WRDs
- Surface water quality in the regions of the WRDs
- Data available to assess the chemical stability of waste rock that may be excavated and stockpiled throughout the life time of the project is limited.

13.0 RESPONSE TO DSD ITEM L: RECOMMENDATIONS

It is recommended that:

- Within five years of closure, further studies are undertaken to understand whether the TSF seepage recovery system should continue to be operated beyond the operational period to minimise post-closure impacts (if relevant). This would address the risks of groundwater levels rising to within the root zone of trees/grasses.
- Erosion susceptibility testwork and modelling of resistance to wind and water erosion is undertaken. The erosion susceptibility testwork could leverage off the studies undertaken by LandLoch for the WRDs and the trials being undertaken by Arrium.
- Geotechnical studies are undertaken to assess the long-term stability of the TSFs. Analyses should be informed by investigations of the strength of the tailings and the location of the phreatic surface.
- If required based on risk, baseline groundwater quality sampling is undertaken in the regions of the WRDs.

- Soil sampling of ephemeral streams down gradient of the WRDs is undertaken and a suitable background site identified prior to Sulfide Breccia mining, to address surface water quality in the regions of the WRDs.
- Samples of the sulfide breccia unit be collected from different mining blocks during pre-production drilling to assess ARD risk variability and develop an ARD block model. This is because geochemical assessments undertaken to date were carried out on a single sample of each rock unit. Implementation of the recommendation could reduce the volume of the sulfide breccia that requires special handling and support the defining of appropriate waste placement/blending strategies.
- Arrium revisits surface water and groundwater monitoring strategies prior to the time that Sulfide Breccia waste rock is likely to be encountered during mining and disposed of in WRDs.
- Chemical testing to support erosion studies is undertaken, primarily to assess whether eroded sediments (e.g. sediment generated from the erosion of sulfide breccia materials) may become sources of contaminants that leach and pose risks to downstream surface water systems.

14.0 IMPORTANT INFORMATION

Your attention is drawn to the document titled – “Important Information Relating to this Report”, which is included in Appendix B of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder Associates has under the contract between it and its client.

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APPENDIX A

List of Provided Reports

APPENDIX B

Important Information

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Appendix D

Iron Duke TSF, Groundwater and surface water chemistry review

D-1: Jacobs Pty Ltd 2018, *Iron Duke Tailings Storage Facility, Groundwater and Surface Water Chemistry Review, 24 April 2018*. Unpublished report prepared for SIMEC Mining, Whyalla, South Australia.

Iron Duke Tailings Storage Facility

Groundwater and Surface Water Chemistry Review

24 April 2018

82406831

Iron Duke Tailings Storage Facility

Project No:	IW153100
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Document No.:	IW153100_RP004
Revision:	1
Date:	24 April 2018
Client Name:	SIMEC Mining
Client No:	82406831
Project Manager:	Andrew Nelson
Author:	Andrew Nelson and Sam Sheppard
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1. Introduction

1.1 Background

SIMEC's Southern Middleback Ranges (SMR) operations are located approximately 50 km southwest of Whyalla in South Australia, with Iron Duke forming the southern-most mine. The Middleback Ranges present as inliers of outcropping Proterozoic rocks with an overlying thin veneer of Quaternary deposits (Worley Parsons, 2009). The SMR comprises banded iron formation which is the targeted ore-bearing unit, and gangue materials consisting of schist and dolomite.

Two Tailing's Storage Facilities (TSFs) are located adjacent SIMEC's Iron Duke mine operations, these have received tailings material from the Haematite Ore Beneficiation Plant (OBP) and Magnetite (Mag) Concentrator respectively until July 2014 when both tailings streams have been deposited into the Concentrator TSF. Following the commissioning of the TSFs, the groundwater level was found to have risen and impacted an area of native vegetation due to waterlogging of the soil by the naturally saline groundwater.

Figure 1-1 shows the location of the Iron Duke mine, the on-site TSFs and key groundwater infrastructure.

Groundwater has been monitored by SIMEC since 2004, with the piezometric surface routinely measured, and samples obtained and analysed for major cations, anions and a suite of trace analytes. However, the most recent Program for Environmental Protection and Rehabilitation (PEPR) submission identifies the potential for leaching of trace elements (boron, chromium, aluminium, copper, uranium and zinc) from the OBP and Magnetite TSFs, at levels which potentially exceed water quality guidelines.

In January 2018, SIMEC installed a new monitoring bore located within the Ironstone Conservation Park west of the SMR Iron Knight operations and north of the TSF operations (Figure 1-2). The intent of this monitoring bore is to provide an indication of background groundwater chemistry data, with a comparison to monitoring data collected adjacent the Iron Duke operations and establishment of new groundwater chemistry trigger values.

1.2 Scope

Jacobs was engaged on 8 February 2018 by SIMEC to provide a review of hydraulic and chemistry data, obtained from the groundwater and surface water systems located adjacent the Iron Duke Tailing Storage Facilities (TSFs). Key tasks of the assessment include:

- Collation, format and QA/QC review of raw datasets and previous GW chemistry reports
- Chemical characterisation of groundwater and surface water systems and relationships to potential changes to GW quality.
- Analysis of chemical trends in comparison to regional/background data, and nomination of a method for the establishment of new site specific trigger levels
- Assessment of risk to GW quality and literature review of elements likely to be toxic to inland saline water ecosystems
- Interpretation of short or long term significant trends

This report seeks to determine whether seepage through the TSF has impacted on the adjacent groundwater and surface water systems, pursuant with the requirements of Ministerial Determination MD005, utilising new hydrogeochemical data from existing monitoring locations.

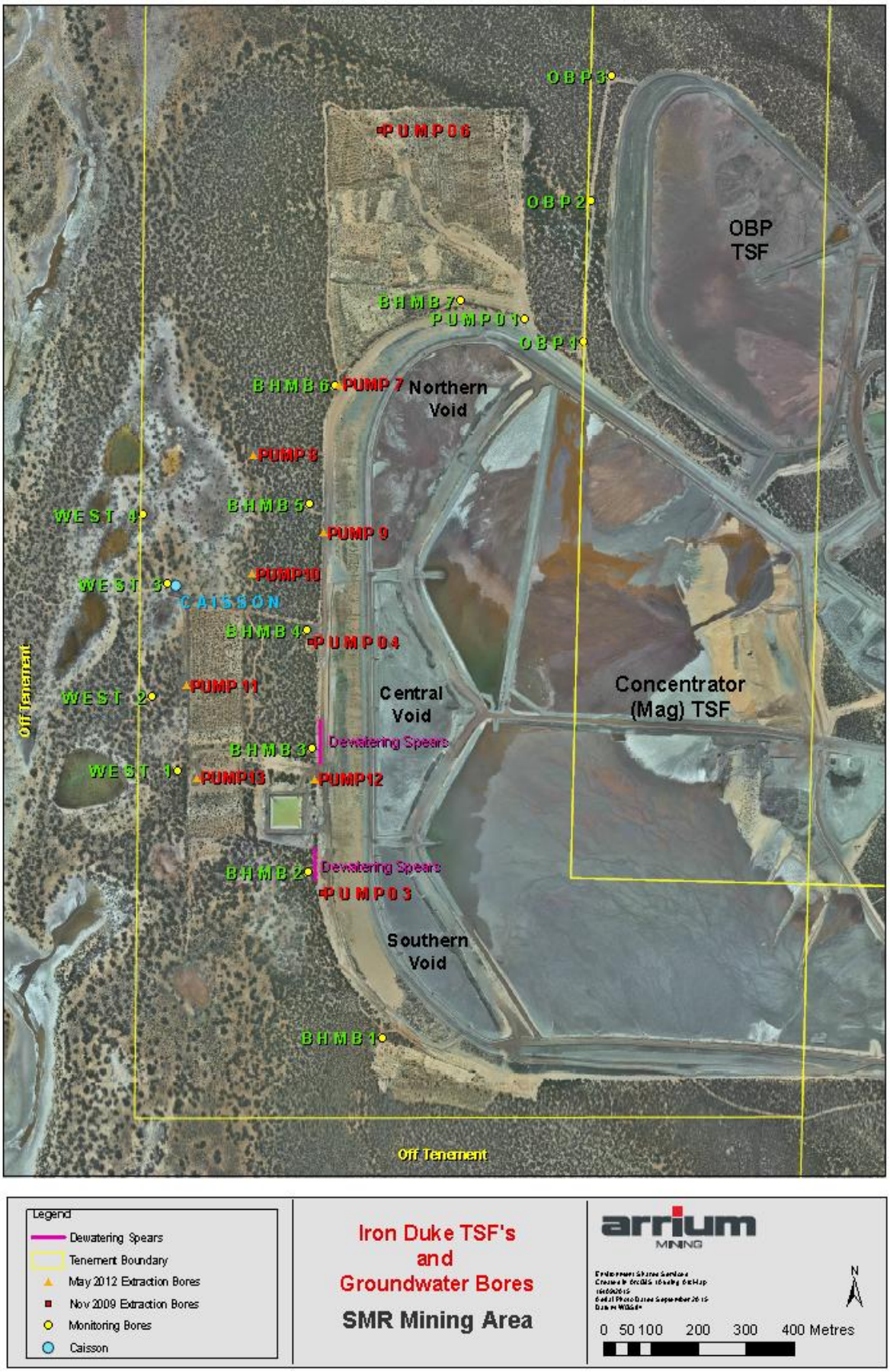


Figure 1-1 : Iron Duke TSF and Groundwater Infrastructure (SIMEC 2018)

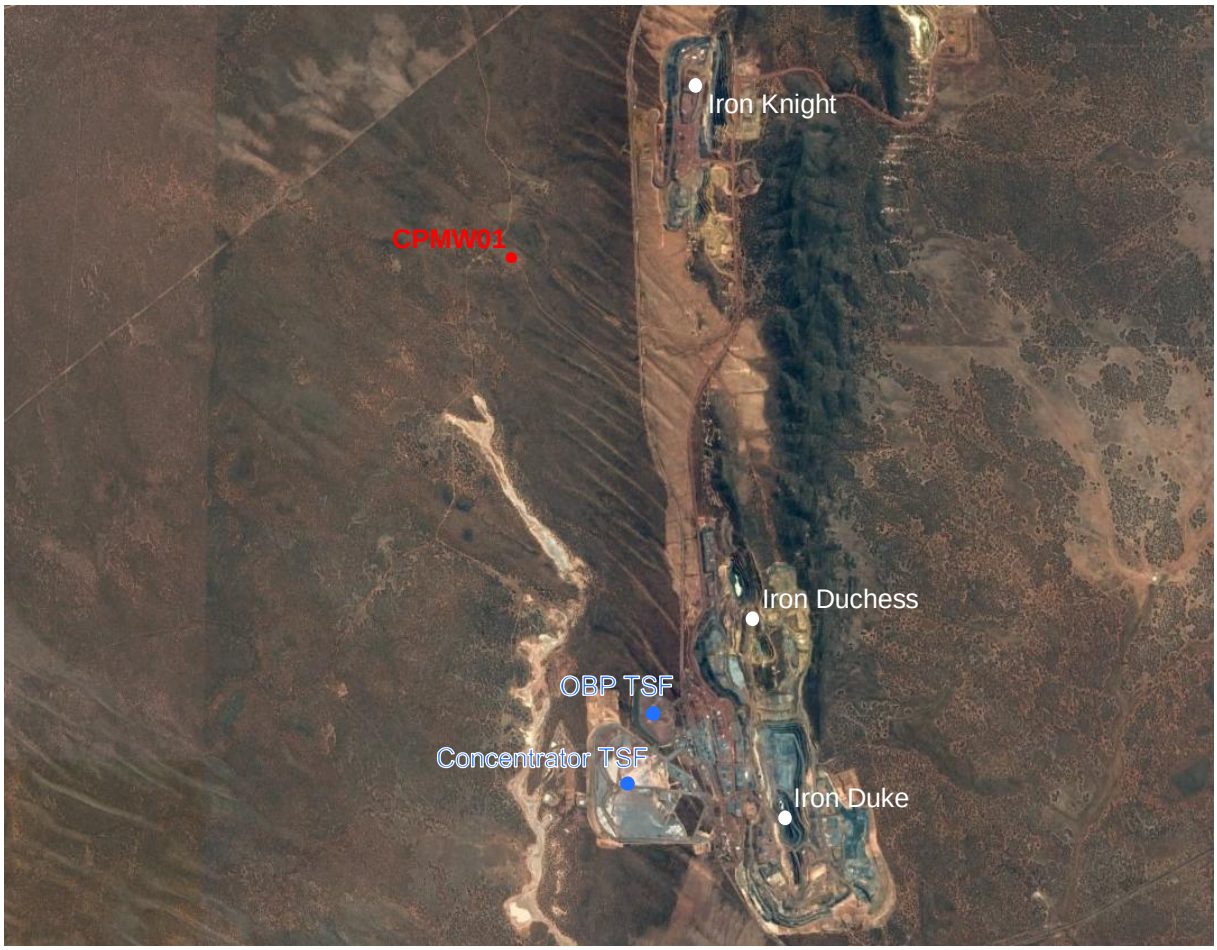


Figure 1-2 : SMR Operations and background monitoring bore

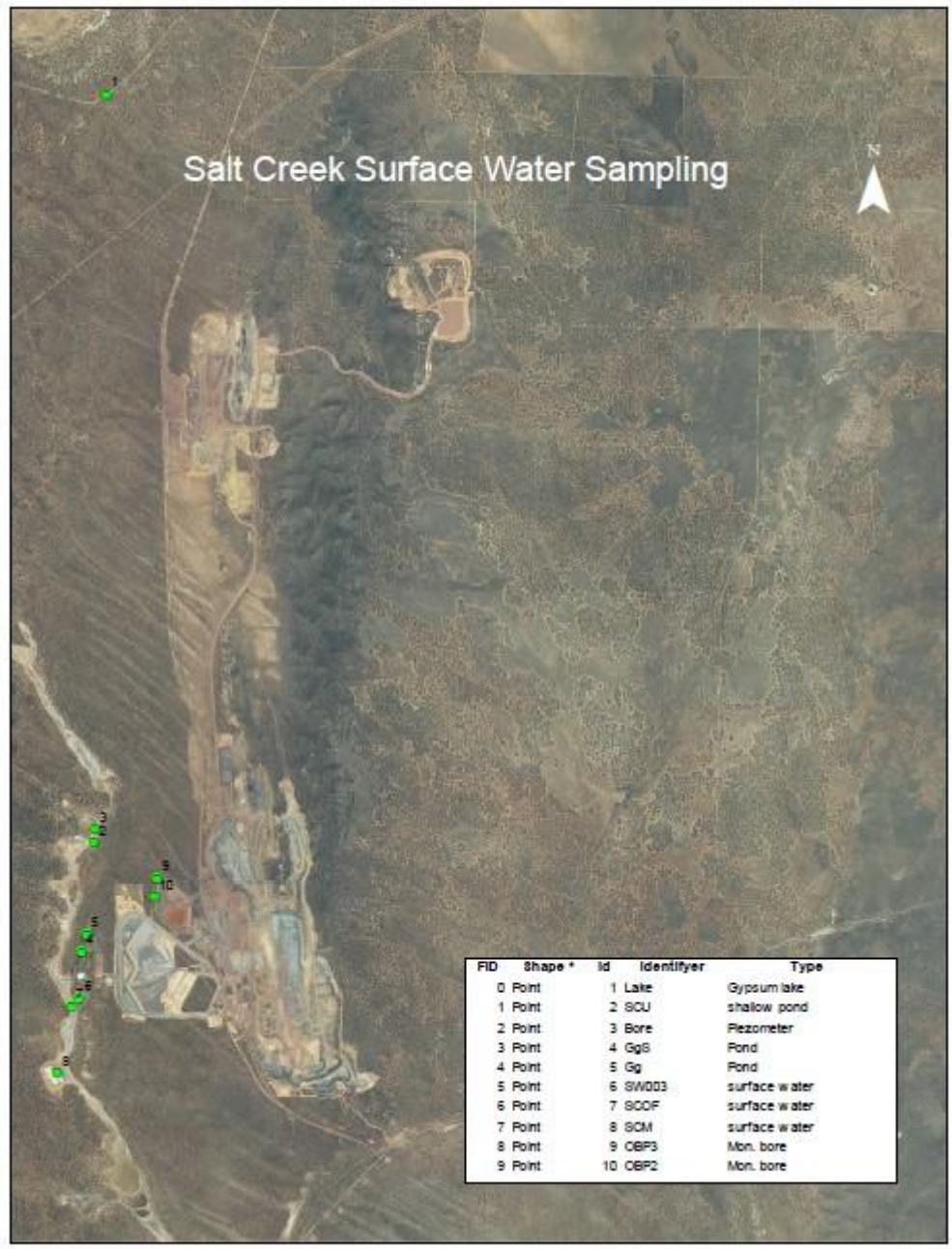


Figure 1-3: Salt Creek surface water monitoring locations

1.3 Hydrogeology

A conceptual hydrogeological model was prepared by Worley Parsons (2009 and 2012) and further refined by Golder (2014 and 2015) and Cardno (2015). The information presented below is a concatenation of these previous studies and further detail on the hydrogeological system is provided in these reports. A summary of the site hydrostratigraphy is presented in Table 1.1 and in the conceptual hydrogeological cross-section in Figure 1-4.

Table 1.1 : Iron Duke TSF Hydrostratigraphic Units

Unit	Lithology	Hydraulic Conductivity
Dune Sand	fine to medium grained,	mostly unsaturated
Silty/Clayey Sand (unconfined)	fine to medium grained	0.01 – 0.2 m/d (Worley Parsons 2009) 0.01 md/ (Worley Parsons 2012)
Sand and Gravel (semi-confined)	interbedded gravel and sands, with gravel lenses up to 3m in thickness	0.2 – 10 m/d (Worley Parsons 2009) 0.1 m/d (Worley Parsons 2012)
Bedrock	underlying banded iron formation (BIF), granitic gneiss and metabasalt	0.02 m/d (Cardno 2015)

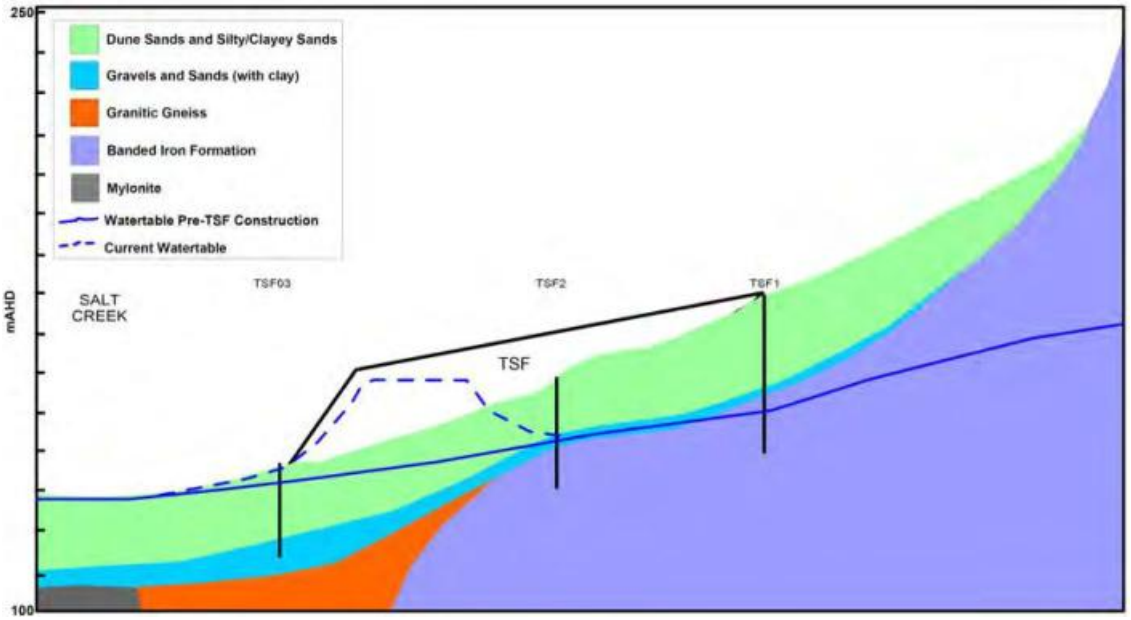


Figure 1-4 : Iron Duke TSF Conceptual Hydrogeological Cross-section (Worley Parsons 2009)

As outlined by Coffey Geosciences (2006), 10 permanent monitoring wells were installed along the western perimeters of both TSFs, seven downgradient of the western embankment of the concentrator TSF (BHMB1 to BHMB7) and three downgradient of the western boundary of the OBP TSF (OBP1 – OPB3). A further four monitoring bores were installed in 2009 (WEST1 – WEST 4), along the western boundary of SIMEC's mining lease and up-gradient of groundwater flow towards an identified high impact vegetation zone.

As presented in Table 1.2, all of the permanent monitoring wells were completed in alluvial sediments except for the southernmost well MB1, which was completed in bedrock (gneiss), which was noted to outcrop nearby prior to construction of the Concentrator TSF. Furthermore, Worley Parsons (2009) reported a flattening of the

watertable at the northern corner of the Concentrator TSF that was identified to correspond with a transmissive palaeochannel in the bedrock.

Table 1.2 : Iron Duke groundwater monitoring network

Bore ID	Screened Interval (m BGL)	Screened Lithology
BHMB1	4.5 – 10.5	Bedrock
BHMB2	9.7 – 15.7	Silty/Clayey Sand
BHMB3	7 – 13	Silty/Clayey Sand
BHMB4	8.9 – 14.9	Silty/Clayey Sand
BHMB5	8.3 – 14.3	Silty/Clayey Sand
BHMB6	12.5 – 18.5	Silty/Clayey Sand
BHMB7	19.4 – 25.4	Silty/Clayey Sand + Sand and Gravel
OBP 1	29 – 35	Sand and Gravel
OBP 2	23 – 29	Sand and Gravel
OBP 3	23.1 – 29.1	Sand and Gravel
WEST 1	N/A	N/A
WEST 2	N/A	N/A
WEST 3	N/A	N/A
WEST 4	N/A	N/A
CPMW01	4 – 13	Silty/Clayey Sand

1.3.1 Local Groundwater Levels

Baseline groundwater elevation contours shows a piezometric surface generally sloping from east to west in the vicinity of the Concentrator and OBP TSFs, with a component of groundwater movement towards Salt Creek in the south (Worley Parsons 2009). Prior to construction, the east-west hydraulic gradient in the vicinity of the Concentrator TSF was assessed as 0.004 with a depth to water ranging from 5.7 m below ground level (bgl) in MB2, to 28.1 mbgl in OBPMB1.

1.3.2 Local Recharge and Discharge

The SMR operations are located in South Australia's Arid Lands region, as such annual mean rainfall at the Iron Duke site (approx. 300 mm) is significantly less than the annual potential evaporation (approx. ~ 2400 mm). Evaporation exceeds rainfall in all months of the year and therefore natural recharge from rainfall is considered to be minimal (Worley Parsons 2009). Conversely, a review of the groundwater hydrograph response to rainfall, undertaken during a review of the groundwater extraction system efficiency (Golder 2014a), indicates that groundwater elevations respond to rainfall recharge events.

Groundwater discharge is considered to be via evapotranspiration from areas with shallow depths to groundwater and discharge of groundwater to the ephemeral Salt Creek ecosystem to the west of the TSFs (Golder 2015).

1.3.3 Groundwater Quality

Prior to construction of the Concentrator and OBP TSFs, ninety-five groundwater bores and wells were identified on the PIRSA data base within 5 km of the SMR mines. Of these, nine had at least one datum of groundwater information (as outlined in Table 1.3). The total dissolved solids (TDS) of groundwater was in general >33,000 mg/L, low abstraction yields (<3 L/s) and acidic to circum-neutral (Golder 2014a).

Table 1.3 : Registered groundwater wells with recorded hydrogeological data

Bore No.	Purpose	pH	TDS (mg/L)	Yield (L/s)	SWL (mBGL)	Construction Date	Depth (mBGL)	Salinity (u/cm)
28	-	7.5	12 417	0.130	-	-	-	20 929
31	-	7.6	44 802	-	-	-	-	67 699
40	Industrial	-	866	-	-	31/01/1957	50.60	1 571
44	Industrial	-	57 530	0.510	-	22/03/1957	11.58	82 186
45	-	-	60 103	1.010	8.23	19/03/1957	30.48	85 861
226	Industrial	-	-	0.120	-	23/05/1985	62.00	-
231	Industrial	-	-	-	0.76	15/08/1985	6.00	-
242	Observation	-	-	2.7	-	4/09/1988	11.50	-
245	Observation	4.0	43 576	-	-	22/08/1988	11.00	62 252
263	Investigation	-	-	2.0	-	19/09/1988	11.50	-

1.4 TSF Operations

The mined banded iron formation yields two ore types – Haematite and Magnetite:

- Haematite ore is processed through an Ore Beneficiation Plant (OBP), with the generated fine tailings deposited into the OBP TSF which was commissioned in 2004.
- Magnetite ore is processed at a Concentrator, with the generated fine tailings deposited into the Concentrator (Mag) TSF which was commissioned in 2007.

Since July 2014 the tailings have been deposited into the Magnetite TSF. Both TSFs are unlined (Golder, 2014b).

1.4.1 Geochemical Assessment

A number of geochemical assessments have been undertaken on tailings material, including material on embankments, to assess the acid forming potential and potential for leaching of heavy metals and other trace elements from the TSFs. Magnetite and Haematite tailings, produced by the Concentrator and OBP respectively, were assessed by PB (2007) and Golder (2014b) with the findings of these investigations presented below:

- The sulphur content of all tailings samples, including the OBP and magnetite tailings, was low <1%, ranging between 0.01% and 0.48% in tailings tested by PB (2007).
- Dolomite, a carbonate mineral with high neutralising capacity, was found to occur in both the OBP tailings (3%) and magnetite tailings (14%) samples.
- The tailings and embankment materials tested by PB (2007) and Golder (2014a) were classified as non-acid forming.
- Tailings tested by PB (2004 and 2007) generated leachate that was characterised by near-neutral pH and low levels of trace elements.
- The OBP and magnetite tailings (Golder, 2014a) indicated potential for leaching of trace elements at levels that could potentially exceed fresh water quality guidelines. These included boron, chromium, aluminium, copper, uranium and zinc. These elements were also found to be elevated in the tailings supernatant. Aluminium, copper and zinc exceeded fresh water quality guidelines and baseline

groundwater quality whilst boron, chromium and uranium exceeded guidelines but not baseline. The pH of the leachates and supernatant were alkaline (7.9-9.1).

Based on the geochemical data of tailings material and the high acid-neutralising capacity identified, the risk of acid-rock drainage/acid-mine drainage (ARD/AMD) generation from the TSFs is low. However, as each facility is unlined, there is potential for metalliferous seepage into groundwater from the tailings and (from a lesser extent) the embankments if conditions favourable to leaching exist.

2. Groundwater Elevations

As outlined in Section 1.2, the primary objective of this document is to present a detailed analysis of the hydrogeochemical trends in groundwater and surface water adjacent the Iron Duke TSF. However, as the primary influence of change to aquifer chemistry relates to the movement of groundwater (i.e. advective flow), this section provides a brief analysis of hydraulic information in an effort to explain the hydrogeochemical trends presented in Section 3.

As shown in the hydrograph presented in Figure 2-1, groundwater elevations immediately adjacent the Concentrator TSF and OBP TSF have been monitored regularly since October 2004. A summary of the groundwater elevation data is presented in Table 2.1 . Consistent with findings detailed by Cardno (2015), salinity variations are not significant enough to alter groundwater flow, and the groundwater elevations remain uncorrected for salinity-driven density variations.

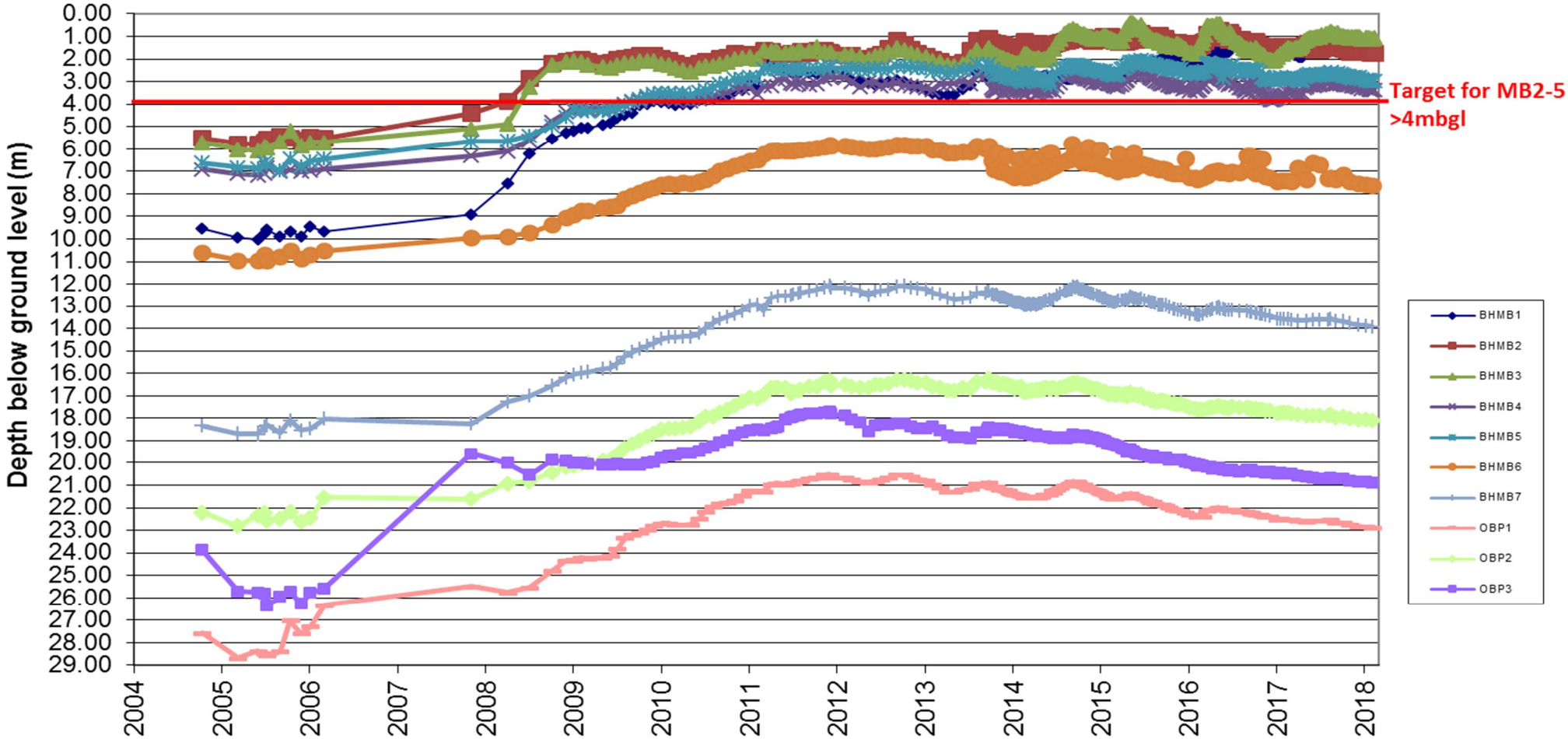
Prior to the commissioning of the OBP TSF and Concentrator TSF in 2007, groundwater elevations remained relatively stable, and are representative of baseline conditions. An immediate response in groundwater, observed across all monitoring infrastructure, correlates with the commencement of tailings deposition at the Concentrator TSF and OBP TSF. The maximum groundwater displacement is typically observed between 2011 and 2012. Subsequent to the installation of a groundwater extraction system in September 2013, with the exception of BHMB1, a decreasing trend of groundwater elevation is noted at all monitoring bores; BHMB1 is the only monitoring bore screened within bedrock (gneiss) and displays an increasing trend in groundwater elevation until September 2016, after which levels plateau.

During the 2015 – 2017 reporting period, groundwater levels in monitoring bores west of the Concentrator TSF (MB1 – MB7) remained stable whilst a decreasing trend is observed in monitoring bores west of the OBP TSF (OBPMB1 – OPBMB3).

Table 2.1 : Summary of Iron Duke Groundwater Elevation Data

Bore ID	Baseline Elevation[1]		Max Displacement			2018 Elevation[3]	
	mAHD	mBGL	mAHD	mBGL	m head	mAHD	mBGL
BHMB1	130.87	9.53	139.07	1.33	8.2	138.545	1.845
BHMB2	129.66	5.51	134.48	0.69	4.82	133.51	1.66
BHMB3	129.94	5.72	135.28	0.38	5.34	134.57	1.09
BHMB4	130.59	6.92	135.07	2.44	4.48	134.125	3.375
BHMB5	130.69	6.62	135.25	2.06	4.56	134.35	2.96
BHMB6	131.20	10.62	136.07	5.75	4.87	134.195	7.615
BHMB7	131.52	18.33	137.79	12.06	6.27	135.94	13.91
OBP1	131.56	27.57	138.61	20.52	7.05	136.215	22.905
OBP 2	131.78	22.21	137.76	16.23	5.98	135.89	18.1
OBP 3	133.97	23.87	140.16	17.68	6.19	136.96	20.88
WEST 1	*N/S*	1.49[2]	*N/S*	0.74	0.75	*N/S*	1.83
WEST 2	*N/S*	1.80[2]	*N/S*	1.03	0.77	*N/S*	2.02
WEST 3	*N/S*	0.72[2]	*N/S*	0.05	0.67	*N/S*	0.71
WEST 4	*N/S*	0.43[2]	*N/S*	-0.13	0.56	*N/S*	0.21

[1] As monitored on 10 October 2014
[2] As monitored on 1 January 2010
[3] As monitored on 1 February 2018
N/S Monitoring well elevation not surveyed



+

Figure 2-1 : Iron Duke Groundwater Hydrograph

3. Hydrogeochemistry

Groundwater samples have been obtained from monitoring bores adjacent the Concentrator and OBP TSFs since October 2004, with a pre-construction groundwater baseline collected during October 2004 to March 2006. Surface water samples from Salt Creek have been obtained during 2012, 2013 and 2014 while surface water was present more often, however due to the intermittent flow of this creek samples cannot always be obtained. Furthermore, opportunistic water samples are routinely obtained from numerous locations across the TSFs, including supernatant fluids at decant and seepage points; this has led to some years having considerably more samples taken.

Hydrogeochemical assessment of groundwater impacts from TSF seepage has been previously completed by Worley Parsons (2009 and 2011), Golder (2014a and 2015) and Cardno (2015). The following section primarily highlights key differences in hydrogeochemical trends during the 2015 to 2017 reporting period, the period since the completion of the last assessment completed by Cardno (2015), however all of the historical data is presented for reference purposes.

The following sections may refer to dissolved ion concentrations in mmol and milliequivalent units, converted from data reported in mg/L or ppm, when comparing concentrations of dissolved analytes. The advantage of these units, over mass-based units, is that they factor in the varying atomic/molecular mass and size of dissolved analytes and are therefore considered a more valid quantity for comparative purposes.

Furthermore, the Iron Duke TSF Environmental Management Plan (TSF EMP; Arrium 2015) utilises the MARP 2007 defined recommended trigger values to assess whether a 'major change' in key groundwater quality parameters has occurred relative to the baseline conditions observed during 2005. These trigger levels include:

- EC / TDS increase by more than 25%.
- A change in pH by more than 2 pH units.
- An increase in one or more trace element (other than iron) concentration defined as follows:
    - baseline concentration > 0.1 mg/L the major change is one order of magnitude.
    - baseline concentration < 0.1 mg/L the major change is two orders of magnitude.

3.1 Major Ions and Water Quality

During the 2015 – 2017 reporting period, analysis of the major ion distribution and water quality parameters was completed on TSF decant/seep water, groundwater and surface water monitoring locations across the Iron Duke mine. A complete collation of the 2015 – 2017 hydrogeochemical data is presented in Appendix A.

3.1.1 Major Changes

The following major changes were recorded during the 2015 – 2017 reporting:

- TDS exceeds the baseline trigger values at BHMB1 on all occasions (Feb-2015; Jun-2015; Jul-2016; Aug-2017), however the final observation in Aug-2017 indicates a return to baseline conditions.
- pH exceeds the baseline trigger values at BHMB1 on three occasions (Feb-2015; Jun-2015; Jul-2016), however the final observation in Aug-2017 indicates a return to baseline conditions.

No other major changes are noted in TDS or pH during the 2015 – 2017 reporting period.

3.1.2 Salinity Analysis

The major ion chemistry of groundwater, surface waters and TSF decant/seep waters, correlates with the observed variation in electrical conductivity (EC) and total dissolved solids (TDS).

During the 2015 – 2017 reporting period, EC in groundwater present in TSF monitoring bores (BHMB1 – BHMB7 and OBPMB1 – OPBMB4) ranged from 15 900 uS/cm (TDS = 10 300 mg/L; BHMB4) to 63 000 uS/cm (TDS = 41 000 mg/L; BHMB1), In comparison, the EC of supernatant fluid at decant and seepage points ranged from 3 780 uS/cm (South Void decant point; TDS = 2 460 mg/L) to 31 600 uS/cm (Mag 2 decant point; TDS = 20 500 mg/L). EC at Salt Creek, the inferred local discharge point for groundwater, ranged from 68 100 uS/cm (TDS = 44 300 mg/L) to 83 600 uS/cm (TDS = 54 300 mg/L).

The changes in salinity validate the conceptual hydrogeological model presented in Section 1.3. Groundwater is subject to evapotranspiration as it migrates along the east-west flowpath, with seepage from the TSFs providing a less saline anthropogenic up-gradient recharge source.

3.1.3 pH Analysis

Changes to pH in groundwater and surface water/TSF decant and seepage locations, observed during the 2015 – 2017 reporting period, are shown respectively in Figure 3-1 and Figure 3-2. In general, a gradual rise in pH (decreasing acidity) is observed in groundwater monitoring bores, corresponding with a return to the moderately acidic conditions observed in baseline data. There is a similarity in pH values between all observation bores and the background bore (CPMW01). Whilst pH has been intermittently monitored at both Salt Creek and TSF decant/seepage waters, pH is generally observed to be circum-neutral in TSF decant water (pH range of 6.1 – 8.4), prior to infiltration through TSF materials whilst the conditions in Salt Creek are moderately acidic (pH range of 2.91 – 4.56).

BHMB1 is the exception with a four-orders of magnitude change in pH units, since the collection of baseline samples in 2005-2006 (a circum-neutral average pH of 7.23), to record a minimum pH of 3.34 in July 2016.

A rapid return to a circum-neutral pH of 7.33 is indicative that either the datum point is erroneous or the monitoring bore is extremely responsive to recharge and is known to be screened in gneiss (bedrock) infer that it's a separate aquifer. Further climate and rainfall analysis is required to confirm this which is outside the scope of work.

As noted by Cardno (2015), whilst trends in pH may have been caused by the recharge from the TSFs, they are not necessarily considered to be a direct effect and are likely to be a geochemical response to a rising water table e.g. hydrolysis of ferric ions. This is further compounded by the geochemical assessment presented in Section 1.4.1, which identified that (due to a high neutralising capacity) the risk of ARD/AMD generation from the TSFs is low, and further discussed in Section 4.

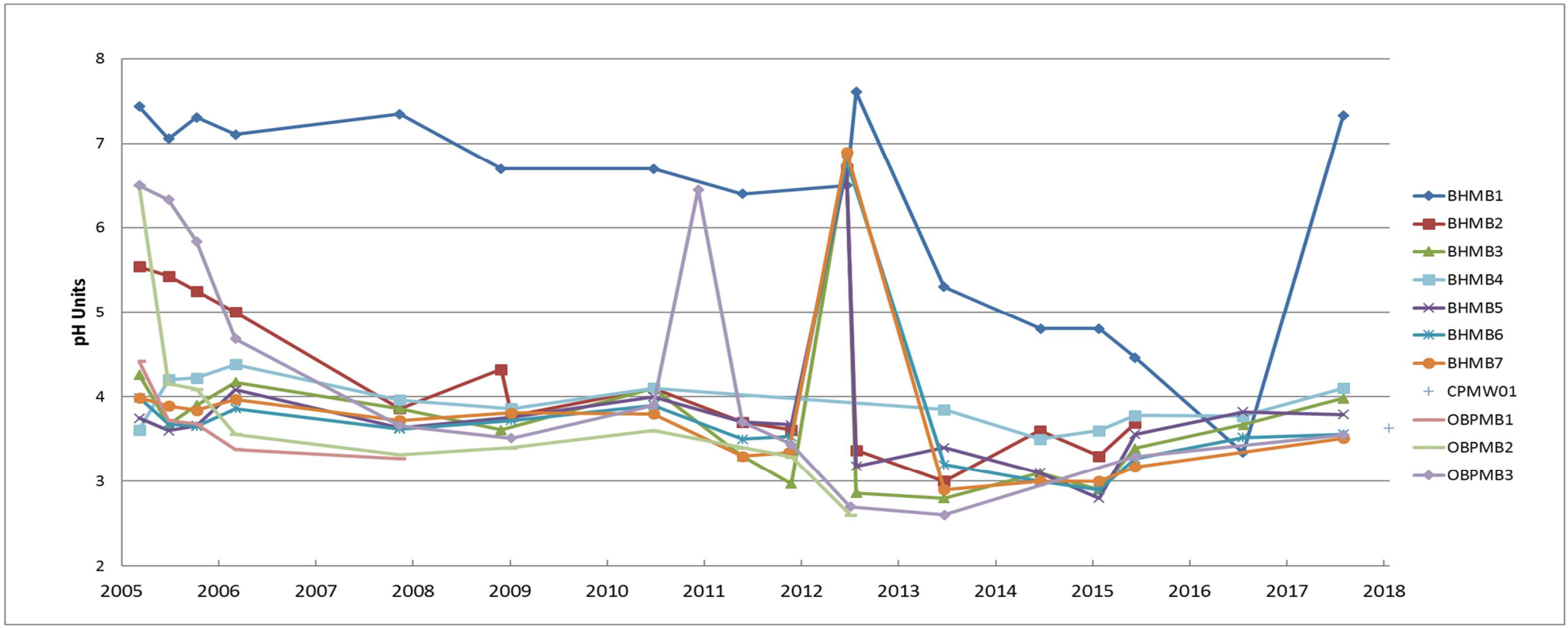


Figure 3-1 : Iron Duke – pH Time Series – Monitoring Bores

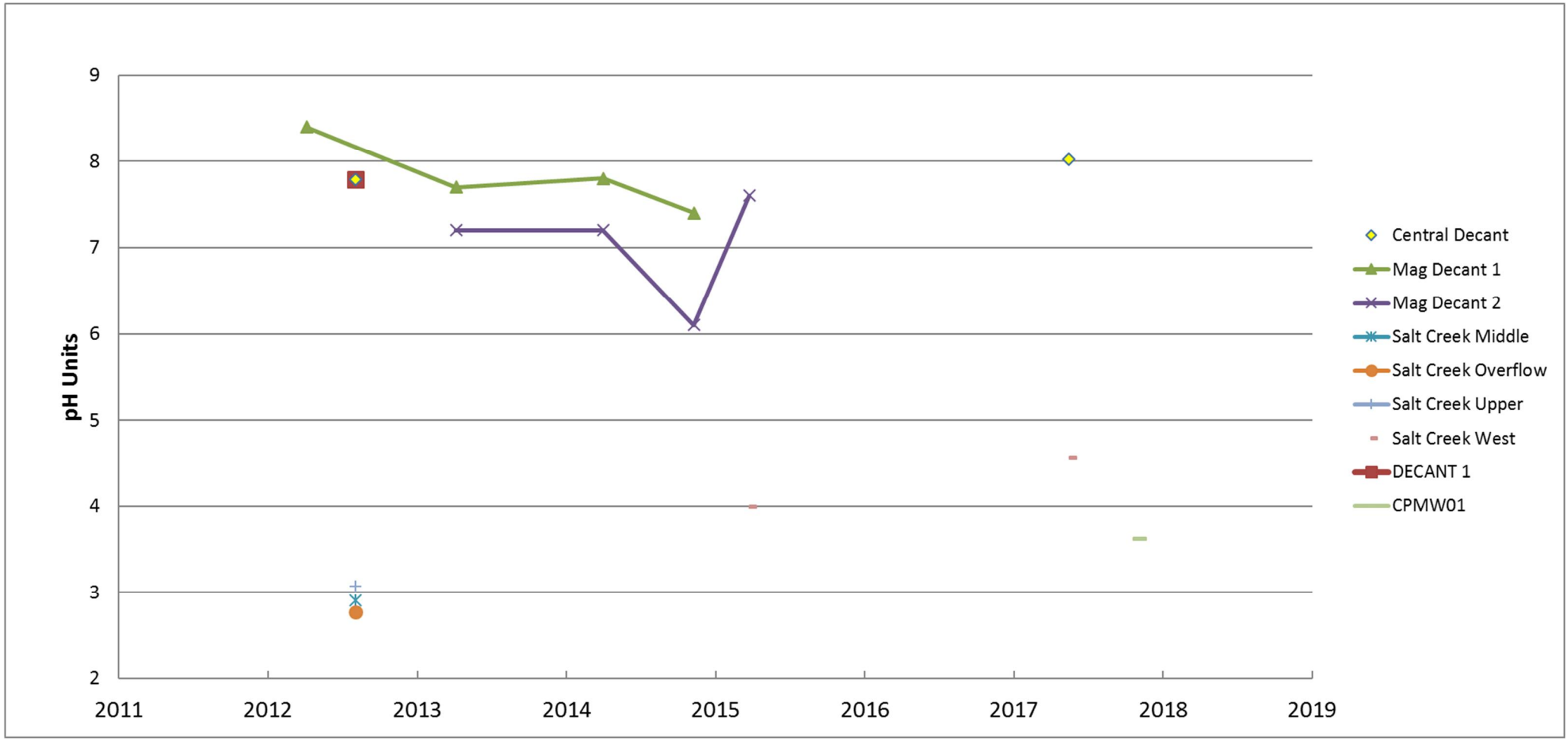


Figure 3-2 : Iron Duke – pH Time Series – Surface Water and TSF Locations

3.1.4 Major Ion Analysis

As shown in Schoeller plots, presented in Figure 3-3 and Figure 3-4, the shallow groundwater and surface water system is dominated by sodium and chloride ions (respective maximums of 24 100 mg/L and 35 000 recorded at West 4), with significant contributions of sulphate (max 5 010 mg/L), magnesium (max 2 320 mg/L) and calcium (max 887 mg/L). No significant change in the Na-Cl dominated water types is identified from Schoeller plots within the 2015 – 2017 reporting period.

The background bore (CPMW01), 2018 ion values are dominated by sodium and chloride (11 700 mg/L and 21 900 mg/L respectively), indicating a similarity to the observation bores and surface water sites. CPMW01 Calcium value (633 mg/L) recorded in 2018, is above all 2015 and 2017 recorded values. A series of Piper plots are presented in Figure 3-5, Figure 3-6 and Figure 3-7 represent the variation of water types from baseline data to the 2015 – 2017 reporting period. A tight grouping of Na-Cl water types is observed in 2005 data (Figure 3-5), with the exception of MB1 due to monitoring bore being screened in basement materials (further described in Section 1.3).

The water types are more varied in the 2015 – 2017 reporting period (Figure 3-6 and Figure 3-7), however are still dominated by concentrations of sodium and chloride. By discretising the sampling points into spatial-based monitoring zones (TSF monitoring bores; TSF seepage and decant waters, Salt Creek and the newly installed background well CPMW01), the hydrogeological conceptualisation is further validated – an evapotranspiration concentration trend is observed, and the Na-Cl water type increases along the local groundwater flowpath.

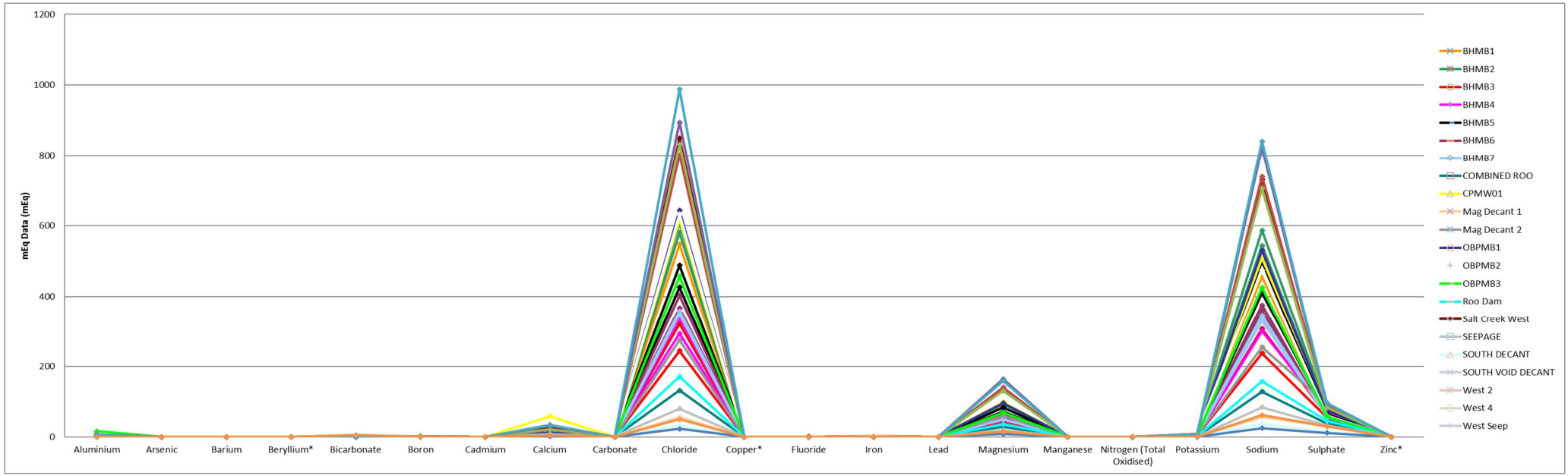


Figure 3-3 : Iron Duke – 2015 Major Ion Schoeller Plot

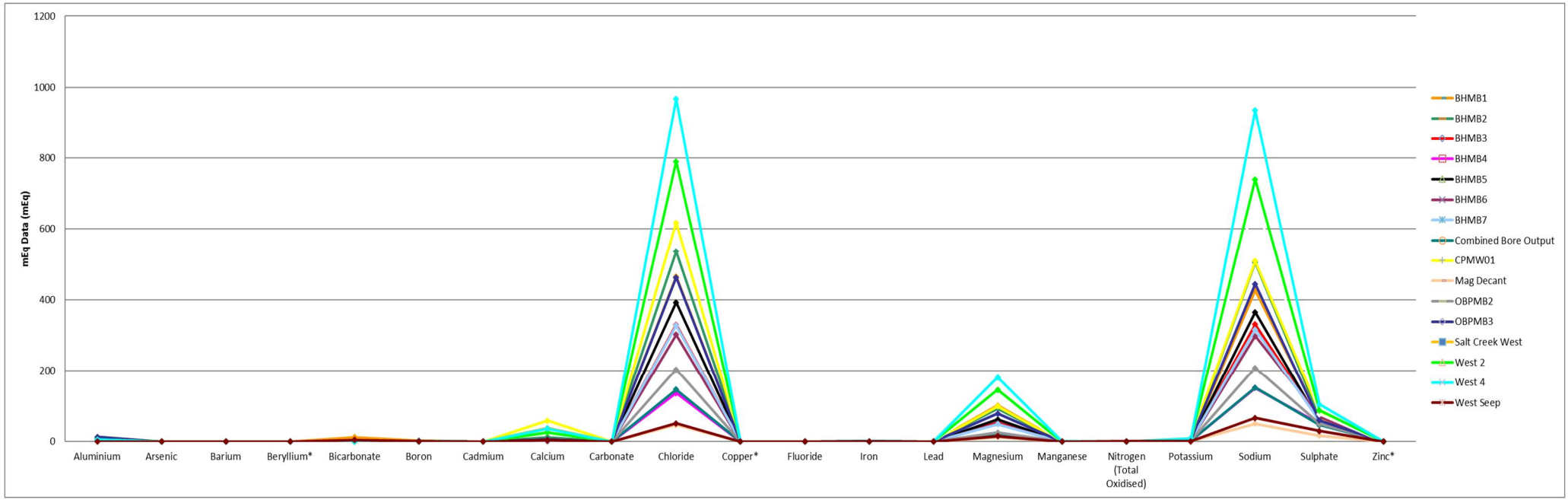


Figure 3-4 : Iron Duke – 2017 Major Ion Schoeller Plot

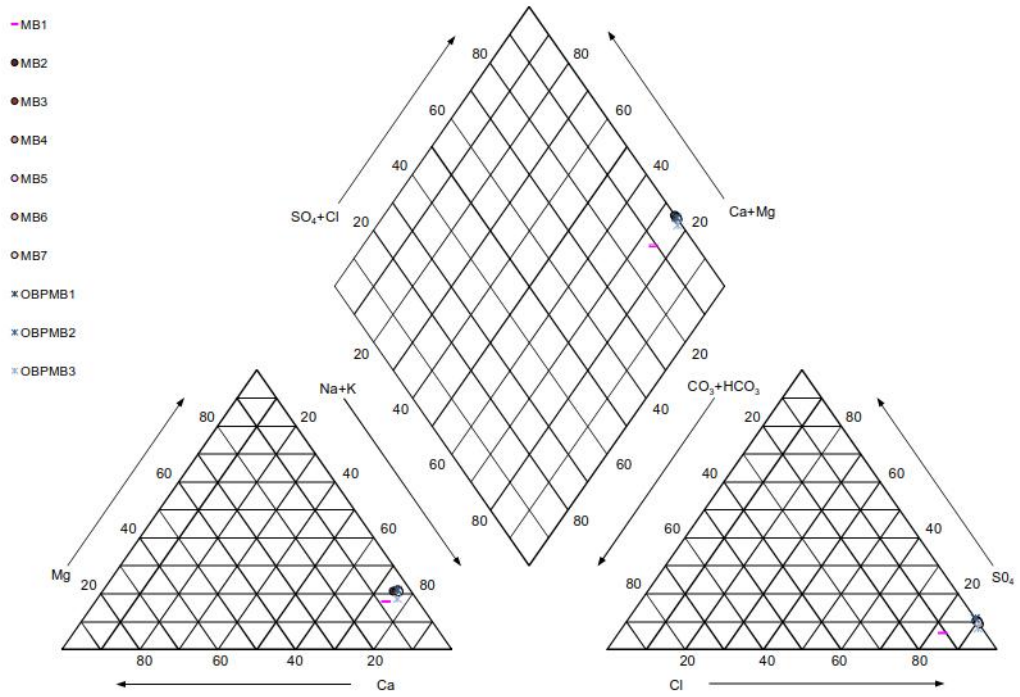


Figure 3-5 : Iron Duke – 2005 Piper Plot (Worley Parsons 2005)

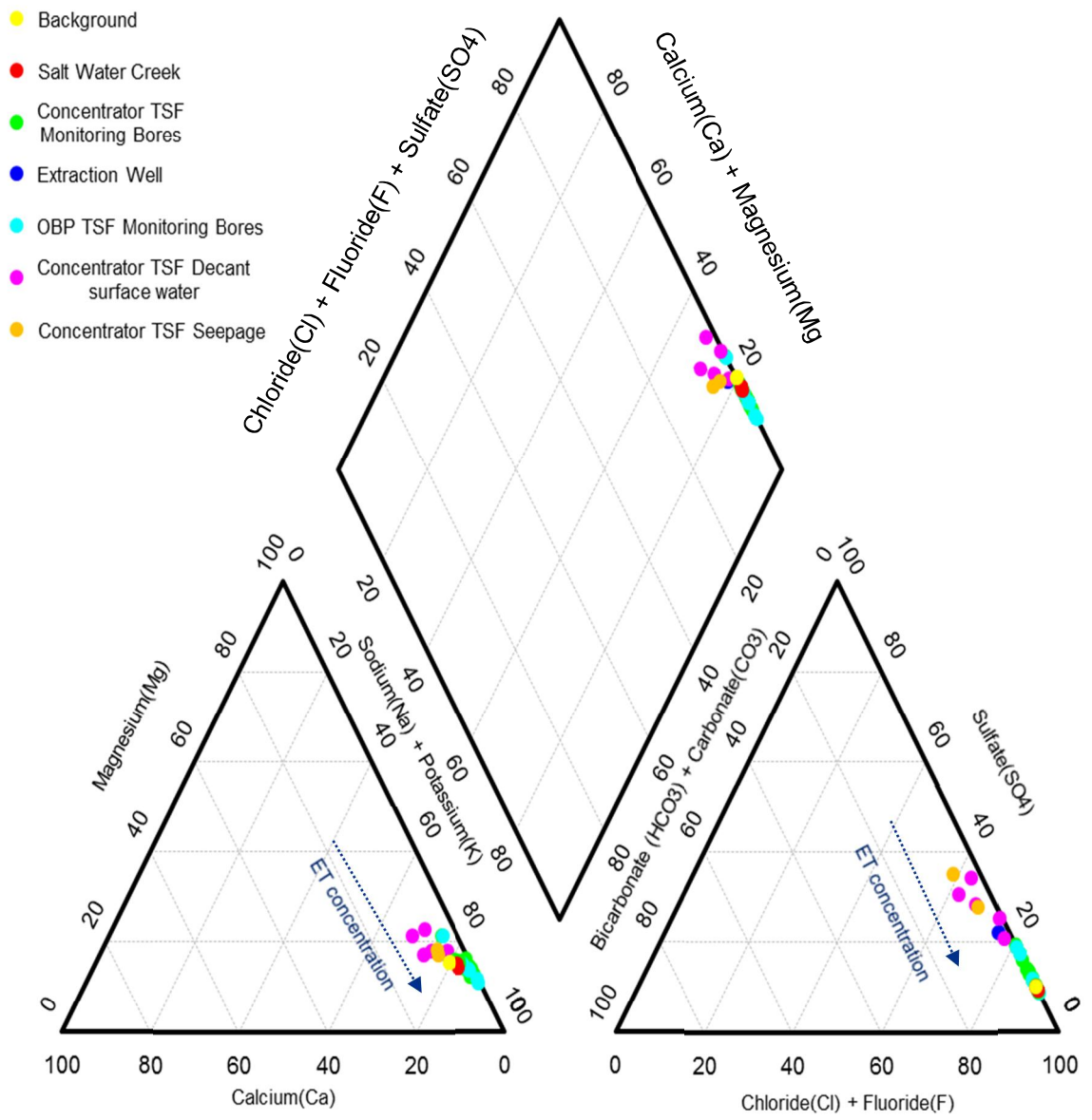


Figure 3-6 : Iron Duke – 2015 Piper Plot

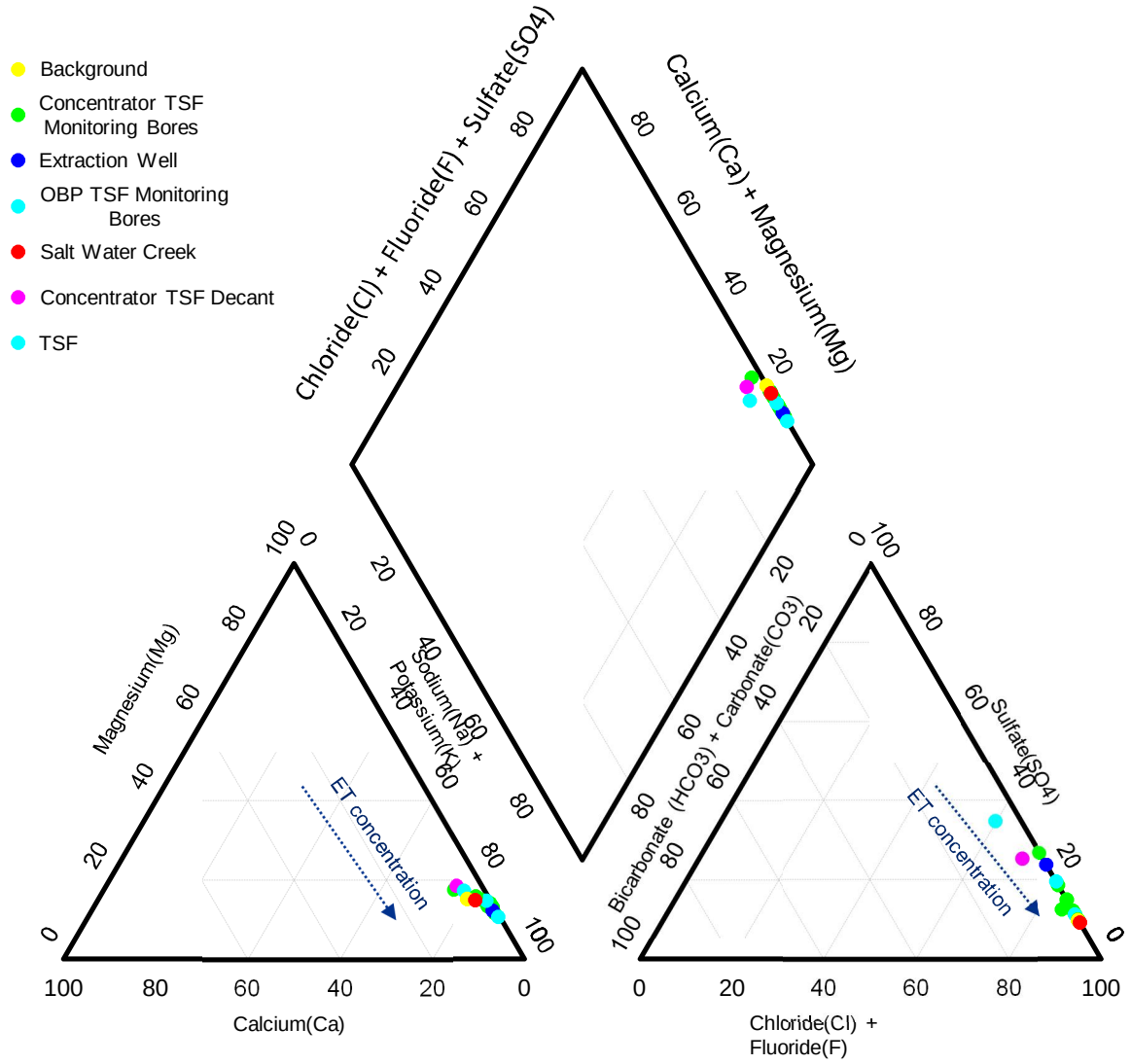


Figure 3-7 : Iron Duke – 2017 Piper Plot

3.2 Dissolved Metals

During the 2015 – 2017 reporting period, a broad suite of dissolved metals analysis was completed on TSF decant/seep water, groundwater and surface water monitoring locations across the Iron Duke mine. A complete collation of the 2015 – 2017 hydrogeochemical data is presented in Appendix A.

3.2.1 Major Changes

The following major changes were recorded during the 2015 – 2017 reporting:

- Aluminium exceeds the baseline trigger values at MB1 on two occasions (Feb-2015; Jul-2016), however the final observation in Aug-2017 indicates a return to baseline conditions.
- Cobalt exceeds the baseline trigger value at MB1 on all occasions (Feb-2015; Jun-2015; Jul-2016; Aug-2017).
- Copper exceeds the baseline trigger value at MB1 on a single occasion (Feb-2015), however all the subsequent observations return to baseline conditions.
- Lead exceeds the baseline trigger value at MB1 on two occasions (Feb-2015; Jun-2015), however the final observation in Aug-2017 indicates a return to baseline conditions.

No other major changes are noted in dissolved metal concentrations during the 2015 – 2017 reporting period.

3.2.2 Trend Analysis

Time-series graphs of key contaminant concentrations observed in groundwater monitoring bores, surface waters and TSF decant/seep water, are presented for aluminium (Figure 3-8 and Figure 3-9); boron (Figure 3.10 and Figure 3-11); copper (Figure 3-12 and Figure 3-13); chromium (Figure 3-14 and Figure 3-15); uranium (Figure 3-16 and Figure 3-17) and zinc (Figure 3-18 and Figure 3-19).

Key observations for aluminium concentrations recorded in groundwater (Figure 3-8), and surface waters and TSF decant/seep water (Figure 3-9):

- BHMB3 observed a drop in July 2016 followed by a plateau.
- BHMB6 observed a rise in February 2016, followed by a drop in July 2016.
- BHMB7 observed a drop in July 2016.
- OBPMB2 observed a rise to 105 mg/L in June 2015, followed by a drop to 52,5 mg/L in July 2016.
- OBPMB3 observed a drop from 144 mg/L in February 2015 to 97.2 mg/L in June 2015.
- Continuous monitoring data in the Salt Creek area is only available at the Salt Creek West monitoring location.

Key observations for boron concentrations recorded in groundwater (Figure 3-12), and surface waters and TSF decant/seep water (Figure 3-13):

- A dip is observed in BHMB1, BHMB2, BHMB3, BHMB6 and BHMB7 in July 2015 and BHMB5 and OBPMB3 in July 2016.
- Continuous monitoring data in the Salt Creek area is only available at the Salt Creek West monitoring location, with a plateau observed in observations.

Key observations for copper concentrations recorded in groundwater (Figure 3-12), and surface waters and TSF decant/seep water (Figure 3-13):

- A spike is observed at BHMB1 (Feb-2015) and OBPMB2 (Jun-2015), however subsequent concentrations return to previous level. No significant trends are noted in other monitoring bores.
- Continuous monitoring data is only available at the Salt Creek West monitoring location, with a plateau observed in observations.

Key observations for chromium concentrations recorded in groundwater (Figure 3-14), and surface waters and TSF decant/seep water (Figure 3-15):

- A spike is observed at MB1 (Feb-2015), MB2 (Jul-2016), MB5 (Feb-2015), and OBPMB3 (Jul-2016), however subsequent concentrations return to previous level. No significant trends are noted in other monitoring bores.
- A gradual increase is observed at the Salt Creek West monitoring location, during the initial three observations, and subsequently decreases.

Key observations for uranium concentrations recorded in groundwater (Figure 3-16), and surface waters and TSF decant/seep water (Figure 3-17):

- BHMB4 observed a peak in June 2015 and has subsequently decreased.
- BHMB6 observed the lowest concentration in the past two sampling events.
- OBPMB2 observed lower concentrations in 2016 and 2017 compared to 2015.

Key observations for zinc concentrations recorded in groundwater (Figure 3-18), and surface waters and TSF decant/seep water (Figure 3-19):

- In general, a gradual decline is observed in all monitoring bores, however spikes are observed at MB5 (Feb-2015) and MB6 (Feb-2015). A dynamic rise is observed at MB7, with discrete drops observed in June 2013 and July 2016.
- A gradual decline is observed at the Salt Creek West monitoring location.

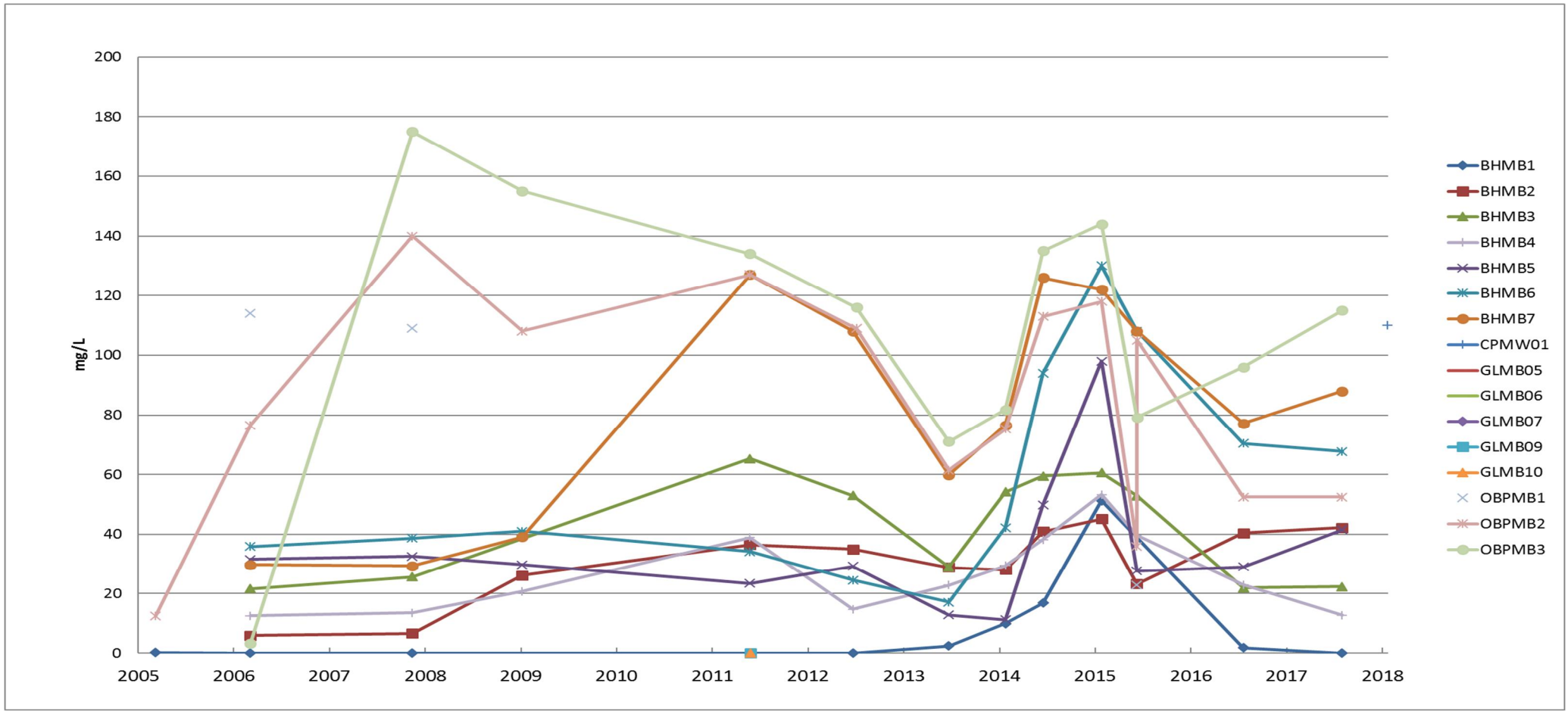


Figure 3-8 : Iron Duke –Aluminium Concentration Time Series – Monitoring Bores

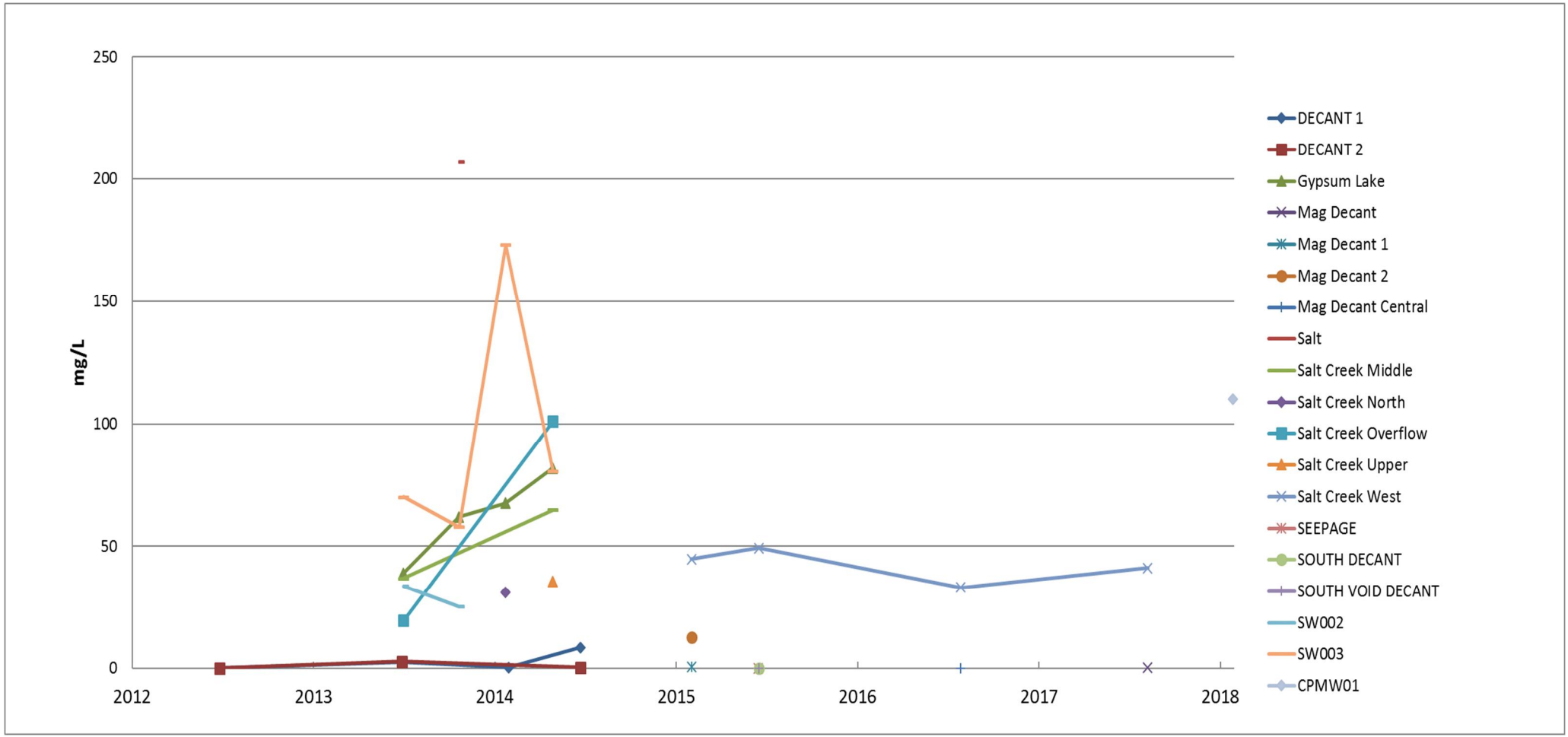


Figure 3-9 : Iron Duke – Aluminium Concentration Time Series – Surface Water and TSF Locations

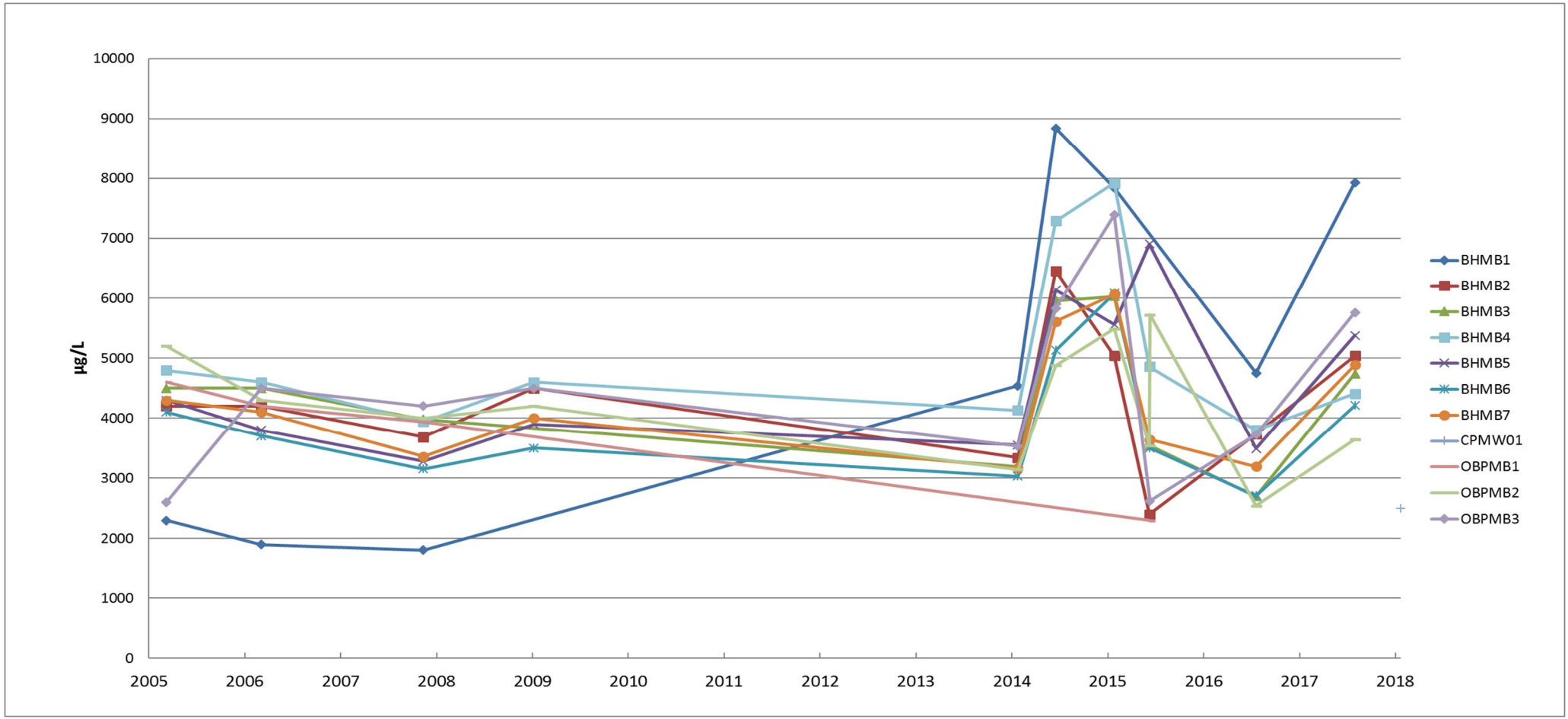


Figure 3.10 : Iron Duke – Boron Concentration Time Series – Monitoring Bores

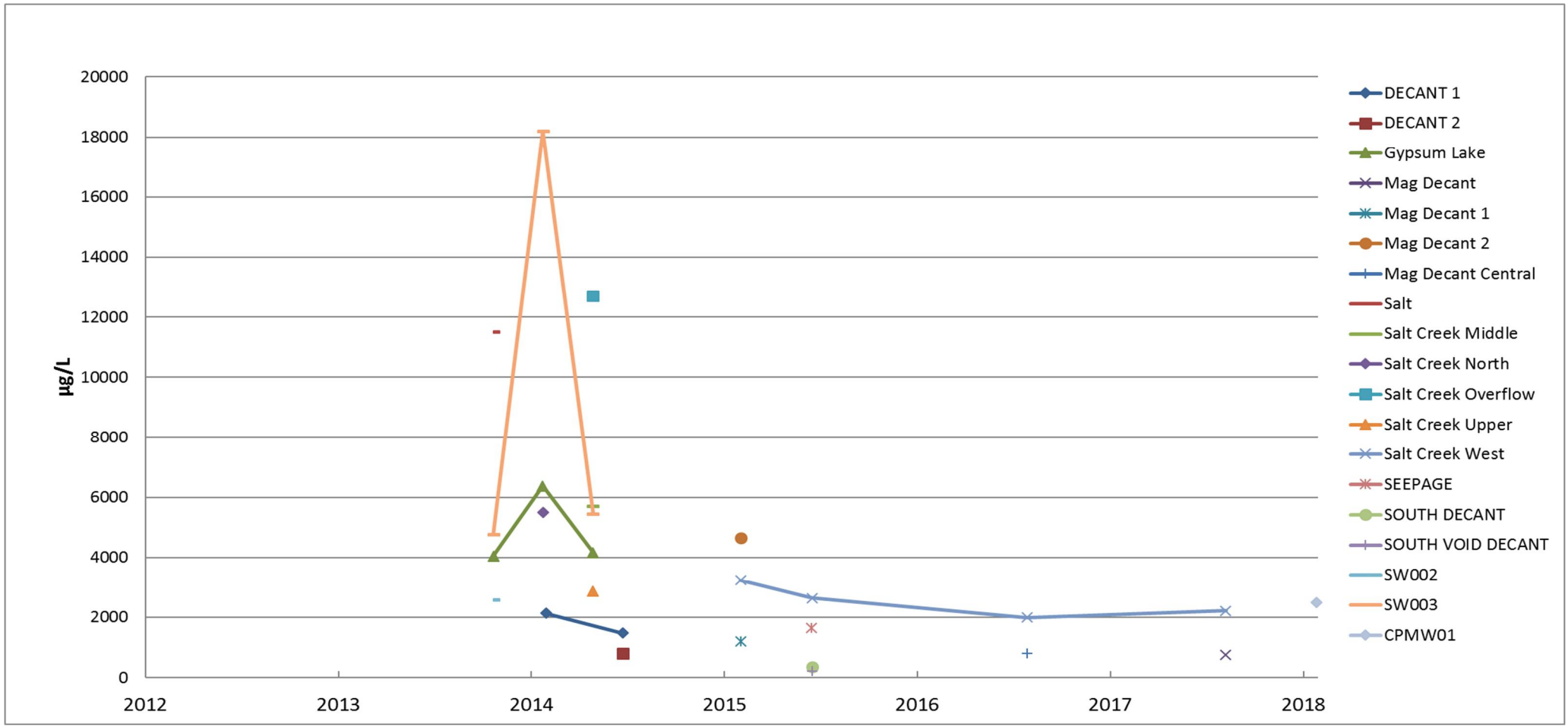


Figure 3-11 : Iron Duke – Boron Concentration Time Series – Surface Water and TSF Locations

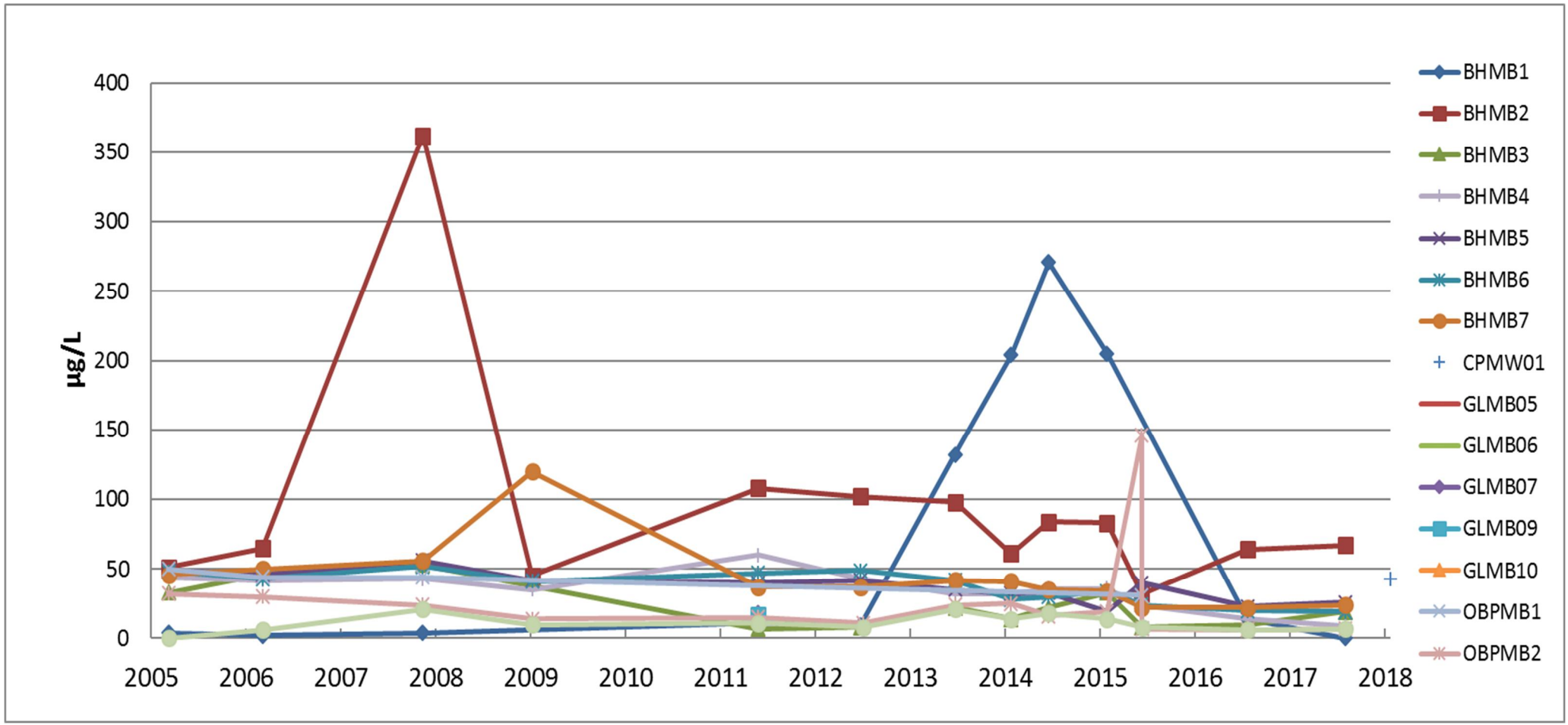


Figure 3-12 : Iron Duke – Copper Concentration Time Series – Monitoring Bores

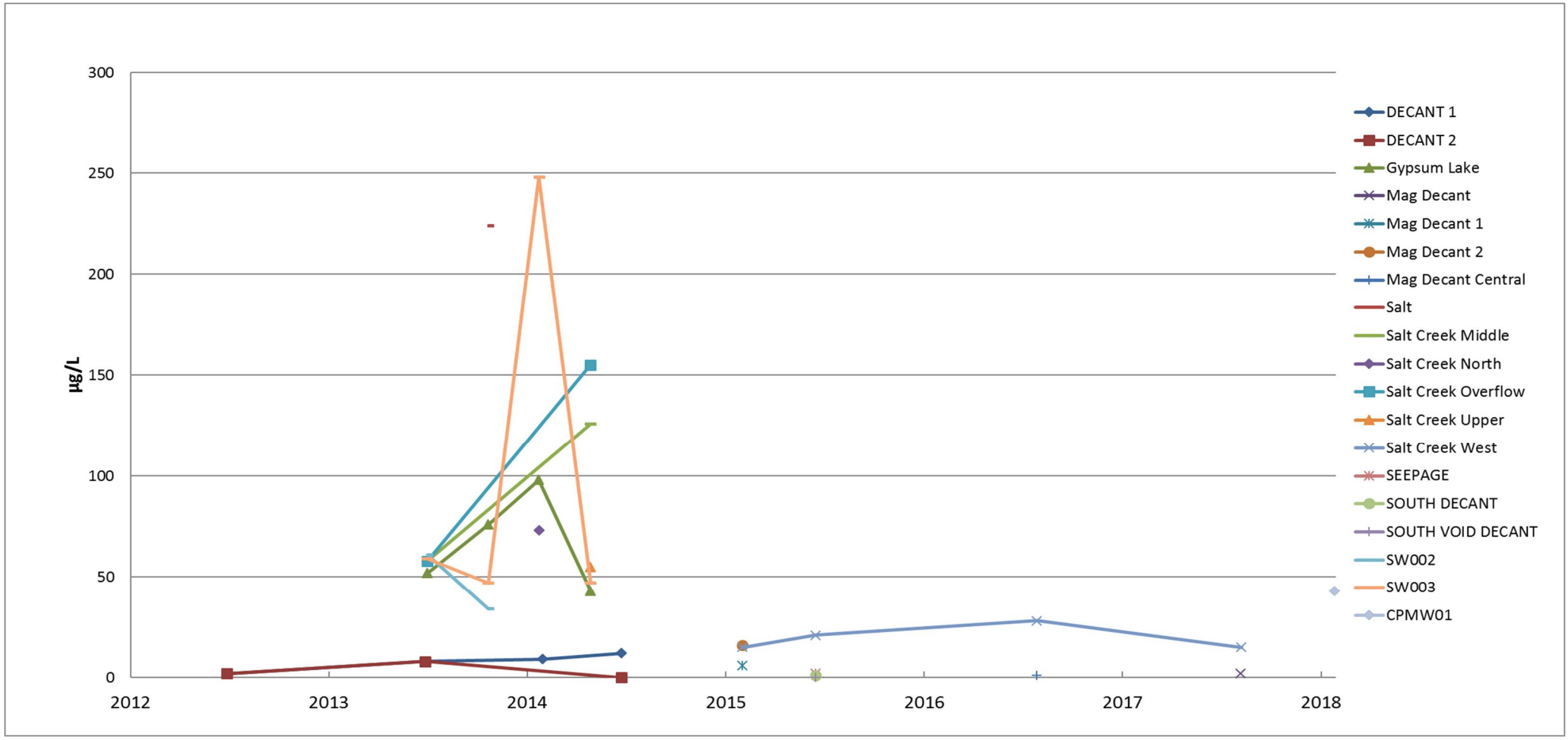


Figure 3-13 : Iron Duke – Copper Concentration Time Series – Surface Water and TSF Locations

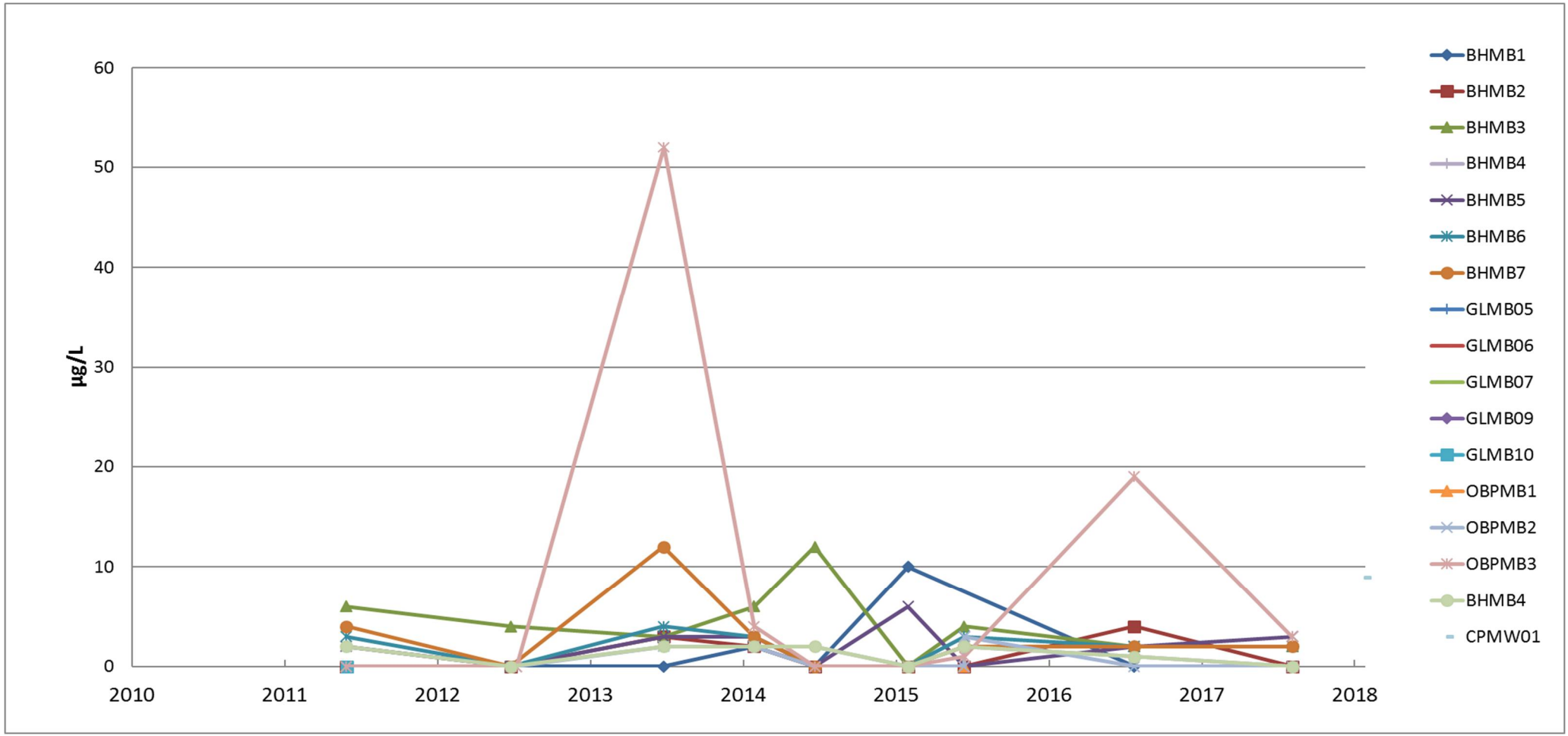


Figure 3-14 : Iron Duke – Total Chromium Concentration Time Series – Monitoring Bores

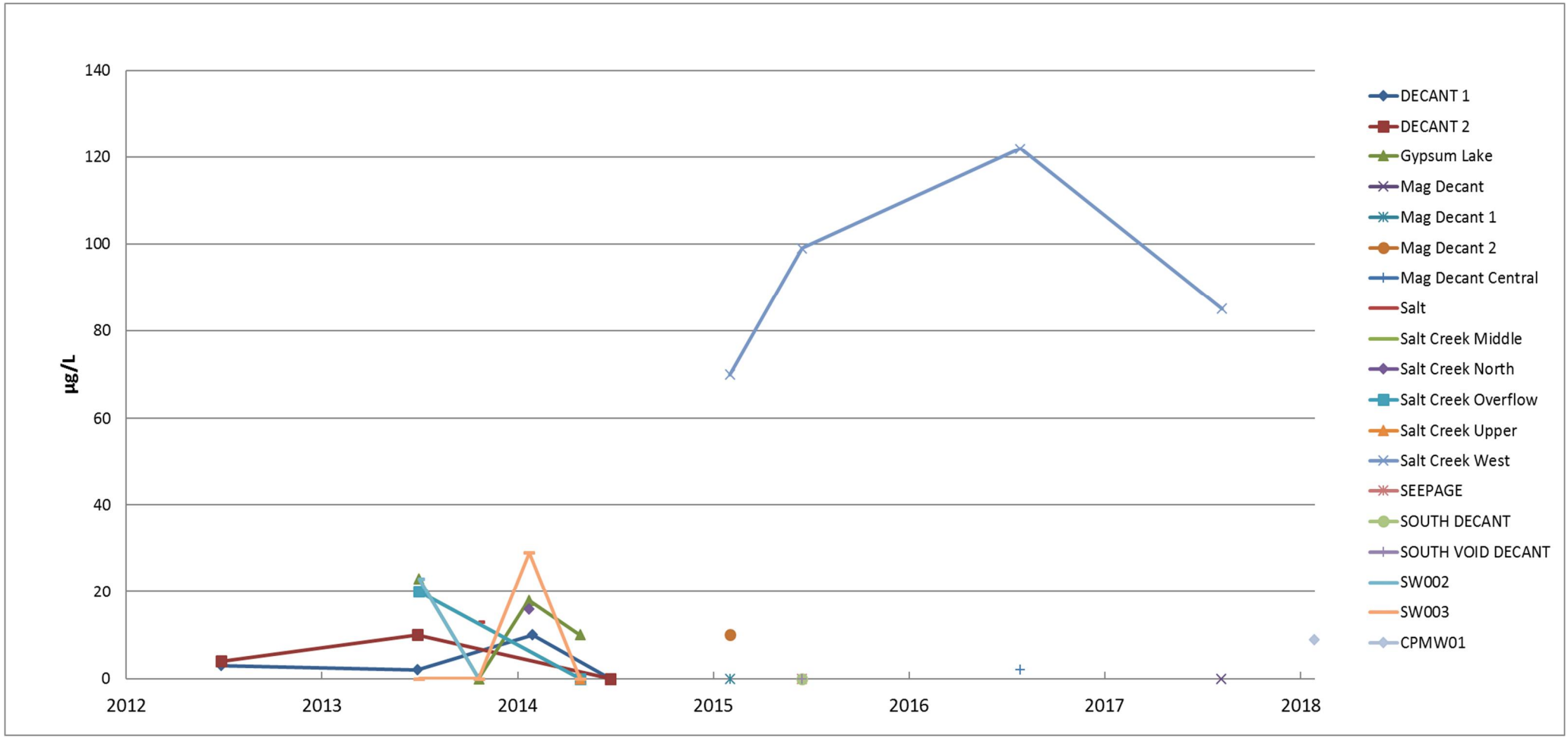


Figure 3-15 : Iron Duke – Total Chromium Concentration Time Series – Surface Water and TSF Locations

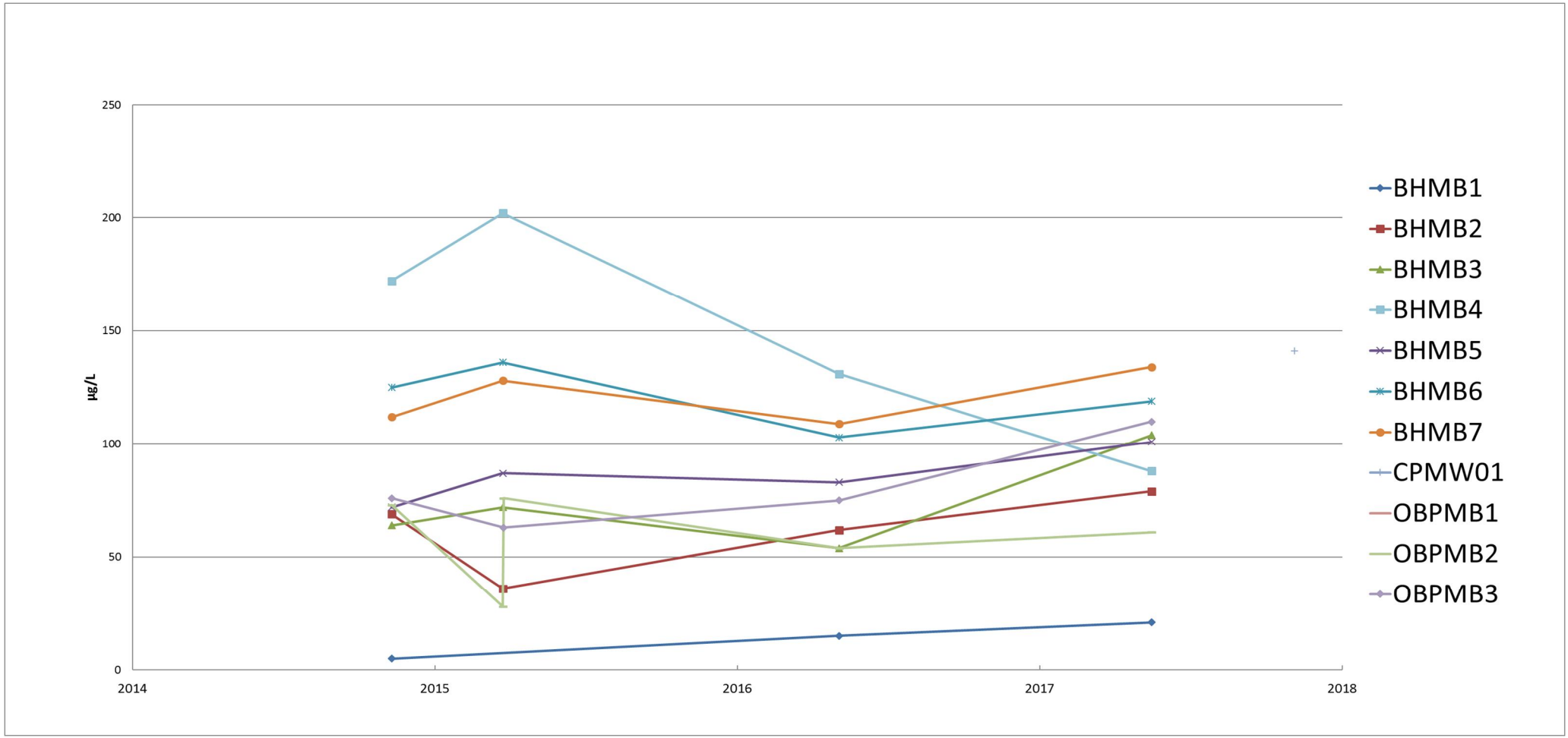


Figure 3-16 : Iron Duke – Uranium Concentration Time Series – Monitoring Bores

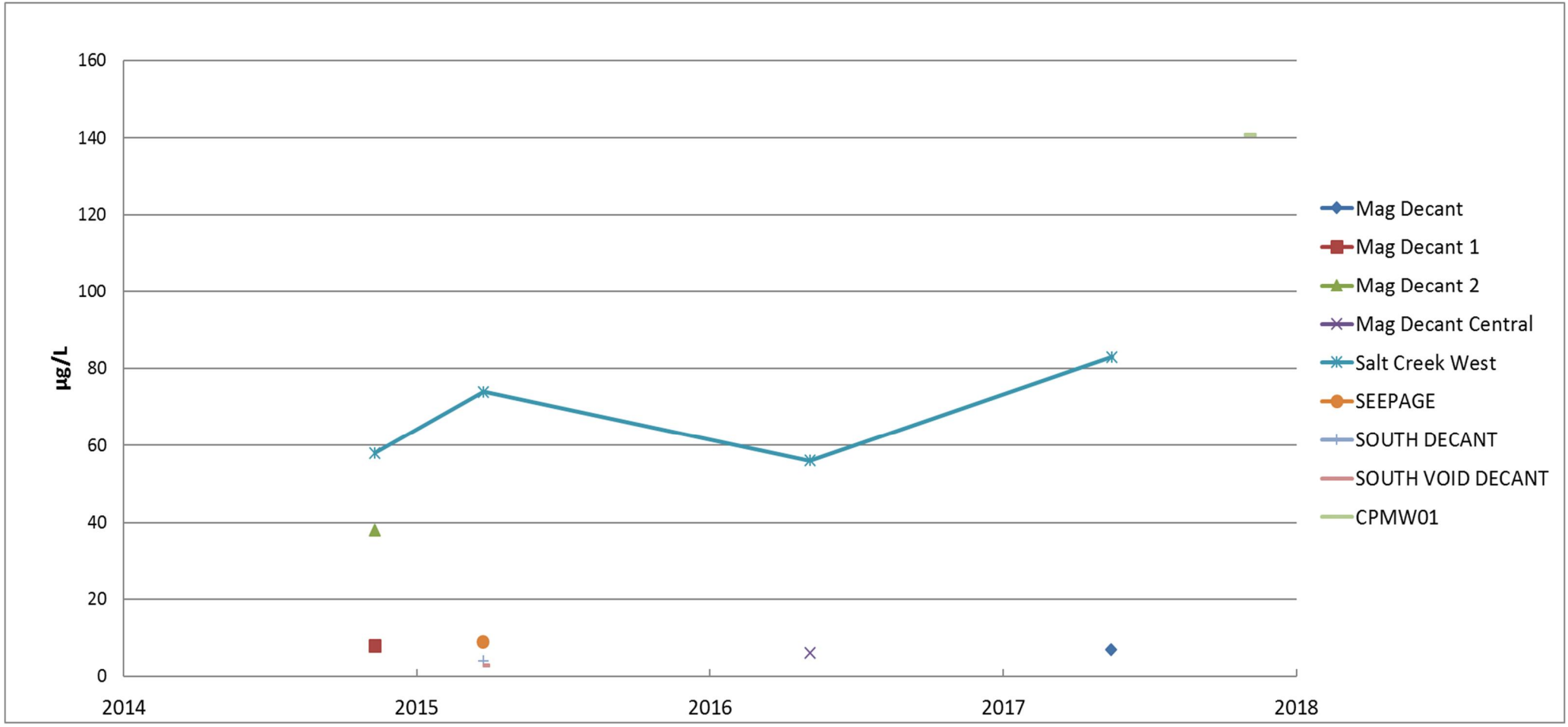


Figure 3-17 : Iron Duke – Uranium Concentration Time Series – Surface Water and TSF Locations

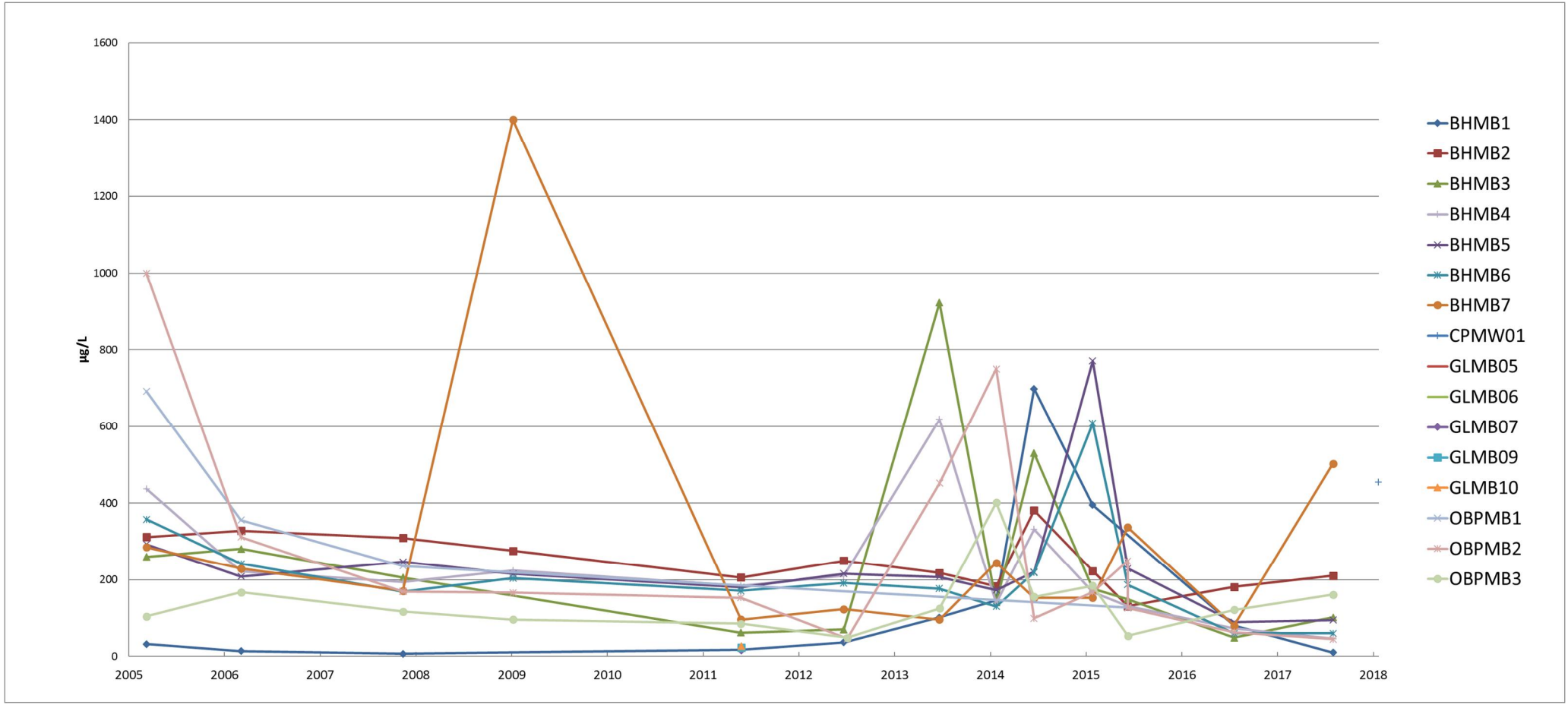


Figure 3-18 : Iron Duke – Zinc Concentration Time Series – Monitoring Bores

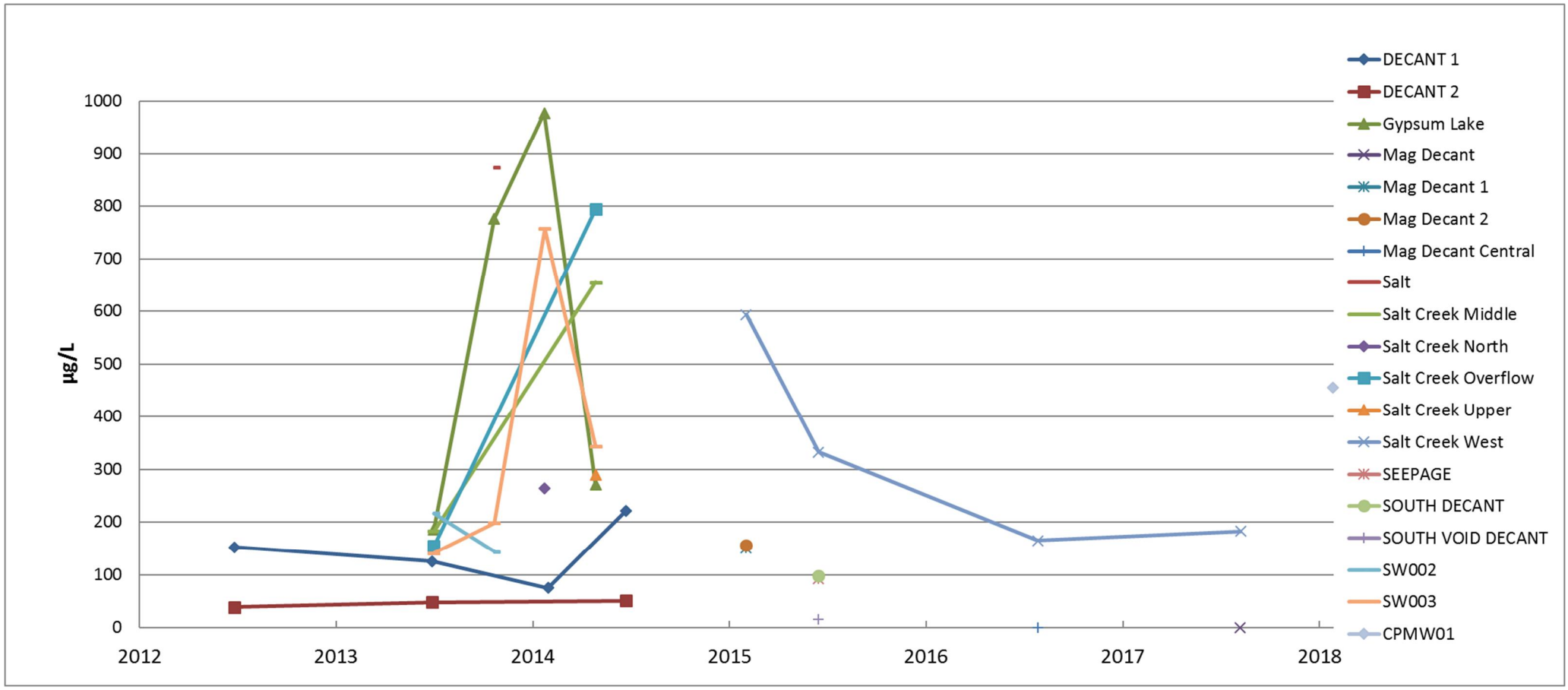


Figure 3-19 : Iron Duke – Zinc Concentration Time Series – Surface Water and TSF Locations

3.3 Ionic Ratios

Characterisation of water types and hydrogeochemical processes can be further delineated by calculation of specific ionic ratios. Utilising the major ion and trace element analysis, collected during the 2015 – 2017 reporting period, ionic ratios have been calculated for all TSF decant/seep water, groundwater and surface water monitoring locations across the Iron Duke mine.

Whilst the ionic ratios are not presented to explicitly define the extent of TSF leakage, when used in conjunction with each other they can indicate the hydrogeochemical processes which groundwater is subject to and highlight the partitioning of sample populations.

3.3.1 Ca:Mg Analysis

A comparison graph, presented in Figure 3-20, identifies that magnesium exceeds calcium in all samples by a factor of generally greater than 3:1, with the difference more pronounced in groundwater wells and as electrical conductivity increases (becomes more saline). Four distinct water types can be inferred from this graph (Figure 3-20): TSF decant and seepage water; Groundwater in monitoring bores screened in a basement paleochannel; Groundwater immediately adjacent the TSFs; and, groundwater and surface waters hydraulically downgradient of the TSFs.

3.3.2 Cl:SO_4 Analysis

Chloride to sulfate ratios are commonly used for assessing the migration of metalliferous mine drainage (EPA Victoria 2009) that may have high buffering capacities and therefore low pH is not a reliable indicator. A comparison graph of chloride and sulfate for the 2015 – 2017 reporting period is presented in Figure 3-21. As identified by EPA Victoria (2009), a mass-based ratio of <4:1 is an indicator of mine drainage impact causation but is not necessarily a direct correlation – it should be noted that this ionic relationship is less commonly applied to hypersaline groundwater identified at Iron Duke. Key observations from Figure 3-21:

- generally, all of the TSF decant/seep samples have a Cl:SO4 ratio of less than 4:1;
- potential mixing of TSF seepage and native groundwater is observed in MB3, MB4, MB6, OBPMB2 and the groundwater extraction system; and,
- all groundwater and Salt Creek monitoring locations, downgradient of hydraulic flow from the TSFs, have a chloride to sulfate ratio of 7:1.

3.3.3 Sodium Adsorption Ratio Analysis

The sodium adsorption ratio (SAR), a measure of the increase of Na at the expense of Ca/Mg over time, has previously been used by Golder (2014a) and Cardno (2015) to trace the migration of TSF seepage into the local groundwater system. Commonly used to assess the sodicity of soils and their suitability for irrigation, the SAR equation is defined below:

Equation 1 $$SAR = \frac{Na^+}{\sqrt{\frac{1}{2}(Ca^{2+} + Mg^{2+})}}$$

Contrary to the geochemical interpretations provided by Golder (2014a) and Cardno (2015), the use of SAR is a proxy for the potential adsorption of heavy metals onto the surface of clay minerals (present in aquifer material) and subsequent desorption of more weakly-bonded ions (i.e. sodium/magnesium/calcium) (Abollino et al. 2003). On this basis, SAR can be used to discern the diffusion front of contaminant plumes in groundwater, in the absence of elevated heavy metal concentrations being observed.

Due to the significant concentrations of sodium, calcium and magnesium in saline groundwater at the Iron Duke mine, a proportionally large concentration of heavy metals would be required to create a discernible change in

the sodium adsorption ratio. On this basis, it is deemed that SAR is more useful as an indirect indicator of TSF seepage (via the observed change in partitioning of groundwater sample populations) and not a direct measure of the diffusion front of a contaminant plume.

A comparison of the SAR components is presented in Figure 3-22, with key observations including:

- generally, all of the Iron Duke water chemistry data sits along a similar SAR trendline which approximates to a 10:1 milliequivalent ratio of Na and Ca/Mg;
- the slight increase in sodium observed in most groundwater monitoring wells adjacent the TSFs could indeed be related to a reduction in calcium via precipitation of Gypsum or amorphous carbonates; and,
- the variance of MB1 from the SAR trendline indicates the presence of different clay minerals and a different geochemical regime in this groundwater, relative to other groundwater bores.

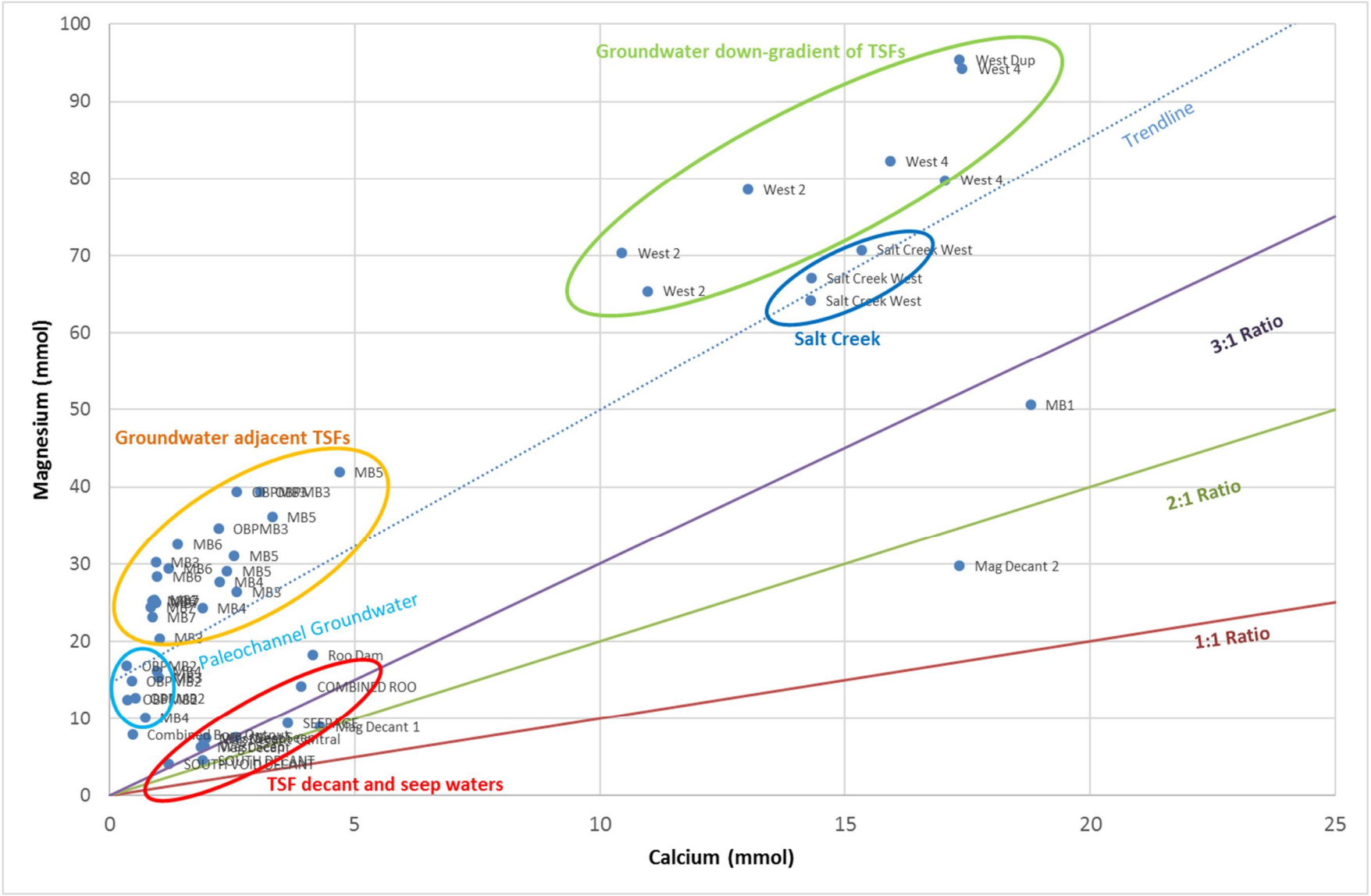


Figure 3-20 : Iron Duke – 2015 to 2017 Comparison of Calcium and Magnesium

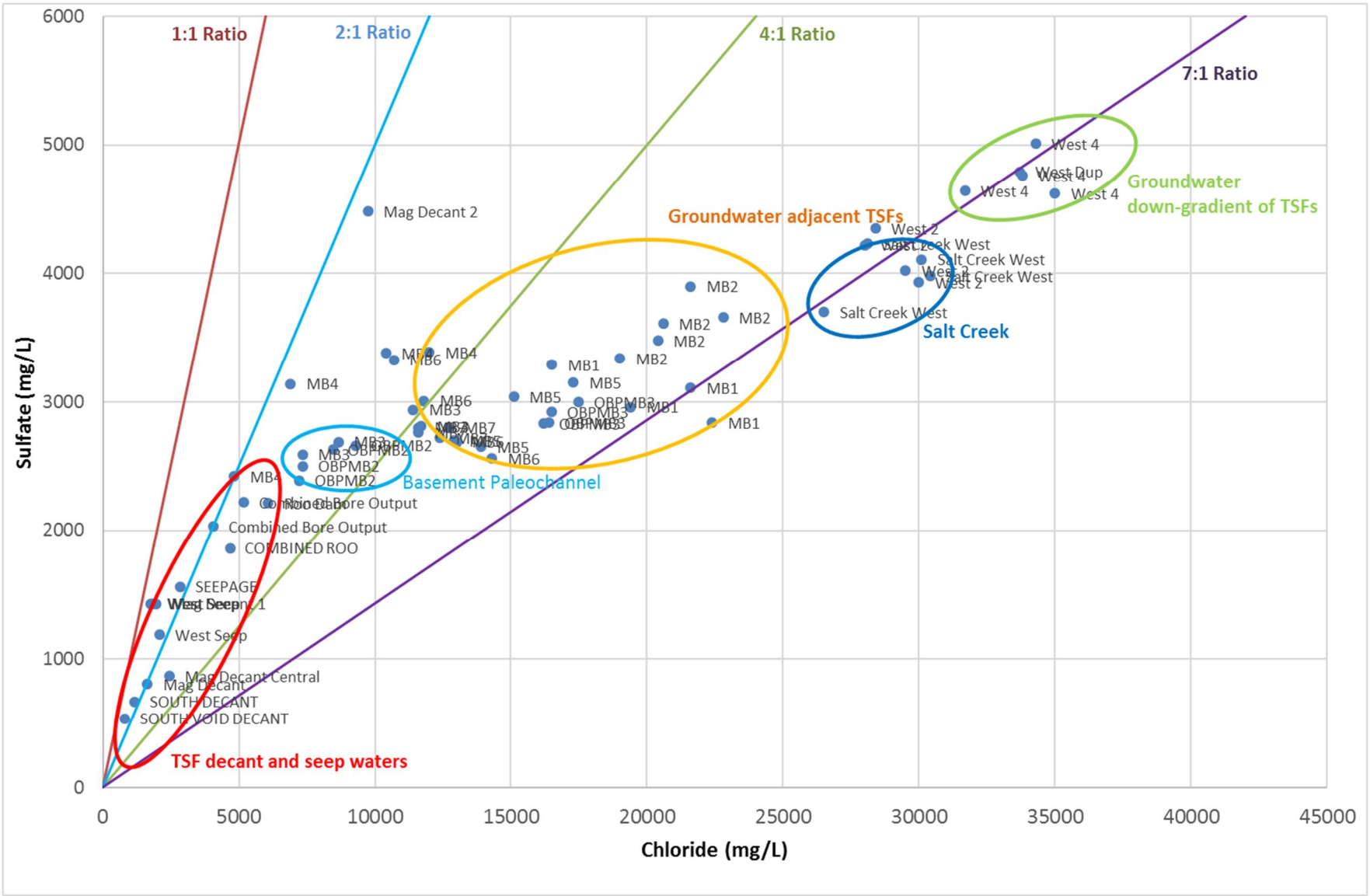


Figure 3-21 : Iron Duke – 2015 to 2017 Comparison of Chloride and Sulfate

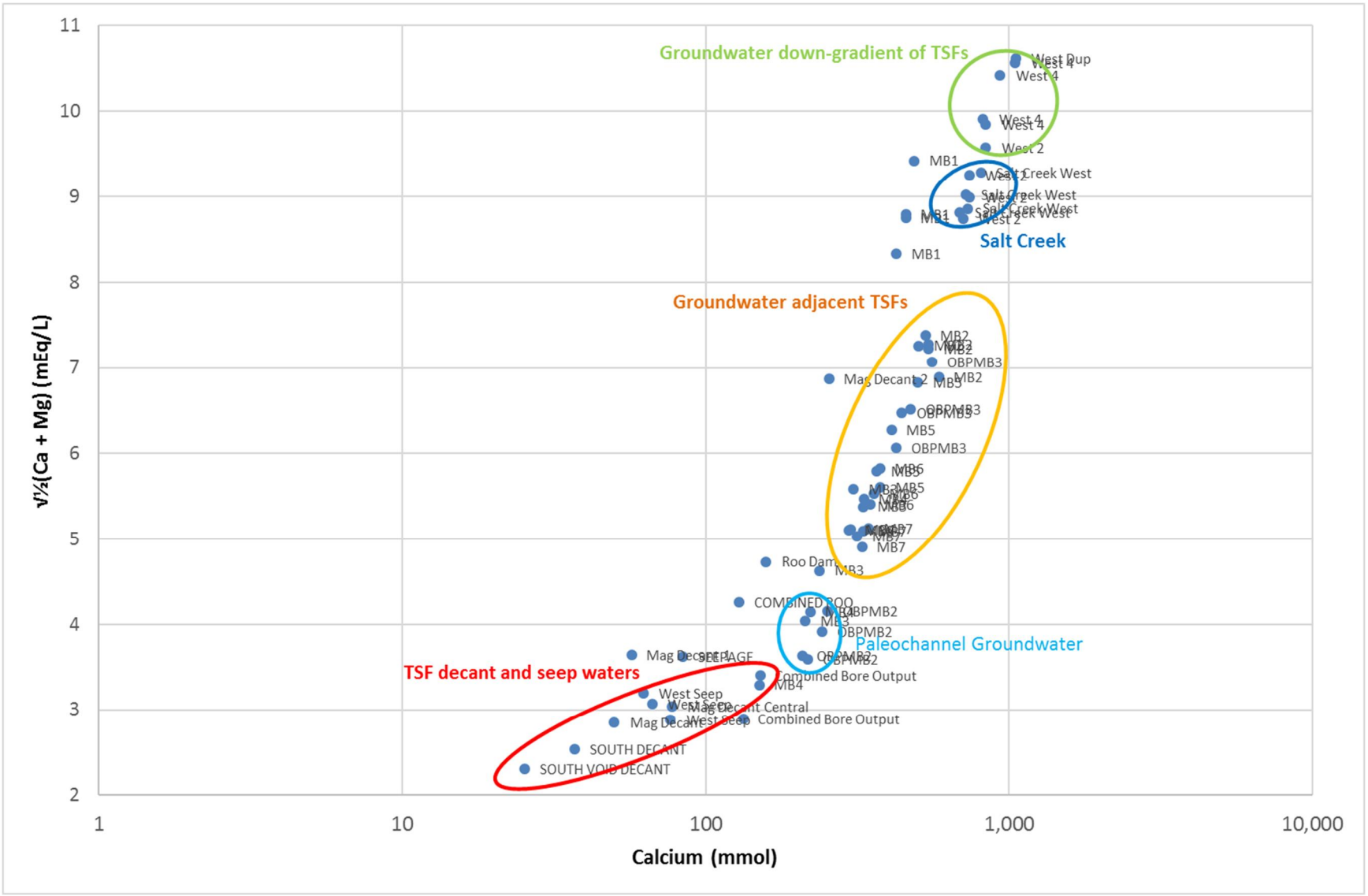


Figure 3-22 : Iron Duke – 2015 to 2017 Comparison of Sodium Adsorption Ratio

3.3.4 Saturation Index

Saturation indices (SIs) of average water chemistry/quality, observed at numerous monitoring locations during the 2015 – 2017 reporting period, were calculated using PHREEQc; a geochemical speciation program, developed by the U.S. Geological Survey. The SI of water provides a thermodynamic indication as to whether water is likely to dissolve (undersaturated) or precipitate (supersaturated) a particular mineral. For the purposes of this investigation, the minerals being dissolved are limited to those present in TSF material, and therefore focuses on the likely precipitates that might be forming as groundwater migrates along the east-west flowpath and becomes exposed to atmospheric conditions.

The PHREEQc geochemical model incorporated the following assumptions:

- The water was assumed to be in equilibrium with atmospheric gases (an oxidising electron potential (pe) of 4.0 was assigned in the model), with the log of partial pressure (required for PHREEQC) for O_2 (-0.67) and CO_2 (-3.5) defined by their relative atmospheric abundance.
- Field parameters were used to define the pH of each solution, however in the absence of other variables groundwater was assumed to be at standard laboratory conditions (i.e. Temperature = 25°C and Pressure = 101.3 kPa.
- The modelling included only simple mixing of fluids, focused on saturation and precipitation evaluations for common metal hydroxides. The potential for groundwater and injection water to interact with suspended sediments (e.g., colloids or clays present in groundwater) and minerals already present in the aquifer was not assessed by modelling.

The PHREEQc geochemical model outputs are presented in Appendix B.

The model accounts for direct precipitation without kinetic restraints (i.e. all reactions were simulated as occurring instantaneously as governed by equilibrium thermodynamics). During injection activities the net rate of precipitation may be slower than predicted by the model, such that the subsequent dispersion and dilution of injected water would result in less precipitates forming than predicted.

Figure 3-23 shows the distribution of SIs at groundwater, surface water and TSF decant/seep monitoring locations across the Iron Duke site. Mineral species are grouped into five types: aluminium oxyhydroxides ($Al_4(OH)_{10}SO_4$, Diaspore), carbonates (Calcite, dissolved CO_2, Dolomite), metal oxides (Cr_2O_3, Cupric Ferrite, Cuprous Ferrite, $FeCr_2O_4$), iron oxide/oxyhydroxides ($Fe_3(OH)_8$, Ferrihydrite, Goethite, Hematite, Lepidocrocite, Magnetite), and sulfates (Alunite, Jarosite-*Na*, Jarosite-*K*, Gypsum). Note: not all of these mineral species form under aqueous precipitation conditions (e.g. Hematite), and a less stable amorphous mineral phase is more likely.

Water from the TSF decant/seep, have the greatest distribution of supersaturated minerals, with metal oxides, iron oxide/oxyhydroxides and carbonates likely to precipitate – due to their exposure to atmospheric conditions the greatest amount of mineral precipitation is likely to occur here. This distribution reflects the minerals likely to have been dissolved by supernatant and groundwater, present in TSF material. The precipitation of carbonates is valid, on the basis that supernatant water migrates through carbonate-rich TSF material (as indicated in Section 1.4.1). Furthermore, with low $Cl:SO_4$ ionic ratios in TSF decant/seep water (as discussed in Section 3.3), sulfate is supersaturated and results in the precipitation of Jarosite and Gypsum, thus removing dissolved sulfate. By the time more oxygenated water from the TSFs has migrated to the perimeter extraction system the majority of these mineral species have precipitated out of solution (as indicated by SIs at the combined bore output sampling point).

The groundwater system and Salt Creek water samples have a smaller distribution of supersaturated minerals relative to the TSF decant/seep and MB1. Mineral precipitation is minimised as groundwater is likely to be under reducing conditions, however Alunite, Cuprous Ferrite, and aluminium oxyhydroxides are likely to precipitate out of solution in aquifer material as the thermodynamic conditions of groundwater change (i.e. adjacent recharge/discharge areas and areas with shallow depth to groundwater). Elevated SIs of dissolved CO_2 is indicative that either there is a source of carbonate minerals present in aquifer material or aerobic respiration by microbial species.

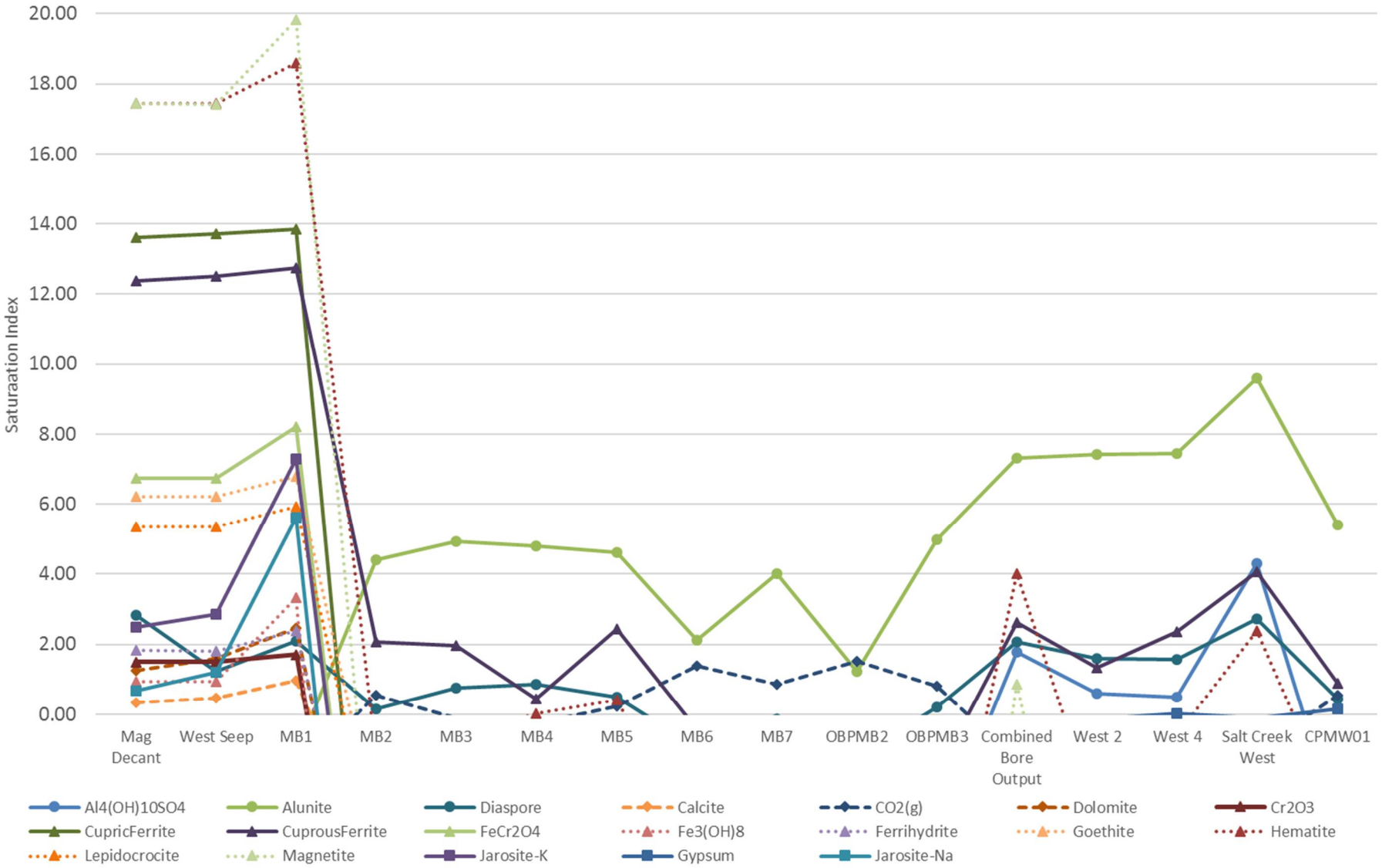


Figure 3-23 : Iron Duke – 2015 to 2017 Average Saturation Indices

4. Hydrogeochemical Discussion

All of the hydrogeochemical reactions presented in this section are as defined by Apello and Postma (2005).

4.1 Ca and Mg Relationship

In reference to the water types identified in Figure 3-20. A distinct jump between TSF decant/seepage water and other groundwater/surface waters was noted, indicating either a source of magnesium being added or calcium being removed adjacent the TSF – potentially via the precipitation of Gypsum ($CaSO_4$) or amorphous carbonate minerals – as TSF seep water moves through and interacts with the tailings material.

This hydrogeochemical conceptualisation is validated by the SIs of TSF decant and seepage water indicating that amorphous forms of Calcite and Dolomite are likely to precipitate via the following reactions:

Reaction A $Ca^{2+} + CO_3^{2-} \leftrightarrow CaCO_{3(a)}$ *Calcite formation*

Reaction B $Ca^{2+} + Mg^{2+} + 2CO_3^{2-} \leftrightarrow CaMg(CO_3)_{2(a)}$ *Dolomite formation*

4.2 Secondary Acid Generation

It is recognised that the oxidation of sulphides produces acidity, however the tailings material has been shown to be low in sulfidic material with a moderate neutralising capacity (Golder, 2014b). The operational implication is TSF decant and seep water at circum-neutral pH.

In contrast to sulphide oxidation at the TSFs, the precipitation of Alunite, the Ferrolysis effect and precipitation of iron/aluminium oxyhydroxides in groundwater is likely to naturally produce acidity. The increased acidity results in a moderately acidic pH in groundwater, which is evident in groundwater baseline data obtained adjacent the TSFs and background data obtained from CPMW01.

The precipitation of Alunite, Ferrolysis effect and precipitation of iron/aluminium oxyhydroxides, occurring as groundwater discharges and an increased exposure to atmospheric oxygen, is defined via Reaction C, Reaction D and Reaction E:

Reaction C $K^+ + 3Al^{3+} + 2SO_4^{2-} + 6H_2O \leftrightarrow KAl_3(SO_4)_2(OH)_{6(a)} + 6H^+$ *Alunite formation*

Reaction D $Fe^{2+} \leftrightarrow Fe^{3+} + e^-$ *Ferrolysis reaction step*

Reaction E $Fe^{3+} + 3H_2O \leftrightarrow Fe(OH)_{3(a)} + 3H^+$ *Iron Oxyhydroxide formation*

Reaction F $Al^{3+} + 3H_2O \leftrightarrow Al(OH)_{3(a)} + 3H^+$ *Aluminium Oxyhydroxide formation*

Ferrolysis and oxyhydroxide mineral formation are relatively slow chemical processes, however the thermodynamics are increased by microbial catalysis which increases oxidation via microbial respiration (Cullimore 2008). This conceptualisation is supported by an increase in dissolved CO_2 in groundwater monitoring wells adjacent the TSFs.

4.3 Dissolved Metal Adsorption

Finally, whilst the SIs presented in Figure 3-23 indicate the precipitation of metal oxides (i.e. Cr_2O_3, Cupric/Cuprous Ferrite, $FeCr_2O_4$), these minerals do not form under aqueous precipitation conditions. More commonly less stable amorphous iron and aluminium oxyhydroxides are likely to precipitate (via Reaction E and Reaction F), with other dissolved metals (i.e. boron, chromium, copper, uranium or zinc) adsorbing onto the oxyhydroxide surfaces and co-precipitating out of solution via Reaction G and Reaction H (where ≡S represents the oxyhydroxide surface and M represents a heavy metals with varying valency):

Reaction G $\equiv SOH + M^{+} \leftrightarrow \equiv SOM + H^{+}$ *Monodentate surface complexation*

Reaction H $2\equiv SOH + M^{2+} \leftrightarrow (\equiv SO)2M + 2H^{+}$ *Bidentate surface complexation*

4.4 Hydrogeochemical Considerations

As dissolved iron and aluminium are present at supersaturated concentrations in background groundwater (CPMW01) and Salt Creek water samples, the secondary acid generation and dissolved metal adsorption reactions (presented in Section 4.2 and Section 4.3) could indeed be a natural hydrogeochemical process that in part explains low pH water and elevated heavy metals present in groundwater adjacent the TSFs and Salt Creek (the inferred discharge point of groundwater). Furthermore, contaminants of concern which may leach from TSF material (boron, chromium, aluminium, copper, uranium and zinc) are being naturally attenuated by the hydrogeochemical processes outlined above.

Distinct water types are identified in the ionic analysis presented above; the Ca:Mg and SAR ionic ratios indicate that the TSF seep water differs from native groundwater present in the alluvial aquifer system, however limited evidence of mixing observed. Furthermore, the observed change in heavy metal concentrations is likely due to anthropogenic affects. On this basis and at present, it is therefore uncertain if this change has been induced directly by TSF seepage mixing with native groundwater present in bedrock, indirectly via the infiltration of oxygenated TSF seep water oxidising bedrock material, or a geochemical response to groundwater levels rising adjacent the TSF (i.e. dissolution of material ordinarily unsaturated in the alluvial sediments).

4.4.1 Revision of Iron Duke Chemistry Trigger Values

Presently, the groundwater chemistry investigation trigger values established from the MARP 2007 in the Iron Duke TSF EMP (Arrium 2015) are based on data collected during the 2005 baseline assessment. As such, the investigation trigger values do not consider the beneficial use of the alluvial aquifer underlying the Iron Duke TSFs nor are they applicable to water quality observed in Salt Creek; the primary discharge point for regional groundwater flow. Furthermore, the Environment Protection Policy (Water Quality) developed by EPA South Australia (EPA SA; 2015) do not provide indicative water quality guidelines for saline/low pH groundwater or surface water systems located in the SA Arid Lands region.

It is proposed that new chemistry trigger values are established using background groundwater chemistry data collected from CPMW01. This monitoring bore is inferred to be of sufficient distance from SIMEC's SMR operations to not be affected by anthropogenic sources. Furthermore, the monitoring bore is located downgradient of regional groundwater flow and therefore is representative of the natural evolution of groundwater chemistry, along the flowpath of the saline alluvial aquifer, due to the hydrogeochemical processes described above. On this basis, it can be argued that whilst seepage from the Iron Duke TSFs may be migrating into the groundwater system, the current and potential beneficial use of the alluvial aquifer is not degraded therefore the salt creek ecosystem has also not been degraded.

In the absence of regulatory water quality guidelines, and on the basis of historical baseline and recent background data, new draft groundwater chemistry trigger values should be established. These values could be based on a variance of two standard deviations above the maximum average concentration of each analyte, where available from the 2005-2006 baseline dataset and the recent background data obtained from CPMW01. These draft trigger values should be finalised upon collection of a more complete background groundwater dataset from CPMW01 by 2019; quarterly sampling is proposed in order to provide an adequate dataset.

Finally, as Salt Creek is the discharge location of regional groundwater, any groundwater chemistry trigger values established from background data collected from CPMW01 are a suitable proxy for the creek and the terminal lake to which it flows into.

5. Conclusion and Recommendations

5.1 Conclusions

During the 2015 – 2017 reporting period, groundwater levels in monitoring bores west of the Concentrator TSF (MB1 – MB7) remained stable whilst a decreasing trend is observed in monitoring bores west of the OBP TSF (OBPMB1 – OPBMB3).

In general, a gradual rise in pH (decreasing acidity) is observed in groundwater monitoring bores, corresponding with a return to the moderately acidic conditions observed in baseline data. This acidification is likely to be due to natural processes associated with the precipitation of Alunite, Ferrolysis effect and precipitation of iron/aluminium oxyhydroxides. Similarly, no significant trends are noted in salinity observations, recorded as TDS concentrations.

Major changes to groundwater, surface water and TSF decant/seep waters, as defined in the Iron Duke TSF EMP (Arrium 2007) were consistently observed at monitoring bore MB1. Major changes in water quality (pH and TDS) where observed at MB1. Similarly, MB1 recorded major changes in dissolved aluminium, copper, cobalt and lead during the 2015 – 2017 reporting period. Furthermore, whilst heavy metal concentrations are elevated in groundwater monitoring bores, above levels observed during 2005-2006 baseline assessment, they do not constitute a major change under the current Iron Duke TSF EMP.

The groundwater system and Salt Creek water samples have a smaller distribution of supersaturated minerals relative to the TSF decant/seep and MB1. Alunite, Cuprous Ferrite, and aluminium oxyhydroxides likely to precipitate upon exposure to atmospheric conditions. Elevated SIs of dissolved CO_2 are indicative that either there is a source of carbonate minerals present in aquifer material or aerobic respiration by microbial species.

Natural hydrogeochemical processes in part explains low pH water and elevated heavy metals present in groundwater adjacent the TSFs and Salt Creek. Furthermore, contaminants of concern which may leach from TSF material (boron, chromium, aluminium, copper, uranium and zinc) are likely being naturally attenuated by similar hydrogeochemical processes.

In the absence of regulatory guidelines for hypersaline groundwater of the SA Arid Lands region and inland saline groundwater dependant ecosystems (GDEs), new groundwater chemistry trigger values are proposed to be established initially in draft and then finalised once a sufficient dataset of monitoring data is collected from CPMW01. The trigger values for each dissolved analyte could be applicable to groundwater adjacent Iron Duke TSFs and Salt Creek surface water.

5.2 Recommendations

In order to confirm the hydrogeochemical processes outlined above and establish a new set of groundwater chemistry trigger values, the following additional investigations are recommended:

- Collection of quarterly groundwater samples from CPMW01 during the period of Winter 2018 to Winter 2019. Analysis of water samples consistent with the analytical suite defined by the Iron Duke TSF EMP. This sampling frequency should be maintained across all available sample sites, such that seasonal impacts might be assessed.

- As mineral precipitation is likely to occur at groundwater discharge locations, collection of sediment samples from the Salt Creek bed which correlate with the same positions as surface water sampling points, to confirm the mineral precipitation and heavy metal adsorption processes outlined previously. Analysis of sediment samples using quantitative X-Ray Diffraction (XRD) spectroscopy techniques.

- In order to assess two of the potential mechanisms for elevated heavy metals in native groundwater (oxygenated TSF seep water oxidising and/or the dissolution of material ordinarily unsaturated in the alluvial sediments), geochemical leach-testing could be conducted on key lithologies to the mobilisation of heavy metals.

- Establishment of new groundwater chemistry trigger values, based on the statistical distribution of analytes observed at CPMW01, and calibrated to determine the concentration effect of evapotranspiration along groundwater flowpaths.

- Development of all groundwater monitoring bores immediately following the next scheduled groundwater monitoring event; a period of 30-days between development and any subsequent sampling should be maintained. The presence of sediment and sludge in the base of groundwater monitoring bores, may result in the alteration of groundwater chemistry (via heavy metal adsorption).

6. References

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Need a reference for PB 2004 – used in text on Page 7

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Worley Parsons (2012) Arrium Whyalla Steelworks Iron Duke TSF Groundwater Chemistry Status Report. Report prepared on behalf of Arrium.

Appendix A. Groundwater Chemistry Data for the 2015 – 2017 Reporting Period

| | | | | Redox Potential | | Metals | | | |

																																				Inorganics			
				Selenium	Selenium (Filtered)	Silicon	Strontium	Tin	Uranium (Filtered)	Vanadium	Vanadium (Filtered)	Zinc	Zinc (Filtered)	Alkalinity (Hydroxide) as CaCO3	Alkalinity (total) as CaCO3	Ammonia as N	Anions Total	Bicarbonate	Bromine	Calcium	Calcium (Filtered)	Calcium	Carbonate	Cations Total	Chloride	Chloride	Cyanide Total	pH (lab)	Electrical conductivity (lab)	Fluoride	Ionic Balance	Kjeldahl Nitrogen Total	Nitrate (as N)	Nitrite (as N)			
				µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	meq/L	mg/L	µg/L	mg/L	mg/L	mmol/L	mg/L	meq/L	mg/L	mmol/L	mg/L	pH Units	uS/cm	mg/L	%	mg/L	mg/L	µg/L			
EQL					10				1		10		5	1	1	0.01	0.01	1			1		1	0.01	1		0.004	0.01	1	0.1	0.01	0.1	0.01	10			
Sampled_Date_Time	Alternative_Name	Site_ID	Lab_Report_Number	Se	Se	Sil	Str	Tir	Ur	Va	Va	Zir	Zir	Alk	Alk	An	An	Bic	Br	Ca	Ca	Ca	Ca	Ca	Ch	Ch	Cy	pH	Ele	Flu	Ion	Kje	Nit	Nit			
2/02/2015	West Seep	IW153100	EM1501209	-	10	-	-	-	10	-	10	-	64	<1	316	-	86	316	-	-	103	2.56986028	<1	83.3	1770	50	-	8.18	8490	0.9	1.62	-	6.77	10			
2/02/2015	Mag Decant 1	IW153100	EM1501209	-	10	-	-	-	8	-	10	-	150	<1	122	-	87.2	122	-	-	172	4.29141717	<1	84.5	1950	55	-	7.92	8600	1	1.61	-	4.54	110			
10/08/2017	MB4	IW153100	EM1710950	-	<10	-	-	-	88	-	<10	-	46	<1	<1	0.22	187	<1	-	-	29	0.72355289	<1	174	4830	136	-	4.1	15,900	2.7	3.35	-	0.18	<10			
2/02/2015	Roo Dam	IW153100	EM1501209	-	<50	-	-	-	28	-	<50	-	309	<1	241	-	222	241	-	-	166	4.14171657	<1	205	6070	171	-	7.8	19,800	1.9	4.09	-	4.04	30			
10/08/2017	OBPMB2	IW153100	EM1710950	-	<10	-	-	-	61	-	<10	-	45	<1	<1	0.09	253	<1	-	-	21	0.5239521	<1	237	7220	204	-	3.56	22,200	0.2	3.27	-	3.7	<10			
28/07/2016	MB4	IW153100	EM1609074	-	20	-	-	-	131	-	<10	-	73	<1	<1	0.3	260	<1	-	-	39	0.97305389	<1	258	6900	195	-	3.77	24,500	4	0.32	-	0.97	<10			
2/02/2015	Mag Decant 2	IW153100	EM1501209	-	<50	-	-	-	38	-	<50	-	156	<1	106	-	370	106	-	-	695	17.3403194	<1	352	9750	275	-	7.69	31,600	1.3	2.49	-	7.57	540			
28/07/2016	OBPMB2	IW153100	EM1609074	-	<10	-	-	-	54	-	<10	-	63	<1	<1	0.07	259	<1	-	-	15	0.3742515	<1	246	7350	207	-	3.39	25,000	0.2	2.74	-	4.18	<10			
29/07/2016	MB3	IW153100	EM1609074	-	10	-	-	-	54	-	<10	-	49	<1	<1	0.31	261	<1	-	-	40	0.99800399	<1	248	7350	207	-	3.62	25,000	0.9	2.57	-	0.22	<10			
17/06/2015	MB3	IW153100	EM1511140	-	10	-	-	-	72	-	<10	-	149	<1	<1	-	300	<1	-	-	41	1.02295409	<1	284	8660	244	-	3.49	27,200	2.3	2.81	-	4.3	<10			
18/06/2015	OBPMB2	IW153100	EM1511216	-	10	-	-	-	63	-	<10	-	54	<1	<1	-	293	<1	-	-	18	0.4491018	<1	276	8460	239	-	3.46	27,400	0.3	3.07	-	3.43	<10			
2/02/2015	OBPMB2	IW153100	EM1501209	-	<50	-	-	-	73	-	<50	-	168	<1	<1	-	318	<1	-	-	14	0.3493014	<1	290	9300	262	-	3.31	29,900	2.5	4.53	-	3.27	<10			
10/08/2017	MB6	IW153100	EM1710950	-	<10	-	-	-	119	-	<10	-	60	<1	<1	0.36	371	<1	-	-	35	0.87325349	<1	354	10,700	302	-	3.56	32,600	0.4	2.37	-	0.22	<10			
2/02/2015	Salt Creek West	IW153100	EM1501209	-	<50	-	-	-	58	-	<50	-	593	<1	<1	-	881	<1	-	-	574	14.3213573	<1	893	28,100	793	-	4.35	77,600	11.4	0.65	-	0.64	<10			
2/02/2015	West 2	IW153100	EM1501209	-	<100	-	-	-	80	-	<100	-	380	<1	<1	-	892	<1	-	-	419	10.4540918	<1	908	28,400	801	-	3.51	69,800	5	0.9	-	0.16	<10			
2/02/2015	West 4	IW153100	EM1501209	-	<100	-	-	-	70	-	<100	-	130	<1	<1	-	991	<1	-	-	638	15.9181637	<1	1030	31,700	894	-	3.38	84,100	7.2	1.76	-	0.18	<10			
17/06/2015	SEEPAGE	IW153100	EM1511140	-	<10	-	-	-	9	-	<10	-	92	<1	257	-	118	220	-	-	146	3.64271457	37	111	2840	80	-	8.72	10,900	1.1	2.91	-	6.78	30			
17/06/2015	COMBINED ROO	IW153100	EM1511140	-	10	-	-	-	20	-	<10	-	50	<1	251	-	176	251	-	-	157	3.91716567	<1	167	4690	132	-	7.95	15,600	1.4	2.74	-	4.16	50			
17/06/2015	MB4	IW153100	EM1511140	-	20	-	-	-	202	-	<10	-	131	<1	<1	-	364	<1	-	-	76	1.89620758	<1	357	10,400	293	-	3.78	33,400	6.6	0.93	-	0.43	<10			
10/08/2017	MB7	IW153100	EM1710950	-	<10	-	-	-	134	-	<10	-	503	<1	<1	0.16	385	<1	-	-	34	0.84830339	<1	371	11,600	327	-	3.51	34,100	0.2	1.79	-	2.8	<10			
10/08/2017	MB3	IW153100	EM1710950	-	<10	-	-	-	104	-	<10	-	102	<1	<1	0.31	388	<1	-	-	104	2.59481038	<1	392	11,700	330	-	3.98	34,900	0.6	0.48	-	0.91	<10			
2/02/2015	MB3	IW153100	EM1501209	-	50	-	-	-	64	-	<50	-	176	<1	<1	-	383	<1	-	-	38	0.94810379	<1	374	11,400	322	-	3.29	35,900	5.4	1.22	-	2.51	<10			
2/02/2015	MB4	IW153100	EM1501209	-	<50	-	-	-	172	-	<50	-	168	<1	<1	-	409	<1	-	-	90	2.24550898	<1	396	12,000	339	-	3.6	37,500	10.8	1.64	-	0.14	<10			
28/07/2016	MB7	IW153100	EM1609074	-	20	-	-	-	109	-	<10	-	80	<1	<1	0.15	386	<1	-	-	35	0.87325349	<1	381	11,600	327	-	3.33	37,600	0.3	0.65	-	2.85	<10			
17/06/2015	MB7	IW153100	EM1511140	-	20	-	-	-	128	-	<10	-	337	<1	<1	-	406	<1	-	-	37	0.92315369	<1	403	12,400	350	-	3.44	37,800	1.6	0.46	-	2.39	<10			
2/02/2015	MB7	IW153100	EM1501209	-	<50	-	-	-	112	-	<50	-	153	<1	<1	-	416	<1	-	-	38	0.94810379	<1	387	12,700	358	-	3.29	38,000	4.2	3.69	-	2.41	<10			
18/06/2015	SOUTH VOID DECANT	IW153100	EM1511216	-	<10	-	-	-	3	-	<10	-	15	<1	153	-	37.2	146	-	-	48	1.19760479	7	36.3	814	23	-	8.45	3780	0.7	1.29	-	1.69	1560			
18/06/2015	SOUTH DECANT	IW153100	EM1511216	-	10	-	-	-	4	-	<10	-	98	<1	134	-	49.6	134	-	-	76	1.89620758	<1	50.4	1170	33	-	8.26	5180	0.9	0.69	-	3.27	450			
10/08/2017	MB5	IW153100	EM1710950	-	<10	-	-	-	101	-	<10	-	95	<1	<1	0.33	447	<1	-	-	102	2.54491018	<1	436	13,900	392	-	3.79	38,900	0.7	1.21	-	0.27	<10			
28/07/2016	MB6	IW153100	EM1609074	-	20	-	-	-	103	-	<10	-	60	<1	<1	0.39	396	<1	-	-	39	0.97305389	<1	412	11,800	333	-	3.34	39,400	0.4	1.98	-	0.15	<10			
18/06/2015	Salt Creek West	IW153100	EM1511216	-	<50	-	-	-	74	-	<50	-	332	<1	<1	-	935	<1	-	-	573	14.2964072	<1	896	30,100	849	-	4.39	75,100	0.6	2.14	-	0.8	<10			
18/06/2015	West 2	IW153100	EM1511216	-	<50	-	-	-	77	-	<50	-	177	<1	<1	-	916	<1	-	-	440	10.9780439	<1	864	29,500	832	-	3.8	72,900	0.3	2.91	-	0.17	<10			
18/06/2015	West 4	IW153100	EM1511216	-	60	-	-	-	69	-	<50	-	271	<1	<1	-	1080	<1	-	-	683	17.0409182	<1	1040	35,000	987	-	3.59	85,000	0.3	1.98	-	0.13	<10			
28/07/2016	West Seep	IW153100	EM1609074	-	<10	-	-	-	7	-	<10	-	6	<1	358	0.02	90.9	358	-	-	78	1.94610778	<1	94	2090	59	-	8.2	8870	0.9	1.64	-	3.7	30			
28/07/2016	Combined Bore Output	IW153100	EM1609074	-	<10	-	-	-	47	-	<10	-	316	<1	<1	0.23	157	<1	-	-	19	0.4740519	<1	152	4070	115	-	4.04	14,200	0.6	1.77	-	0.83	20			
17/06/2015	MB6	IW153100	EM1511140	-	10	-	-	-	136	-	<10	-	187	<1	<1	-	423	<1	-	-	48	1.19760479	<1	426	13,000	367	-	3.45	39,900	3.6	0.34	-	0.36	<10			
28/07/2016	MB5	IW153100	EM1609074	-	30	-	-	-	83	-	<10	-	89	<1	<1	0.38	420	<1	-	-	96	2.39520958	<1	444	12,900	364	-	3.61	42,500	3.6	2.73	-	0.99	<10			
2/02/2015	MB6	IW153100	EM1501209	-	<50	-	-	-	125	-	<50	-	608	<1	<1	-	457	<1	-	-	56	1.39720559	<1	448	14,300	403	-	3.29	44,000	11.3	0.93	-	0.11	<10			
10/08/2017	OBPMB3	IW153100	EM1710950	-	<20	-	-	-	110	-	<20	-	161	<1	<1	0.28	522	<1	-	-	104	2.59481038	<1	533	16,400	463	-	3.55	46,400	0.1	1.05	-	1.93	<10			
10/08/2017	MB1	IW153100	EM1710950	-	<20	-	-	-	21	-	<20	-	10	<1	744	0.39	549	744	-	-	753	18.7874251	<1	571	16,500	465	-	7.33	46,500	2.7	1.98	-	0.03	10			
2/02/2015	MB5	IW153100	EM1501209	-	<50	-	-	-	72	-	<50	-	771	<1	<1	-	489	<1	-	-	133	3.31836327	<1	494	15,100	426	-	3.36	46,700	5.1	0.5	-	0.08	<10			
2/02/2015	OBPMB3	IW153100	EM1501209	-	70	-	-	-	76	-	<50	-	184	<1	<1	-	516	<1	-	-	89	2.22055888	<1	504	16,200	457	-	3.28	48,400	2.9	1.17	-	1.4	<10			
29/07/2016	Mag Decant Central	IW153100	EM1609074	-	20	-	-	-	6	-	<10	-	<5	<1	160	0.2	90.4	160	-	-	77	1.92115768	<1	96.7	2450	69	-	7.72	8490	1	3.35	-	9.14	1060			
18/06/2015	OBPMB3	IW153100	EM1511216	-	40	-	-	-	76	-	<20	-	126	<1	<1	-	526	<1	-	-	123	3.06886228	<1	564	16,500	465	-	3.51	50,000	0.2	3.5	-	1.31	<10			
17/06/2015	MB5	IW153100	EM1511140	-	<50	-	-	-	87	-	<50	-	229	<1	<1	-	554	<1	-	-	188	4.69061876	<1	599	17,300	488	-	3.9	51,100	2.7	3.9	-	0.18	<10			
29/07/2016	Salt Creek West	IW153100	EM1609074	-	<50	-	-	-	56	-	<50	-	165	<1	<1	1.52	940	<1	-	-	615	15.3443114	<1	989	30,400	858	-	4.42	83,600	0.6	2.48	-	0.6	10			
29/07/2016	West 2	IW153100	EM1609074	-	<50	-	-	-	78	-	<50	-	189	<1	<1	0.86	928	<1	-	-	522	13.0239521	<1	1030	30,000	846	-	3.72	84,600	0.2	5.17	-	0.14	<10			
29/07/2016	West 4	IW153100	EM1609074	-	<50	-	-	-	65	-	<50	-	180	<1	<1	1.11	1050	<1	-	-	697	17.3902196	<1	1280	33,800	953	-	3.49	102,000	0.2	9.72	-	0.12	<10			
29/07/2016	West Dup	IW153100	EM1609074	-	<50	-	-	-	64	-	<50	-	174	<1	<1	1.11	1050	<1	-	-	695	17.3403194	<1	1290	33,700	951	-	3.47	102,000	0.2	10.1	-	0.12	<10			
10/08/2017	Mag Decant	IW153100	EM1710950	-	<10	-	-	-	7	-	<10	-	<5	<1	182	0.61	66.7	182	-	-	75	1.87125749	<1	67.1	1640	46	-	8.02	6560	0.8	0.29	-	6.11	330			
10/08/2017	West Seep	IW153100	EM1710950	-	<10	-	-	-	9	-	<10	-	9	<1	291	0.09	86.6	291	-	-	79	1.97105788	<1	86.2	1810	51	-	8.02	8050	0.7	0.27	-	5.89	30			
10/08/2017	MB2	IW153100	EM1710950	-	<20	-	-	-	79	-	<20	-	210	<1	<1	0.65	606	<1	-	-	250	6.23752495	<1	615	19,000	536	-	4.33	51,500	0.3	0.78	-	0.03	<10			
10/08/2017	Combined Bore Output	IW153100	EM1710950	-	<10	-	-	-	67	-	<10	-	37	<1	<1	0.25	193	<1	-	-	29	0.72355289	<1	177	5190	146	-	4.46	16,900	1.6	4.22	-	1.39	20			
2/02/2015	MB1	IW153100	EM1501209	-	<50	-	-	-	5	-	<50	-	395	<1	<1	-	609	<1	-	-	461	11.501996	<1	621	19,400	547	-	4.41	55,400	17.8	0.95	-	<0.01	<10			
17/06/2015	MB1	IW153100	EM1511140	-	<50	-	-	-	<5	-	<50	-	249	<1	<1	-	691	<1	-	-	414	10.3293413	<1	620	22,400	632	-	4.21	57,300	2.3	5.44	-	<0.01	<10			
28/07/2016	OBPMB3	IW153100	EM1609074	-	30	-	-	-	75	-	<20	-	121	<1	<1	0.24	556	<1	-	-	141	3.51796407	<1	662	17,500	494	-	3.29	57,800	0.1	8.7	-	1.82	<10			
2/02/2015	MB2	IW153100	EM1501209	-	<50	-	-	-	69	-	<50	-	223	<1	<1	-	690	<1	-	-	221	5.51397206	<1	688	21,600	609	-	3.56	59,500	4.6	0.18	-	<0.01	<10			
17/06/2015	MB2	IW153100	EM1511140	-	<50	-	-	-	28	-	<50	-	127	<1	<1	-	719	<1	-	-	252	6.28742515	<1	645	22,800	643	-	3.57	60,100	2	5.49	-	0.02	<10			
17/06/2015	MB2	IW153100	EM1511140	-	<50	-	-	-	36	-	<50	-	131	<1	<1	-	656	<1	-	-	258	6.43712575	<1	655	20,600	581	-	3.93	62,500	2.1	0.13	-	0.02	<10			
29/07/2016	MB2	IW153100	EM1609074	-	<20	-	-	-	62	-	<20	-	181	<1	<1	0.67	648	<1	-	-	246	6.13772455	<1	653	20,400	575	-	4.05	62,700	1.3	0.36	-	<0.01	<10			
28/07/2016	MB1	IW153100	EM1609074	-	<20	-	-	-	15	-	<20	-	80	<1	487	0.64	684	487	-	-	887	22.1307385	<1	671	21,600	609	-	6.67	63,000	2.9	0.92	-	0.04	<10			
10/08/2017	West 2	IW153100	EM1710950	-	<20	-	-	-	125	-	<20	-	218	<1	<1	1.37	878	<1	-	-	513	12.7994012	<1	918	28,000	790	-	4.17	72,100	0.3	2.22	-	0.14	<10			
10/08/2017	West 4	IW153100	EM1710950	-	<50	-	-	-	85	-	<50	-	251	<1	<1	2.02	1070	<1	-	-	737	18.3882236	<1	1160	34,300	968	-	3.79	87,900	0.2	3.99	-	0.1	<10			
11/08/2017	Salt Creek West	IW153100	EM1710950	-	<20	-	-	-	83	-	<20	-	183	<1	<1	1.65	824	<1	-	-	554	13.8223553	<1	850	26,500	748	-	4.56	68,100	0.6	1.5	-	0.46	90			

				Nitrogen (Total Oxidised)	Nitrogen (Total)	Reactive Phosphorus as P	Silica	Sodium	Sodium (Filtered)	Sodium	Sulphate	Sulfate as SO4 - Turbidimetric	Sulfate as SO4 - Turbidimetric (Filtered)	Sulphate	Total Dissolved Solids	Total Dissolved Solids (Filtered)	Hardness as CaCO3 (Filtered)
				mg/L	mg/L	mg/L	µg/L	mg/L	mg/L	mmol/L	mg/L	mg/L	mg/L	mmol/L	mg/L	mg/L	mg/L
EQL				0.01	0.1	0.01			1		1		1		1		1
Sampled_Date_Time	Alternative_Name	Site_ID	Lab_Report_Number	Nit	Nit	Re	Sil	So	So	So	Su	Su	Su	Su	To	To	Ha
2/02/2015	West Seep	IW153100	EM1501209	6.78	-	<0.01	-	-	1430	62	-	-	1430	20.70663191	5520	-	-
2/02/2015	Mag Decant 1	IW153100	EM1501209	4.65	-	<0.01	-	-	1310	57	-	-	1430	20.70663191	5590	-	-
10/08/2017	MB4	IW153100	EM1710950	0.18	-	<0.01	-	-	3460	151	-	-	2420	35.04199247	10,300	-	1080
2/02/2015	Roo Dam	IW153100	EM1501209	4.07	-	<0.01	-	-	3630	158	-	-	2210	32.00115841	12,900	-	-
10/08/2017	OBPMB2	IW153100	EM1710950	3.7	-	<0.01	-	-	4780	208	-	-	2390	34.6075876	14,400	-	1320
28/07/2016	MB4	IW153100	EM1609074	0.97	-	0.01	-	-	5090	221	-	-	3140	45.46770924	15,900	-	1720
2/02/2015	Mag Decant 2	IW153100	EM1501209	8.11	-	<0.01	-	-	5870	255	-	-	4480	64.87112656	20,500	-	-
28/07/2016	OBPMB2	IW153100	EM1609074	4.18	-	<0.01	-	-	4990	217	-	-	2500	36.20040544	16,200	-	1290
29/07/2016	MB3	IW153100	EM1609074	0.22	-	0.02	-	-	4900	213	-	-	2590	37.50362004	16,200	-	1640
17/06/2015	MB3	IW153100	EM1511140	4.3	-	<0.01	-	-	5470	238	-	-	2690	38.95163626	17,700	-	-
18/06/2015	OBPMB2	IW153100	EM1511216	3.43	-	<0.01	-	-	5560	242	-	-	2630	38.08282653	17,800	-	-
2/02/2015	OBPMB2	IW153100	EM1501209	3.27	-	<0.01	-	-	5800	252	-	-	2660	38.51723139	19,400	-	-
10/08/2017	MB6	IW153100	EM1710950	0.22	-	<0.01	-	-	6840	298	-	-	3330	48.21894005	21,200	-	2610
2/02/2015	Salt Creek West	IW153100	EM1501209	0.64	-	<0.01	-	-	16,600	722	-	-	4230	61.25108601	50,400	-	-
2/02/2015	West 2	IW153100	EM1501209	0.16	-	<0.01	-	-	17,000	739	-	-	4350	62.98870547	45,400	-	-
2/02/2015	West 4	IW153100	EM1501209	0.18	-	<0.01	-	-	18,900	822	-	-	4640	67.18795251	54,700	-	-
17/06/2015	SEEPAGE	IW153100	EM1511140	6.81	-	<0.01	-	-	1930	84	-	-	1560	22.589053	7080	-	-
17/06/2015	COMBINED ROO	IW153100	EM1511140	4.21	-	<0.01	-	-	2960	129	-	-	1860	26.93310165	10,100	-	-
17/06/2015	MB4	IW153100	EM1511140	0.43	-	<0.01	-	-	6920	301	-	-	3380	48.94294816	21,700	-	-
10/08/2017	MB7	IW153100	EM1710950	2.8	-	<0.01	-	-	7260	316	-	-	2760	39.96524761	22,200	-	2530
10/08/2017	MB3	IW153100	EM1710950	0.91	-	<0.01	-	-	7600	331	-	-	2810	40.68925572	22,700	-	2900
2/02/2015	MB3	IW153100	EM1501209	2.51	-	<0.01	-	-	7070	308	-	-	2940	42.5716768	23,300	-	-
2/02/2015	MB4	IW153100	EM1501209	0.14	-	<0.01	-	-	7640	332	-	-	3390	49.08774978	24,400	-	-
28/07/2016	MB7	IW153100	EM1609074	2.85	-	<0.01	-	-	7550	328	-	-	2800	40.5444541	24,400	-	2400
17/06/2015	MB7	IW153100	EM1511140	2.39	-	<0.01	-	-	7940	345	-	-	2720	39.38604112	24,600	-	-
2/02/2015	MB7	IW153100	EM1501209	2.41	-	<0.01	-	-	7600	331	-	-	2800	40.5444541	24,700	-	-
18/06/2015	SOUTH VOID DECANT	IW153100	EM1511216	3.25	-	<0.01	-	-	581	25	-	-	539	7.804807414	2460	-	-
18/06/2015	SOUTH DECANT	IW153100	EM1511216	3.72	-	<0.01	-	-	849	37	-	-	671	9.716188821	3370	-	-
10/08/2017	MB5	IW153100	EM1710950	0.27	-	<0.01	-	-	8390	365	-	-	2650	38.37242977	25,300	-	3360
28/07/2016	MB6	IW153100	EM1609074	0.15	-	<0.01	-	-	8020	349	-	-	3010	43.58528816	25,600	-	2930
18/06/2015	Salt Creek West	IW153100	EM1511216	0.8	-	<0.01	-	-	16,800	731	-	-	4110	59.51346655	48,800	-	-
18/06/2015	West 2	IW153100	EM1511216	0.17	-	<0.01	-	-	16,200	705	-	-	4020	58.21025195	47,400	-	-
18/06/2015	West 4	IW153100	EM1511216	0.13	-	<0.01	-	-	19,300	839	-	-	4620	66.89834926	55,200	-	-
28/07/2016	West Seep	IW153100	EM1609074	3.73	-	<0.01	-	-	1760	77	-	-	1190	17.23139299	5760	-	833
28/07/2016	Combined Bore Output	IW153100	EM1609074	0.85	-	0.04	-	-	3060	133	-	-	2030	29.39472922	9230	-	838
17/06/2015	MB6	IW153100	EM1511140	0.36	-	<0.01	-	-	8270	360	-	-	2690	38.95163626	25,900	-	-
28/07/2016	MB5	IW153100	EM1609074	0.99	-	<0.01	-	-	8670	377	-	-	2700	39.09643788	27,600	-	3150
2/02/2015	MB6	IW153100	EM1501209	0.11	-	<0.01	-	-	8640	376	-	-	2560	37.06921518	28,600	-	-
10/08/2017	OBPMB3	IW153100	EM1710950	1.93	-	0.01	-	-	10,200	444	-	-	2840	41.12366058	30,200	-	4200
10/08/2017	MB1	IW153100	EM1710950	0.04	-	<0.01	-	-	9800	426	-	-	3290	47.63973357	30,200	-	6940
2/02/2015	MB5	IW153100	EM1501209	0.08	-	<0.01	-	-	9440	411	-	-	3040	44.01969302	30,400	-	-
2/02/2015	OBPMB3	IW153100	EM1501209	1.4	-	<0.01	-	-	9780	425	-	-	2830	40.97885896	31,500	-	-
29/07/2016	Mag Decant Central	IW153100	EM1609074	10.2	-	<0.01	-	-	1780	77	-	-	869	12.58326093	5520	-	921
18/06/2015	OBPMB3	IW153100	EM1511216	1.31	-	0.01	-	-	10,900	474	-	-	2920	42.28207356	32,500	-	-
17/06/2015	MB5	IW153100	EM1511140	0.18	-	<0.01	-	-	11,500	500	-	-	3150	45.61251086	33,200	-	-
29/07/2016	Salt Creek West	IW153100	EM1609074	0.61	-	<0.01	-	-	18,600	809	-	-	3980	57.63104547	54,300	-	8620
29/07/2016	West 2	IW153100	EM1609074	0.14	-	0.01	-	-	19,300	839	-	-	3930	56.90703736	55,000	-	9170
29/07/2016	West 4	IW153100	EM1609074	0.12	-	<0.01	-	-	24,100	1,048	-	-	4760	68.92557197	66,300	-	11,200
29/07/2016	West Dup	IW153100	EM1609074	0.12	-	<0.01	-	-	24,200	1,053	-	-	4790	69.35997683	66,300	-	11,300
10/08/2017	Mag Decant	IW153100	EM1710950	6.44	-	<0.01	-	-	1150	50	-	-	806	11.67101072	4260	-	813
10/08/2017	West Seep	IW153100	EM1710950	5.92	-	<0.01	-	-	1530	67	-	-	1430	20.70663191	5230	-	943
10/08/2017	MB2	IW153100	EM1710950	0.03	-	<0.01	-	-	11,600	505	-	-	3340	48.36374167	33,500	-	5280
10/08/2017	Combined Bore Output	IW153100	EM1710950	1.41	-	0.07	-	-	3480	151	-	-	2220	32.14596003	11,000	-	1160
2/02/2015	MB1	IW153100	EM1501209	<0.01	-	<0.01	-	-	10,500	457	-	-	2960	42.86128005	36,000	-	-
17/06/2015	MB1	IW153100	EM1511140	<0.01	-	<0.01	-	-	10,500	457	-	-	2840	41.12366058	37,200	-	-
28/07/2016	OBPMB3	IW153100	EM1609074	1.82	-	<0.01	-	-	12,800	557	-	-	3000	43.44048653	37,600	-	5000
2/02/2015	MB2	IW153100	EM1501209	<0.01	-	<0.01	-	-	13,500	587	-	-	3900	56.47263249	38,700	-	-
17/06/2015	MB2	IW153100	EM1511140	0.02	-	<0.01	-	-	12,200	531	-	-	3660	52.99739357	39,100	-	-
17/06/2015	MB2	IW153100	EM1511140	0.02	-	<0.01	-	-	12,500	544	-	-	3610	52.27338546	40,600	-	-
29/07/2016	MB2	IW153100	EM1609074	<0.01	-	<0.01	-	-	12,500	544	-	-	3480	50.39096438	40,800	-	5230
28/07/2016	MB1	IW153100	EM1609074	0.04	-	<0.01	-	-	11,200	487	-	-	3110	45.03330437	41,000	-	8880
10/08/2017	West 2	IW153100	EM1710950	0.14	-	<0.01	-	-	17,000	739	-	-	4220	61.10628439	46,900	-	8570
10/08/2017	West 4	IW153100	EM1710950	0.1	-	<0.01	-	-	21,500	935	-	-	5010	72.54561251	57,100	-	10,800
11/08/2017	Salt Creek West	IW153100	EM1710950	0.55	-	0.02	-	-	15,800	687	-	-	3700	53.57660006	44,300	-	7770

Appendix B. PHREEQc Geochemical Modelling Output

```
   Input file: C:\Users\nelsona\Desktop\Iron Duke SIs_alt.pqi
  Output file: C:\Users\nelsona\Desktop\Iron Duke SIs_alt.pqo
Database file: C:\Program Files (x86)\USGS\Phreeqc Interactive 3.3.12-12704\database
\minteq.dat

------------------
Reading data base.
------------------

      SOLUTION_MASTER_SPECIES
      SOLUTION_SPECIES
      SOLUTION_SPECIES
      PHASES
      SURFACE_MASTER_SPECIES
      SURFACE_SPECIES
      END
-----------------------------------
Reading input data for simulation 1.
-----------------------------------

      DATABASE C:\Program Files (x86)\USGS\Phreeqc Interactive 3.3.12-12704\database
\minteq.dat
      SOLUTION_SPREAD
          units    mg/l
          Al           B    Ca      Cl        Cr    Cu     Fe           K    Mg      Mn
           Na         pH     U    Zn  Alkalinity  S(6)
       mg/l  ug/l  mg/l    mg/l      ug/l  ug/l   mg/l       mg/l  mg/l    ug/l
         mg/l            ug/l  ug/l        mg/l  mg/l
        12.7       4410    29    4830       0.5     9   1.19         92   246     233
         3460       4.1    88    46         0.5  2420
        52.5       3640    21    7220       0.5     7  0.025        120   308     143
         4780       3.2    61    45         0.5  2390
        67.7       4210    35  10,700         2    19   4.29        169   612     254
         6840      3.26   119    60         0.5  3330
          88       4890    34  11,600         2    24  0.025        186   594     344
         7260      3.51   134   503         0.5  2760
        22.4       4740   104  11,700         2    19   1.26        146   641     683
         7600      3.98   104   102         0.5  2810
        41.5       5380   102  13,900         3    26     16        175   754     896
         8390      3.79   101    95         0.5  2650
         115       5760   104  16,400         3     7  0.025        207   956     656
       10,200      3.55   110   161         0.5  2840
        0.01       7930   753  16,500         1     1   0.69        230  1230    2900
         9800      7.33    21    10         744  3290
        0.19        760    75    1640       0.5     2  0.025         31   152      34
         1150      8.02     7   2.5         182   806
       0.005       2010    79    1810       0.5     3  0.025         31   181       3
         1530      8.02     9     9         291  1430
        42.2       5040   250  19,000         1    67   4.73        197  1130    1170
       11,600      3.69    79   210         0.5  3340
        17.1       3510    29    5190         2     7   9.69         97   264     251
         3480      4.46    67    37         0.5  2220
        46.8       4180   513  28,000         7    33  0.025        271  1770    5100
       17,000      4.17   125   218         0.5  4220
        47.1       2960   737  34,300       2.5    26   0.38        344  2190  14,000
       21,500      4.17    85   251         0.5  5010
         114       2530  1170  21,900        25    42   1.03        316  1600     599
       11,400      3.63   130   135         0.5  3990
-----------------------------------------
Beginning of initial solution calculations.
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Initial solution 1.

-----------------------------Solution composition-----------------------------
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Elements	Molality	Moles
Al	4.760e-04	4.760e-04
Alkalinity	8.286e-06	8.286e-06
B	4.125e-04	4.125e-04
Ca	7.317e-04	7.317e-04
Cl	1.378e-01	1.378e-01
Cr	9.724e-09	9.724e-09
Cu	1.432e-07	1.432e-07
Fe	2.155e-05	2.155e-05
K	2.379e-03	2.379e-03
Mg	1.023e-02	1.023e-02
Mn	4.289e-06	4.289e-06
Na	1.522e-01	1.522e-01
S(6)	2.547e-02	2.547e-02
U	3.739e-07	3.739e-07
Zn	7.116e-07	7.116e-07

----------Description of solution----------

pH	= 4.100
pe	= 4.000
Activity of water	= 0.994
Ionic strength (mol/kgw)	= 2.017e-01
Mass of water (kg)	= 1.000e+00
Total carbon (mol/kg)	= 1.748e-02
Total CO2 (mol/kg)	= 1.748e-02
Temperature (°C)	= 25.00
Electrical balance (eq)	= -1.074e-02
Percent error, 100*(Cat-|An|)/(Cat+|An|)	= -3.09
Iterations	= 13
Total H	= 1.110486e+02
Total O	= 5.566180e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	9.963e-05	7.943e-05	-4.002	-4.100	-0.098	0.00
OH-	1.780e-10	1.257e-10	-9.749	-9.901	-0.151	(0)
H2O	5.551e+01	9.942e-01	1.744	-0.003	0.000	18.07
Al	4.760e-04					
Al+3	2.046e-04	2.662e-05	-3.689	-4.575	-0.886	(0)
AlSO4+	1.872e-04	1.363e-04	-3.728	-3.865	-0.138	(0)
Al(SO4)2-	7.271e-05	5.296e-05	-4.138	-4.276	-0.138	(0)
AlOH+2	1.103e-05	3.410e-06	-4.957	-5.467	-0.510	(0)
Al(OH)2+	4.443e-07	3.313e-07	-6.352	-6.480	-0.127	(0)
Al(OH)3	4.984e-09	5.220e-09	-8.302	-8.282	0.020	(0)
Al(OH)4-	8.971e-12	6.534e-12	-11.047	-11.185	-0.138	(0)
B	4.125e-04					
H3BO3	4.125e-04	4.321e-04	-3.385	-3.364	0.020	(0)
H2BO3-	4.593e-09	3.124e-09	-8.338	-8.505	-0.167	(0)
C(4)	1.748e-02					
H2CO3	1.733e-02	1.815e-02	-1.761	-1.741	0.020	(0)
HCO3-	1.365e-04	1.018e-04	-3.865	-3.992	-0.127	(0)
NaHCO3	6.036e-06	6.323e-06	-5.219	-5.199	0.020	(0)
MgHCO3+	4.864e-06	3.491e-06	-5.313	-5.457	-0.144	(0)
CaHCO3+	2.694e-07	2.036e-07	-6.570	-6.691	-0.122	(0)
UO2CO3	3.390e-08	3.551e-08	-7.470	-7.450	0.020	(0)
MnHCO3+	2.475e-09	1.827e-09	-8.606	-8.738	-0.132	(0)
ZnHCO3+	2.423e-09	1.808e-09	-8.616	-8.743	-0.127	(0)
CO3-2	1.940e-10	5.997e-11	-9.712	-10.222	-0.510	(0)
NaCO3-	1.646e-10	1.227e-10	-9.784	-9.911	-0.127	(0)
MgCO3	1.594e-10	1.670e-10	-9.798	-9.777	0.020	(0)
UO2(CO3)2-2	5.489e-11	1.701e-11	-10.260	-10.769	-0.509	(0)

CuHCO3+	3.055e-11	2.280e-11	-10.515	-10.642	-0.127	(0)
CaCO3	1.571e-11	1.646e-11	-10.804	-10.784	0.020	(0)
ZnCO3	1.726e-12	1.808e-12	-11.763	-11.743	0.020	(0)
CuCO3	1.471e-13	1.541e-13	-12.832	-12.812	0.020	(0)
UO2(CO3)3-4	2.665e-15	2.457e-17	-14.574	-16.610	-2.035	(0)
Zn(CO3)2-2	7.481e-18	2.318e-18	-17.126	-17.635	-0.509	(0)
Cu(CO3)2-2	3.755e-20	1.164e-20	-19.425	-19.934	-0.509	(0)
Ca	7.317e-04					
Ca+2	5.477e-04	1.931e-04	-3.261	-3.714	-0.453	(0)
CaSO4	1.837e-04	1.924e-04	-3.736	-3.716	0.020	(0)
CaHCO3+	2.694e-07	2.036e-07	-6.570	-6.691	-0.122	(0)
CaCO3	1.571e-11	1.646e-11	-10.804	-10.784	0.020	(0)
CaOH+	8.069e-13	6.100e-13	-12.093	-12.215	-0.122	(0)
Cl	1.378e-01					
Cl-	1.378e-01	9.625e-02	-0.861	-1.017	-0.156	(0)
MnCl+	5.081e-07	3.751e-07	-6.294	-6.426	-0.132	(0)
CuCl2-	1.025e-07	7.356e-08	-6.989	-7.133	-0.144	(0)
ZnCl+	5.453e-08	3.914e-08	-7.263	-7.407	-0.144	(0)
CuCl3-2	3.778e-08	1.122e-08	-7.423	-7.950	-0.527	(0)
UO2Cl+	1.007e-08	7.515e-09	-7.997	-8.124	-0.127	(0)
MnCl2	9.362e-09	9.807e-09	-8.029	-8.008	0.020	(0)
ZnCl2	3.765e-09	3.944e-09	-8.424	-8.404	0.020	(0)
ZnCl3-	5.935e-10	4.260e-10	-9.227	-9.371	-0.144	(0)
MnCl3-	5.764e-10	4.255e-10	-9.239	-9.371	-0.132	(0)
CuCl+	1.727e-10	1.240e-10	-9.763	-9.907	-0.144	(0)
CrCl+2	8.052e-11	2.495e-11	-10.094	-10.603	-0.509	(0)
ZnCl4-2	6.903e-11	2.050e-11	-10.161	-10.688	-0.527	(0)
CuCl2	6.116e-12	6.407e-12	-11.214	-11.193	0.020	(0)
ZnOHCl	5.753e-12	6.027e-12	-11.240	-11.220	0.020	(0)
CrCl2+	6.271e-13	4.679e-13	-12.203	-12.330	-0.127	(0)
FeCl+2	5.033e-14	1.495e-14	-13.298	-13.825	-0.527	(0)
CrOHCl2	1.128e-14	1.181e-14	-13.948	-13.928	0.020	(0)
FeCl2+	8.705e-15	6.426e-15	-14.060	-14.192	-0.132	(0)
CuCl3-	3.049e-15	2.188e-15	-14.516	-14.660	-0.144	(0)
FeCl3	5.905e-17	6.185e-17	-16.229	-16.209	0.020	(0)
CuCl4-2	3.554e-18	1.055e-18	-17.449	-17.977	-0.527	(0)
UCl+3	9.116e-22	6.531e-23	-21.040	-22.185	-1.145	(0)
CrO3Cl-	0.000e+00	0.000e+00	-43.319	-43.446	-0.127	(0)
Cr(2)	3.171e-20					
Cr+2	3.171e-20	9.826e-21	-19.499	-20.008	-0.509	(0)
Cr(3)	9.724e-09					
Cr+3	6.460e-09	4.628e-10	-8.190	-9.335	-1.145	(0)
Cr(OH)+2	1.869e-09	5.793e-10	-8.728	-9.237	-0.509	(0)
CrOHSO4	1.223e-09	1.281e-09	-8.913	-8.892	0.020	(0)
CrCl+2	8.052e-11	2.495e-11	-10.094	-10.603	-0.509	(0)
CrSO4+	6.720e-11	5.013e-11	-10.173	-10.300	-0.127	(0)
Cr(OH)2+	2.331e-11	1.739e-11	-10.632	-10.760	-0.127	(0)
CrCl2+	6.271e-13	4.679e-13	-12.203	-12.330	-0.127	(0)
Cr(OH)3	1.540e-14	1.614e-14	-13.812	-13.792	0.020	(0)
CrOHCl2	1.128e-14	1.181e-14	-13.948	-13.928	0.020	(0)
Cr2(OH)2SO4+2	4.354e-16	1.349e-16	-15.361	-15.870	-0.509	(0)
Cr2(OH)2(SO4)2	1.486e-20	1.557e-20	-19.828	-19.808	0.020	(0)
CrO2-	6.637e-21	4.952e-21	-20.178	-20.305	-0.127	(0)
Cr(OH)4-	2.585e-21	1.929e-21	-20.587	-20.715	-0.127	(0)
Cr(6)	9.895e-40					
HCrO4-	9.895e-40	7.383e-40	-39.005	-39.132	-0.127	(0)
CrO4-2	0.000e+00	0.000e+00	-40.965	-41.541	-0.576	(0)
NaCrO4-	0.000e+00	0.000e+00	-41.674	-41.801	-0.127	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-42.546	-43.055	-0.509	(0)
CrO3Cl-	0.000e+00	0.000e+00	-43.319	-43.446	-0.127	(0)
KCrO4-	0.000e+00	0.000e+00	-43.408	-43.535	-0.127	(0)
H2CrO4	0.000e+00	0.000e+00	-44.110	-44.089	0.020	(0)
Cr2O7-2	0.000e+00	0.000e+00	-76.213	-76.722	-0.509	(0)
Cu(1)	1.403e-07					
CuCl2-	1.025e-07	7.356e-08	-6.989	-7.133	-0.144	(0)
CuCl3-2	3.778e-08	1.122e-08	-7.423	-7.950	-0.527	(0)

Cu+	3.692e-11	2.511e-11	-10.433	-10.600	-0.167	(0)
Cu(2)	2.900e-09					
Cu+2	2.235e-09	4.785e-10	-8.651	-9.320	-0.669	(0)
CuSO4	4.561e-10	4.778e-10	-9.341	-9.321	0.020	(0)
CuCl+	1.727e-10	1.240e-10	-9.763	-9.907	-0.144	(0)
CuHCO3+	3.055e-11	2.280e-11	-10.515	-10.642	-0.127	(0)
CuCl2	6.116e-12	6.407e-12	-11.214	-11.193	0.020	(0)
CuCO3	1.471e-13	1.541e-13	-12.832	-12.812	0.020	(0)
CuOH+	8.345e-14	5.989e-14	-13.079	-13.223	-0.144	(0)
CuCl3-	3.049e-15	2.188e-15	-14.516	-14.660	-0.144	(0)
Cu(OH)2	1.495e-15	1.566e-15	-14.825	-14.805	0.020	(0)
CuCl4-2	3.554e-18	1.055e-18	-17.449	-17.977	-0.527	(0)
Cu(CO3)2-2	3.755e-20	1.164e-20	-19.425	-19.934	-0.509	(0)
Cu2(OH)2+2	5.065e-21	1.570e-21	-20.295	-20.804	-0.509	(0)
Cu(OH)3-	1.587e-24	1.184e-24	-23.799	-23.927	-0.127	(0)
Cu(OH)4-2	9.520e-33	2.950e-33	-32.021	-32.530	-0.509	(0)
Fe(2)	2.155e-05					
Fe+2	1.695e-05	5.536e-06	-4.771	-5.257	-0.486	(0)
FeSO4	4.596e-06	4.814e-06	-5.338	-5.317	0.020	(0)
FeOH+	2.968e-11	2.191e-11	-10.528	-10.659	-0.132	(0)
Fe(OH)2	2.228e-18	2.334e-18	-17.652	-17.632	0.020	(0)
Fe(OH)3-	1.470e-24	1.086e-24	-23.833	-23.964	-0.132	(0)
Fe(3)	4.135e-12					
Fe(OH)2+	2.310e-12	1.722e-12	-11.636	-11.764	-0.127	(0)
FeOH+2	1.399e-12	4.156e-13	-11.854	-12.381	-0.527	(0)
FeSO4+	2.834e-13	2.092e-13	-12.548	-12.679	-0.132	(0)
FeCl+2	5.033e-14	1.495e-14	-13.298	-13.825	-0.527	(0)
Fe(SO4)2-	4.336e-14	3.235e-14	-13.363	-13.490	-0.127	(0)
Fe+3	3.952e-14	5.143e-15	-13.403	-14.289	-0.886	(0)
FeCl2+	8.705e-15	6.426e-15	-14.060	-14.192	-0.132	(0)
Fe(OH)3	2.418e-16	2.533e-16	-15.617	-15.596	0.020	(0)
FeCl3	5.905e-17	6.185e-17	-16.229	-16.209	0.020	(0)
Fe(OH)4-	4.252e-20	3.170e-20	-19.371	-19.499	-0.127	(0)
Fe2(OH)2+4	5.042e-22	4.649e-24	-21.297	-23.333	-2.035	(0)
Fe3(OH)4+5	2.533e-30	1.673e-33	-29.596	-32.776	-3.180	(0)
H(0)	8.528e-20					
H2	4.264e-20	4.467e-20	-19.370	-19.350	0.020	(0)
K	2.379e-03					
K+	2.305e-03	1.610e-03	-2.637	-2.793	-0.156	(0)
KSO4-	7.421e-05	5.533e-05	-4.130	-4.257	-0.127	(0)
KCrO4-	0.000e+00	0.000e+00	-43.408	-43.535	-0.127	(0)
Mg	1.023e-02					
Mg+2	7.805e-03	2.917e-03	-2.108	-2.535	-0.427	(0)
MgSO4	2.422e-03	2.537e-03	-2.616	-2.596	0.020	(0)
MgHCO3+	4.864e-06	3.491e-06	-5.313	-5.457	-0.144	(0)
MgCO3	1.594e-10	1.670e-10	-9.798	-9.777	0.020	(0)
MgOH+	7.851e-11	5.998e-11	-10.105	-10.222	-0.117	(0)
Mn(2)	4.289e-06					
Mn+2	2.950e-06	9.633e-07	-5.530	-6.016	-0.486	(0)
MnSO4	8.184e-07	8.573e-07	-6.087	-6.067	0.020	(0)
MnCl+	5.081e-07	3.751e-07	-6.294	-6.426	-0.132	(0)
MnCl2	9.362e-09	9.807e-09	-8.029	-8.008	0.020	(0)
MnHCO3+	2.475e-09	1.827e-09	-8.606	-8.738	-0.132	(0)
MnCl3-	5.764e-10	4.255e-10	-9.239	-9.371	-0.132	(0)
MnOH+	4.198e-13	3.099e-13	-12.377	-12.509	-0.132	(0)
Mn(OH)3-	4.055e-29	2.994e-29	-28.392	-28.524	-0.132	(0)
Mn(3)	2.304e-27					
Mn+3	2.304e-27	2.998e-28	-26.638	-27.523	-0.886	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-75.139	-75.666	-0.527	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-80.892	-81.050	-0.159	(0)
Na	1.522e-01					
Na+	1.486e-01	1.104e-01	-0.828	-0.957	-0.129	(0)
NaSO4-	3.629e-03	2.706e-03	-2.440	-2.568	-0.127	(0)
NaHCO3	6.036e-06	6.323e-06	-5.219	-5.199	0.020	(0)

NaCO3-	1.646e-10	1.227e-10	-9.784	-9.911	-0.127	(0)
NaCrO4-	0.000e+00	0.000e+00	-41.674	-41.801	-0.127	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-53.705	-53.685	0.020	(0)
S(6)	2.547e-02					
SO4-2	1.878e-02	4.890e-03	-1.726	-2.311	-0.584	(0)
NaSO4-	3.629e-03	2.706e-03	-2.440	-2.568	-0.127	(0)
MgSO4	2.422e-03	2.537e-03	-2.616	-2.596	0.020	(0)
AlSO4+	1.872e-04	1.363e-04	-3.728	-3.865	-0.138	(0)
CaSO4	1.837e-04	1.924e-04	-3.736	-3.716	0.020	(0)
KSO4-	7.421e-05	5.533e-05	-4.130	-4.257	-0.127	(0)
Al(SO4)2-	7.271e-05	5.296e-05	-4.138	-4.276	-0.138	(0)
HSO4-	5.175e-05	3.769e-05	-4.286	-4.424	-0.138	(0)
FeSO4	4.596e-06	4.814e-06	-5.338	-5.317	0.020	(0)
MnSO4	8.184e-07	8.573e-07	-6.087	-6.067	0.020	(0)
ZnSO4	1.653e-07	1.732e-07	-6.782	-6.761	0.020	(0)
UO2SO4	1.124e-07	1.177e-07	-6.949	-6.929	0.020	(0)
UO2(SO4)2-2	5.534e-08	1.715e-08	-7.257	-7.766	-0.509	(0)
Zn(SO4)2-2	2.222e-08	6.885e-09	-7.653	-8.162	-0.509	(0)
CrOHSO4	1.223e-09	1.281e-09	-8.913	-8.892	0.020	(0)
CuSO4	4.561e-10	4.778e-10	-9.341	-9.321	0.020	(0)
CrSO4+	6.720e-11	5.013e-11	-10.173	-10.300	-0.127	(0)
FeSO4+	2.834e-13	2.092e-13	-12.548	-12.679	-0.132	(0)
Fe(SO4)2-	4.336e-14	3.235e-14	-13.363	-13.490	-0.127	(0)
Cr2(OH)2SO4+2	4.354e-16	1.349e-16	-15.361	-15.870	-0.509	(0)
U(SO4)2	3.991e-18	4.181e-18	-17.399	-17.379	0.020	(0)
USO4+2	1.421e-19	4.405e-20	-18.847	-19.356	-0.509	(0)
Cr2(OH)2(SO4)2	1.486e-20	1.557e-20	-19.828	-19.808	0.020	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-42.546	-43.055	-0.509	(0)
U(3)	6.957e-35					
U+3	6.957e-35	4.984e-36	-34.158	-35.302	-1.145	(0)
U(4)	4.333e-15					
U(OH)4	2.319e-15	2.429e-15	-14.635	-14.615	0.020	(0)
U(OH)5-	9.732e-16	7.261e-16	-15.012	-15.139	-0.127	(0)
U(OH)3+	9.511e-16	7.096e-16	-15.022	-15.149	-0.127	(0)
U(OH)2+2	8.460e-17	2.621e-17	-16.073	-16.581	-0.509	(0)
U(SO4)2	3.991e-18	4.181e-18	-17.399	-17.379	0.020	(0)
UOH+3	1.184e-18	8.479e-20	-17.927	-19.072	-1.145	(0)
USO4+2	1.421e-19	4.405e-20	-18.847	-19.356	-0.509	(0)
U+4	3.379e-21	3.116e-23	-20.471	-22.506	-2.035	(0)
UCl+3	9.116e-22	6.531e-23	-21.040	-22.185	-1.145	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-80.502	-90.805	-10.304	(0)
U(5)	3.844e-09					
UO2+	3.844e-09	2.868e-09	-8.415	-8.542	-0.127	(0)
U(6)	3.700e-07					
UO2+2	1.518e-07	4.705e-08	-6.819	-7.327	-0.509	(0)
UO2SO4	1.124e-07	1.177e-07	-6.949	-6.929	0.020	(0)
UO2(SO4)2-2	5.534e-08	1.715e-08	-7.257	-7.766	-0.509	(0)
UO2CO3	3.390e-08	3.551e-08	-7.470	-7.450	0.020	(0)
UO2Cl+	1.007e-08	7.515e-09	-7.997	-8.124	-0.127	(0)
UO2OH+	6.415e-09	4.787e-09	-8.193	-8.320	-0.127	(0)
UO2(CO3)2-2	5.489e-11	1.701e-11	-10.260	-10.769	-0.509	(0)
(UO2)2(OH)2+2	2.534e-12	7.853e-13	-11.596	-12.105	-0.509	(0)
UO2(CO3)3-4	2.665e-15	2.457e-17	-14.574	-16.610	-2.035	(0)
(UO2)3(OH)5+	1.095e-17	8.166e-18	-16.961	-17.088	-0.127	(0)
Zn	7.116e-07					
Zn+2	4.626e-07	1.511e-07	-6.335	-6.821	-0.486	(0)
ZnSO4	1.653e-07	1.732e-07	-6.782	-6.761	0.020	(0)
ZnCl+	5.453e-08	3.914e-08	-7.263	-7.407	-0.144	(0)
Zn(SO4)2-2	2.222e-08	6.885e-09	-7.653	-8.162	-0.509	(0)
ZnCl2	3.765e-09	3.944e-09	-8.424	-8.404	0.020	(0)
ZnHCO3+	2.423e-09	1.808e-09	-8.616	-8.743	-0.127	(0)
ZnCl3-	5.935e-10	4.260e-10	-9.227	-9.371	-0.144	(0)
ZnCl4-2	6.903e-11	2.050e-11	-10.161	-10.688	-0.527	(0)
ZnOHCl	5.753e-12	6.027e-12	-11.240	-11.220	0.020	(0)
ZnOH+	2.779e-12	2.073e-12	-11.556	-11.683	-0.127	(0)

ZnCO3	1.726e-12	1.808e-12	-11.763	-11.743	0.020	(0)
Zn(OH)2	2.851e-16	2.987e-16	-15.545	-15.525	0.020	(0)
Zn(CO3)2-2	7.481e-18	2.318e-18	-17.126	-17.635	-0.509	(0)
Zn(OH)3-	1.584e-23	1.182e-23	-22.800	-22.927	-0.127	(0)
Zn(OH)4-2	7.567e-32	2.345e-32	-31.121	-31.630	-0.509	(0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-2.66	7.72	10.38	Al(OH)3
Al2O3	-7.54	15.44	22.98	Al2O3
Al4(OH)10SO4	-2.33	20.37	22.70	Al4(OH)10SO4
AlOHSO4	0.44	-2.79	-3.23	AlOHSO4
AlumK	-6.85	-12.02	-5.17	KAl(SO4)2:12H2O
Alunite	4.79	3.45	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-1.39	-6.02	-4.64	CaSO4
Antlerite	-22.17	-13.88	8.29	Cu3(OH)4SO4
Aragonite	-5.60	-13.94	-8.34	CaCO3
Artinite	-16.70	-7.10	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-14.70	-7.36	7.34	Cu2(OH)3Cl
Azurite	-23.29	-40.21	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-4.68	0.87	5.54	UO2(OH)2
Bianchite	-7.38	-9.15	-1.76	ZnSO4:6H2O
Birnessite	-25.22	-7.13	18.09	MnO2
Bixbyite	-29.84	-30.45	-0.61	Mn2O3
Boehmite	-0.86	7.72	8.58	AlOOH
Brochantite	-30.35	-15.01	15.34	Cu4(OH)6SO4
Brucite	-11.13	5.66	16.79	Mg(OH)2
CaCrO4	-42.99	-45.25	-2.27	CaCrO4
Calcite	-5.46	-13.94	-8.47	CaCO3
CH4(g)	-43.11	-83.21	-40.10	CH4
Chalcanthite	-9.00	-11.64	-2.64	CuSO4:5H2O
CO2(g)	-0.26	-18.42	-18.16	CO2
Cr(OH)2	-22.63	-11.81	10.82	Cr(OH)2
Cr(OH)3(A)	-5.91	-6.66	-0.75	Cr(OH)3
Cr(OH)3(C)	-8.36	-6.66	1.70	Cr(OH)3
Cr2O3	-9.92	-13.32	-3.39	Cr2O3
CrCl2	-37.91	-22.04	15.87	CrCl2
CrCl3	-35.51	-22.00	13.51	CrCl3
CrMetal	-60.25	-28.01	32.24	Cr
CrO3	-46.53	-49.74	-3.21	CrO3
Cu(OH)2	-9.77	-1.13	8.64	Cu(OH)2
Cu2SO4	-21.56	-23.51	-1.95	Cu2SO4
CuCO3	-9.91	-19.54	-9.63	CuCO3
CuCrO4	-45.39	-50.86	-5.48	CuCrO4
CuMetal	-5.84	-14.60	-8.76	Cu
CuOCuSO4	-24.28	-12.75	11.53	CuO:CuSO4
CupricFerrite	-10.99	-5.11	5.88	CuFe2O4
Cuprite	-11.45	-13.00	-1.55	Cu2O
CuprousFerrite	0.43	-8.49	-8.92	CuFeO2
CuSO4	-14.64	-11.63	3.01	CuSO4
Diaspore	0.85	7.72	6.87	AlOOH
Dolomite	-9.69	-26.69	-17.00	CaMg(CO3)2
Epsomite	-2.72	-4.86	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-0.49	-3.53	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-39.09	-35.51	3.58	Fe2(SO4)3
Fe3(OH)8	-21.28	-1.05	20.22	Fe3(OH)8
FeCr2O4	-9.47	-10.38	-0.90	FeCr2O4
Ferrihydrite	-6.89	-2.00	4.89	Fe(OH)3
Gibbsite(C)	-1.05	7.72	8.77	Al(OH)3
Goethite	-2.49	-1.99	0.50	FeOOH
Goslarite	-7.19	-9.15	-1.96	ZnSO4:7H2O
Gummite	-9.53	0.87	10.40	UO3
Gypsum	-1.42	-6.03	-4.61	CaSO4:2H2O
Halite	-3.56	-1.97	1.58	NaCl

Hausmannite	-38.80	22.74	61.54	Mn3O4
Hematite	0.02	-3.99	-4.01	Fe2O3
Hercynite	-8.78	18.38	27.16	FeAl2O4
Huntite	-22.24	-52.21	-29.97	CaMg3(CO3)4
Hydromagnesite	-36.61	-45.38	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-14.91	-27.01	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-10.90	-25.70	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-12.66	-23.86	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-81.19	-96.87	-15.67	K2Cr2O7
K2CrO4	-47.13	-47.13	0.01	K2CrO4
Langite	-31.80	-15.01	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-3.36	-1.99	1.37	FeOOH
Lime	-28.31	4.48	32.80	CaO
Maghemite	-10.37	-3.99	6.39	Fe2O3
Magnesite	-4.73	-12.76	-8.03	MgCO3
Magnetite	-4.78	-1.04	3.74	Fe3O4
Malachite	-15.49	-20.67	-5.18	Cu2(OH)2CO3
Manganite	-14.99	-15.23	-0.24	MnOOH
Melanothallite	-15.08	-11.35	3.73	CuCl2
Melanterite	-5.12	-7.59	-2.47	FeSO4:7H2O
Mg-Ferrite	-15.09	1.68	16.77	MgFe2O4
MgCr2O4	-19.73	-7.65	12.08	MgCr2O4
MgCrO4	-49.46	-44.08	5.38	MgCrO4
Mirabilite	-3.14	-4.25	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-56.27	-61.98	-5.71	Mn2(SO4)3
MnCl2:4H2O	-10.77	-8.06	2.71	MnCl2:4H2O
MnSO4	-11.00	-8.33	2.67	MnSO4
Na2Cr2O7	-83.30	-93.19	-9.90	Na2Cr2O7
Na2CrO4	-46.72	-43.45	3.26	Na2CrO4
Nantokite	-4.86	-11.62	-6.76	CuCl
Natron	-10.85	-12.16	-1.31	Na2CO3:10H2O
Nesquehonite	-7.14	-12.76	-5.62	MgCO3:3H2O
Nsutite	-24.63	-7.13	17.50	MnO2
O2(g)	-50.73	32.39	83.12	O2
Periclase	-15.85	5.66	21.51	MgO
Portlandite	-18.19	4.48	22.68	Ca(OH)2
Pyrocroite	-12.91	2.18	15.09	Mn(OH)2
Pyrolusite	-22.99	-7.13	15.86	MnO2
Rhodochrosite	-5.83	-16.24	-10.41	MnCO3
Rutherfordine	-3.09	-17.55	-14.46	UO2CO3
Schoepite	-4.54	0.86	5.40	UO2(OH)2:H2O
Siderite	-4.93	-15.48	-10.55	FeCO3
Smithsonite	-7.04	-17.04	-10.00	ZnCO3
Spinel	-15.23	21.11	36.33	MgAl2O4
Tenorite	-8.74	-1.12	7.62	CuO
Thenardite	-4.05	-4.22	-0.18	Na2SO4
Thermonatrite	-12.26	-12.14	0.13	Na2CO3:H2O
U3O8(C)	-7.05	14.06	21.11	U3O8
U4O9(C)	-4.86	-8.25	-3.38	U4O9
UO2(am)	-7.05	-6.11	0.93	UO2
UO3(C)	-6.85	0.87	7.72	UO3
Uraninite	-1.41	-6.11	-4.70	UO2
Zincite	-9.76	1.38	11.14	ZnO
Zincosite	-12.14	-9.13	3.01	ZnSO4
Zn(BO2)2	-13.63	-5.34	8.29	Zn(BO2)2
Zn(OH)2(A)	-11.08	1.37	12.45	Zn(OH)2
Zn(OH)2(B)	-10.38	1.37	11.75	Zn(OH)2
Zn(OH)2(C)	-10.83	1.37	12.20	Zn(OH)2
Zn(OH)2(E)	-10.13	1.37	11.50	Zn(OH)2
Zn(OH)2(G)	-10.34	1.37	11.71	Zn(OH)2
Zn2(OH)2SO4	-15.26	-7.76	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-17.57	-2.37	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-35.91	-16.89	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-33.41	-5.01	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-41.86	-3.36	38.50	Zn5(OH)8Cl2
ZnCl2	-15.88	-8.85	7.03	ZnCl2

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  ZnCO3:H2O        -6.79    -17.05  -10.26  ZnCO3:H2O
  ZnMetal         -40.58    -14.82   25.76  Zn
  ZnO(Active)      -9.93      1.38   11.31  ZnO
  ZnSO4:H2O        -8.56     -9.13   -0.57  ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 2.

-----------------------------Solution composition------------------------------

      Elements           Molality       Moles

      Al                1.975e-03   1.975e-03
      Alkalinity        8.318e-06   8.318e-06
      B                 3.418e-04   3.418e-04
      Ca                5.319e-04   5.319e-04
      Cl                2.067e-01   2.067e-01
      Cr                9.762e-09   9.762e-09
      Cu                1.118e-07   1.118e-07
      Fe                4.544e-07   4.544e-07
      K                 3.115e-03   3.115e-03
      Mg                1.286e-02   1.286e-02
      Mn                2.642e-06   2.642e-06
      Na                2.111e-01   2.111e-01
      S(6)              2.526e-02   2.526e-02
      U                 2.601e-07   2.601e-07
      Zn                6.988e-07   6.988e-07

----------------------------Description of solution----------------------------

                                    pH  =   3.200
                                    pe  =   4.000
                       Activity of water  =   0.975
                  Ionic strength (mol/kgw)  =   2.727e-01
                        Mass of water (kg)  =   1.000e+00
                   Total carbon (mol/kg)  =   1.002e+00
                      Total CO2 (mol/kg)  =   1.002e+00
                        Temperature (°C)  =  25.00
                  Electrical balance (eq)  =  -1.035e-02
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  -2.14
                                Iterations  =  15
                                   Total H  = 1.130166e+02
                                   Total O  = 5.861299e+01

----------------------------Distribution of species----------------------------

                                                 Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma   cm³/mol

   H+               8.030e-04   6.310e-04    -3.095    -3.200    -0.105      0.00
   OH-              2.278e-11   1.553e-11   -10.642   -10.809    -0.166     (0)
   H2O              5.551e+01   9.752e-01     1.744    -0.011     0.000     18.07
Al            1.975e-03
   Al+3             1.056e-03   1.206e-04    -2.976    -3.919    -0.942     (0)
   AlSO4+           6.966e-04   4.928e-04    -3.157    -3.307    -0.150     (0)
   Al(SO4)2-        2.159e-04   1.528e-04    -3.666    -3.816    -0.150     (0)
   AlOH+2           6.815e-06   1.907e-06    -5.167    -5.720    -0.553     (0)
   Al(OH)2+         3.146e-08   2.288e-08    -7.502    -7.640    -0.138     (0)
   Al(OH)3          4.182e-11   4.453e-11   -10.379   -10.351     0.027     (0)
   Al(OH)4-         9.729e-15   6.883e-15   -14.012   -14.162    -0.150     (0)
B             3.418e-04
   H3BO3            3.418e-04   3.640e-04    -3.466    -3.439     0.027     (0)
   H2BO3-           5.088e-10   3.313e-10    -9.293    -9.480    -0.186     (0)
C(4)          1.002e+00
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H2CO3	1.000e+00	1.065e+00	0.000	0.027	0.027	(0)
HCO3-	1.034e-03	7.518e-04	-2.986	-3.124	-0.138	(0)
NaHCO3	5.992e-05	6.380e-05	-4.222	-4.195	0.027	(0)
MgHCO3+	4.703e-05	3.269e-05	-4.328	-4.486	-0.158	(0)
CaHCO3+	1.484e-06	1.097e-06	-5.829	-5.960	-0.131	(0)
UO2CO3	2.398e-08	2.553e-08	-7.620	-7.593	0.027	(0)
ZnHCO3+	1.668e-08	1.227e-08	-7.778	-7.911	-0.133	(0)
MnHCO3+	1.064e-08	7.647e-09	-7.973	-8.117	-0.143	(0)
NaCO3-	2.143e-10	1.559e-10	-9.669	-9.807	-0.138	(0)
CO3-2	1.993e-10	5.578e-11	-9.700	-10.254	-0.553	(0)
MgCO3	1.849e-10	1.968e-10	-9.733	-9.706	0.027	(0)
CuHCO3+	7.269e-11	5.348e-11	-10.139	-10.272	-0.133	(0)
UO2(CO3)2-2	3.880e-11	1.137e-11	-10.411	-10.944	-0.533	(0)
CaCO3	1.048e-11	1.116e-11	-10.980	-10.952	0.027	(0)
ZnCO3	1.451e-12	1.545e-12	-11.838	-11.811	0.027	(0)
CuCO3	4.275e-14	4.552e-14	-13.369	-13.342	0.027	(0)
UO2(CO3)3-4	2.070e-15	1.528e-17	-14.684	-16.816	-2.132	(0)
Zn(CO3)2-2	6.287e-18	1.843e-18	-17.202	-17.735	-0.533	(0)
Cu(CO3)2-2	1.091e-20	3.197e-21	-19.962	-20.495	-0.533	(0)
Ca	5.319e-04					
Ca+2	4.253e-04	1.408e-04	-3.371	-3.851	-0.480	(0)
CaSO4	1.051e-04	1.119e-04	-3.978	-3.951	0.027	(0)
CaHCO3+	1.484e-06	1.097e-06	-5.829	-5.960	-0.131	(0)
CaCO3	1.048e-11	1.116e-11	-10.980	-10.952	0.027	(0)
CaOH+	7.430e-14	5.492e-14	-13.129	-13.260	-0.131	(0)
Cl	2.067e-01					
Cl-	2.067e-01	1.392e-01	-0.685	-0.856	-0.172	(0)
MnCl+	4.276e-07	3.074e-07	-6.369	-6.512	-0.143	(0)
ZnCl+	7.484e-08	5.202e-08	-7.126	-7.284	-0.158	(0)
CuCl2-	7.031e-08	4.887e-08	-7.153	-7.311	-0.158	(0)
CuCl3-2	4.038e-08	1.078e-08	-7.394	-7.967	-0.573	(0)
UO2Cl+	1.142e-08	8.402e-09	-7.942	-8.076	-0.133	(0)
MnCl2	1.092e-08	1.162e-08	-7.962	-7.935	0.027	(0)
ZnCl2	7.121e-09	7.583e-09	-8.147	-8.120	0.027	(0)
ZnCl3-	1.704e-09	1.184e-09	-8.769	-8.927	-0.158	(0)
MnCl3-	1.015e-09	7.294e-10	-8.994	-9.137	-0.143	(0)
ZnCl4-2	3.088e-10	8.244e-11	-9.510	-10.084	-0.573	(0)
CrCl+2	1.528e-10	4.480e-11	-9.816	-10.349	-0.533	(0)
CuCl+	8.192e-11	5.694e-11	-10.087	-10.245	-0.158	(0)
CuCl2	3.998e-12	4.257e-12	-11.398	-11.371	0.027	(0)
CrCl2+	1.651e-12	1.215e-12	-11.782	-11.915	-0.133	(0)
ZnOHCl	9.290e-13	9.892e-13	-12.032	-12.005	0.027	(0)
CrOHCl2	3.558e-15	3.788e-15	-14.449	-14.422	0.027	(0)
CuCl3-	3.025e-15	2.102e-15	-14.519	-14.677	-0.158	(0)
FeCl+2	1.661e-15	4.435e-16	-14.780	-15.353	-0.573	(0)
FeCl2+	3.836e-16	2.758e-16	-15.416	-15.559	-0.143	(0)
CuCl4-2	5.493e-18	1.467e-18	-17.260	-17.834	-0.573	(0)
UCl+3	4.779e-18	3.021e-19	-17.321	-18.520	-1.199	(0)
FeCl3	3.605e-18	3.839e-18	-17.443	-17.416	0.027	(0)
CrO3Cl-	0.000e+00	0.000e+00	-48.484	-48.617	-0.133	(0)
Cr(2)	4.162e-20					
Cr+2	4.162e-20	1.220e-20	-19.381	-19.914	-0.533	(0)
Cr(3)	9.762e-09					
Cr+3	9.089e-09	5.745e-10	-8.041	-9.241	-1.199	(0)
Cr(OH)+2	3.030e-10	8.880e-11	-9.519	-10.052	-0.533	(0)
CrCl+2	1.528e-10	4.480e-11	-9.816	-10.349	-0.533	(0)
CrOHSO4	1.472e-10	1.567e-10	-9.832	-9.805	0.027	(0)
CrSO4+	6.750e-11	4.967e-11	-10.171	-10.304	-0.133	(0)
CrCl2+	1.651e-12	1.215e-12	-11.782	-11.915	-0.133	(0)
Cr(OH)2+	4.475e-13	3.293e-13	-12.349	-12.482	-0.133	(0)
CrOHCl2	3.558e-15	3.788e-15	-14.449	-14.422	0.027	(0)
Cr(OH)3	3.543e-17	3.773e-17	-16.451	-16.423	0.027	(0)
Cr2(OH)2SO4+2	8.633e-18	2.530e-18	-17.064	-17.597	-0.533	(0)
Cr2(OH)2(SO4)2	2.188e-22	2.330e-22	-21.660	-21.633	0.027	(0)
CrO2-	2.019e-24	1.486e-24	-23.695	-23.828	-0.133	(0)
Cr(OH)4-	7.569e-25	5.569e-25	-24.121	-24.254	-0.133	(0)

Cr(6)	0.000e+00					
HCrO4-	0.000e+00	0.000e+00	-45.238	-45.371	-0.133	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-47.951	-48.484	-0.533	(0)
CrO4-2	0.000e+00	0.000e+00	-48.048	-48.680	-0.632	(0)
CrO3Cl-	0.000e+00	0.000e+00	-48.484	-48.617	-0.133	(0)
NaCrO4-	0.000e+00	0.000e+00	-48.672	-48.806	-0.133	(0)
H2CrO4	0.000e+00	0.000e+00	-49.456	-49.429	0.027	(0)
KCrO4-	0.000e+00	0.000e+00	-50.437	-50.570	-0.133	(0)
Cr2O7-2	0.000e+00	0.000e+00	-88.660	-89.192	-0.533	(0)
Cu(1)	1.107e-07					
CuCl2-	7.031e-08	4.887e-08	-7.153	-7.311	-0.158	(0)
CuCl3-2	4.038e-08	1.078e-08	-7.394	-7.967	-0.573	(0)
Cu+	1.225e-11	7.976e-12	-10.912	-11.098	-0.186	(0)
Cu(2)	1.118e-09					
Cu+2	8.460e-10	1.520e-10	-9.073	-9.818	-0.746	(0)
CuSO4	1.137e-10	1.211e-10	-9.944	-9.917	0.027	(0)
CuCl+	8.192e-11	5.694e-11	-10.087	-10.245	-0.158	(0)
CuHCO3+	7.269e-11	5.348e-11	-10.139	-10.272	-0.133	(0)
CuCl2	3.998e-12	4.257e-12	-11.398	-11.371	0.027	(0)
CuCO3	4.275e-14	4.552e-14	-13.369	-13.342	0.027	(0)
CuOH+	3.379e-15	2.349e-15	-14.471	-14.629	-0.158	(0)
CuCl3-	3.025e-15	2.102e-15	-14.519	-14.677	-0.158	(0)
Cu(OH)2	7.124e-18	7.586e-18	-17.147	-17.120	0.027	(0)
CuCl4-2	5.493e-18	1.467e-18	-17.260	-17.834	-0.573	(0)
Cu(CO3)2-2	1.091e-20	3.197e-21	-19.962	-20.495	-0.533	(0)
Cu2(OH)2+2	8.237e-24	2.414e-24	-23.084	-23.617	-0.533	(0)
Cu(OH)3-	9.624e-28	7.081e-28	-27.017	-27.150	-0.133	(0)
Cu(OH)4-2	7.433e-37	2.179e-37	-36.129	-36.662	-0.533	(0)
Fe(2)	4.544e-07					
Fe+2	3.804e-07	1.136e-07	-6.420	-6.945	-0.525	(0)
FeSO4	7.401e-08	7.881e-08	-7.131	-7.103	0.027	(0)
FeOH+	7.722e-14	5.551e-14	-13.112	-13.256	-0.143	(0)
Fe(OH)2	6.858e-22	7.302e-22	-21.164	-21.137	0.027	(0)
Fe(OH)3-	5.834e-29	4.194e-29	-28.234	-28.377	-0.143	(0)
Fe(3)	1.299e-14					
FeSO4+	4.764e-15	3.424e-15	-14.322	-14.465	-0.143	(0)
FeOH+2	3.943e-15	1.053e-15	-14.404	-14.978	-0.573	(0)
FeCl+2	1.661e-15	4.435e-16	-14.780	-15.353	-0.573	(0)
Fe+3	9.237e-16	1.055e-16	-15.034	-15.977	-0.942	(0)
Fe(OH)2+	7.409e-16	5.389e-16	-15.130	-15.269	-0.138	(0)
Fe(SO4)2-	5.743e-16	4.226e-16	-15.241	-15.374	-0.133	(0)
FeCl2+	3.836e-16	2.758e-16	-15.416	-15.559	-0.143	(0)
FeCl3	3.605e-18	3.839e-18	-17.443	-17.416	0.027	(0)
Fe(OH)3	9.190e-21	9.786e-21	-20.037	-20.009	0.027	(0)
Fe(OH)4-	2.080e-25	1.513e-25	-24.682	-24.820	-0.138	(0)
Fe2(OH)2+4	4.042e-27	2.983e-29	-26.393	-28.525	-2.132	(0)
Fe3(OH)4+5	7.199e-39	0.000e+00	-38.143	-41.474	-3.331	(0)
H(0)	5.294e-18					
H2	2.647e-18	2.818e-18	-17.577	-17.550	0.027	(0)
K	3.115e-03					
K+	3.038e-03	2.046e-03	-2.517	-2.689	-0.172	(0)
KSO4-	7.712e-05	5.610e-05	-4.113	-4.251	-0.138	(0)
KCrO4-	0.000e+00	0.000e+00	-50.437	-50.570	-0.133	(0)
Mg	1.286e-02					
Mg+2	1.040e-02	3.698e-03	-1.983	-2.432	-0.449	(0)
MgSO4	2.410e-03	2.566e-03	-2.618	-2.591	0.027	(0)
MgHCO3+	4.703e-05	3.269e-05	-4.328	-4.486	-0.158	(0)
MgCO3	1.849e-10	1.968e-10	-9.733	-9.706	0.027	(0)
MgOH+	1.255e-11	9.389e-12	-10.901	-11.027	-0.126	(0)
Mn(2)	2.642e-06					
Mn+2	1.828e-06	5.458e-07	-5.738	-6.263	-0.525	(0)
MnCl+	4.276e-07	3.074e-07	-6.369	-6.512	-0.143	(0)
MnSO4	3.640e-07	3.876e-07	-6.439	-6.412	0.027	(0)
MnCl2	1.092e-08	1.162e-08	-7.962	-7.935	0.027	(0)
MnHCO3+	1.064e-08	7.647e-09	-7.973	-8.117	-0.143	(0)
MnCl3-	1.015e-09	7.294e-10	-8.994	-9.137	-0.143	(0)

MnOH+	3.016e-14	2.168e-14	-13.521	-13.664	-0.143	(0)
Mn(OH)3-	4.443e-32	3.194e-32	-31.352	-31.496	-0.143	(0)
Mn(3)	1.487e-27					
Mn+3	1.487e-27	1.698e-28	-26.828	-27.770	-0.942	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-82.573	-83.147	-0.573	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-88.355	-88.531	-0.176	(0)
Na	2.111e-01					
Na+	2.069e-01	1.508e-01	-0.684	-0.822	-0.138	(0)
NaSO4-	4.055e-03	2.949e-03	-2.392	-2.530	-0.138	(0)
NaHCO3	5.992e-05	6.380e-05	-4.222	-4.195	0.027	(0)
NaCO3-	2.143e-10	1.559e-10	-9.669	-9.807	-0.138	(0)
NaCrO4-	0.000e+00	0.000e+00	-48.672	-48.806	-0.133	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-57.329	-57.302	0.027	(0)
S(6)	2.526e-02					
SO4-2	1.714e-02	3.902e-03	-1.766	-2.409	-0.643	(0)
NaSO4-	4.055e-03	2.949e-03	-2.392	-2.530	-0.138	(0)
MgSO4	2.410e-03	2.566e-03	-2.618	-2.591	0.027	(0)
AlSO4+	6.966e-04	4.928e-04	-3.157	-3.307	-0.150	(0)
HSO4-	3.377e-04	2.389e-04	-3.471	-3.622	-0.150	(0)
Al(SO4)2-	2.159e-04	1.528e-04	-3.666	-3.816	-0.150	(0)
CaSO4	1.051e-04	1.119e-04	-3.978	-3.951	0.027	(0)
KSO4-	7.712e-05	5.610e-05	-4.113	-4.251	-0.138	(0)
MnSO4	3.640e-07	3.876e-07	-6.439	-6.412	0.027	(0)
ZnSO4	1.193e-07	1.270e-07	-6.923	-6.896	0.027	(0)
FeSO4	7.401e-08	7.881e-08	-7.131	-7.103	0.027	(0)
UO2SO4	6.820e-08	7.262e-08	-7.166	-7.139	0.027	(0)
UO2(SO4)2-2	2.880e-08	8.441e-09	-7.541	-8.074	-0.533	(0)
Zn(SO4)2-2	1.375e-08	4.029e-09	-7.862	-8.395	-0.533	(0)
CrOHSO4	1.472e-10	1.567e-10	-9.832	-9.805	0.027	(0)
CuSO4	1.137e-10	1.211e-10	-9.944	-9.917	0.027	(0)
CrSO4+	6.750e-11	4.967e-11	-10.171	-10.304	-0.133	(0)
U(SO4)2	7.996e-15	8.515e-15	-14.097	-14.070	0.027	(0)
FeSO4+	4.764e-15	3.424e-15	-14.322	-14.465	-0.143	(0)
Fe(SO4)2-	5.743e-16	4.226e-16	-15.241	-15.374	-0.133	(0)
USO4+2	3.835e-16	1.124e-16	-15.416	-15.949	-0.533	(0)
Cr2(OH)2SO4+2	8.633e-18	2.530e-18	-17.064	-17.597	-0.533	(0)
Cr2(OH)2(SO4)2	2.188e-22	2.330e-22	-21.660	-21.633	0.027	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-47.951	-48.484	-0.533	(0)
U(3)	2.522e-31					
U+3	2.522e-31	1.594e-32	-30.598	-31.798	-1.199	(0)
U(4)	2.089e-14					
U(SO4)2	7.996e-15	8.515e-15	-14.097	-14.070	0.027	(0)
U(OH)3+	5.809e-15	4.274e-15	-14.236	-14.369	-0.133	(0)
U(OH)2+2	4.362e-15	1.279e-15	-14.360	-14.893	-0.533	(0)
U(OH)4	1.697e-15	1.807e-15	-14.770	-14.743	0.027	(0)
UOH+3	5.298e-16	3.349e-17	-15.276	-16.475	-1.199	(0)
USO4+2	3.835e-16	1.124e-16	-15.416	-15.949	-0.533	(0)
U(OH)5-	9.064e-17	6.669e-17	-16.043	-16.176	-0.133	(0)
U+4	1.350e-17	9.965e-20	-16.870	-19.002	-2.132	(0)
UCl+3	4.779e-18	3.021e-19	-17.321	-18.520	-1.199	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-72.609	-83.401	-10.793	(0)
U(5)	3.013e-09					
UO2+	3.013e-09	2.217e-09	-8.521	-8.654	-0.133	(0)
U(6)	2.571e-07					
UO2+2	1.241e-07	3.637e-08	-6.906	-7.439	-0.533	(0)
UO2SO4	6.820e-08	7.262e-08	-7.166	-7.139	0.027	(0)
UO2(SO4)2-2	2.880e-08	8.441e-09	-7.541	-8.074	-0.533	(0)
UO2CO3	2.398e-08	2.553e-08	-7.620	-7.593	0.027	(0)
UO2Cl+	1.142e-08	8.402e-09	-7.942	-8.076	-0.133	(0)
UO2OH+	6.210e-10	4.569e-10	-9.207	-9.340	-0.133	(0)
UO2(CO3)2-2	3.880e-11	1.137e-11	-10.411	-10.944	-0.533	(0)
(UO2)2(OH)2+2	2.441e-14	7.156e-15	-13.612	-14.145	-0.533	(0)
UO2(CO3)3-4	2.070e-15	1.528e-17	-14.684	-16.816	-2.132	(0)

(UO2)3(OH)5+	1.472e-22	1.083e-22	-21.832	-21.965	-0.133 (0)
Zn	6.988e-07				
Zn+2	4.651e-07	1.388e-07	-6.332	-6.857	-0.525 (0)
ZnSO4	1.193e-07	1.270e-07	-6.923	-6.896	0.027 (0)
ZnCl+	7.484e-08	5.202e-08	-7.126	-7.284	-0.158 (0)
ZnHCO3+	1.668e-08	1.227e-08	-7.778	-7.911	-0.133 (0)
Zn(SO4)2-2	1.375e-08	4.029e-09	-7.862	-8.395	-0.533 (0)
ZnCl2	7.121e-09	7.583e-09	-8.147	-8.120	0.027 (0)
ZnCl3-	1.704e-09	1.184e-09	-8.769	-8.927	-0.158 (0)
ZnCl4-2	3.088e-10	8.244e-11	-9.510	-10.084	-0.573 (0)
ZnCO3	1.451e-12	1.545e-12	-11.838	-11.811	0.027 (0)
ZnOHCl	9.290e-13	9.892e-13	-12.032	-12.005	0.027 (0)
ZnOH+	3.198e-13	2.353e-13	-12.495	-12.628	-0.133 (0)
Zn(CO3)2-2	6.287e-18	1.843e-18	-17.202	-17.735	-0.533 (0)
Zn(OH)2	3.931e-18	4.186e-18	-17.406	-17.378	0.027 (0)
Zn(OH)3-	2.781e-26	2.046e-26	-25.556	-25.689	-0.133 (0)
Zn(OH)4-2	1.710e-35	5.012e-36	-34.767	-35.300	-0.533 (0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-4.73	5.65	10.38	Al(OH)3
Al2O3	-11.65	11.33	22.98	Al2O3
Al4(OH)10SO4	-8.89	13.81	22.70	Al4(OH)10SO4
AlOHSO4	0.09	-3.14	-3.23	AlOHSO4
AlumK	-6.39	-11.56	-5.17	KAl(SO4)2:12H2O
Alunite	1.22	-0.13	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-1.62	-6.26	-4.64	CaSO4
Antlerite	-27.40	-19.11	8.29	Cu3(OH)4SO4
Aragonite	-5.77	-14.10	-8.34	CaCO3
Artinite	-18.37	-8.77	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-18.27	-10.93	7.34	Cu2(OH)3Cl
Azurite	-26.66	-43.58	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-6.61	-1.06	5.54	UO2(OH)2
Bianchite	-7.57	-9.33	-1.76	ZnSO4:6H2O
Birnessite	-29.08	-10.99	18.09	MnO2
Bixbyite	-35.76	-36.37	-0.61	Mn2O3
Boehmite	-2.92	5.66	8.58	AlOOH
Brochantite	-37.89	-22.55	15.34	Cu4(OH)6SO4
Brucite	-12.85	3.95	16.79	Mg(OH)2
CaCrO4	-50.27	-52.53	-2.27	CaCrO4
Calcite	-5.63	-14.10	-8.47	CaCO3
CH4(g)	-34.12	-74.22	-40.10	CH4
Chalcanthite	-9.64	-12.28	-2.64	CuSO4:5H2O
CO2(g)	1.52	-16.64	-18.16	CO2
Cr(OH)2	-24.35	-13.54	10.82	Cr(OH)2
Cr(OH)3(A)	-8.54	-9.29	-0.75	Cr(OH)3
Cr(OH)3(C)	-10.99	-9.29	1.70	Cr(OH)3
Cr2O3	-15.16	-18.55	-3.39	Cr2O3
CrCl2	-37.49	-21.63	15.87	CrCl2
CrCl3	-34.94	-21.43	13.51	CrCl3
CrMetal	-60.16	-27.91	32.24	Cr
CrO3	-51.86	-55.07	-3.21	CrO3
Cu(OH)2	-12.08	-3.44	8.64	Cu(OH)2
Cu2SO4	-22.66	-24.61	-1.95	Cu2SO4
CuCO3	-10.44	-20.07	-9.63	CuCO3
CuCrO4	-53.02	-58.50	-5.48	CuCrO4
CuMetal	-6.34	-15.10	-8.76	Cu
CuOCuSO4	-27.19	-15.66	11.53	CuO:CuSO4
CupricFerrite	-22.10	-16.22	5.88	CuFe2O4
Cuprite	-14.26	-15.81	-1.55	Cu2O
CuprousFerrite	-5.38	-14.30	-8.92	CuFeO2
CuSO4	-15.24	-12.23	3.01	CuSO4
Diaspore	-1.21	5.66	6.87	AlOOH
Dolomite	-9.79	-26.79	-17.00	CaMg(CO3)2

Epsomite	-2.78	-4.92	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-4.58	-7.62	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-42.76	-39.18	3.58	Fe2(SO4)3
Fe3(OH)8	-33.61	-13.39	20.22	Fe3(OH)8
FeCr2O4	-18.21	-19.11	-0.90	FeCr2O4
Ferrihydrite	-11.30	-6.41	4.89	Fe(OH)3
Gibbsite(C)	-3.12	5.65	8.77	Al(OH)3
Goethite	-6.90	-6.40	0.50	FeOOH
Goslarite	-7.38	-9.34	-1.96	ZnSO4:7H2O
Gummite	-11.45	-1.05	10.40	UO3
Gypsum	-1.67	-6.28	-4.61	CaSO4:2H2O
Halite	-3.26	-1.68	1.58	NaCl
Hausmannite	-46.77	14.77	61.54	Mn3O4
Hematite	-8.78	-12.79	-4.01	Fe2O3
Hercynite	-16.39	10.77	27.16	FeAl2O4
Huntite	-22.19	-52.16	-29.97	CaMg3(CO3)4
Hydromagnesite	-38.07	-46.84	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-24.72	-36.82	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-21.50	-36.30	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-23.23	-34.43	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-93.46	-109.13	-15.67	K2Cr2O7
K2CrO4	-54.07	-54.06	0.01	K2CrO4
Langite	-39.35	-22.56	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-7.77	-6.40	1.37	FeOOH
Lime	-30.26	2.54	32.80	CaO
Maghemite	-19.17	-12.79	6.39	Fe2O3
Magnesite	-4.66	-12.69	-8.03	MgCO3
Magnetite	-17.08	-13.34	3.74	Fe3O4
Malachite	-18.33	-23.51	-5.18	Cu2(OH)2CO3
Manganite	-17.95	-18.19	-0.24	MnOOH
Melanothallite	-15.26	-11.53	3.73	CuCl2
Melanterite	-6.96	-9.43	-2.47	FeSO4:7H2O
Mg-Ferrite	-25.59	-8.83	16.77	MgFe2O4
MgCr2O4	-26.68	-14.60	12.08	MgCr2O4
MgCrO4	-56.49	-51.11	5.38	MgCrO4
Mirabilite	-3.05	-4.16	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-57.05	-62.77	-5.71	Mn2(SO4)3
MnCl2:4H2O	-10.73	-8.02	2.71	MnCl2:4H2O
MnSO4	-11.34	-8.67	2.67	MnSO4
Na2Cr2O7	-95.50	-105.39	-9.90	Na2Cr2O7
Na2CrO4	-53.59	-50.32	3.26	Na2CrO4
Nantokite	-5.19	-11.95	-6.76	CuCl
Natron	-10.69	-12.01	-1.31	Na2CO3:10H2O
Nesquehonite	-7.10	-12.72	-5.62	MgCO3:3H2O
Nsutite	-28.50	-10.99	17.50	MnO2
O2(g)	-54.34	28.78	83.12	O2
Periclase	-17.55	3.96	21.51	MgO
Portlandite	-20.15	2.53	22.68	Ca(OH)2
Pyrocroite	-14.97	0.12	15.09	Mn(OH)2
Pyrolusite	-26.85	-10.99	15.86	MnO2
Rhodochrosite	-6.11	-16.52	-10.41	MnCO3
Rutherfordine	-3.23	-17.69	-14.46	UO2CO3
Schoepite	-6.48	-1.07	5.40	UO2(OH)2:H2O
Siderite	-6.65	-17.20	-10.55	FeCO3
Smithsonite	-7.11	-17.11	-10.00	ZnCO3
Spinel	-21.05	15.29	36.33	MgAl2O4
Tenorite	-11.05	-3.43	7.62	CuO
Thenardite	-3.87	-4.05	-0.18	Na2SO4
Thermonatrite	-12.03	-11.91	0.13	Na2CO3:H2O
U3O8(C)	-11.00	10.11	21.11	U3O8
U4O9(C)	-7.12	-10.50	-3.38	U4O9
UO2(am)	-7.16	-6.22	0.93	UO2
UO3(C)	-8.77	-1.05	7.72	UO3
Uraninite	-1.52	-6.22	-4.70	UO2
Zincite	-11.61	-0.47	11.14	ZnO
Zincosite	-12.28	-9.27	3.01	ZnSO4

Zn(BO2)2	-15.60	-7.31	8.29	Zn(BO2)2
Zn(OH)2(A)	-12.93	-0.48	12.45	Zn(OH)2
Zn(OH)2(B)	-12.23	-0.48	11.75	Zn(OH)2
Zn(OH)2(C)	-12.68	-0.48	12.20	Zn(OH)2
Zn(OH)2(E)	-11.98	-0.48	11.50	Zn(OH)2
Zn(OH)2(G)	-12.19	-0.48	11.71	Zn(OH)2
Zn2(OH)2SO4	-17.25	-9.75	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-20.20	-5.00	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-38.02	-19.00	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-39.10	-10.70	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-48.99	-10.49	38.50	Zn5(OH)8Cl2
ZnCl2	-15.60	-8.57	7.03	ZnCl2
ZnCO3:H2O	-6.86	-17.12	-10.26	ZnCO3:H2O
ZnMetal	-40.61	-14.86	25.76	Zn
ZnO(Active)	-11.78	-0.47	11.31	ZnO
ZnSO4:H2O	-8.71	-9.28	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 3.

-----------------------------Solution composition-----------------------------

Elements	Molality	Moles
Al	2.537e-03	2.537e-03
Alkalinity	8.286e-06	8.286e-06
B	3.938e-04	3.938e-04
Ca	8.830e-04	8.830e-04
Cl	2.852e-04	2.852e-04
Cr	3.890e-08	3.890e-08
Cu	3.023e-07	3.023e-07
Fe	7.768e-05	7.768e-05
K	4.370e-03	4.370e-03
Mg	2.545e-02	2.545e-02
Mn	4.675e-06	4.675e-06
Na	3.009e-01	3.009e-01
S(6)	3.505e-02	3.505e-02
U	5.055e-07	5.055e-07
Zn	9.281e-07	9.281e-07

----------------------------Description of solution----------------------------

pH	= 3.260
pe	= 4.000
Activity of water	= 0.981
Ionic strength (mol/kgw)	= 2.401e-01
Mass of water (kg)	= 1.000e+00
Total carbon (mol/kg)	= 7.689e-01
Total CO2 (mol/kg)	= 7.689e-01
Temperature (°C)	= 25.00
Electrical balance (eq)	= 2.953e-01
Percent error, 100*(Cat-|An|)/(Cat+|An|)	= 75.18
Iterations	= 16
Total H	= 1.125515e+02
Total O	= 5.795441e+01

---------------------------Distribution of species---------------------------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	6.951e-04	5.495e-04	-3.158	-3.260	-0.102	0.00
OH-	2.591e-11	1.793e-11	-10.587	-10.746	-0.160	(0)
H2O	5.551e+01	9.809e-01	1.744	-0.008	0.000	18.07

Al	2.537e-03					
Al+3	1.168e-03	1.409e-04	-2.932	-3.851	-0.919	(0)
AlSO4+	9.855e-04	7.059e-04	-3.006	-3.151	-0.145	(0)
Al(SO4)2-	3.744e-04	2.682e-04	-3.427	-3.572	-0.145	(0)
AlOH+2	8.820e-06	2.574e-06	-5.055	-5.589	-0.535	(0)
Al(OH)2+	4.853e-08	3.567e-08	-7.314	-7.448	-0.134	(0)
Al(OH)3	7.584e-11	8.015e-11	-10.120	-10.096	0.024	(0)
Al(OH)4-	1.997e-14	1.431e-14	-13.700	-13.844	-0.145	(0)
B	3.938e-04					
H3BO3	3.938e-04	4.162e-04	-3.405	-3.381	0.024	(0)
H2BO3-	6.556e-10	4.349e-10	-9.183	-9.362	-0.178	(0)
C(4)	7.689e-01					
H2CO3	7.679e-01	8.115e-01	-0.115	-0.091	0.024	(0)
HCO3-	8.947e-04	6.576e-04	-3.048	-3.182	-0.134	(0)
MgHCO3+	7.817e-05	5.508e-05	-4.107	-4.259	-0.152	(0)
NaHCO3	7.555e-05	7.985e-05	-4.122	-4.098	0.024	(0)
CaHCO3+	2.081e-06	1.553e-06	-5.682	-5.809	-0.127	(0)
UO2CO3	4.442e-08	4.694e-08	-7.352	-7.328	0.024	(0)
ZnHCO3+	2.139e-08	1.582e-08	-7.670	-7.801	-0.131	(0)
MnHCO3+	1.938e-08	1.409e-08	-7.713	-7.851	-0.138	(0)
CuHCO3+	1.911e-08	1.414e-08	-7.719	-7.850	-0.131	(0)
MgCO3	3.603e-10	3.808e-10	-9.443	-9.419	0.024	(0)
NaCO3-	3.048e-10	2.240e-10	-9.516	-9.650	-0.134	(0)
CO3-2	1.919e-10	5.602e-11	-9.717	-10.252	-0.535	(0)
UO2(CO3)2-2	7.017e-11	2.100e-11	-10.154	-10.678	-0.524	(0)
CaCO3	1.716e-11	1.814e-11	-10.765	-10.741	0.024	(0)
CuCO3	1.307e-11	1.382e-11	-10.884	-10.860	0.024	(0)
ZnCO3	2.163e-12	2.286e-12	-11.665	-11.641	0.024	(0)
UO2(CO3)3-4	3.533e-15	2.833e-17	-14.452	-16.548	-2.096	(0)
Zn(CO3)2-2	9.150e-18	2.738e-18	-17.039	-17.563	-0.524	(0)
Cu(CO3)2-2	3.256e-18	9.742e-19	-17.487	-18.011	-0.524	(0)
Ca	8.830e-04					
Ca+2	6.709e-04	2.279e-04	-3.173	-3.642	-0.469	(0)
CaSO4	2.101e-04	2.220e-04	-3.678	-3.654	0.024	(0)
CaHCO3+	2.081e-06	1.553e-06	-5.682	-5.809	-0.127	(0)
CaCO3	1.716e-11	1.814e-11	-10.765	-10.741	0.024	(0)
CaOH+	1.376e-13	1.026e-13	-12.862	-12.989	-0.127	(0)
Cl	2.852e-04					
Cl-	2.852e-04	1.951e-04	-3.545	-3.710	-0.165	(0)
MnCl+	1.248e-09	9.074e-10	-8.904	-9.042	-0.138	(0)
ZnCl+	1.525e-10	1.074e-10	-9.817	-9.969	-0.152	(0)
CuCl2-	4.117e-11	2.901e-11	-10.385	-10.537	-0.152	(0)
CuCl+	3.422e-11	2.412e-11	-10.466	-10.618	-0.152	(0)
UO2Cl+	2.915e-11	2.156e-11	-10.535	-10.666	-0.131	(0)
CrCl+2	8.765e-13	2.623e-13	-12.057	-12.581	-0.524	(0)
MnCl2	4.550e-14	4.809e-14	-13.342	-13.318	0.024	(0)
CuCl3-2	3.211e-14	8.970e-15	-13.493	-14.047	-0.554	(0)
ZnCl2	2.076e-14	2.195e-14	-13.683	-13.659	0.024	(0)
CuCl2	2.391e-15	2.527e-15	-14.621	-14.597	0.024	(0)
ZnOHCl	2.232e-15	2.359e-15	-14.651	-14.627	0.024	(0)
FeCl+2	3.777e-16	1.055e-16	-15.423	-15.977	-0.554	(0)
CrCl2+	1.348e-17	9.971e-18	-16.870	-17.001	-0.131	(0)
ZnCl3-	6.817e-18	4.804e-18	-17.166	-17.318	-0.152	(0)
MnCl3-	5.818e-18	4.230e-18	-17.235	-17.374	-0.138	(0)
FeCl2+	1.265e-19	9.194e-20	-18.898	-19.037	-0.138	(0)
CrOHCl2	3.397e-20	3.590e-20	-19.469	-19.445	0.024	(0)
UCl+3	6.657e-21	4.409e-22	-20.177	-21.356	-1.179	(0)
CuCl3-	2.482e-21	1.749e-21	-20.605	-20.757	-0.152	(0)
ZnCl4-2	1.678e-21	4.686e-22	-20.775	-21.329	-0.554	(0)
FeCl3	1.697e-24	1.794e-24	-23.770	-23.746	0.024	(0)
CuCl4-2	6.123e-27	1.710e-27	-26.213	-26.767	-0.554	(0)
CrO3Cl-	0.000e+00	0.000e+00	-50.351	-50.482	-0.131	(0)
Cr(2)	1.703e-19					
Cr+2	1.703e-19	5.096e-20	-18.769	-19.293	-0.524	(0)
Cr(3)	3.890e-08					
Cr+3	3.624e-08	2.400e-09	-7.441	-8.620	-1.179	(0)

Cr(OH)+2	1.432e-09	4.284e-10	-8.844	-9.368	-0.524	(0)
CrOHSO4	8.769e-10	9.268e-10	-9.057	-9.033	0.024	(0)
CrSO4+	3.438e-10	2.543e-10	-9.464	-9.595	-0.131	(0)
Cr(OH)2+	2.480e-12	1.834e-12	-11.606	-11.736	-0.131	(0)
CrCl+2	8.765e-13	2.623e-13	-12.057	-12.581	-0.524	(0)
Cr2(OH)2SO4+2	2.412e-16	7.219e-17	-15.618	-16.142	-0.524	(0)
Cr(OH)3	2.297e-16	2.427e-16	-15.639	-15.615	0.024	(0)
CrCl2+	1.348e-17	9.971e-18	-16.870	-17.001	-0.131	(0)
CrOHCl2	3.397e-20	3.590e-20	-19.469	-19.445	0.024	(0)
Cr2(OH)2(SO4)2	7.708e-21	8.146e-21	-20.113	-20.089	0.024	(0)
CrO2-	1.475e-23	1.091e-23	-22.831	-22.962	-0.131	(0)
Cr(OH)4-	5.594e-24	4.137e-24	-23.252	-23.383	-0.131	(0)
Cr(6)	0.000e+00					
HCrO4-	0.000e+00	0.000e+00	-44.189	-44.320	-0.131	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-46.884	-47.408	-0.524	(0)
CrO4-2	0.000e+00	0.000e+00	-46.961	-47.569	-0.608	(0)
NaCrO4-	0.000e+00	0.000e+00	-47.408	-47.539	-0.131	(0)
H2CrO4	0.000e+00	0.000e+00	-48.462	-48.438	0.024	(0)
KCrO4-	0.000e+00	0.000e+00	-49.177	-49.308	-0.131	(0)
CrO3Cl-	0.000e+00	0.000e+00	-50.351	-50.482	-0.131	(0)
Cr2O7-2	0.000e+00	0.000e+00	-86.569	-87.093	-0.524	(0)
Cu(1)	3.674e-09					
Cu+	3.633e-09	2.410e-09	-8.440	-8.618	-0.178	(0)
CuCl2-	4.117e-11	2.901e-11	-10.385	-10.537	-0.152	(0)
CuCl3-2	3.211e-14	8.970e-15	-13.493	-14.047	-0.554	(0)
Cu(2)	2.987e-07					
Cu+2	2.371e-07	4.593e-08	-6.625	-7.338	-0.713	(0)
CuSO4	4.243e-08	4.485e-08	-7.372	-7.348	0.024	(0)
CuHCO3+	1.911e-08	1.414e-08	-7.719	-7.850	-0.131	(0)
CuCl+	3.422e-11	2.412e-11	-10.466	-10.618	-0.152	(0)
CuCO3	1.307e-11	1.382e-11	-10.884	-10.860	0.024	(0)
CuOH+	1.163e-12	8.197e-13	-11.934	-12.086	-0.152	(0)
Cu(OH)2	2.893e-15	3.057e-15	-14.539	-14.515	0.024	(0)
CuCl2	2.391e-15	2.527e-15	-14.621	-14.597	0.024	(0)
Cu(CO3)2-2	3.256e-18	9.742e-19	-17.487	-18.011	-0.524	(0)
Cu2(OH)2+2	9.825e-19	2.940e-19	-18.008	-18.532	-0.524	(0)
CuCl3-	2.482e-21	1.749e-21	-20.605	-20.757	-0.152	(0)
Cu(OH)3-	4.455e-25	3.295e-25	-24.351	-24.482	-0.131	(0)
CuCl4-2	6.123e-27	1.710e-27	-26.213	-26.767	-0.554	(0)
Cu(OH)4-2	3.913e-34	1.171e-34	-33.408	-33.931	-0.524	(0)
Fe(2)	7.768e-05					
Fe+2	6.216e-05	1.928e-05	-4.206	-4.715	-0.509	(0)
FeSO4	1.551e-05	1.639e-05	-4.809	-4.785	0.024	(0)
FeOH+	1.497e-11	1.088e-11	-10.825	-10.963	-0.138	(0)
Fe(OH)2	1.564e-19	1.653e-19	-18.806	-18.782	0.024	(0)
Fe(OH)3-	1.508e-26	1.096e-26	-25.822	-25.960	-0.138	(0)
Fe(3)	2.179e-12					
FeSO4+	9.799e-13	7.123e-13	-12.009	-12.147	-0.138	(0)
FeOH+2	7.388e-13	2.064e-13	-12.131	-12.685	-0.554	(0)
Fe(OH)2+	1.659e-13	1.220e-13	-12.780	-12.914	-0.134	(0)
Fe+3	1.484e-13	1.791e-14	-12.828	-13.747	-0.919	(0)
Fe(SO4)2-	1.457e-13	1.077e-13	-12.837	-12.968	-0.131	(0)
FeCl+2	3.777e-16	1.055e-16	-15.423	-15.977	-0.554	(0)
Fe(OH)3	2.420e-18	2.558e-18	-17.616	-17.592	0.024	(0)
FeCl2+	1.265e-19	9.194e-20	-18.898	-19.037	-0.138	(0)
Fe2(OH)2+4	1.429e-22	1.146e-24	-21.845	-23.941	-2.096	(0)
Fe(OH)4-	6.211e-23	4.565e-23	-22.207	-22.341	-0.134	(0)
FeCl3	1.697e-24	1.794e-24	-23.770	-23.746	0.024	(0)
Fe3(OH)4+5	5.499e-32	2.921e-35	-31.260	-34.535	-3.275	(0)
H(0)	4.046e-18					
H2	2.023e-18	2.138e-18	-17.694	-17.670	0.024	(0)
K	4.370e-03					
K+	4.238e-03	2.899e-03	-2.373	-2.538	-0.165	(0)
KSO4-	1.325e-04	9.742e-05	-3.878	-4.011	-0.134	(0)
KCrO4-	0.000e+00	0.000e+00	-49.177	-49.308	-0.131	(0)
Mg	2.545e-02					

Mg+2	1.964e-02	7.124e-03	-1.707	-2.147	-0.441	(0)
MgSO4	5.733e-03	6.059e-03	-2.242	-2.218	0.024	(0)
MgHCO3+	7.817e-05	5.508e-05	-4.107	-4.259	-0.152	(0)
MgCO3	3.603e-10	3.808e-10	-9.443	-9.419	0.024	(0)
MgOH+	2.767e-11	2.088e-11	-10.558	-10.680	-0.122	(0)
Mn(2)	4.675e-06					
Mn+2	3.708e-06	1.150e-06	-5.431	-5.939	-0.509	(0)
MnSO4	9.468e-07	1.001e-06	-6.024	-6.000	0.024	(0)
MnHCO3+	1.938e-08	1.409e-08	-7.713	-7.851	-0.138	(0)
MnCl+	1.248e-09	9.074e-10	-8.904	-9.042	-0.138	(0)
MnOH+	7.255e-14	5.275e-14	-13.139	-13.278	-0.138	(0)
MnCl2	4.550e-14	4.809e-14	-13.342	-13.318	0.024	(0)
MnCl3-	5.818e-18	4.230e-18	-17.235	-17.374	-0.138	(0)
Mn(OH)3-	1.425e-31	1.036e-31	-30.846	-30.985	-0.138	(0)
Mn(3)	2.966e-27					
Mn+3	2.966e-27	3.577e-28	-26.528	-27.446	-0.919	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-81.779	-82.333	-0.554	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-87.548	-87.717	-0.169	(0)
Na	3.009e-01					
Na+	2.937e-01	2.157e-01	-0.532	-0.666	-0.134	(0)
NaSO4-	7.036e-03	5.172e-03	-2.153	-2.286	-0.134	(0)
NaHCO3	7.555e-05	7.985e-05	-4.122	-4.098	0.024	(0)
NaCO3-	3.048e-10	2.240e-10	-9.516	-9.650	-0.134	(0)
NaCrO4-	0.000e+00	0.000e+00	-47.408	-47.539	-0.131	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-57.081	-57.057	0.024	(0)
S(6)	3.505e-02					
SO4-2	1.983e-02	4.783e-03	-1.703	-2.320	-0.618	(0)
NaSO4-	7.036e-03	5.172e-03	-2.153	-2.286	-0.134	(0)
MgSO4	5.733e-03	6.059e-03	-2.242	-2.218	0.024	(0)
AlSO4+	9.855e-04	7.059e-04	-3.006	-3.151	-0.145	(0)
Al(SO4)2-	3.744e-04	2.682e-04	-3.427	-3.572	-0.145	(0)
HSO4-	3.561e-04	2.550e-04	-3.448	-3.593	-0.145	(0)
CaSO4	2.101e-04	2.220e-04	-3.678	-3.654	0.024	(0)
KSO4-	1.325e-04	9.742e-05	-3.878	-4.011	-0.134	(0)
FeSO4	1.551e-05	1.639e-05	-4.809	-4.785	0.024	(0)
MnSO4	9.468e-07	1.001e-06	-6.024	-6.000	0.024	(0)
ZnSO4	2.170e-07	2.294e-07	-6.663	-6.639	0.024	(0)
UO2SO4	1.542e-07	1.629e-07	-6.812	-6.788	0.024	(0)
UO2(SO4)2-2	7.757e-08	2.321e-08	-7.110	-7.634	-0.524	(0)
CuSO4	4.243e-08	4.485e-08	-7.372	-7.348	0.024	(0)
Zn(SO4)2-2	2.980e-08	8.917e-09	-7.526	-8.050	-0.524	(0)
CrOHSO4	8.769e-10	9.268e-10	-9.057	-9.033	0.024	(0)
CrSO4+	3.438e-10	2.543e-10	-9.464	-9.595	-0.131	(0)
FeSO4+	9.799e-13	7.123e-13	-12.009	-12.147	-0.138	(0)
Fe(SO4)2-	1.457e-13	1.077e-13	-12.837	-12.968	-0.131	(0)
U(SO4)2	1.260e-14	1.332e-14	-13.900	-13.876	0.024	(0)
USO4+2	4.795e-16	1.435e-16	-15.319	-15.843	-0.524	(0)
Cr2(OH)2SO4+2	2.412e-16	7.219e-17	-15.618	-16.142	-0.524	(0)
Cr2(OH)2(SO4)2	7.708e-21	8.146e-21	-20.113	-20.089	0.024	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-46.884	-47.408	-0.524	(0)
U(3)	2.506e-31					
U+3	2.506e-31	1.660e-32	-30.601	-31.780	-1.179	(0)
U(4)	3.226e-14					
U(SO4)2	1.260e-14	1.332e-14	-13.900	-13.876	0.024	(0)
U(OH)3+	9.267e-15	6.854e-15	-14.033	-14.164	-0.131	(0)
U(OH)2+2	5.933e-15	1.776e-15	-14.227	-14.751	-0.524	(0)
U(OH)4	3.166e-15	3.346e-15	-14.499	-14.475	0.024	(0)
UOH+3	6.080e-16	4.027e-17	-15.216	-16.395	-1.179	(0)
USO4+2	4.795e-16	1.435e-16	-15.319	-15.843	-0.524	(0)
U(OH)5-	1.928e-16	1.426e-16	-15.715	-15.846	-0.131	(0)
U+4	1.294e-17	1.038e-19	-16.888	-18.984	-2.096	(0)
UCl+3	6.657e-21	4.409e-22	-20.177	-21.356	-1.179	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-71.748	-82.358	-10.610	(0)

U(5)	5.487e-09					
UO2+	5.487e-09	4.058e-09	-8.261	-8.392	-0.131	(0)
U(6)	5.001e-07					
UO2+2	2.225e-07	6.658e-08	-6.653	-7.177	-0.524	(0)
UO2SO4	1.542e-07	1.629e-07	-6.812	-6.788	0.024	(0)
UO2(SO4)2-2	7.757e-08	2.321e-08	-7.110	-7.634	-0.524	(0)
UO2CO3	4.442e-08	4.694e-08	-7.352	-7.328	0.024	(0)
UO2OH+	1.306e-09	9.660e-10	-8.884	-9.015	-0.131	(0)
UO2(CO3)2-2	7.017e-11	2.100e-11	-10.154	-10.678	-0.524	(0)
UO2Cl+	2.915e-11	2.156e-11	-10.535	-10.666	-0.131	(0)
(UO2)2(OH)2+2	1.069e-13	3.198e-14	-12.971	-13.495	-0.524	(0)
UO2(CO3)3-4	3.533e-15	2.833e-17	-14.452	-16.548	-2.096	(0)
(UO2)3(OH)5+	1.845e-21	1.365e-21	-20.734	-20.865	-0.131	(0)
Zn	9.281e-07					
Zn+2	6.598e-07	2.046e-07	-6.181	-6.689	-0.509	(0)
ZnSO4	2.170e-07	2.294e-07	-6.663	-6.639	0.024	(0)
Zn(SO4)2-2	2.980e-08	8.917e-09	-7.526	-8.050	-0.524	(0)
ZnHCO3+	2.139e-08	1.582e-08	-7.670	-7.801	-0.131	(0)
ZnCl+	1.525e-10	1.074e-10	-9.817	-9.969	-0.152	(0)
ZnCO3	2.163e-12	2.286e-12	-11.665	-11.641	0.024	(0)
ZnOH+	5.413e-13	4.004e-13	-12.267	-12.398	-0.131	(0)
ZnCl2	2.076e-14	2.195e-14	-13.683	-13.659	0.024	(0)
ZnOHCl	2.232e-15	2.359e-15	-14.651	-14.627	0.024	(0)
Zn(CO3)2-2	9.150e-18	2.738e-18	-17.039	-17.563	-0.524	(0)
Zn(OH)2	7.782e-18	8.224e-18	-17.109	-17.085	0.024	(0)
ZnCl3-	6.817e-18	4.804e-18	-17.166	-17.318	-0.152	(0)
ZnCl4-2	1.678e-21	4.686e-22	-20.775	-21.329	-0.554	(0)
Zn(OH)3-	6.276e-26	4.642e-26	-25.202	-25.333	-0.131	(0)
Zn(OH)4-2	4.388e-35	1.313e-35	-34.358	-34.882	-0.524	(0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-4.48	5.90	10.38	Al(OH)3
Al2O3	-11.15	11.83	22.98	Al2O3
Al4(OH)10SO4	-7.91	14.79	22.70	Al4(OH)10SO4
AlOHSO4	0.31	-2.92	-3.23	AlOHSO4
AlumK	-5.96	-11.13	-5.17	KAl(SO4)2:12H2O
Alunite	2.12	0.78	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-1.33	-5.96	-4.64	CaSO4
Antlerite	-19.62	-11.33	8.29	Cu3(OH)4SO4
Aragonite	-5.56	-13.89	-8.34	CaCO3
Artinite	-17.67	-8.07	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-15.97	-8.63	7.34	Cu2(OH)3Cl
Azurite	-19.09	-36.01	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-6.22	-0.67	5.54	UO2(OH)2
Bianchite	-7.29	-9.06	-1.76	ZnSO4:6H2O
Birnessite	-28.51	-10.42	18.09	MnO2
Bixbyite	-34.75	-35.36	-0.61	Mn2O3
Boehmite	-2.67	5.91	8.58	AlOOH
Brochantite	-27.50	-12.16	15.34	Cu4(OH)6SO4
Brucite	-12.44	4.36	16.79	Mg(OH)2
CaCrO4	-48.95	-51.21	-2.27	CaCrO4
Calcite	-5.42	-13.89	-8.47	CaCO3
CH4(g)	-34.73	-74.83	-40.10	CH4
Chalcanthite	-7.06	-9.70	-2.64	CuSO4:5H2O
CO2(g)	1.40	-16.76	-18.16	CO2
Cr(OH)2	-23.61	-12.79	10.82	Cr(OH)2
Cr(OH)3(A)	-7.73	-8.48	-0.75	Cr(OH)3
Cr(OH)3(C)	-10.19	-8.48	1.70	Cr(OH)3
Cr2O3	-13.55	-16.94	-3.39	Cr2O3
CrCl2	-42.58	-26.71	15.87	CrCl2
CrCl3	-42.88	-29.37	13.51	CrCl3
CrMetal	-59.54	-27.29	32.24	Cr
CrO3	-50.87	-54.08	-3.21	CrO3

Cu(OH)2	-9.47	-0.83	8.64	Cu(OH)2
Cu2SO4	-17.61	-19.56	-1.95	Cu2SO4
CuCO3	-7.96	-17.59	-9.63	CuCO3
CuCrO4	-49.43	-54.91	-5.48	CuCrO4
CuMetal	-3.86	-12.62	-8.76	Cu
CuOCuSO4	-22.01	-10.48	11.53	CuO:CuSO4
CupricFerrite	-14.67	-8.79	5.88	CuFe2O4
Cuprite	-9.17	-10.72	-1.55	Cu2O
CuprousFerrite	-0.42	-9.34	-8.92	CuFeO2
CuSO4	-12.67	-9.66	3.01	CuSO4
Diaspore	-0.96	5.91	6.87	AlOOH
Dolomite	-9.29	-26.29	-17.00	CaMg(CO3)2
Epsomite	-2.39	-4.53	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-3.04	-6.08	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-38.03	-34.45	3.58	Fe2(SO4)3
Fe3(OH)8	-26.42	-6.20	20.22	Fe3(OH)8
FeCr2O4	-14.25	-15.15	-0.90	FeCr2O4
Ferrihydrite	-8.88	-3.99	4.89	Fe(OH)3
Gibbsite(C)	-2.87	5.90	8.77	Al(OH)3
Goethite	-4.48	-3.98	0.50	FeOOH
Goslarite	-7.11	-9.07	-1.96	ZnSO4:7H2O
Gummite	-11.07	-0.67	10.40	UO3
Gypsum	-1.37	-5.98	-4.61	CaSO4:2H2O
Halite	-5.96	-4.38	1.58	NaCl
Hausmannite	-45.31	16.23	61.54	Mn3O4
Hematite	-3.95	-7.96	-4.01	Fe2O3
Hercynite	-13.53	13.63	27.16	FeAl2O4
Huntite	-21.12	-51.09	-29.97	CaMg3(CO3)4
Hydromagnesite	-36.51	-45.27	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-17.54	-29.64	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-14.11	-28.91	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-15.84	-27.04	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-91.05	-106.73	-15.67	K2Cr2O7
K2CrO4	-52.65	-52.64	0.01	K2CrO4
Langite	-28.96	-12.17	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-5.35	-3.98	1.37	FeOOH
Lime	-29.93	2.87	32.80	CaO
Maghemite	-14.35	-7.96	6.39	Fe2O3
Magnesite	-4.37	-12.40	-8.03	MgCO3
Magnetite	-9.90	-6.16	3.74	Fe3O4
Malachite	-13.24	-18.42	-5.18	Cu2(OH)2CO3
Manganite	-17.45	-17.68	-0.24	MnOOH
Melanothallite	-18.49	-14.76	3.73	CuCl2
Melanterite	-4.62	-7.09	-2.47	FeSO4:7H2O
Mg-Ferrite	-20.36	-3.59	16.77	MgFe2O4
MgCr2O4	-24.66	-12.58	12.08	MgCr2O4
MgCrO4	-55.10	-49.72	5.38	MgCrO4
Mirabilite	-2.62	-3.74	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-56.14	-61.85	-5.71	Mn2(SO4)3
MnCl2:4H2O	-16.10	-13.39	2.71	MnCl2:4H2O
MnSO4	-10.93	-8.26	2.67	MnSO4
Na2Cr2O7	-93.09	-102.98	-9.90	Na2Cr2O7
Na2CrO4	-52.16	-48.90	3.26	Na2CrO4
Nantokite	-5.57	-12.33	-6.76	CuCl
Natron	-10.36	-11.67	-1.31	Na2CO3:10H2O
Nesquehonite	-6.80	-12.42	-5.62	MgCO3:3H2O
Nsutite	-27.93	-10.42	17.50	MnO2
O2(g)	-54.10	29.02	83.12	O2
Periclase	-17.15	4.36	21.51	MgO
Portlandite	-19.81	2.86	22.68	Ca(OH)2
Pyrocroite	-14.52	0.56	15.09	Mn(OH)2
Pyrolusite	-26.28	-10.42	15.86	MnO2
Rhodochrosite	-5.78	-16.19	-10.41	MnCO3
Rutherfordine	-2.97	-17.43	-14.46	UO2CO3
Schoepite	-6.09	-0.68	5.40	UO2(OH)2:H2O
Siderite	-4.42	-14.97	-10.55	FeCO3

Smithsonite	-6.94	-16.94	-10.00	ZnCO3
Spinel	-20.14	16.20	36.33	MgAl2O4
Tenorite	-8.45	-0.83	7.62	CuO
Thenardite	-3.47	-3.65	-0.18	Na2SO4
Thermonatrite	-11.72	-11.59	0.13	Na2CO3:H2O
U3O8(C)	-9.97	11.14	21.11	U3O8
U4O9(C)	-5.95	-9.33	-3.38	U4O9
UO2(am)	-6.89	-5.96	0.93	UO2
UO3(C)	-8.38	-0.67	7.72	UO3
Uraninite	-1.26	-5.96	-4.70	UO2
Zincite	-11.32	-0.18	11.14	ZnO
Zincosite	-12.02	-9.01	3.01	ZnSO4
Zn(BO2)2	-15.20	-6.91	8.29	Zn(BO2)2
Zn(OH)2(A)	-12.64	-0.19	12.45	Zn(OH)2
Zn(OH)2(B)	-11.94	-0.19	11.75	Zn(OH)2
Zn(OH)2(C)	-12.39	-0.19	12.20	Zn(OH)2
Zn(OH)2(E)	-11.69	-0.19	11.50	Zn(OH)2
Zn(OH)2(G)	-11.90	-0.19	11.71	Zn(OH)2
Zn2(OH)2SO4	-16.70	-9.20	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-22.53	-7.33	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-37.22	-18.20	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-37.97	-9.57	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-53.35	-14.85	38.50	Zn5(OH)8Cl2
ZnCl2	-21.14	-14.11	7.03	ZnCl2
ZnCO3:H2O	-6.69	-16.95	-10.26	ZnCO3:H2O
ZnMetal	-40.45	-14.69	25.76	Zn
ZnO(Active)	-11.49	-0.18	11.31	ZnO
ZnSO4:H2O	-8.45	-9.02	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 4.

-----------------------------Solution composition-----------------------------

Elements	Molality	Moles
Al	3.298e-03	3.298e-03
Alkalinity	8.285e-06	8.285e-06
B	4.574e-04	4.574e-04
Ca	8.577e-04	8.577e-04
Cl	3.137e-04	3.137e-04
Cr	3.889e-08	3.889e-08
Cu	3.819e-07	3.819e-07
Fe	4.526e-07	4.526e-07
K	4.809e-03	4.809e-03
Mg	2.470e-02	2.470e-02
Mn	6.331e-06	6.331e-06
Na	3.193e-01	3.193e-01
S(6)	2.905e-02	2.905e-02
U	5.692e-07	5.692e-07
Zn	7.780e-06	7.780e-06

----------------------------Description of solution----------------------------

pH	=	3.510
pe	=	4.000
Activity of water	=	0.990
Ionic strength (mol/kgw)	=	2.448e-01
Mass of water (kg)	=	1.000e+00
Total carbon (mol/kg)	=	2.191e-01
Total CO2 (mol/kg)	=	2.191e-01
Temperature (°C)	=	25.00
Electrical balance (eq)	=	3.267e-01
Percent error, 100*(Cat-|An|)/(Cat+|An|)	=	80.53

Iterations = 13
Total H = 1.114520e+02
Total O = 5.628103e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	3.913e-04	3.090e-04	-3.408	-3.510	-0.102	0.00
OH-	4.661e-11	3.218e-11	-10.332	-10.492	-0.161	(0)
H2O	5.551e+01	9.900e-01	1.744	-0.004	0.000	18.07
Al	3.298e-03					
Al+3	1.745e-03	2.087e-04	-2.758	-3.680	-0.922	(0)
AlSO4+	1.172e-03	8.378e-04	-2.931	-3.077	-0.146	(0)
Al(SO4)2-	3.568e-04	2.551e-04	-3.448	-3.593	-0.146	(0)
AlOH+2	2.359e-05	6.842e-06	-4.627	-5.165	-0.538	(0)
Al(OH)2+	2.319e-07	1.701e-07	-6.635	-6.769	-0.134	(0)
Al(OH)3	6.486e-10	6.862e-10	-9.188	-9.164	0.024	(0)
Al(OH)4-	3.075e-13	2.198e-13	-12.512	-12.658	-0.146	(0)
B	4.574e-04					
H3BO3	4.574e-04	4.839e-04	-3.340	-3.315	0.024	(0)
H2BO3-	1.359e-09	8.992e-10	-8.867	-9.046	-0.179	(0)
C(4)	2.191e-01					
H2CO3	2.185e-01	2.312e-01	-0.660	-0.636	0.024	(0)
HCO3-	4.540e-04	3.332e-04	-3.343	-3.477	-0.134	(0)
NaHCO3	4.072e-05	4.308e-05	-4.390	-4.366	0.024	(0)
MgHCO3+	4.029e-05	2.833e-05	-4.395	-4.548	-0.153	(0)
CaHCO3+	1.074e-06	8.005e-07	-5.969	-6.097	-0.128	(0)
ZnHCO3+	9.725e-08	7.186e-08	-7.012	-7.143	-0.131	(0)
UO2CO3	5.118e-08	5.414e-08	-7.291	-7.266	0.024	(0)
MnHCO3+	1.384e-08	1.005e-08	-7.859	-7.998	-0.139	(0)
CuHCO3+	1.289e-08	9.523e-09	-7.890	-8.021	-0.131	(0)
MgCO3	3.291e-10	3.482e-10	-9.483	-9.458	0.024	(0)
NaCO3-	2.929e-10	2.149e-10	-9.533	-9.668	-0.134	(0)
CO3-2	1.740e-10	5.047e-11	-9.759	-10.297	-0.538	(0)
UO2(CO3)2-2	7.317e-11	2.182e-11	-10.136	-10.661	-0.525	(0)
ZnCO3	1.746e-11	1.847e-11	-10.758	-10.733	0.024	(0)
CaCO3	1.572e-11	1.663e-11	-10.804	-10.779	0.024	(0)
CuCO3	1.564e-11	1.655e-11	-10.806	-10.781	0.024	(0)
UO2(CO3)3-4	3.354e-15	2.653e-17	-14.474	-16.576	-2.102	(0)
Zn(CO3)2-2	6.683e-17	1.993e-17	-16.175	-16.700	-0.525	(0)
Cu(CO3)2-2	3.526e-18	1.051e-18	-17.453	-17.978	-0.525	(0)
Ca	8.577e-04					
Ca+2	6.855e-04	2.319e-04	-3.164	-3.635	-0.471	(0)
CaSO4	1.712e-04	1.811e-04	-3.767	-3.742	0.024	(0)
CaHCO3+	1.074e-06	8.005e-07	-5.969	-6.097	-0.128	(0)
CaCO3	1.572e-11	1.663e-11	-10.804	-10.779	0.024	(0)
CaOH+	2.516e-13	1.875e-13	-12.599	-12.727	-0.128	(0)
Cl	3.137e-04					
Cl-	3.137e-04	2.141e-04	-3.503	-3.669	-0.166	(0)
MnCl+	1.931e-09	1.401e-09	-8.714	-8.853	-0.139	(0)
ZnCl+	1.503e-09	1.057e-09	-8.823	-8.976	-0.153	(0)
CuCl2-	6.603e-11	4.643e-11	-10.180	-10.333	-0.153	(0)
CuCl+	5.003e-11	3.518e-11	-10.301	-10.454	-0.153	(0)
UO2Cl+	4.098e-11	3.028e-11	-10.387	-10.519	-0.131	(0)
CrCl+2	9.234e-13	2.754e-13	-12.035	-12.560	-0.525	(0)
ZnCl2	2.239e-13	2.369e-13	-12.650	-12.625	0.024	(0)
MnCl2	7.701e-14	8.148e-14	-13.113	-13.089	0.024	(0)
CuCl3-2	5.679e-14	1.575e-14	-13.246	-13.803	-0.557	(0)
ZnOHCl	3.937e-14	4.166e-14	-13.405	-13.380	0.024	(0)
CuCl2	3.822e-15	4.044e-15	-14.418	-14.393	0.024	(0)
ZnCl3-	8.092e-17	5.690e-17	-16.092	-16.245	-0.153	(0)
CrCl2+	1.554e-17	1.149e-17	-16.808	-16.940	-0.131	(0)
MnCl3-	1.083e-17	7.863e-18	-16.965	-17.104	-0.139	(0)
FeCl+2	2.520e-18	6.991e-19	-17.599	-18.155	-0.557	(0)

CrOHCl2	7.015e-20	7.421e-20	-19.154	-19.130	0.024	(0)
ZnCl4-2	2.196e-20	6.091e-21	-19.658	-20.215	-0.557	(0)
CuCl3-	4.368e-21	3.072e-21	-20.360	-20.513	-0.153	(0)
UCl+3	9.252e-22	6.080e-23	-21.034	-22.216	-1.182	(0)
FeCl2+	9.210e-22	6.684e-22	-21.036	-21.175	-0.139	(0)
FeCl3	1.352e-26	1.431e-26	-25.869	-25.844	0.024	(0)
CuCl4-2	1.188e-26	3.295e-27	-25.925	-26.482	-0.557	(0)
CrO3Cl-	0.000e+00	0.000e+00	-48.818	-48.949	-0.131	(0)
Cr(2)	1.635e-19					
Cr+2	1.635e-19	4.876e-20	-18.786	-19.312	-0.525	(0)
Cr(3)	3.889e-08					
Cr+3	3.494e-08	2.297e-09	-7.457	-8.639	-1.182	(0)
Cr(OH)+2	2.467e-09	7.357e-10	-8.608	-9.133	-0.525	(0)
CrOHSO4	1.206e-09	1.276e-09	-8.919	-8.894	0.024	(0)
CrSO4+	2.639e-10	1.950e-10	-9.579	-9.710	-0.131	(0)
Cr(OH)2+	7.651e-12	5.654e-12	-11.116	-11.248	-0.131	(0)
CrCl+2	9.234e-13	2.754e-13	-12.035	-12.560	-0.525	(0)
Cr(OH)3	1.269e-15	1.343e-15	-14.897	-14.872	0.024	(0)
Cr2(OH)2SO4+2	5.721e-16	1.706e-16	-15.243	-15.768	-0.525	(0)
CrCl2+	1.554e-17	1.149e-17	-16.808	-16.940	-0.131	(0)
CrOHCl2	7.015e-20	7.421e-20	-19.154	-19.130	0.024	(0)
Cr2(OH)2(SO4)2	1.458e-20	1.543e-20	-19.836	-19.812	0.024	(0)
CrO2-	1.439e-22	1.064e-22	-21.842	-21.973	-0.131	(0)
Cr(OH)4-	5.559e-23	4.108e-23	-22.255	-22.386	-0.131	(0)
Cr(6)	0.000e+00					
HCrO4-	0.000e+00	0.000e+00	-42.442	-42.574	-0.131	(0)
CrO4-2	0.000e+00	0.000e+00	-44.961	-45.572	-0.612	(0)
NaCrO4-	0.000e+00	0.000e+00	-45.383	-45.515	-0.131	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-45.485	-46.011	-0.525	(0)
H2CrO4	0.000e+00	0.000e+00	-46.966	-46.941	0.024	(0)
KCrO4-	0.000e+00	0.000e+00	-47.137	-47.268	-0.131	(0)
CrO3Cl-	0.000e+00	0.000e+00	-48.818	-48.949	-0.131	(0)
Cr2O7-2	0.000e+00	0.000e+00	-83.078	-83.603	-0.525	(0)
Cu(1)	4.910e-09					
Cu+	4.844e-09	3.204e-09	-8.315	-8.494	-0.179	(0)
CuCl2-	6.603e-11	4.643e-11	-10.180	-10.333	-0.153	(0)
CuCl3-2	5.679e-14	1.575e-14	-13.246	-13.803	-0.557	(0)
Cu(2)	3.769e-07					
Cu+2	3.188e-07	6.106e-08	-6.496	-7.214	-0.718	(0)
CuSO4	4.517e-08	4.779e-08	-7.345	-7.321	0.024	(0)
CuHCO3+	1.289e-08	9.523e-09	-7.890	-8.021	-0.131	(0)
CuCl+	5.003e-11	3.518e-11	-10.301	-10.454	-0.153	(0)
CuCO3	1.564e-11	1.655e-11	-10.806	-10.781	0.024	(0)
CuOH+	2.782e-12	1.956e-12	-11.556	-11.709	-0.153	(0)
Cu(OH)2	1.237e-14	1.309e-14	-13.907	-13.883	0.024	(0)
CuCl2	3.822e-15	4.044e-15	-14.418	-14.393	0.024	(0)
Cu2(OH)2+2	5.614e-18	1.674e-18	-17.251	-17.776	-0.525	(0)
Cu(CO3)2-2	3.526e-18	1.051e-18	-17.453	-17.978	-0.525	(0)
CuCl3-	4.368e-21	3.072e-21	-20.360	-20.513	-0.153	(0)
Cu(OH)3-	3.428e-24	2.533e-24	-23.465	-23.596	-0.131	(0)
CuCl4-2	1.188e-26	3.295e-27	-25.925	-26.482	-0.557	(0)
Cu(OH)4-2	5.417e-33	1.615e-33	-32.266	-32.792	-0.525	(0)
Fe(2)	4.526e-07					
Fe+2	3.776e-07	1.164e-07	-6.423	-6.934	-0.511	(0)
FeSO4	7.500e-08	7.935e-08	-7.125	-7.100	0.024	(0)
FeOH+	1.625e-13	1.179e-13	-12.789	-12.928	-0.139	(0)
Fe(OH)2	3.039e-21	3.215e-21	-20.517	-20.493	0.024	(0)
Fe(OH)3-	5.273e-28	3.827e-28	-27.278	-27.417	-0.139	(0)
Fe(3)	1.752e-14					
FeOH+2	8.063e-15	2.237e-15	-14.094	-14.650	-0.557	(0)
FeSO4+	4.751e-15	3.448e-15	-14.323	-14.462	-0.139	(0)
Fe(OH)2+	3.233e-15	2.373e-15	-14.490	-14.625	-0.134	(0)
Fe+3	9.041e-16	1.081e-16	-15.044	-15.966	-0.922	(0)
Fe(SO4)2-	5.656e-16	4.179e-16	-15.248	-15.379	-0.131	(0)
FeCl+2	2.520e-18	6.991e-19	-17.599	-18.155	-0.557	(0)
Fe(OH)3	8.441e-20	8.930e-20	-19.074	-19.049	0.024	(0)

FeCl2+	9.210e-22	6.684e-22	-21.036	-21.175	-0.139	(0)
Fe(OH)4-	3.898e-24	2.861e-24	-23.409	-23.544	-0.134	(0)
Fe2(OH)2+4	1.702e-26	1.346e-28	-25.769	-27.871	-2.102	(0)
FeCl3	1.352e-26	1.431e-26	-25.869	-25.844	0.024	(0)
Fe3(OH)4+5	1.284e-37	0.000e+00	-36.891	-40.176	-3.284	(0)
H(0)	1.278e-18					
H2	6.390e-19	6.761e-19	-18.194	-18.170	0.024	(0)
K	4.809e-03					
K+	4.692e-03	3.202e-03	-2.329	-2.495	-0.166	(0)
KSO4-	1.175e-04	8.623e-05	-3.930	-4.064	-0.134	(0)
KCrO4-	0.000e+00	0.000e+00	-47.137	-47.268	-0.131	(0)
Mg	2.470e-02					
Mg+2	2.000e-02	7.231e-03	-1.699	-2.141	-0.442	(0)
MgSO4	4.659e-03	4.929e-03	-2.332	-2.307	0.024	(0)
MgHCO3+	4.029e-05	2.833e-05	-4.395	-4.548	-0.153	(0)
MgCO3	3.291e-10	3.482e-10	-9.483	-9.458	0.024	(0)
MgOH+	5.047e-11	3.805e-11	-10.297	-10.420	-0.123	(0)
Mn(2)	6.331e-06					
Mn+2	5.248e-06	1.618e-06	-5.280	-5.791	-0.511	(0)
MnSO4	1.067e-06	1.129e-06	-5.972	-5.947	0.024	(0)
MnHCO3+	1.384e-08	1.005e-08	-7.859	-7.998	-0.139	(0)
MnCl+	1.931e-09	1.401e-09	-8.714	-8.853	-0.139	(0)
MnOH+	1.836e-13	1.332e-13	-12.736	-12.875	-0.139	(0)
MnCl2	7.701e-14	8.148e-14	-13.113	-13.089	0.024	(0)
MnCl3-	1.083e-17	7.863e-18	-16.965	-17.104	-0.139	(0)
Mn(OH)3-	1.162e-30	8.430e-31	-29.935	-30.074	-0.139	(0)
Mn(3)	4.209e-27					
Mn+3	4.209e-27	5.035e-28	-26.376	-27.298	-0.922	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-79.612	-80.169	-0.557	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-85.383	-85.553	-0.170	(0)
Na	3.193e-01					
Na+	3.132e-01	2.298e-01	-0.504	-0.639	-0.135	(0)
NaSO4-	6.015e-03	4.414e-03	-2.221	-2.355	-0.134	(0)
NaHCO3	4.072e-05	4.308e-05	-4.390	-4.366	0.024	(0)
NaCO3-	2.929e-10	2.149e-10	-9.533	-9.668	-0.134	(0)
NaCrO4-	0.000e+00	0.000e+00	-45.383	-45.515	-0.131	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-56.073	-56.049	0.024	(0)
S(6)	2.905e-02					
SO4-2	1.604e-02	3.833e-03	-1.795	-2.416	-0.622	(0)
NaSO4-	6.015e-03	4.414e-03	-2.221	-2.355	-0.134	(0)
MgSO4	4.659e-03	4.929e-03	-2.332	-2.307	0.024	(0)
AlSO4+	1.172e-03	8.378e-04	-2.931	-3.077	-0.146	(0)
Al(SO4)2-	3.568e-04	2.551e-04	-3.448	-3.593	-0.146	(0)
CaSO4	1.712e-04	1.811e-04	-3.767	-3.742	0.024	(0)
HSO4-	1.608e-04	1.150e-04	-3.794	-3.939	-0.146	(0)
KSO4-	1.175e-04	8.623e-05	-3.930	-4.064	-0.134	(0)
ZnSO4	1.558e-06	1.648e-06	-5.807	-5.783	0.024	(0)
MnSO4	1.067e-06	1.129e-06	-5.972	-5.947	0.024	(0)
Zn(SO4)2-2	1.722e-07	5.136e-08	-6.764	-7.289	-0.525	(0)
UO2SO4	1.580e-07	1.672e-07	-6.801	-6.777	0.024	(0)
FeSO4	7.500e-08	7.935e-08	-7.125	-7.100	0.024	(0)
UO2(SO4)2-2	6.401e-08	1.909e-08	-7.194	-7.719	-0.525	(0)
CuSO4	4.517e-08	4.779e-08	-7.345	-7.321	0.024	(0)
CrOHSO4	1.206e-09	1.276e-09	-8.919	-8.894	0.024	(0)
CrSO4+	2.639e-10	1.950e-10	-9.579	-9.710	-0.131	(0)
FeSO4+	4.751e-15	3.448e-15	-14.323	-14.462	-0.139	(0)
U(SO4)2	1.016e-15	1.075e-15	-14.993	-14.968	0.024	(0)
Cr2(OH)2SO4+2	5.721e-16	1.706e-16	-15.243	-15.768	-0.525	(0)
Fe(SO4)2-	5.656e-16	4.179e-16	-15.248	-15.379	-0.131	(0)
USO4+2	4.846e-17	1.445e-17	-16.315	-16.840	-0.525	(0)
Cr2(OH)2(SO4)2	1.458e-20	1.543e-20	-19.836	-19.812	0.024	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-45.485	-46.011	-0.525	(0)
U(3)	3.175e-32					

U+3	3.175e-32	2.086e-33	-31.498	-32.681	-1.182 (0)
U(4)	1.493e-14				
U(OH)3+	6.739e-15	4.980e-15	-14.171	-14.303	-0.131 (0)
U(OH)4	4.125e-15	4.364e-15	-14.385	-14.360	0.024 (0)
U(OH)2+2	2.410e-15	7.188e-16	-14.618	-15.143	-0.525 (0)
U(SO4)2	1.016e-15	1.075e-15	-14.993	-14.968	0.024 (0)
U(OH)5-	4.517e-16	3.338e-16	-15.345	-15.476	-0.131 (0)
UOH+3	1.382e-16	9.084e-18	-15.859	-17.042	-1.182 (0)
USO4+2	4.846e-17	1.445e-17	-16.315	-16.840	-0.525 (0)
U+4	1.649e-18	1.304e-20	-17.783	-19.885	-2.102 (0)
UCl+3	9.252e-22	6.080e-23	-21.034	-22.216	-1.182 (0)
U6(OH)15+9	0.000e+00	0.000e+00	-73.312	-83.952	-10.641 (0)
U(5)	7.031e-09				
UO2+	7.031e-09	5.196e-09	-8.153	-8.284	-0.131 (0)
U(6)	5.622e-07				
UO2+2	2.858e-07	8.524e-08	-6.544	-7.069	-0.525 (0)
UO2SO4	1.580e-07	1.672e-07	-6.801	-6.777	0.024 (0)
UO2(SO4)2-2	6.401e-08	1.909e-08	-7.194	-7.719	-0.525 (0)
UO2CO3	5.118e-08	5.414e-08	-7.291	-7.266	0.024 (0)
UO2OH+	3.003e-09	2.220e-09	-8.522	-8.654	-0.131 (0)
UO2(CO3)2-2	7.317e-11	2.182e-11	-10.136	-10.661	-0.525 (0)
UO2Cl+	4.098e-11	3.028e-11	-10.387	-10.519	-0.131 (0)
(UO2)2(OH)2+2	5.662e-13	1.689e-13	-12.247	-12.772	-0.525 (0)
UO2(CO3)3-4	3.354e-15	2.653e-17	-14.474	-16.576	-2.102 (0)
(UO2)3(OH)5+	7.218e-20	5.334e-20	-19.142	-19.273	-0.131 (0)
Zn	7.780e-06				
Zn+2	5.951e-06	1.834e-06	-5.225	-5.736	-0.511 (0)
ZnSO4	1.558e-06	1.648e-06	-5.807	-5.783	0.024 (0)
Zn(SO4)2-2	1.722e-07	5.136e-08	-6.764	-7.289	-0.525 (0)
ZnHCO3+	9.725e-08	7.186e-08	-7.012	-7.143	-0.131 (0)
ZnCl+	1.503e-09	1.057e-09	-8.823	-8.976	-0.153 (0)
ZnCO3	1.746e-11	1.847e-11	-10.758	-10.733	0.024 (0)
ZnOH+	8.720e-12	6.444e-12	-11.060	-11.191	-0.131 (0)
ZnCl2	2.239e-13	2.369e-13	-12.650	-12.625	0.024 (0)
ZnOHCl	3.937e-14	4.166e-14	-13.405	-13.380	0.024 (0)
Zn(OH)2	2.245e-16	2.376e-16	-15.649	-15.624	0.024 (0)
ZnCl3-	8.092e-17	5.690e-17	-16.092	-16.245	-0.153 (0)
Zn(CO3)2-2	6.683e-17	1.993e-17	-16.175	-16.700	-0.525 (0)
ZnCl4-2	2.196e-20	6.091e-21	-19.658	-20.215	-0.557 (0)
Zn(OH)3-	3.257e-24	2.406e-24	-23.487	-23.619	-0.131 (0)
Zn(OH)4-2	4.097e-33	1.222e-33	-32.388	-32.913	-0.525 (0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-3.54	6.84	10.38	Al(OH)3
Al2O3	-9.29	13.69	22.98	Al2O3
Al4(OH)10SO4	-4.78	17.92	22.70	Al4(OH)10SO4
AlOHSO4	0.64	-2.59	-3.23	AlOHSO4
AlumK	-5.89	-11.06	-5.17	KAl(SO4)2:12H2O
Alunite	4.01	2.66	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-1.41	-6.05	-4.64	CaSO4
Antlerite	-18.33	-10.04	8.29	Cu3(OH)4SO4
Aragonite	-5.60	-13.93	-8.34	CaCO3
Artinite	-17.18	-7.58	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-14.92	-7.58	7.34	Cu2(OH)3Cl
Azurite	-18.31	-35.23	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.60	-0.06	5.54	UO2(OH)2
Bianchite	-6.41	-8.18	-1.76	ZnSO4:6H2O
Birnessite	-27.36	-9.27	18.09	MnO2
Bixbyite	-32.94	-33.55	-0.61	Mn2O3
Boehmite	-1.74	6.84	8.58	AlOOH
Brochantite	-25.58	-10.24	15.34	Cu4(OH)6SO4
Brucite	-11.92	4.87	16.79	Mg(OH)2
CaCrO4	-46.94	-49.21	-2.27	CaCrO4

Calcite	-5.46	-13.93	-8.47	CaCO3
CH4(g)	-37.28	-77.38	-40.10	CH4
Chalcanthite	-7.01	-9.65	-2.64	CuSO4:5H2O
CO2(g)	0.85	-17.31	-18.16	CO2
Cr(OH)2	-23.12	-12.30	10.82	Cr(OH)2
Cr(OH)3(A)	-6.99	-7.74	-0.75	Cr(OH)3
Cr(OH)3(C)	-9.44	-7.74	1.70	Cr(OH)3
Cr2O3	-12.08	-15.47	-3.39	Cr2O3
CrCl2	-42.52	-26.65	15.87	CrCl2
CrCl3	-42.77	-29.27	13.51	CrCl3
CrMetal	-59.56	-27.31	32.24	Cr
CrO3	-49.38	-52.59	-3.21	CrO3
Cu(OH)2	-8.84	-0.20	8.64	Cu(OH)2
Cu2SO4	-17.45	-19.40	-1.95	Cu2SO4
CuCO3	-7.88	-17.51	-9.63	CuCO3
CuCrO4	-47.31	-52.79	-5.48	CuCrO4
CuMetal	-3.73	-12.49	-8.76	Cu
CuOCuSO4	-21.36	-9.83	11.53	CuO:CuSO4
CupricFerrite	-16.96	-11.08	5.88	CuFe2O4
Cuprite	-8.42	-9.97	-1.55	Cu2O
CuprousFerrite	-1.51	-10.43	-8.92	CuFeO2
CuSO4	-12.64	-9.63	3.01	CuSO4
Diaspore	-0.03	6.84	6.87	AlOOH
Dolomite	-9.37	-26.37	-17.00	CaMg(CO3)2
Epsomite	-2.45	-4.59	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-4.56	-7.60	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-42.76	-39.18	3.58	Fe2(SO4)3
Fe3(OH)8	-31.04	-10.82	20.22	Fe3(OH)8
FeCr2O4	-14.49	-15.39	-0.90	FeCr2O4
Ferrihydrite	-10.34	-5.45	4.89	Fe(OH)3
Gibbsite(C)	-1.93	6.84	8.77	Al(OH)3
Goethite	-5.94	-5.44	0.50	FeOOH
Goslarite	-6.22	-8.18	-1.96	ZnSO4:7H2O
Gummite	-10.46	-0.05	10.40	UO3
Gypsum	-1.45	-6.06	-4.61	CaSO4:2H2O
Halite	-5.89	-4.31	1.58	NaCl
Hausmannite	-42.85	18.69	61.54	Mn3O4
Hematite	-6.88	-10.89	-4.01	Fe2O3
Hercynite	-13.39	13.77	27.16	FeAl2O4
Huntite	-21.28	-51.25	-29.97	CaMg3(CO3)4
Hydromagnesite	-36.13	-44.90	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-23.11	-35.21	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-19.39	-34.19	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-21.14	-32.34	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-87.48	-103.15	-15.67	K2Cr2O7
K2CrO4	-50.57	-50.56	0.01	K2CrO4
Langite	-27.03	-10.24	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-6.82	-5.44	1.37	FeOOH
Lime	-29.42	3.38	32.80	CaO
Maghemite	-17.27	-10.89	6.39	Fe2O3
Magnesite	-4.41	-12.44	-8.03	MgCO3
Magnetite	-14.54	-10.80	3.74	Fe3O4
Malachite	-12.53	-17.71	-5.18	Cu2(OH)2CO3
Manganite	-16.54	-16.78	-0.24	MnOOH
Melanothallite	-18.28	-14.55	3.73	CuCl2
Melanterite	-6.91	-9.38	-2.47	FeSO4:7H2O
Mg-Ferrite	-22.78	-6.01	16.77	MgFe2O4
MgCr2O4	-22.68	-10.60	12.08	MgCr2O4
MgCrO4	-53.09	-47.71	5.38	MgCrO4
Mirabilite	-2.62	-3.74	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-56.13	-61.85	-5.71	Mn2(SO4)3
MnCl2:4H2O	-15.86	-13.15	2.71	MnCl2:4H2O
MnSO4	-10.88	-8.21	2.67	MnSO4
Na2Cr2O7	-89.54	-99.44	-9.90	Na2Cr2O7
Na2CrO4	-50.11	-46.85	3.26	Na2CrO4
Nantokite	-5.40	-12.16	-6.76	CuCl

Natron	-10.31	-11.62	-1.31	Na2CO3:10H2O
Nesquehonite	-6.83	-12.45	-5.62	MgCO3:3H2O
Nsutite	-26.77	-9.27	17.50	MnO2
O2(g)	-53.09	30.03	83.12	O2
Periclase	-16.64	4.87	21.51	MgO
Portlandite	-19.30	3.38	22.68	Ca(OH)2
Pyrocroite	-13.87	1.22	15.09	Mn(OH)2
Pyrolusite	-25.13	-9.27	15.86	MnO2
Rhodochrosite	-5.68	-16.09	-10.41	MnCO3
Rutherfordine	-2.90	-17.37	-14.46	UO2CO3
Schoepite	-5.47	-0.06	5.40	UO2(OH)2:H2O
Siderite	-6.68	-17.23	-10.55	FeCO3
Smithsonite	-6.03	-16.03	-10.00	ZnCO3
Spinel	-17.77	18.56	36.33	MgAl2O4
Tenorite	-7.82	-0.20	7.62	CuO
Thenardite	-3.51	-3.69	-0.18	Na2SO4
Thermonatrite	-11.70	-11.58	0.13	Na2CO3:H2O
U3O8(C)	-8.64	12.47	21.11	U3O8
U4O9(C)	-5.01	-8.40	-3.38	U4O9
UO2(am)	-6.79	-5.85	0.93	UO2
UO3(C)	-7.77	-0.05	7.72	UO3
Uraninite	-1.15	-5.85	-4.70	UO2
Zincite	-9.86	1.28	11.14	ZnO
Zincosite	-11.16	-8.15	3.01	ZnSO4
Zn(BO2)2	-13.63	-5.34	8.29	Zn(BO2)2
Zn(OH)2(A)	-11.18	1.27	12.45	Zn(OH)2
Zn(OH)2(B)	-10.48	1.27	11.75	Zn(OH)2
Zn(OH)2(C)	-10.93	1.27	12.20	Zn(OH)2
Zn(OH)2(E)	-10.23	1.27	11.50	Zn(OH)2
Zn(OH)2(G)	-10.44	1.27	11.71	Zn(OH)2
Zn2(OH)2SO4	-14.38	-6.88	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-19.83	-4.63	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-34.05	-15.03	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-32.73	-4.33	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-46.48	-7.98	38.50	Zn5(OH)8Cl2
ZnCl2	-20.11	-13.08	7.03	ZnCl2
ZnCO3:H2O	-5.78	-16.04	-10.26	ZnCO3:H2O
ZnMetal	-39.49	-13.74	25.76	Zn
ZnO(Active)	-10.03	1.28	11.31	ZnO
ZnSO4:H2O	-7.59	-8.16	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 5.

----------Solution composition----------

Elements	Molality	Moles
Al	8.397e-04	8.397e-04
Alkalinity	8.288e-06	8.288e-06
B	4.435e-04	4.435e-04
Ca	2.625e-03	2.625e-03
Cl	3.138e-04	3.138e-04
Cr	3.891e-08	3.891e-08
Cu	3.024e-07	3.024e-07
Fe	2.282e-05	2.282e-05
K	3.777e-03	3.777e-03
Mg	2.667e-02	2.667e-02
Mn	1.257e-05	1.257e-05
Na	3.344e-01	3.344e-01
S(6)	2.959e-02	2.959e-02
U	4.419e-07	4.419e-07
Zn	1.578e-06	1.578e-06

----------Description of solution----------

pH	=	3.980
pe	=	4.000
Activity of water	=	0.993
Ionic strength (mol/kgw)	=	2.524e-01
Mass of water (kg)	=	1.000e+00
Total carbon (mol/kg)	=	2.451e-02
Total CO2 (mol/kg)	=	2.451e-02
Temperature (°C)	=	25.00
Electrical balance (eq)	=	3.398e-01
Percent error, 100*(Cat-|An|)/(Cat+|An|)	=	80.65
Iterations	=	14
Total H	=	1.110628e+02
Total O	=	5.569945e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	1.328e-04	1.047e-04	-3.877	-3.980	-0.103	0.00
OH-	1.385e-10	9.527e-11	-9.859	-10.021	-0.162	(0)
H2O	5.551e+01	9.930e-01	1.744	-0.003	0.000	18.07
Al	8.397e-04					
Al+3	4.323e-04	5.103e-05	-3.364	-4.292	-0.928	(0)
AlSO4+	2.965e-04	2.114e-04	-3.528	-3.675	-0.147	(0)
Al(SO4)2-	9.317e-05	6.641e-05	-4.031	-4.178	-0.147	(0)
AlOH+2	1.725e-05	4.952e-06	-4.763	-5.305	-0.542	(0)
Al(OH)2+	4.980e-07	3.646e-07	-6.303	-6.438	-0.135	(0)
Al(OH)3	4.107e-09	4.352e-09	-8.387	-8.361	0.025	(0)
Al(OH)4-	5.791e-12	4.127e-12	-11.237	-11.384	-0.147	(0)
B	4.435e-04					
H3BO3	4.435e-04	4.700e-04	-3.353	-3.328	0.025	(0)
H2BO3-	3.914e-09	2.578e-09	-8.407	-8.589	-0.181	(0)
C(4)	2.451e-02					
H2CO3	2.433e-02	2.579e-02	-1.614	-1.589	0.025	(0)
HCO3-	1.498e-04	1.097e-04	-3.824	-3.960	-0.135	(0)
MgHCO3+	1.424e-05	9.981e-06	-4.846	-5.001	-0.154	(0)
NaHCO3	1.398e-05	1.481e-05	-4.855	-4.829	0.025	(0)
CaHCO3+	1.074e-06	7.983e-07	-5.969	-6.098	-0.129	(0)
UO2CO3	3.754e-08	3.978e-08	-7.426	-7.400	0.025	(0)
MnHCO3+	8.974e-09	6.495e-09	-8.047	-8.187	-0.140	(0)
ZnHCO3+	6.462e-09	4.769e-09	-8.190	-8.322	-0.132	(0)
CuHCO3+	3.377e-09	2.492e-09	-8.471	-8.603	-0.132	(0)
MgCO3	3.417e-10	3.621e-10	-9.466	-9.441	0.025	(0)
NaCO3-	2.980e-10	2.181e-10	-9.526	-9.661	-0.135	(0)
CO3-2	1.708e-10	4.902e-11	-9.768	-10.310	-0.542	(0)
UO2(CO3)2-2	5.250e-11	1.558e-11	-10.280	-10.808	-0.528	(0)
CaCO3	4.617e-11	4.893e-11	-10.336	-10.310	0.025	(0)
CuCO3	1.206e-11	1.278e-11	-10.919	-10.893	0.025	(0)
ZnCO3	3.414e-12	3.618e-12	-11.467	-11.442	0.025	(0)
UO2(CO3)3-4	2.374e-15	1.839e-17	-14.624	-16.735	-2.111	(0)
Zn(CO3)2-2	1.278e-17	3.792e-18	-16.893	-17.421	-0.528	(0)
Cu(CO3)2-2	2.659e-18	7.889e-19	-17.575	-18.103	-0.528	(0)
Ca	2.625e-03					
Ca+2	2.089e-03	7.025e-04	-2.680	-3.153	-0.473	(0)
CaSO4	5.341e-04	5.661e-04	-3.272	-3.247	0.025	(0)
CaHCO3+	1.074e-06	7.983e-07	-5.969	-6.098	-0.129	(0)
CaCO3	4.617e-11	4.893e-11	-10.336	-10.310	0.025	(0)
CaOH+	2.261e-12	1.681e-12	-11.646	-11.774	-0.129	(0)
Cl	3.138e-04					
Cl-	3.138e-04	2.133e-04	-3.503	-3.671	-0.168	(0)
MnCl+	3.790e-09	2.743e-09	-8.421	-8.562	-0.140	(0)
ZnCl+	3.030e-10	2.124e-10	-9.519	-9.673	-0.154	(0)
CuCl2-	5.232e-11	3.667e-11	-10.281	-10.436	-0.154	(0)

CuCl+	3.977e-11	2.788e-11	-10.400	-10.555	-0.154	(0)
UO2Cl+	3.093e-11	2.283e-11	-10.510	-10.642	-0.132	(0)
CrCl+2	7.705e-13	2.286e-13	-12.113	-12.641	-0.528	(0)
MnCl2	1.500e-13	1.590e-13	-12.824	-12.799	0.025	(0)
CuCl3-2	4.519e-14	1.240e-14	-13.345	-13.907	-0.562	(0)
ZnCl2	4.477e-14	4.745e-14	-13.349	-13.324	0.025	(0)
ZnOHCl	2.338e-14	2.478e-14	-13.631	-13.606	0.025	(0)
CuCl2	3.014e-15	3.194e-15	-14.521	-14.496	0.025	(0)
FeCl+2	1.264e-16	3.469e-17	-15.898	-16.460	-0.562	(0)
MnCl3-	2.113e-17	1.529e-17	-16.675	-16.816	-0.140	(0)
ZnCl3-	1.621e-17	1.136e-17	-16.790	-16.945	-0.154	(0)
CrCl2+	1.288e-17	9.502e-18	-16.890	-17.022	-0.132	(0)
CrOHCl2	1.715e-19	1.818e-19	-18.766	-18.741	0.025	(0)
FeCl2+	4.568e-20	3.306e-20	-19.340	-19.481	-0.140	(0)
ZnCl4-2	4.415e-21	1.212e-21	-20.355	-20.917	-0.562	(0)
CuCl3-	3.450e-21	2.418e-21	-20.462	-20.617	-0.154	(0)
UCl+3	9.245e-24	6.005e-25	-23.034	-24.221	-1.187	(0)
FeCl3	6.656e-25	7.054e-25	-24.177	-24.152	0.025	(0)
CuCl4-2	9.421e-27	2.585e-27	-26.026	-26.587	-0.562	(0)
CrO3Cl-	0.000e+00	0.000e+00	-46.074	-46.206	-0.132	(0)
Cr(2)	1.369e-19					
Cr+2	1.369e-19	4.061e-20	-18.864	-19.391	-0.528	(0)
Cr(3)	3.891e-08					
Cr+3	2.945e-08	1.913e-09	-7.531	-8.718	-1.187	(0)
Cr(OH)+2	6.114e-09	1.814e-09	-8.214	-8.741	-0.528	(0)
CrOHSO4	3.062e-09	3.245e-09	-8.514	-8.489	0.025	(0)
CrSO4+	2.271e-10	1.676e-10	-9.644	-9.776	-0.132	(0)
Cr(OH)2+	5.591e-11	4.126e-11	-10.253	-10.384	-0.132	(0)
CrCl+2	7.705e-13	2.286e-13	-12.113	-12.641	-0.528	(0)
Cr(OH)3	2.737e-14	2.901e-14	-13.563	-13.537	0.025	(0)
Cr2(OH)2SO4+2	3.607e-15	1.070e-15	-14.443	-14.971	-0.528	(0)
CrCl2+	1.288e-17	9.502e-18	-16.890	-17.022	-0.132	(0)
CrOHCl2	1.715e-19	1.818e-19	-18.766	-18.741	0.025	(0)
Cr2(OH)2(SO4)2	9.422e-20	9.986e-20	-19.026	-19.001	0.025	(0)
CrO2-	9.160e-21	6.760e-21	-20.038	-20.170	-0.132	(0)
Cr(OH)4-	3.560e-21	2.627e-21	-20.449	-20.581	-0.132	(0)
Cr(6)	5.947e-40					
HCrO4-	5.947e-40	4.389e-40	-39.226	-39.358	-0.132	(0)
CrO4-2	0.000e+00	0.000e+00	-41.269	-41.887	-0.617	(0)
NaCrO4-	0.000e+00	0.000e+00	-41.678	-41.810	-0.132	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-42.725	-43.253	-0.528	(0)
KCrO4-	0.000e+00	0.000e+00	-43.557	-43.689	-0.132	(0)
H2CrO4	0.000e+00	0.000e+00	-44.220	-44.195	0.025	(0)
CrO3Cl-	0.000e+00	0.000e+00	-46.074	-46.206	-0.132	(0)
Cr2O7-2	0.000e+00	0.000e+00	-76.645	-77.173	-0.528	(0)
Cu(1)	3.921e-09					
Cu+	3.869e-09	2.548e-09	-8.412	-8.594	-0.181	(0)
CuCl2-	5.232e-11	3.667e-11	-10.281	-10.436	-0.154	(0)
CuCl3-2	4.519e-14	1.240e-14	-13.345	-13.907	-0.562	(0)
Cu(2)	2.985e-07					
Cu+2	2.581e-07	4.855e-08	-6.588	-7.314	-0.726	(0)
CuSO4	3.699e-08	3.921e-08	-7.432	-7.407	0.025	(0)
CuHCO3+	3.377e-09	2.492e-09	-8.471	-8.603	-0.132	(0)
CuCl+	3.977e-11	2.788e-11	-10.400	-10.555	-0.154	(0)
CuCO3	1.206e-11	1.278e-11	-10.919	-10.893	0.025	(0)
CuOH+	6.569e-12	4.604e-12	-11.183	-11.337	-0.154	(0)
Cu(OH)2	8.607e-14	9.122e-14	-13.065	-13.040	0.025	(0)
CuCl2	3.014e-15	3.194e-15	-14.521	-14.496	0.025	(0)
Cu2(OH)2+2	3.126e-17	9.275e-18	-16.505	-17.033	-0.528	(0)
Cu(CO3)2-2	2.659e-18	7.889e-19	-17.575	-18.103	-0.528	(0)
CuCl3-	3.450e-21	2.418e-21	-20.462	-20.617	-0.154	(0)
Cu(OH)3-	7.079e-23	5.225e-23	-22.150	-22.282	-0.132	(0)
CuCl4-2	9.421e-27	2.585e-27	-26.026	-26.587	-0.562	(0)
Cu(OH)4-2	3.325e-31	9.863e-32	-30.478	-31.006	-0.528	(0)
Fe(2)	2.282e-05					
Fe+2	1.897e-05	5.796e-06	-4.722	-5.237	-0.515	(0)

FeSO4	3.847e-06	4.077e-06	-5.415	-5.390	0.025	(0)
FeOH+	2.402e-11	1.738e-11	-10.619	-10.760	-0.140	(0)
Fe(OH)2	1.324e-18	1.403e-18	-17.878	-17.853	0.025	(0)
Fe(OH)3-	6.830e-25	4.943e-25	-24.166	-24.306	-0.140	(0)
Fe(3)	2.936e-12					
Fe(OH)2+	1.414e-12	1.035e-12	-11.849	-11.985	-0.135	(0)
FeOH+2	1.201e-12	3.297e-13	-11.920	-12.482	-0.562	(0)
FeSO4+	2.448e-13	1.771e-13	-12.611	-12.752	-0.140	(0)
Fe+3	4.561e-14	5.385e-15	-13.341	-14.269	-0.928	(0)
Fe(SO4)2-	3.002e-14	2.216e-14	-13.523	-13.654	-0.132	(0)
FeCl+2	1.264e-16	3.469e-17	-15.898	-16.460	-0.562	(0)
Fe(OH)3	1.088e-16	1.154e-16	-15.963	-15.938	0.025	(0)
FeCl2+	4.568e-20	3.306e-20	-19.340	-19.481	-0.140	(0)
Fe(OH)4-	1.494e-20	1.094e-20	-19.826	-19.961	-0.135	(0)
Fe2(OH)2+4	3.777e-22	2.926e-24	-21.423	-23.534	-2.111	(0)
FeCl3	6.656e-25	7.054e-25	-24.177	-24.152	0.025	(0)
Fe3(OH)4+5	1.258e-30	6.329e-34	-29.900	-33.199	-3.298	(0)
H(0)	1.465e-19					
H2	7.324e-20	7.762e-20	-19.135	-19.110	0.025	(0)
K	3.777e-03					
K+	3.682e-03	2.503e-03	-2.434	-2.602	-0.168	(0)
KSO4-	9.503e-05	6.956e-05	-4.022	-4.158	-0.135	(0)
KCrO4-	0.000e+00	0.000e+00	-43.557	-43.689	-0.132	(0)
Mg	2.667e-02					
Mg+2	2.152e-02	7.740e-03	-1.667	-2.111	-0.444	(0)
MgSO4	5.137e-03	5.444e-03	-2.289	-2.264	0.025	(0)
MgHCO3+	1.424e-05	9.981e-06	-4.846	-5.001	-0.154	(0)
MgCO3	3.417e-10	3.621e-10	-9.466	-9.441	0.025	(0)
MgOH+	1.603e-10	1.206e-10	-9.795	-9.919	-0.124	(0)
Mn(2)	1.257e-05					
Mn+2	1.040e-05	3.178e-06	-4.983	-5.498	-0.515	(0)
MnSO4	2.158e-06	2.288e-06	-5.666	-5.641	0.025	(0)
MnHCO3+	8.974e-09	6.495e-09	-8.047	-8.187	-0.140	(0)
MnCl+	3.790e-09	2.743e-09	-8.421	-8.562	-0.140	(0)
MnOH+	1.070e-12	7.747e-13	-11.970	-12.111	-0.140	(0)
MnCl2	1.500e-13	1.590e-13	-12.824	-12.799	0.025	(0)
MnCl3-	2.113e-17	1.529e-17	-16.675	-16.816	-0.140	(0)
Mn(OH)3-	5.935e-29	4.296e-29	-28.227	-28.367	-0.140	(0)
Mn(3)	8.377e-27					
Mn+3	8.377e-27	9.890e-28	-26.077	-27.005	-0.928	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-75.548	-76.110	-0.562	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-81.323	-81.494	-0.171	(0)
Na	3.344e-01					
Na+	3.279e-01	2.400e-01	-0.484	-0.620	-0.135	(0)
NaSO4-	6.500e-03	4.758e-03	-2.187	-2.323	-0.135	(0)
NaHCO3	1.398e-05	1.481e-05	-4.855	-4.829	0.025	(0)
NaCO3-	2.980e-10	2.181e-10	-9.526	-9.661	-0.135	(0)
NaCrO4-	0.000e+00	0.000e+00	-41.678	-41.810	-0.132	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-54.191	-54.166	0.025	(0)
S(6)	2.959e-02					
SO4-2	1.678e-02	3.955e-03	-1.775	-2.403	-0.627	(0)
NaSO4-	6.500e-03	4.758e-03	-2.187	-2.323	-0.135	(0)
MgSO4	5.137e-03	5.444e-03	-2.289	-2.264	0.025	(0)
CaSO4	5.341e-04	5.661e-04	-3.272	-3.247	0.025	(0)
AlSO4+	2.965e-04	2.114e-04	-3.528	-3.675	-0.147	(0)
KSO4-	9.503e-05	6.956e-05	-4.022	-4.158	-0.135	(0)
Al(SO4)2-	9.317e-05	6.641e-05	-4.031	-4.178	-0.147	(0)
HSO4-	5.638e-05	4.019e-05	-4.249	-4.396	-0.147	(0)
FeSO4	3.847e-06	4.077e-06	-5.415	-5.390	0.025	(0)
MnSO4	2.158e-06	2.288e-06	-5.666	-5.641	0.025	(0)
ZnSO4	3.236e-07	3.430e-07	-6.490	-6.465	0.025	(0)
UO2SO4	1.231e-07	1.305e-07	-6.910	-6.884	0.025	(0)
UO2(SO4)2-2	5.182e-08	1.537e-08	-7.286	-7.813	-0.528	(0)

Zn(SO4)2-2	3.717e-08	1.103e-08	-7.430	-7.958	-0.528	(0)
CuSO4	3.699e-08	3.921e-08	-7.432	-7.407	0.025	(0)
CrOHSO4	3.062e-09	3.245e-09	-8.514	-8.489	0.025	(0)
CrSO4+	2.271e-10	1.676e-10	-9.644	-9.776	-0.132	(0)
FeSO4+	2.448e-13	1.771e-13	-12.611	-12.752	-0.140	(0)
Fe(SO4)2-	3.002e-14	2.216e-14	-13.523	-13.654	-0.132	(0)
Cr2(OH)2SO4+2	3.607e-15	1.070e-15	-14.443	-14.971	-0.528	(0)
U(SO4)2	1.070e-17	1.135e-17	-16.970	-16.945	0.025	(0)
USO4+2	4.982e-19	1.478e-19	-18.303	-18.830	-0.528	(0)
Cr2(OH)2(SO4)2	9.422e-20	9.986e-20	-19.026	-19.001	0.025	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-42.725	-43.253	-0.528	(0)
U(3)	3.183e-34					
U+3	3.183e-34	2.068e-35	-33.497	-34.685	-1.187	(0)
U(4)	6.113e-15					
U(OH)4	3.134e-15	3.321e-15	-14.504	-14.479	0.025	(0)
U(OH)3+	1.735e-15	1.280e-15	-14.761	-14.893	-0.132	(0)
U(OH)5-	1.019e-15	7.520e-16	-14.992	-15.124	-0.132	(0)
U(OH)2+2	2.104e-16	6.243e-17	-15.677	-16.205	-0.528	(0)
U(SO4)2	1.070e-17	1.135e-17	-16.970	-16.945	0.025	(0)
UOH+3	4.103e-18	2.665e-19	-17.387	-18.574	-1.187	(0)
USO4+2	4.982e-19	1.478e-19	-18.303	-18.830	-0.528	(0)
U+4	1.669e-20	1.293e-22	-19.778	-21.889	-2.111	(0)
UCl+3	9.245e-24	6.005e-25	-23.034	-24.221	-1.187	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-78.219	-88.906	-10.686	(0)
U(5)	5.325e-09					
UO2+	5.325e-09	3.930e-09	-8.274	-8.406	-0.132	(0)
U(6)	4.366e-07					
UO2+2	2.173e-07	6.447e-08	-6.663	-7.191	-0.528	(0)
UO2SO4	1.231e-07	1.305e-07	-6.910	-6.884	0.025	(0)
UO2(SO4)2-2	5.182e-08	1.537e-08	-7.286	-7.813	-0.528	(0)
UO2CO3	3.754e-08	3.978e-08	-7.426	-7.400	0.025	(0)
UO2OH+	6.734e-09	4.970e-09	-8.172	-8.304	-0.132	(0)
UO2(CO3)2-2	5.250e-11	1.558e-11	-10.280	-10.808	-0.528	(0)
UO2Cl+	3.093e-11	2.283e-11	-10.510	-10.642	-0.132	(0)
(UO2)2(OH)2+2	2.854e-12	8.466e-13	-11.545	-12.072	-0.528	(0)
UO2(CO3)3-4	2.374e-15	1.839e-17	-14.624	-16.735	-2.111	(0)
(UO2)3(OH)5+	7.109e-18	5.247e-18	-17.148	-17.280	-0.132	(0)
Zn	1.578e-06					
Zn+2	1.211e-06	3.699e-07	-5.917	-6.432	-0.515	(0)
ZnSO4	3.236e-07	3.430e-07	-6.490	-6.465	0.025	(0)
Zn(SO4)2-2	3.717e-08	1.103e-08	-7.430	-7.958	-0.528	(0)
ZnHCO3+	6.462e-09	4.769e-09	-8.190	-8.322	-0.132	(0)
ZnCl+	3.030e-10	2.124e-10	-9.519	-9.673	-0.154	(0)
ZnOH+	5.211e-12	3.846e-12	-11.283	-11.415	-0.132	(0)
ZnCO3	3.414e-12	3.618e-12	-11.467	-11.442	0.025	(0)
ZnCl2	4.477e-14	4.745e-14	-13.349	-13.324	0.025	(0)
ZnOHCl	2.338e-14	2.478e-14	-13.631	-13.606	0.025	(0)
Zn(OH)2	3.960e-16	4.197e-16	-15.402	-15.377	0.025	(0)
ZnCl3-	1.621e-17	1.136e-17	-16.790	-16.945	-0.154	(0)
Zn(CO3)2-2	1.278e-17	3.792e-18	-16.893	-17.421	-0.528	(0)
ZnCl4-2	4.415e-21	1.212e-21	-20.355	-20.917	-0.562	(0)
Zn(OH)3-	1.706e-23	1.259e-23	-22.768	-22.900	-0.132	(0)
Zn(OH)4-2	6.377e-32	1.892e-32	-31.195	-31.723	-0.528	(0)

----------Saturation indices----------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-2.74	7.64	10.38	Al(OH)3
Al2O3	-7.69	15.29	22.98	Al2O3
Al4(OH)10SO4	-2.50	20.20	22.70	Al4(OH)10SO4
AlOHSO4	0.51	-2.72	-3.23	AlOHSO4
AlumK	-6.57	-11.74	-5.17	KAl(SO4)2:12H2O
Alunite	4.92	3.58	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-0.92	-5.56	-4.64	CaSO4
Antlerite	-16.73	-8.44	8.29	Cu3(OH)4SO4

Aragonite	-5.13	-13.46	-8.34	CaCO3
Artinite	-16.19	-6.59	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-13.71	-6.37	7.34	Cu2(OH)3Cl
Azurite	-17.69	-34.61	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-4.78	0.76	5.54	UO2(OH)2
Bianchite	-7.09	-8.85	-1.76	ZnSO4:6H2O
Birnessite	-25.18	-7.09	18.09	MnO2
Bixbyite	-29.53	-30.14	-0.61	Mn2O3
Boehmite	-0.94	7.64	8.58	AlOOH
Brochantite	-23.14	-7.80	15.34	Cu4(OH)6SO4
Brucite	-10.95	5.84	16.79	Mg(OH)2
CaCrO4	-42.77	-45.04	-2.27	CaCrO4
Calcite	-4.99	-13.46	-8.47	CaCO3
CH4(g)	-42.00	-82.10	-40.10	CH4
Chalcanthite	-7.09	-9.73	-2.64	CuSO4:5H2O
CO2(g)	-0.11	-18.27	-18.16	CO2
Cr(OH)2	-22.26	-11.44	10.82	Cr(OH)2
Cr(OH)3(A)	-5.66	-6.41	-0.75	Cr(OH)3
Cr(OH)3(C)	-8.11	-6.41	1.70	Cr(OH)3
Cr2O3	-9.41	-12.81	-3.39	Cr2O3
CrCl2	-42.60	-26.73	15.87	CrCl2
CrCl3	-42.86	-29.35	13.51	CrCl3
CrMetal	-59.64	-27.39	32.24	Cr
CrO3	-46.63	-49.84	-3.21	CrO3
Cu(OH)2	-8.00	0.64	8.64	Cu(OH)2
Cu2SO4	-17.64	-19.59	-1.95	Cu2SO4
CuCO3	-7.99	-17.62	-9.63	CuCO3
CuCrO4	-43.72	-49.20	-5.48	CuCrO4
CuMetal	-3.83	-12.59	-8.76	Cu
CuOCuSO4	-20.60	-9.07	11.53	CuO:CuSO4
CupricFerrite	-9.90	-4.02	5.88	CuFe2O4
Cuprite	-7.68	-9.23	-1.55	Cu2O
CuprousFerrite	1.97	-6.95	-8.92	CuFeO2
CuSO4	-12.73	-9.72	3.01	CuSO4
Diaspore	0.77	7.64	6.87	AlOOH
Dolomite	-8.88	-25.88	-17.00	CaMg(CO3)2
Epsomite	-2.40	-4.54	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-1.59	-4.63	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-39.33	-35.75	3.58	Fe2(SO4)3
Fe3(OH)8	-22.18	-1.96	20.22	Fe3(OH)8
FeCr2O4	-9.18	-10.09	-0.90	FeCr2O4
Ferrihydrite	-7.23	-2.34	4.89	Fe(OH)3
Gibbsite(C)	-1.13	7.64	8.77	Al(OH)3
Goethite	-2.83	-2.33	0.50	FeOOH
Goslarite	-6.90	-8.86	-1.96	ZnSO4:7H2O
Gummite	-9.64	0.77	10.40	UO3
Gypsum	-0.95	-5.56	-4.61	CaSO4:2H2O
Halite	-5.87	-4.29	1.58	NaCl
Hausmannite	-38.21	23.33	61.54	Mn3O4
Hematite	-0.66	-4.67	-4.01	Fe2O3
Hercynite	-9.16	18.01	27.16	FeAl2O4
Huntite	-20.76	-50.73	-29.97	CaMg3(CO3)4
Hydromagnesite	-35.09	-43.85	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-15.63	-27.73	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-11.55	-26.35	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-13.17	-24.37	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-81.26	-96.93	-15.67	K2Cr2O7
K2CrO4	-47.10	-47.09	0.01	K2CrO4
Langite	-24.59	-7.80	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-3.71	-2.33	1.37	FeOOH
Lime	-27.99	4.80	32.80	CaO
Maghemite	-11.05	-4.67	6.39	Fe2O3
Magnesite	-4.39	-12.42	-8.03	MgCO3
Magnetite	-5.68	-1.95	3.74	Fe3O4
Malachite	-11.80	-16.98	-5.18	Cu2(OH)2CO3
Manganite	-14.83	-15.07	-0.24	MnOOH

Melanothallite	-18.39	-14.66	3.73	CuCl2
Melanterite	-5.19	-7.66	-2.47	FeSO4:7H2O
Mg-Ferrite	-15.59	1.18	16.77	MgFe2O4
MgCr2O4	-19.04	-6.96	12.08	MgCr2O4
MgCrO4	-49.38	-44.00	5.38	MgCrO4
Mirabilite	-2.56	-3.67	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-55.51	-61.22	-5.71	Mn2(SO4)3
MnCl2:4H2O	-15.56	-12.85	2.71	MnCl2:4H2O
MnSO4	-10.57	-7.90	2.67	MnSO4
Na2Cr2O7	-83.07	-92.97	-9.90	Na2Cr2O7
Na2CrO4	-46.39	-43.13	3.26	Na2CrO4
Nantokite	-5.50	-12.26	-6.76	CuCl
Natron	-10.27	-11.58	-1.31	Na2CO3:10H2O
Nesquehonite	-6.81	-12.43	-5.62	MgCO3:3H2O
Nsutite	-24.59	-7.09	17.50	MnO2
O2(g)	-51.21	31.91	83.12	O2
Periclase	-15.66	5.85	21.51	MgO
Portlandite	-17.87	4.80	22.68	Ca(OH)2
Pyrocroite	-12.63	2.46	15.09	Mn(OH)2
Pyrolusite	-22.95	-7.09	15.86	MnO2
Rhodochrosite	-5.40	-15.81	-10.41	MnCO3
Rutherfordine	-3.04	-17.50	-14.46	UO2CO3
Schoepite	-4.64	0.76	5.40	UO2(OH)2:H2O
Siderite	-5.00	-15.55	-10.55	FeCO3
Smithsonite	-6.74	-16.74	-10.00	ZnCO3
Spinel	-15.20	21.13	36.33	MgAl2O4
Tenorite	-6.98	0.64	7.62	CuO
Thenardite	-3.46	-3.64	-0.18	Na2SO4
Thermonatrite	-11.68	-11.55	0.13	Na2CO3:H2O
U3O8(C)	-7.12	13.99	21.11	U3O8
U4O9(C)	-4.56	-7.94	-3.38	U4O9
UO2(am)	-6.91	-5.97	0.93	UO2
UO3(C)	-6.95	0.77	7.72	UO3
Uraninite	-1.27	-5.97	-4.70	UO2
Zincite	-9.61	1.53	11.14	ZnO
Zincosite	-11.84	-8.83	3.01	ZnSO4
Zn(BO2)2	-13.41	-5.12	8.29	Zn(BO2)2
Zn(OH)2(A)	-10.93	1.52	12.45	Zn(OH)2
Zn(OH)2(B)	-10.23	1.52	11.75	Zn(OH)2
Zn(OH)2(C)	-10.68	1.52	12.20	Zn(OH)2
Zn(OH)2(E)	-9.98	1.52	11.50	Zn(OH)2
Zn(OH)2(G)	-10.19	1.52	11.71	Zn(OH)2
Zn2(OH)2SO4	-14.81	-7.31	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-19.80	-4.60	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-35.16	-16.14	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-32.67	-4.27	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-46.19	-7.69	38.50	Zn5(OH)8Cl2
ZnCl2	-20.80	-13.77	7.03	ZnCl2
ZnCO3:H2O	-6.48	-16.74	-10.26	ZnCO3:H2O
ZnMetal	-40.19	-14.43	25.76	Zn
ZnO(Active)	-9.78	1.53	11.31	ZnO
ZnSO4:H2O	-8.27	-8.84	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 6.

----------Solution composition----------

Elements	Molality	Moles
Al	1.557e-03	1.557e-03
Alkalinity	8.295e-06	8.295e-06
B	5.038e-04	5.038e-04
Ca	2.576e-03	2.576e-03

Cl	3.712e-04	3.712e-04
Cr	5.841e-08	5.841e-08
Cu	4.142e-07	4.142e-07
Fe	2.900e-04	2.900e-04
K	4.531e-03	4.531e-03
Mg	3.139e-02	3.139e-02
Mn	1.651e-05	1.651e-05
Na	3.694e-01	3.694e-01
S(6)	2.793e-02	2.793e-02
U	4.295e-07	4.295e-07
Zn	1.471e-06	1.471e-06

----------Description of solution----------

pH	= 3.790
pe	= 4.000
Activity of water	= 0.992
Ionic strength (mol/kgw)	= 2.789e-01
Mass of water (kg)	= 1.000e+00
Total carbon (mol/kg)	= 5.441e-02
Total CO2 (mol/kg)	= 5.441e-02
Temperature (°C)	= 25.00
Electrical balance (eq)	= 3.910e-01
Percent error, 100*(Cat-|An|)/(Cat+|An|)	= 84.02
Iterations	= 13
Total H	= 1.111228e+02
Total O	= 5.578269e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	2.066e-04	1.622e-04	-3.685	-3.790	-0.105	0.00
OH-	9.037e-11	6.144e-11	-10.044	-10.212	-0.168	(0)
H2O	5.551e+01	9.918e-01	1.744	-0.004	0.000	18.07
Al	1.557e-03					
Al+3	8.906e-04	1.007e-04	-3.050	-3.997	-0.946	(0)
AlSO4+	5.068e-04	3.577e-04	-3.295	-3.446	-0.151	(0)
Al(SO4)2-	1.365e-04	9.636e-05	-3.865	-4.016	-0.151	(0)
AlOH+2	2.270e-05	6.304e-06	-4.644	-5.200	-0.556	(0)
Al(OH)2+	4.123e-07	2.993e-07	-6.385	-6.524	-0.139	(0)
Al(OH)3	2.161e-09	2.304e-09	-8.665	-8.637	0.028	(0)
Al(OH)4-	1.996e-12	1.409e-12	-11.700	-11.851	-0.151	(0)
B	5.038e-04					
H3BO3	5.038e-04	5.372e-04	-3.298	-3.270	0.028	(0)
H2BO3-	2.932e-09	1.902e-09	-8.533	-8.721	-0.188	(0)
C(4)	5.441e-02					
H2CO3	5.415e-02	5.774e-02	-1.266	-1.239	0.028	(0)
HCO3-	2.184e-04	1.585e-04	-3.661	-3.800	-0.139	(0)
MgHCO3+	2.489e-05	1.726e-05	-4.604	-4.763	-0.159	(0)
NaHCO3	2.211e-05	2.358e-05	-4.655	-4.627	0.028	(0)
CaHCO3+	1.557e-06	1.149e-06	-5.808	-5.940	-0.132	(0)
UO2CO3	3.658e-08	3.901e-08	-7.437	-7.409	0.028	(0)
MnHCO3+	1.718e-08	1.233e-08	-7.765	-7.909	-0.144	(0)
ZnHCO3+	8.840e-09	6.500e-09	-8.054	-8.187	-0.134	(0)
CuHCO3+	6.455e-09	4.745e-09	-8.190	-8.324	-0.134	(0)
MgCO3	3.791e-10	4.043e-10	-9.421	-9.393	0.028	(0)
NaCO3-	3.087e-10	2.241e-10	-9.510	-9.649	-0.139	(0)
CO3-2	1.647e-10	4.576e-11	-9.783	-10.340	-0.556	(0)
UO2(CO3)2-2	4.879e-11	1.425e-11	-10.312	-10.846	-0.534	(0)
CaCO3	4.264e-11	4.547e-11	-10.370	-10.342	0.028	(0)
CuCO3	1.474e-11	1.571e-11	-10.832	-10.804	0.028	(0)
ZnCO3	2.985e-12	3.183e-12	-11.525	-11.497	0.028	(0)
UO2(CO3)3-4	2.156e-15	1.571e-17	-14.666	-16.804	-2.137	(0)
Zn(CO3)2-2	1.066e-17	3.114e-18	-16.972	-17.507	-0.534	(0)

Cu(CO3)2-2	3.098e-18	9.052e-19	-17.509	-18.043	-0.534	(0)
Ca	2.576e-03					
Ca+2	2.122e-03	6.994e-04	-2.673	-3.155	-0.482	(0)
CaSO4	4.531e-04	4.832e-04	-3.344	-3.316	0.028	(0)
CaHCO3+	1.557e-06	1.149e-06	-5.808	-5.940	-0.132	(0)
CaCO3	4.264e-11	4.547e-11	-10.370	-10.342	0.028	(0)
CaOH+	1.463e-12	1.079e-12	-11.835	-11.967	-0.132	(0)
Cl	3.712e-04					
Cl-	3.712e-04	2.492e-04	-3.430	-3.603	-0.173	(0)
MnCl+	5.865e-09	4.208e-09	-8.232	-8.376	-0.144	(0)
ZnCl+	3.373e-10	2.339e-10	-9.472	-9.631	-0.159	(0)
CuCl2-	9.508e-11	6.593e-11	-10.022	-10.181	-0.159	(0)
CuCl+	6.187e-11	4.290e-11	-10.209	-10.368	-0.159	(0)
UO2Cl+	3.811e-11	2.802e-11	-10.419	-10.553	-0.134	(0)
CrCl+2	1.467e-12	4.287e-13	-11.834	-12.368	-0.534	(0)
MnCl2	2.672e-13	2.849e-13	-12.573	-12.545	0.028	(0)
CuCl3-2	9.832e-14	2.604e-14	-13.007	-13.584	-0.577	(0)
ZnCl2	5.725e-14	6.105e-14	-13.242	-13.214	0.028	(0)
ZnOHCl	1.650e-14	1.760e-14	-13.782	-13.755	0.028	(0)
CuCl2	5.385e-15	5.742e-15	-14.269	-14.241	0.028	(0)
FeCl+2	1.944e-15	5.150e-16	-14.711	-15.288	-0.577	(0)
MnCl3-	4.462e-17	3.201e-17	-16.350	-16.495	-0.144	(0)
CrCl2+	2.832e-17	2.082e-17	-16.548	-16.682	-0.134	(0)
ZnCl3-	2.462e-17	1.707e-17	-16.609	-16.768	-0.159	(0)
FeCl2+	7.992e-19	5.733e-19	-18.097	-18.242	-0.144	(0)
CrOHCl2	2.408e-19	2.568e-19	-18.618	-18.590	0.028	(0)
ZnCl4-2	8.033e-21	2.128e-21	-20.095	-20.672	-0.577	(0)
CuCl3-	7.323e-21	5.078e-21	-20.135	-20.294	-0.159	(0)
UCl+3	6.774e-23	4.251e-24	-22.169	-23.371	-1.202	(0)
FeCl3	1.340e-23	1.429e-23	-22.873	-22.845	0.028	(0)
CuCl4-2	2.395e-26	6.343e-27	-25.621	-26.198	-0.577	(0)
CrO3Cl-	0.000e+00	0.000e+00	-46.941	-47.074	-0.134	(0)
Cr(2)	2.231e-19					
Cr+2	2.231e-19	6.520e-20	-18.651	-19.186	-0.534	(0)
Cr(3)	5.841e-08					
Cr+3	4.893e-08	3.071e-09	-7.310	-8.513	-1.202	(0)
Cr(OH)+2	6.427e-09	1.878e-09	-8.192	-8.726	-0.534	(0)
CrOHSO4	2.701e-09	2.880e-09	-8.568	-8.541	0.028	(0)
CrSO4+	3.137e-10	2.307e-10	-9.503	-9.637	-0.134	(0)
Cr(OH)2+	3.747e-11	2.755e-11	-10.426	-10.560	-0.134	(0)
CrCl+2	1.467e-12	4.287e-13	-11.834	-12.368	-0.534	(0)
Cr(OH)3	1.171e-14	1.249e-14	-13.931	-13.903	0.028	(0)
Cr2(OH)2SO4+2	3.365e-15	9.832e-16	-14.473	-15.007	-0.534	(0)
CrCl2+	2.832e-17	2.082e-17	-16.548	-16.682	-0.134	(0)
CrOHCl2	2.408e-19	2.568e-19	-18.618	-18.590	0.028	(0)
Cr2(OH)2(SO4)2	7.378e-20	7.867e-20	-19.132	-19.104	0.028	(0)
CrO2-	2.559e-21	1.881e-21	-20.592	-20.726	-0.134	(0)
Cr(OH)4-	9.921e-22	7.294e-22	-21.003	-21.137	-0.134	(0)
Cr(6)	0.000e+00					
HCrO4-	0.000e+00	0.000e+00	-40.351	-40.484	-0.134	(0)
CrO4-2	0.000e+00	0.000e+00	-42.567	-43.203	-0.636	(0)
NaCrO4-	0.000e+00	0.000e+00	-42.951	-43.085	-0.134	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-43.721	-44.255	-0.534	(0)
KCrO4-	0.000e+00	0.000e+00	-44.797	-44.930	-0.134	(0)
H2CrO4	0.000e+00	0.000e+00	-45.160	-45.132	0.028	(0)
CrO3Cl-	0.000e+00	0.000e+00	-46.941	-47.074	-0.134	(0)
Cr2O7-2	0.000e+00	0.000e+00	-78.891	-79.425	-0.534	(0)
Cu(1)	5.268e-09					
Cu+	5.172e-09	3.356e-09	-8.286	-8.474	-0.188	(0)
CuCl2-	9.508e-11	6.593e-11	-10.022	-10.181	-0.159	(0)
CuCl3-2	9.832e-14	2.604e-14	-13.007	-13.584	-0.577	(0)
Cu(2)	4.089e-07					
Cu+2	3.609e-07	6.395e-08	-6.443	-7.194	-0.752	(0)
CuSO4	4.152e-08	4.428e-08	-7.382	-7.354	0.028	(0)
CuHCO3+	6.455e-09	4.745e-09	-8.190	-8.324	-0.134	(0)
CuCl+	6.187e-11	4.290e-11	-10.209	-10.368	-0.159	(0)

CuCO3	1.474e-11	1.571e-11	-10.832	-10.804	0.028	(0)
CuOH+	5.640e-12	3.911e-12	-11.249	-11.408	-0.159	(0)
Cu(OH)2	4.686e-14	4.997e-14	-13.329	-13.301	0.028	(0)
CuCl2	5.385e-15	5.742e-15	-14.269	-14.241	0.028	(0)
Cu2(OH)2+2	2.291e-17	6.692e-18	-16.640	-17.174	-0.534	(0)
Cu(CO3)2-2	3.098e-18	9.052e-19	-17.509	-18.043	-0.534	(0)
CuCl3-	7.323e-21	5.078e-21	-20.135	-20.294	-0.159	(0)
Cu(OH)3-	2.510e-23	1.846e-23	-22.600	-22.734	-0.134	(0)
CuCl4-2	2.395e-26	6.343e-27	-25.621	-26.198	-0.577	(0)
Cu(OH)4-2	7.690e-32	2.247e-32	-31.114	-31.648	-0.534	(0)
Fe(2)	2.900e-04					
Fe+2	2.484e-04	7.365e-05	-3.605	-4.133	-0.528	(0)
FeSO4	4.165e-05	4.441e-05	-4.380	-4.352	0.028	(0)
FeOH+	1.985e-10	1.424e-10	-9.702	-9.846	-0.144	(0)
Fe(OH)2	6.953e-18	7.414e-18	-17.158	-17.130	0.028	(0)
Fe(OH)3-	2.348e-24	1.685e-24	-23.629	-23.774	-0.144	(0)
Fe(3)	2.131e-11					
FeOH+2	1.020e-11	2.702e-12	-10.991	-11.568	-0.577	(0)
Fe(OH)2+	7.536e-12	5.471e-12	-11.123	-11.262	-0.139	(0)
FeSO4+	2.690e-12	1.930e-12	-11.570	-11.714	-0.144	(0)
Fe+3	6.048e-13	6.842e-14	-12.218	-13.165	-0.946	(0)
Fe(SO4)2-	2.815e-13	2.070e-13	-12.551	-12.684	-0.134	(0)
FeCl+2	1.944e-15	5.150e-16	-14.711	-15.288	-0.577	(0)
Fe(OH)3	3.686e-16	3.931e-16	-15.433	-15.406	0.028	(0)
FeCl2+	7.992e-19	5.733e-19	-18.097	-18.242	-0.144	(0)
Fe(OH)4-	3.311e-20	2.404e-20	-19.480	-19.619	-0.139	(0)
Fe2(OH)2+4	2.696e-20	1.964e-22	-19.569	-21.707	-2.137	(0)
FeCl3	1.340e-23	1.429e-23	-22.873	-22.845	0.028	(0)
Fe3(OH)4+5	4.910e-28	2.245e-31	-27.309	-30.649	-3.340	(0)
H(0)	3.493e-19					
H2	1.746e-19	1.862e-19	-18.758	-18.730	0.028	(0)
K	4.531e-03					
K+	4.433e-03	2.976e-03	-2.353	-2.526	-0.173	(0)
KSO4-	9.769e-05	7.092e-05	-4.010	-4.149	-0.139	(0)
KCrO4-	0.000e+00	0.000e+00	-44.797	-44.930	-0.134	(0)
Mg	3.139e-02					
Mg+2	2.613e-02	9.259e-03	-1.583	-2.033	-0.451	(0)
MgSO4	5.236e-03	5.584e-03	-2.281	-2.253	0.028	(0)
MgHCO3+	2.489e-05	1.726e-05	-4.604	-4.763	-0.159	(0)
MgCO3	3.791e-10	4.043e-10	-9.421	-9.393	0.028	(0)
MgOH+	1.245e-10	9.301e-11	-9.905	-10.031	-0.127	(0)
Mn(2)	1.651e-05					
Mn+2	1.407e-05	4.173e-06	-4.852	-5.380	-0.528	(0)
MnSO4	2.415e-06	2.575e-06	-5.617	-5.589	0.028	(0)
MnHCO3+	1.718e-08	1.233e-08	-7.765	-7.909	-0.144	(0)
MnCl+	5.865e-09	4.208e-09	-8.232	-8.376	-0.144	(0)
MnOH+	9.143e-13	6.559e-13	-12.039	-12.183	-0.144	(0)
MnCl2	2.672e-13	2.849e-13	-12.573	-12.545	0.028	(0)
MnCl3-	4.462e-17	3.201e-17	-16.350	-16.495	-0.144	(0)
Mn(OH)3-	2.109e-29	1.513e-29	-28.676	-28.820	-0.144	(0)
Mn(3)	1.148e-26					
Mn+3	1.148e-26	1.298e-27	-25.940	-26.887	-0.946	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-76.937	-77.514	-0.577	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-82.721	-82.898	-0.177	(0)
Na	3.694e-01					
Na+	3.632e-01	2.643e-01	-0.440	-0.578	-0.138	(0)
NaSO4-	6.187e-03	4.492e-03	-2.208	-2.348	-0.139	(0)
NaHCO3	2.211e-05	2.358e-05	-4.655	-4.627	0.028	(0)
NaCO3-	3.087e-10	2.241e-10	-9.510	-9.649	-0.139	(0)
NaCrO4-	0.000e+00	0.000e+00	-42.951	-43.085	-0.134	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-54.955	-54.927	0.028	(0)
S(6)	2.793e-02					
SO4-2	1.505e-02	3.391e-03	-1.822	-2.470	-0.647	(0)

NaSO4-	6.187e-03	4.492e-03	-2.208	-2.348	-0.139	(0)
MgSO4	5.236e-03	5.584e-03	-2.281	-2.253	0.028	(0)
AlSO4+	5.068e-04	3.577e-04	-3.295	-3.446	-0.151	(0)
CaSO4	4.531e-04	4.832e-04	-3.344	-3.316	0.028	(0)
Al(SO4)2-	1.365e-04	9.636e-05	-3.865	-4.016	-0.151	(0)
KSO4-	9.769e-05	7.092e-05	-4.010	-4.149	-0.139	(0)
HSO4-	7.561e-05	5.337e-05	-4.121	-4.273	-0.151	(0)
FeSO4	4.165e-05	4.441e-05	-4.380	-4.352	0.028	(0)
MnSO4	2.415e-06	2.575e-06	-5.617	-5.589	0.028	(0)
ZnSO4	2.599e-07	2.772e-07	-6.585	-6.557	0.028	(0)
UO2SO4	1.102e-07	1.175e-07	-6.958	-6.930	0.028	(0)
CuSO4	4.152e-08	4.428e-08	-7.382	-7.354	0.028	(0)
UO2(SO4)2-2	4.063e-08	1.187e-08	-7.391	-7.926	-0.534	(0)
Zn(SO4)2-2	2.615e-08	7.641e-09	-7.583	-8.117	-0.534	(0)
CrOHSO4	2.701e-09	2.880e-09	-8.568	-8.541	0.028	(0)
CrSO4+	3.137e-10	2.307e-10	-9.503	-9.637	-0.134	(0)
FeSO4+	2.690e-12	1.930e-12	-11.570	-11.714	-0.144	(0)
Fe(SO4)2-	2.815e-13	2.070e-13	-12.551	-12.684	-0.134	(0)
Cr2(OH)2SO4+2	3.365e-15	9.832e-16	-14.473	-15.007	-0.534	(0)
U(SO4)2	4.739e-17	5.054e-17	-16.324	-16.296	0.028	(0)
USO4+2	2.628e-18	7.678e-19	-17.580	-18.115	-0.534	(0)
Cr2(OH)2(SO4)2	7.378e-20	7.867e-20	-19.132	-19.104	0.028	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-43.721	-44.255	-0.534	(0)
U(3)	1.996e-33					
U+3	1.996e-33	1.253e-34	-32.700	-33.902	-1.202	(0)
U(4)	7.391e-15					
U(OH)4	3.264e-15	3.481e-15	-14.486	-14.458	0.028	(0)
U(OH)3+	2.830e-15	2.081e-15	-14.548	-14.682	-0.134	(0)
U(OH)5-	6.914e-16	5.083e-16	-15.160	-15.294	-0.134	(0)
U(OH)2+2	5.385e-16	1.573e-16	-15.269	-15.803	-0.534	(0)
U(SO4)2	4.739e-17	5.054e-17	-16.324	-16.296	0.028	(0)
UOH+3	1.659e-17	1.041e-18	-16.780	-17.982	-1.202	(0)
USO4+2	2.628e-18	7.678e-19	-17.580	-18.115	-0.534	(0)
U+4	1.075e-19	7.833e-22	-18.969	-21.106	-2.137	(0)
UCl+3	6.774e-23	4.251e-24	-22.169	-23.371	-1.202	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-76.248	-87.069	-10.821	(0)
U(5)	5.615e-09					
UO2+	5.615e-09	4.129e-09	-8.251	-8.384	-0.134	(0)
U(6)	4.239e-07					
UO2+2	2.318e-07	6.773e-08	-6.635	-7.169	-0.534	(0)
UO2SO4	1.102e-07	1.175e-07	-6.958	-6.930	0.028	(0)
UO2(SO4)2-2	4.063e-08	1.187e-08	-7.391	-7.926	-0.534	(0)
UO2CO3	3.658e-08	3.901e-08	-7.437	-7.409	0.028	(0)
UO2OH+	4.580e-09	3.367e-09	-8.339	-8.473	-0.134	(0)
UO2(CO3)2-2	4.879e-11	1.425e-11	-10.312	-10.846	-0.534	(0)
UO2Cl+	3.811e-11	2.802e-11	-10.419	-10.553	-0.134	(0)
(UO2)2(OH)2+2	1.330e-12	3.886e-13	-11.876	-12.411	-0.534	(0)
UO2(CO3)3-4	2.156e-15	1.571e-17	-14.666	-16.804	-2.137	(0)
(UO2)3(OH)5+	9.229e-19	6.785e-19	-18.035	-18.168	-0.134	(0)
Zn	1.471e-06					
Zn+2	1.176e-06	3.487e-07	-5.930	-6.458	-0.528	(0)
ZnSO4	2.599e-07	2.772e-07	-6.585	-6.557	0.028	(0)
Zn(SO4)2-2	2.615e-08	7.641e-09	-7.583	-8.117	-0.534	(0)
ZnHCO3+	8.840e-09	6.500e-09	-8.054	-8.187	-0.134	(0)
ZnCl+	3.373e-10	2.339e-10	-9.472	-9.631	-0.159	(0)
ZnOH+	3.180e-12	2.338e-12	-11.498	-11.631	-0.134	(0)
ZnCO3	2.985e-12	3.183e-12	-11.525	-11.497	0.028	(0)
ZnCl2	5.725e-14	6.105e-14	-13.242	-13.214	0.028	(0)
ZnOHCl	1.650e-14	1.760e-14	-13.782	-13.755	0.028	(0)
Zn(OH)2	1.543e-16	1.646e-16	-15.812	-15.784	0.028	(0)
ZnCl3-	2.462e-17	1.707e-17	-16.609	-16.768	-0.159	(0)
Zn(CO3)2-2	1.066e-17	3.114e-18	-16.972	-17.507	-0.534	(0)
ZnCl4-2	8.033e-21	2.128e-21	-20.095	-20.672	-0.577	(0)
Zn(OH)3-	4.328e-24	3.182e-24	-23.364	-23.497	-0.134	(0)
Zn(OH)4-2	1.056e-32	3.084e-33	-31.976	-32.511	-0.534	(0)

-------------------------------Saturation indices-------------------------------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-3.02	7.36	10.38	Al(OH)3
Al2O3	-8.24	14.74	22.98	Al2O3
Al4(OH)10SO4	-3.29	19.41	22.70	Al4(OH)10SO4
AlOHSO4	0.55	-2.68	-3.23	AlOHSO4
AlumK	-6.34	-11.51	-5.17	KAl(SO4)2:12H2O
Alunite	4.61	3.26	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-0.99	-5.62	-4.64	CaSO4
Antlerite	-17.20	-8.91	8.29	Cu3(OH)4SO4
Aragonite	-5.16	-13.49	-8.34	CaCO3
Artinite	-16.44	-6.84	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-13.97	-6.63	7.34	Cu2(OH)3Cl
Azurite	-17.77	-34.69	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.14	0.40	5.54	UO2(OH)2
Bianchite	-7.18	-8.95	-1.76	ZnSO4:6H2O
Birnessite	-25.82	-7.73	18.09	MnO2
Bixbyite	-30.43	-31.04	-0.61	Mn2O3
Boehmite	-1.21	7.37	8.58	AlOOH
Brochantite	-23.87	-8.53	15.34	Cu4(OH)6SO4
Brucite	-11.25	5.54	16.79	Mg(OH)2
CaCrO4	-44.09	-46.36	-2.27	CaCrO4
Calcite	-5.02	-13.49	-8.47	CaCO3
CH4(g)	-40.13	-80.23	-40.10	CH4
Chalcanthite	-7.04	-9.68	-2.64	CuSO4:5H2O
CO2(g)	0.24	-17.92	-18.16	CO2
Cr(OH)2	-22.43	-11.61	10.82	Cr(OH)2
Cr(OH)3(A)	-6.02	-6.77	-0.75	Cr(OH)3
Cr(OH)3(C)	-8.47	-6.77	1.70	Cr(OH)3
Cr2O3	-10.14	-13.54	-3.39	Cr2O3
CrCl2	-42.26	-26.39	15.87	CrCl2
CrCl3	-42.45	-28.94	13.51	CrCl3
CrMetal	-59.43	-27.19	32.24	Cr
CrO3	-47.57	-50.78	-3.21	CrO3
Cu(OH)2	-8.26	0.38	8.64	Cu(OH)2
Cu2SO4	-17.47	-19.42	-1.95	Cu2SO4
CuCO3	-7.90	-17.53	-9.63	CuCO3
CuCrO4	-44.92	-50.40	-5.48	CuCrO4
CuMetal	-3.71	-12.47	-8.76	Cu
CuOCuSO4	-20.81	-9.28	11.53	CuO:CuSO4
CupricFerrite	-9.10	-3.22	5.88	CuFe2O4
Cuprite	-7.82	-9.37	-1.55	Cu2O
CuprousFerrite	2.43	-6.49	-8.92	CuFeO2
CuSO4	-12.67	-9.66	3.01	CuSO4
Diaspore	0.49	7.37	6.87	AlOOH
Dolomite	-8.87	-25.87	-17.00	CaMg(CO3)2
Epsomite	-2.39	-4.53	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-0.98	-4.02	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-37.32	-33.74	3.58	Fe2(SO4)3
Fe3(OH)8	-20.39	-0.17	20.22	Fe3(OH)8
FeCr2O4	-9.19	-10.09	-0.90	FeCr2O4
Ferrihydrite	-6.70	-1.81	4.89	Fe(OH)3
Gibbsite(C)	-1.41	7.36	8.77	Al(OH)3
Goethite	-2.30	-1.80	0.50	FeOOH
Goslarite	-6.99	-8.95	-1.96	ZnSO4:7H2O
Gummite	-10.00	0.41	10.40	UO3
Gypsum	-1.02	-5.63	-4.61	CaSO4:2H2O
Halite	-5.76	-4.18	1.58	NaCl
Hausmannite	-39.37	22.17	61.54	Mn3O4
Hematite	0.41	-3.60	-4.01	Fe2O3
Hercynite	-8.98	18.18	27.16	FeAl2O4
Huntite	-20.65	-50.61	-29.97	CaMg3(CO3)4
Hydromagnesite	-35.20	-43.97	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-13.41	-25.51	-12.10	(H3O)Fe3(SO4)2(OH)6

Jarosite-K	-9.44	-24.24	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-11.09	-22.29	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-83.36	-99.04	-15.67	K2Cr2O7
K2CrO4	-48.26	-48.26	0.01	K2CrO4
Langite	-25.32	-8.53	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-3.17	-1.80	1.37	FeOOH
Lime	-28.38	4.42	32.80	CaO
Maghemite	-9.99	-3.60	6.39	Fe2O3
Magnesite	-4.34	-12.37	-8.03	MgCO3
Magnetite	-3.89	-0.16	3.74	Fe3O4
Malachite	-11.98	-17.16	-5.18	Cu2(OH)2CO3
Manganite	-15.29	-15.52	-0.24	MnOOH
Melanothallite	-18.13	-14.40	3.73	CuCl2
Melanterite	-4.16	-6.63	-2.47	FeSO4:7H2O
Mg-Ferrite	-14.82	1.94	16.77	MgFe2O4
MgCr2O4	-20.07	-7.99	12.08	MgCr2O4
MgCrO4	-50.62	-45.24	5.38	MgCrO4
Mirabilite	-2.55	-3.66	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-55.47	-61.18	-5.71	Mn2(SO4)3
MnCl2:4H2O	-15.31	-12.60	2.71	MnCl2:4H2O
MnSO4	-10.52	-7.85	2.67	MnSO4
Na2Cr2O7	-85.24	-95.14	-9.90	Na2Cr2O7
Na2CrO4	-47.62	-44.36	3.26	Na2CrO4
Nantokite	-5.32	-12.08	-6.76	CuCl
Natron	-10.22	-11.53	-1.31	Na2CO3:10H2O
Nesquehonite	-6.76	-12.38	-5.62	MgCO3:3H2O
Nsutite	-25.24	-7.73	17.50	MnO2
O2(g)	-51.97	31.15	83.12	O2
Periclase	-15.97	5.54	21.51	MgO
Portlandite	-18.26	4.42	22.68	Ca(OH)2
Pyrocroite	-12.89	2.19	15.09	Mn(OH)2
Pyrolusite	-23.59	-7.73	15.86	MnO2
Rhodochrosite	-5.31	-15.72	-10.41	MnCO3
Rutherfordine	-3.05	-17.51	-14.46	UO2CO3
Schoepite	-5.00	0.40	5.40	UO2(OH)2:H2O
Siderite	-3.92	-14.47	-10.55	FeCO3
Smithsonite	-6.80	-16.80	-10.00	ZnCO3
Spinel	-16.05	20.28	36.33	MgAl2O4
Tenorite	-7.24	0.38	7.62	CuO
Thenardite	-3.45	-3.63	-0.18	Na2SO4
Thermonatrite	-11.62	-11.50	0.13	Na2CO3:H2O
U3O8(C)	-7.81	13.29	21.11	U3O8
U4O9(C)	-4.85	-8.24	-3.38	U4O9
UO2(am)	-6.89	-5.95	0.93	UO2
UO3(C)	-7.31	0.41	7.72	UO3
Uraninite	-1.25	-5.95	-4.70	UO2
Zincite	-10.02	1.12	11.14	ZnO
Zincosite	-11.94	-8.93	3.01	ZnSO4
Zn(BO2)2	-13.70	-5.41	8.29	Zn(BO2)2
Zn(OH)2(A)	-11.33	1.12	12.45	Zn(OH)2
Zn(OH)2(B)	-10.63	1.12	11.75	Zn(OH)2
Zn(OH)2(C)	-11.08	1.12	12.20	Zn(OH)2
Zn(OH)2(E)	-10.38	1.12	11.50	Zn(OH)2
Zn(OH)2(G)	-10.59	1.12	11.71	Zn(OH)2
Zn2(OH)2SO4	-15.31	-7.81	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-20.36	-5.16	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-35.76	-16.74	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-33.98	-5.58	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-47.70	-9.20	38.50	Zn5(OH)8Cl2
ZnCl2	-20.69	-13.66	7.03	ZnCl2
ZnCO3:H2O	-6.54	-16.80	-10.26	ZnCO3:H2O
ZnMetal	-40.21	-14.46	25.76	Zn
ZnO(Active)	-10.19	1.12	11.31	ZnO
ZnSO4:H2O	-8.36	-8.93	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.

For ideal gases, phi = 1.

Initial solution 7.

----------Solution composition----------

Elements	Molality	Moles
Al	4.280e-03	4.280e-03
Alkalinity	8.229e-06	8.229e-06
B	5.351e-04	5.351e-04
Ca	2.606e-03	2.606e-03
Cl	4.532e-04	4.532e-04
Cr	5.794e-08	5.794e-08
Cu	1.106e-07	1.106e-07
Fe	4.496e-07	4.496e-07
K	5.316e-03	5.316e-03
Mg	3.949e-02	3.949e-02
Mn	1.199e-05	1.199e-05
Na	4.368e-04	4.368e-04
S(6)	2.969e-02	2.969e-02
U	4.641e-07	4.641e-07
Zn	2.473e-06	2.473e-06

----------Description of solution----------

pH	= 3.550
pe	= 4.000
Activity of water	= 0.995
Ionic strength (mol/kgw)	= 1.024e-01
Mass of water (kg)	= 1.000e+00
Total carbon (mol/kg)	= 2.101e-01
Total CO2 (mol/kg)	= 2.101e-01
Temperature (°C)	= 25.00
Electrical balance (eq)	= 4.297e-02
Percent error, 100*(Cat-|An|)/(Cat+|An|)	= 40.96
Iterations	= 14
Total H	= 1.114344e+02
Total O	= 5.625704e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	3.419e-04	2.818e-04	-3.466	-3.550	-0.084	0.00
OH-	4.669e-11	3.548e-11	-10.331	-10.450	-0.119	(0)
H2O	5.551e+01	9.953e-01	1.744	-0.002	0.000	18.07
Al	4.280e-03					
AlSO4+	1.899e-03	1.471e-03	-2.722	-2.832	-0.111	(0)
Al+3	1.603e-03	2.820e-04	-2.795	-3.550	-0.755	(0)
Al(SO4)2-	7.514e-04	5.822e-04	-3.124	-3.235	-0.111	(0)
AlOH+2	2.658e-05	1.019e-05	-4.575	-4.992	-0.416	(0)
Al(OH)2+	3.550e-07	2.793e-07	-6.450	-6.554	-0.104	(0)
Al(OH)3	1.213e-09	1.242e-09	-8.916	-8.906	0.010	(0)
Al(OH)4-	5.660e-13	4.385e-13	-12.247	-12.358	-0.111	(0)
B	5.351e-04					
H3BO3	5.351e-04	5.479e-04	-3.272	-3.261	0.010	(0)
H2BO3-	1.503e-09	1.116e-09	-8.823	-8.952	-0.129	(0)
C(4)	2.101e-01					
H2CO3	2.096e-01	2.146e-01	-0.679	-0.668	0.010	(0)
HCO3-	4.310e-04	3.391e-04	-3.366	-3.470	-0.104	(0)
MgHCO3+	6.410e-05	4.920e-05	-4.193	-4.308	-0.115	(0)
CaHCO3+	3.378e-06	2.682e-06	-5.471	-5.571	-0.100	(0)
NaHCO3	6.207e-08	6.355e-08	-7.207	-7.197	0.010	(0)
UO2CO3	4.575e-08	4.684e-08	-7.340	-7.329	0.010	(0)

ZnHCO3+	3.298e-08	2.572e-08	-7.482	-7.590	-0.108	(0)
MnHCO3+	2.844e-08	2.223e-08	-7.546	-7.653	-0.107	(0)
CuHCO3+	4.938e-09	3.851e-09	-8.306	-8.414	-0.108	(0)
MgCO3	6.478e-10	6.632e-10	-9.189	-9.178	0.010	(0)
CO3-2	1.469e-10	5.633e-11	-9.833	-10.249	-0.416	(0)
CaCO3	5.967e-11	6.109e-11	-10.224	-10.214	0.010	(0)
UO2(CO3)2-2	5.696e-11	2.107e-11	-10.244	-10.676	-0.432	(0)
CuCO3	7.167e-12	7.338e-12	-11.145	-11.134	0.010	(0)
ZnCO3	7.080e-12	7.249e-12	-11.150	-11.140	0.010	(0)
NaCO3-	4.418e-13	3.476e-13	-12.355	-12.459	-0.104	(0)
UO2(CO3)3-4	1.527e-15	2.859e-17	-14.816	-16.544	-1.728	(0)
Zn(CO3)2-2	2.360e-17	8.730e-18	-16.627	-17.059	-0.432	(0)
Cu(CO3)2-2	1.407e-18	5.204e-19	-17.852	-18.284	-0.432	(0)
Ca	2.606e-03					
Ca+2	1.846e-03	7.634e-04	-2.734	-3.117	-0.383	(0)
CaSO4	7.567e-04	7.748e-04	-3.121	-3.111	0.010	(0)
CaHCO3+	3.378e-06	2.682e-06	-5.471	-5.571	-0.100	(0)
CaCO3	5.967e-11	6.109e-11	-10.224	-10.214	0.010	(0)
CaOH+	8.566e-13	6.803e-13	-12.067	-12.167	-0.100	(0)
Cl	4.532e-04					
Cl-	4.532e-04	3.418e-04	-3.344	-3.466	-0.123	(0)
MnCl+	6.223e-09	4.864e-09	-8.206	-8.313	-0.107	(0)
ZnCl+	7.731e-10	5.934e-10	-9.112	-9.227	-0.115	(0)
CuCl2-	6.128e-11	4.703e-11	-10.213	-10.328	-0.115	(0)
UO2Cl+	4.805e-11	3.747e-11	-10.318	-10.426	-0.108	(0)
CuCl+	2.908e-11	2.232e-11	-10.536	-10.651	-0.115	(0)
CrCl+2	2.666e-12	9.862e-13	-11.574	-12.006	-0.432	(0)
MnCl2	4.411e-13	4.516e-13	-12.355	-12.345	0.010	(0)
ZnCl2	2.074e-13	2.124e-13	-12.683	-12.673	0.010	(0)
CuCl3-2	6.825e-14	2.548e-14	-13.166	-13.594	-0.428	(0)
ZnOHCl	2.518e-14	2.578e-14	-13.599	-13.589	0.010	(0)
CuCl2	4.001e-15	4.097e-15	-14.398	-14.388	0.010	(0)
ZnCl3-	1.061e-16	8.144e-17	-15.974	-16.089	-0.115	(0)
MnCl3-	8.903e-17	6.959e-17	-16.050	-16.157	-0.107	(0)
CrCl2+	8.422e-17	6.568e-17	-16.075	-16.183	-0.108	(0)
FeCl+2	3.417e-18	1.276e-18	-17.466	-17.894	-0.428	(0)
CrOHCl2	4.569e-19	4.678e-19	-18.340	-18.330	0.010	(0)
ZnCl4-2	3.729e-20	1.392e-20	-19.428	-19.856	-0.428	(0)
CuCl3-	6.473e-21	4.968e-21	-20.189	-20.304	-0.115	(0)
FeCl2+	2.492e-21	1.948e-21	-20.604	-20.710	-0.107	(0)
UCl+3	4.826e-22	5.151e-23	-21.316	-22.288	-0.972	(0)
FeCl3	6.502e-26	6.657e-26	-25.187	-25.177	0.010	(0)
CuCl4-2	2.280e-26	8.510e-27	-25.642	-26.070	-0.428	(0)
CrO3Cl-	0.000e+00	0.000e+00	-48.040	-48.148	-0.108	(0)
Cr(2)	2.957e-19					
Cr+2	2.957e-19	1.094e-19	-18.529	-18.961	-0.432	(0)
Cr(3)	5.794e-08					
Cr+3	4.827e-08	5.151e-09	-7.316	-8.288	-0.972	(0)
Cr(OH)+2	4.918e-09	1.819e-09	-8.308	-8.740	-0.432	(0)
CrOHSO4	4.004e-09	4.099e-09	-8.398	-8.387	0.010	(0)
CrSO4+	7.290e-10	5.685e-10	-9.137	-9.245	-0.108	(0)
Cr(OH)2+	1.976e-11	1.541e-11	-10.704	-10.812	-0.108	(0)
CrCl+2	2.666e-12	9.862e-13	-11.574	-12.006	-0.432	(0)
Cr(OH)3	3.940e-15	4.034e-15	-14.405	-14.394	0.010	(0)
Cr2(OH)2SO4+2	3.665e-15	1.356e-15	-14.436	-14.868	-0.432	(0)
CrCl2+	8.422e-17	6.568e-17	-16.075	-16.183	-0.108	(0)
CrOHCl2	4.569e-19	4.678e-19	-18.340	-18.330	0.010	(0)
Cr2(OH)2(SO4)2	1.556e-19	1.594e-19	-18.808	-18.798	0.010	(0)
CrO2-	4.469e-22	3.485e-22	-21.350	-21.458	-0.108	(0)
Cr(OH)4-	1.744e-22	1.360e-22	-21.758	-21.866	-0.108	(0)
Cr(6)	0.000e+00					
HCrO4-	0.000e+00	0.000e+00	-41.825	-41.933	-0.108	(0)
CrO4-2	0.000e+00	0.000e+00	-44.433	-44.892	-0.460	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-44.867	-45.299	-0.432	(0)
H2CrO4	0.000e+00	0.000e+00	-46.351	-46.341	0.010	(0)
KCrO4-	0.000e+00	0.000e+00	-46.397	-46.505	-0.108	(0)

NaCrO4-	0.000e+00	0.000e+00	-47.566	-47.674	-0.108	(0)
CrO3Cl-	0.000e+00	0.000e+00	-48.040	-48.148	-0.108	(0)
Cr2O7-2	0.000e+00	0.000e+00	-81.894	-82.325	-0.432	(0)
Cu(1)	1.776e-09					
Cu+	1.714e-09	1.273e-09	-8.766	-8.895	-0.129	(0)
CuCl2-	6.128e-11	4.703e-11	-10.213	-10.328	-0.115	(0)
CuCl3-2	6.825e-14	2.548e-14	-13.166	-13.594	-0.428	(0)
Cu(2)	1.089e-07					
Cu+2	7.977e-08	2.426e-08	-7.098	-7.615	-0.517	(0)
CuSO4	2.410e-08	2.468e-08	-7.618	-7.608	0.010	(0)
CuHCO3+	4.938e-09	3.851e-09	-8.306	-8.414	-0.108	(0)
CuCl+	2.908e-11	2.232e-11	-10.536	-10.651	-0.115	(0)
CuCO3	7.167e-12	7.338e-12	-11.145	-11.134	0.010	(0)
CuOH+	1.116e-12	8.567e-13	-11.952	-12.067	-0.115	(0)
Cu(OH)2	6.173e-15	6.321e-15	-14.209	-14.199	0.010	(0)
CuCl2	4.001e-15	4.097e-15	-14.398	-14.388	0.010	(0)
Cu(CO3)2-2	1.407e-18	5.204e-19	-17.852	-18.284	-0.432	(0)
Cu2(OH)2+2	8.681e-19	3.211e-19	-18.061	-18.493	-0.432	(0)
CuCl3-	6.473e-21	4.968e-21	-20.189	-20.304	-0.115	(0)
Cu(OH)3-	1.729e-24	1.348e-24	-23.762	-23.870	-0.108	(0)
CuCl4-2	2.280e-26	8.510e-27	-25.642	-26.070	-0.428	(0)
Cu(OH)4-2	2.562e-33	9.476e-34	-32.591	-33.023	-0.432	(0)
Fe(2)	4.496e-07					
Fe+2	3.344e-07	1.330e-07	-6.476	-6.876	-0.400	(0)
FeSO4	1.151e-07	1.179e-07	-6.939	-6.929	0.010	(0)
FeOH+	1.901e-13	1.486e-13	-12.721	-12.828	-0.107	(0)
Fe(OH)2	4.361e-21	4.465e-21	-20.360	-20.350	0.010	(0)
Fe(OH)3-	7.495e-28	5.859e-28	-27.125	-27.232	-0.107	(0)
Fe(3)	2.003e-14					
FeOH+2	7.548e-15	2.818e-15	-14.122	-14.550	-0.428	(0)
FeSO4+	6.552e-15	5.122e-15	-14.184	-14.291	-0.107	(0)
Fe(OH)2+	4.188e-15	3.295e-15	-14.378	-14.482	-0.104	(0)
Fe(SO4)2-	1.035e-15	8.070e-16	-14.985	-15.093	-0.108	(0)
Fe+3	7.027e-16	1.236e-16	-15.153	-15.908	-0.755	(0)
FeCl+2	3.417e-18	1.276e-18	-17.466	-17.894	-0.428	(0)
Fe(OH)3	1.335e-19	1.367e-19	-18.874	-18.864	0.010	(0)
FeCl2+	2.492e-21	1.948e-21	-20.604	-20.710	-0.107	(0)
Fe(OH)4-	6.136e-24	4.828e-24	-23.212	-23.316	-0.104	(0)
FeCl3	6.502e-26	6.657e-26	-25.187	-25.177	0.010	(0)
Fe2(OH)2+4	1.141e-26	2.137e-28	-25.943	-27.670	-1.728	(0)
Fe3(OH)4+5	7.363e-38	1.471e-40	-37.133	-39.832	-2.699	(0)
H(0)	1.098e-18					
H2	5.492e-19	5.623e-19	-18.260	-18.250	0.010	(0)
K	5.316e-03					
K+	5.144e-03	3.879e-03	-2.289	-2.411	-0.123	(0)
KSO4-	1.726e-04	1.358e-04	-3.763	-3.867	-0.104	(0)
KCrO4-	0.000e+00	0.000e+00	-46.397	-46.505	-0.108	(0)
Mg	3.949e-02					
Mg+2	2.875e-02	1.234e-02	-1.541	-1.909	-0.367	(0)
MgSO4	1.068e-02	1.093e-02	-1.972	-1.961	0.010	(0)
MgHCO3+	6.410e-05	4.920e-05	-4.193	-4.308	-0.115	(0)
MgCO3	6.478e-10	6.632e-10	-9.189	-9.178	0.010	(0)
MgOH+	8.947e-11	7.157e-11	-10.048	-10.145	-0.097	(0)
Mn(2)	1.199e-05					
Mn+2	8.842e-06	3.517e-06	-5.053	-5.454	-0.400	(0)
MnSO4	3.115e-06	3.189e-06	-5.507	-5.496	0.010	(0)
MnHCO3+	2.844e-08	2.223e-08	-7.546	-7.653	-0.107	(0)
MnCl+	6.223e-09	4.864e-09	-8.206	-8.313	-0.107	(0)
MnCl2	4.411e-13	4.516e-13	-12.355	-12.345	0.010	(0)
MnOH+	4.085e-13	3.193e-13	-12.389	-12.496	-0.107	(0)
MnCl3-	8.903e-17	6.959e-17	-16.050	-16.157	-0.107	(0)
Mn(OH)3-	3.141e-30	2.455e-30	-29.503	-29.610	-0.107	(0)
Mn(3)	6.223e-27					
Mn+3	6.223e-27	1.095e-27	-26.206	-26.961	-0.755	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-79.074	-79.502	-0.428	(0)

Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-84.762	-84.886	-0.124	(0)
Na	4.368e-04					
Na+	4.262e-04	3.330e-04	-3.370	-3.478	-0.107	(0)
NaSO4-	1.057e-05	8.315e-06	-4.976	-5.080	-0.104	(0)
NaHCO3	6.207e-08	6.355e-08	-7.207	-7.197	0.010	(0)
NaCO3-	4.418e-13	3.476e-13	-12.355	-12.459	-0.104	(0)
NaCrO4-	0.000e+00	0.000e+00	-47.566	-47.674	-0.108	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-55.894	-55.884	0.010	(0)
S(6)	2.969e-02					
SO4-2	1.449e-02	4.982e-03	-1.839	-2.303	-0.464	(0)
MgSO4	1.068e-02	1.093e-02	-1.972	-1.961	0.010	(0)
AlSO4+	1.899e-03	1.471e-03	-2.722	-2.832	-0.111	(0)
CaSO4	7.567e-04	7.748e-04	-3.121	-3.111	0.010	(0)
Al(SO4)2-	7.514e-04	5.822e-04	-3.124	-3.235	-0.111	(0)
HSO4-	1.759e-04	1.363e-04	-3.755	-3.866	-0.111	(0)
KSO4-	1.726e-04	1.358e-04	-3.763	-3.867	-0.104	(0)
NaSO4-	1.057e-05	8.315e-06	-4.976	-5.080	-0.104	(0)
MnSO4	3.115e-06	3.189e-06	-5.507	-5.496	0.010	(0)
ZnSO4	7.358e-07	7.533e-07	-6.133	-6.123	0.010	(0)
UO2SO4	1.645e-07	1.684e-07	-6.784	-6.774	0.010	(0)
FeSO4	1.151e-07	1.179e-07	-6.939	-6.929	0.010	(0)
Zn(SO4)2-2	8.247e-08	3.051e-08	-7.084	-7.516	-0.432	(0)
UO2(SO4)2-2	6.757e-08	2.499e-08	-7.170	-7.602	-0.432	(0)
CuSO4	2.410e-08	2.468e-08	-7.618	-7.608	0.010	(0)
CrOHSO4	4.004e-09	4.099e-09	-8.398	-8.387	0.010	(0)
CrSO4+	7.290e-10	5.685e-10	-9.137	-9.245	-0.108	(0)
FeSO4+	6.552e-15	5.122e-15	-14.184	-14.291	-0.107	(0)
Cr2(OH)2SO4+2	3.665e-15	1.356e-15	-14.436	-14.868	-0.432	(0)
Fe(SO4)2-	1.035e-15	8.070e-16	-14.985	-15.093	-0.108	(0)
U(SO4)2	9.413e-16	9.637e-16	-15.026	-15.016	0.010	(0)
USO4+2	2.694e-17	9.966e-18	-16.570	-17.001	-0.432	(0)
Cr2(OH)2(SO4)2	1.556e-19	1.594e-19	-18.808	-18.798	0.010	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-44.867	-45.299	-0.432	(0)
U(3)	1.037e-32					
U+3	1.037e-32	1.107e-33	-31.984	-32.956	-0.972	(0)
U(4)	1.052e-14					
U(OH)3+	4.538e-15	3.539e-15	-14.343	-14.451	-0.108	(0)
U(OH)4	3.339e-15	3.419e-15	-14.476	-14.466	0.010	(0)
U(OH)2+2	1.253e-15	4.634e-16	-14.902	-15.334	-0.432	(0)
U(SO4)2	9.413e-16	9.637e-16	-15.026	-15.016	0.010	(0)
U(OH)5-	3.696e-16	2.883e-16	-15.432	-15.540	-0.108	(0)
UOH+3	4.978e-17	5.313e-18	-16.303	-17.275	-0.972	(0)
USO4+2	2.694e-17	9.966e-18	-16.570	-17.001	-0.432	(0)
U+4	3.696e-19	6.920e-21	-18.432	-20.160	-1.728	(0)
UCl+3	4.826e-22	5.151e-23	-21.316	-22.288	-0.972	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-76.223	-84.969	-8.746	(0)
U(5)	5.163e-09					
UO2+	5.163e-09	4.027e-09	-8.287	-8.395	-0.108	(0)
U(6)	4.589e-07					
UO2+2	1.786e-07	6.606e-08	-6.748	-7.180	-0.432	(0)
UO2SO4	1.645e-07	1.684e-07	-6.784	-6.774	0.010	(0)
UO2(SO4)2-2	6.757e-08	2.499e-08	-7.170	-7.602	-0.432	(0)
UO2CO3	4.575e-08	4.684e-08	-7.340	-7.329	0.010	(0)
UO2OH+	2.432e-09	1.896e-09	-8.614	-8.722	-0.108	(0)
UO2(CO3)2-2	5.696e-11	2.107e-11	-10.244	-10.676	-0.432	(0)
UO2Cl+	4.805e-11	3.747e-11	-10.318	-10.426	-0.108	(0)
(UO2)2(OH)2+2	3.332e-13	1.233e-13	-12.477	-12.909	-0.432	(0)
UO2(CO3)3-4	1.527e-15	2.859e-17	-14.816	-16.544	-1.728	(0)
(UO2)3(OH)5+	5.183e-20	4.042e-20	-19.285	-19.393	-0.108	(0)
Zn	2.473e-06					
Zn+2	1.621e-06	6.450e-07	-5.790	-6.190	-0.400	(0)
ZnSO4	7.358e-07	7.533e-07	-6.133	-6.123	0.010	(0)
Zn(SO4)2-2	8.247e-08	3.051e-08	-7.084	-7.516	-0.432	(0)
ZnHCO3+	3.298e-08	2.572e-08	-7.482	-7.590	-0.108	(0)

ZnCl+	7.731e-10	5.934e-10	-9.112	-9.227	-0.115	(0)
ZnCO3	7.080e-12	7.249e-12	-11.150	-11.140	0.010	(0)
ZnOH+	3.202e-12	2.497e-12	-11.495	-11.603	-0.108	(0)
ZnCl2	2.074e-13	2.124e-13	-12.683	-12.673	0.010	(0)
ZnOHCl	2.518e-14	2.578e-14	-13.599	-13.589	0.010	(0)
ZnCl3-	1.061e-16	8.144e-17	-15.974	-16.089	-0.115	(0)
Zn(OH)2	9.913e-17	1.015e-16	-16.004	-15.994	0.010	(0)
Zn(CO3)2-2	2.360e-17	8.730e-18	-16.627	-17.059	-0.432	(0)
ZnCl4-2	3.729e-20	1.392e-20	-19.428	-19.856	-0.428	(0)
Zn(OH)3-	1.453e-24	1.133e-24	-23.838	-23.946	-0.108	(0)
Zn(OH)4-2	1.715e-33	6.343e-34	-32.766	-33.198	-0.432	(0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-3.29	7.09	10.38	Al(OH)3
Al2O3	-8.79	14.19	22.98	Al2O3
Al4(OH)10SO4	-3.72	18.98	22.70	Al4(OH)10SO4
AlOHSO4	0.93	-2.30	-3.23	AlOHSO4
AlumK	-5.42	-10.59	-5.17	KAl(SO4)2:12H2O
Alunite	4.97	3.62	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-0.78	-5.42	-4.64	CaSO4
Antlerite	-19.25	-10.96	8.29	Cu3(OH)4SO4
Aragonite	-5.03	-13.37	-8.34	CaCO3
Artinite	-16.58	-6.98	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-15.39	-8.05	7.34	Cu2(OH)3Cl
Azurite	-19.33	-36.25	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.63	-0.08	5.54	UO2(OH)2
Bianchite	-6.74	-8.51	-1.76	ZnSO4:6H2O
Birnessite	-26.86	-8.76	18.09	MnO2
Bixbyite	-32.02	-32.63	-0.61	Mn2O3
Boehmite	-1.48	7.10	8.58	AlOOH
Brochantite	-26.82	-11.48	15.34	Cu4(OH)6SO4
Brucite	-11.60	5.19	16.79	Mg(OH)2
CaCrO4	-45.74	-48.01	-2.27	CaCrO4
Calcite	-4.89	-13.37	-8.47	CaCO3
CH4(g)	-37.64	-77.74	-40.10	CH4
Chalcanthite	-7.29	-9.93	-2.64	CuSO4:5H2O
CO2(g)	0.81	-17.35	-18.16	CO2
Cr(OH)2	-22.68	-11.87	10.82	Cr(OH)2
Cr(OH)3(A)	-6.51	-7.26	-0.75	Cr(OH)3
Cr(OH)3(C)	-8.96	-7.26	1.70	Cr(OH)3
Cr2O3	-11.13	-14.52	-3.39	Cr2O3
CrCl2	-41.76	-25.89	15.87	CrCl2
CrCl3	-41.81	-28.31	13.51	CrCl3
CrMetal	-59.21	-26.96	32.24	Cr
CrO3	-48.78	-51.99	-3.21	CrO3
Cu(OH)2	-9.16	-0.52	8.64	Cu(OH)2
Cu2SO4	-18.14	-20.09	-1.95	Cu2SO4
CuCO3	-8.23	-17.86	-9.63	CuCO3
CuCrO4	-47.03	-52.51	-5.48	CuCrO4
CuMetal	-4.14	-12.90	-8.76	Cu
CuOCuSO4	-21.96	-10.43	11.53	CuO:CuSO4
CupricFerrite	-16.92	-11.04	5.88	CuFe2O4
Cuprite	-9.14	-10.69	-1.55	Cu2O
CuprousFerrite	-1.69	-10.61	-8.92	CuFeO2
CuSO4	-12.93	-9.92	3.01	CuSO4
Diaspore	0.22	7.10	6.87	AlOOH
Dolomite	-8.52	-25.52	-17.00	CaMg(CO3)2
Epsomite	-2.09	-4.23	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-4.33	-7.37	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-42.30	-38.72	3.58	Fe2(SO4)3
Fe3(OH)8	-30.53	-10.31	20.22	Fe3(OH)8
FeCr2O4	-13.40	-14.30	-0.90	FeCr2O4
Ferrihydrite	-10.16	-5.26	4.89	Fe(OH)3

Gibbsite(C)	-1.68	7.09	8.77	Al(OH)3
Goethite	-5.76	-5.26	0.50	FeOOH
Goslarite	-6.55	-8.51	-1.96	ZnSO4:7H2O
Gummite	-10.49	-0.08	10.40	UO3
Gypsum	-0.81	-5.42	-4.61	CaSO4:2H2O
Halite	-8.53	-6.94	1.58	NaCl
Hausmannite	-41.51	20.03	61.54	Mn3O4
Hematite	-6.51	-10.52	-4.01	Fe2O3
Hercynite	-12.75	14.42	27.16	FeAl2O4
Huntite	-19.87	-49.84	-29.97	CaMg3(CO3)4
Hydromagnesite	-34.69	-43.45	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-22.49	-34.59	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-18.65	-33.45	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-23.32	-34.52	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-86.03	-101.71	-15.67	K2Cr2O7
K2CrO4	-49.72	-49.71	0.01	K2CrO4
Langite	-28.27	-11.48	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-6.63	-5.26	1.37	FeOOH
Lime	-28.82	3.98	32.80	CaO
Maghemite	-16.91	-10.52	6.39	Fe2O3
Magnesite	-4.13	-12.16	-8.03	MgCO3
Magnetite	-14.04	-10.30	3.74	Fe3O4
Malachite	-13.20	-18.38	-5.18	Cu2(OH)2CO3
Manganite	-16.08	-16.31	-0.24	MnOOH
Melanothallite	-18.28	-14.55	3.73	CuCl2
Melanterite	-6.72	-9.19	-2.47	FeSO4:7H2O
Mg-Ferrite	-22.10	-5.33	16.77	MgFe2O4
MgCr2O4	-21.41	-9.33	12.08	MgCr2O4
MgCrO4	-52.18	-46.80	5.38	MgCrO4
Mirabilite	-8.16	-9.28	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-55.12	-60.83	-5.71	Mn2(SO4)3
MnCl2:4H2O	-15.10	-12.39	2.71	MnCl2:4H2O
MnSO4	-10.43	-7.76	2.67	MnSO4
Na2Cr2O7	-93.94	-103.84	-9.90	Na2Cr2O7
Na2CrO4	-55.11	-51.85	3.26	Na2CrO4
Nantokite	-5.60	-12.36	-6.76	CuCl
Natron	-15.91	-17.23	-1.31	Na2CO3:10H2O
Nesquehonite	-6.54	-12.16	-5.62	MgCO3:3H2O
Nsutite	-26.27	-8.76	17.50	MnO2
O2(g)	-52.92	30.20	83.12	O2
Periclase	-16.32	5.19	21.51	MgO
Portlandite	-18.70	3.98	22.68	Ca(OH)2
Pyrocroite	-13.45	1.64	15.09	Mn(OH)2
Pyrolusite	-24.63	-8.76	15.86	MnO2
Rhodochrosite	-5.29	-15.70	-10.41	MnCO3
Rutherfordine	-2.97	-17.43	-14.46	UO2CO3
Schoepite	-5.49	-0.09	5.40	UO2(OH)2:H2O
Siderite	-6.58	-17.13	-10.55	FeCO3
Smithsonite	-6.44	-16.44	-10.00	ZnCO3
Spinel	-16.95	19.38	36.33	MgAl2O4
Tenorite	-8.14	-0.52	7.62	CuO
Thenardite	-9.08	-9.26	-0.18	Na2SO4
Thermonatrite	-17.33	-17.21	0.13	Na2CO3:H2O
U3O8(C)	-8.80	12.30	21.11	U3O8
U4O9(C)	-5.37	-8.76	-3.38	U4O9
UO2(am)	-6.90	-5.96	0.93	UO2
UO3(C)	-7.80	-0.08	7.72	UO3
Uraninite	-1.26	-5.96	-4.70	UO2
Zincite	-10.23	0.91	11.14	ZnO
Zincosite	-11.50	-8.49	3.01	ZnSO4
Zn(BO2)2	-13.90	-5.61	8.29	Zn(BO2)2
Zn(OH)2(A)	-11.54	0.91	12.45	Zn(OH)2
Zn(OH)2(B)	-10.84	0.91	11.75	Zn(OH)2
Zn(OH)2(C)	-11.29	0.91	12.20	Zn(OH)2
Zn(OH)2(E)	-10.59	0.91	11.50	Zn(OH)2
Zn(OH)2(G)	-10.80	0.91	11.71	Zn(OH)2

Zn2(OH)2SO4	-15.09	-7.59	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-20.40	-5.20	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-35.10	-16.08	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-34.18	-5.78	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-48.00	-9.50	38.50	Zn5(OH)8Cl2
ZnCl2	-20.15	-13.12	7.03	ZnCl2
ZnCO3:H2O	-6.18	-16.44	-10.26	ZnCO3:H2O
ZnMetal	-39.95	-14.19	25.76	Zn
ZnO(Active)	-10.40	0.91	11.31	ZnO
ZnSO4:H2O	-7.93	-8.50	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 8.

----------Solution composition----------

Elements	Molality	Moles
Al	3.767e-07	3.767e-07
Alkalinity	1.239e-02	1.239e-02
B	7.456e-04	7.456e-04
Ca	1.909e-02	1.909e-02
Cl	4.587e-04	4.587e-04
Cr	1.955e-08	1.955e-08
Cu	1.599e-08	1.599e-08
Fe	1.256e-05	1.256e-05
K	5.978e-03	5.978e-03
Mg	5.142e-02	5.142e-02
Mn	5.365e-05	5.365e-05
Na	4.332e-01	4.332e-01
S(6)	3.481e-02	3.481e-02
U	8.967e-08	8.967e-08
Zn	1.555e-07	1.555e-07

----------Description of solution----------

pH	= 7.330
pe	= 4.000
Activity of water	= 0.991
Ionic strength (mol/kgw)	= 3.738e-01
Mass of water (kg)	= 1.000e+00
Total carbon (mol/kg)	= 1.279e-02
Total CO2 (mol/kg)	= 1.279e-02
Temperature (°C)	= 25.00
Electrical balance (eq)	= 4.979e-01
Percent error, 100*(Cat-|An|)/(Cat+|An|)	= 83.17
Iterations	= 11
Total H	= 1.110279e+02
Total O	= 5.568606e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
OH-	3.244e-07	2.128e-07	-6.489	-6.672	-0.183	(0)
H+	6.040e-08	4.677e-08	-7.219	-7.330	-0.111	0.00
H2O	5.551e+01	9.909e-01	1.744	-0.004	0.000	18.07
Al	3.767e-07					
Al(OH)4-	2.866e-07	1.965e-07	-6.543	-6.707	-0.164	(0)
Al(OH)3	8.512e-08	9.277e-08	-7.070	-7.033	0.037	(0)
Al(OH)2+	4.909e-09	3.479e-09	-8.309	-8.459	-0.150	(0)
AlOH+2	8.390e-11	2.115e-11	-10.076	-10.675	-0.598	(0)
Al+3	9.750e-13	9.758e-14	-12.011	-13.011	-1.000	(0)

AlSO4+	4.921e-13	3.375e-13	-12.308	-12.472	-0.164	(0)
Al(SO4)2-	1.291e-13	8.855e-14	-12.889	-13.053	-0.164	(0)
B	7.456e-04					
H3BO3	7.298e-04	7.954e-04	-3.137	-3.099	0.037	(0)
H2BO3-	1.575e-05	9.766e-06	-4.803	-5.010	-0.208	(0)
C(4)	1.279e-02					
HCO3-	8.945e-03	6.338e-03	-2.048	-2.198	-0.150	(0)
MgHCO3+	1.593e-03	1.070e-03	-2.798	-2.971	-0.173	(0)
NaHCO3	9.966e-04	1.086e-03	-3.001	-2.964	0.037	(0)
H2CO3	6.109e-04	6.658e-04	-3.214	-3.177	0.037	(0)
CaHCO3+	4.444e-04	3.209e-04	-3.352	-3.494	-0.141	(0)
MgCO3	7.974e-05	8.691e-05	-4.098	-4.061	0.037	(0)
NaCO3-	5.053e-05	3.580e-05	-4.296	-4.446	-0.150	(0)
CaCO3	4.040e-05	4.403e-05	-4.394	-4.356	0.037	(0)
CO3-2	2.516e-05	6.343e-06	-4.599	-5.198	-0.598	(0)
MnHCO3+	2.060e-06	1.440e-06	-5.686	-5.842	-0.156	(0)
UO2(CO3)3-4	7.782e-08	5.129e-10	-7.109	-9.290	-2.181	(0)
ZnCO3	2.479e-08	2.702e-08	-7.606	-7.568	0.037	(0)
ZnHCO3+	2.177e-08	1.591e-08	-7.662	-7.798	-0.136	(0)
Zn(CO3)2-2	1.286e-08	3.664e-09	-7.891	-8.436	-0.545	(0)
UO2(CO3)2-2	1.178e-08	3.357e-09	-7.929	-8.474	-0.545	(0)
CuCO3	9.492e-09	1.035e-08	-8.023	-7.985	0.037	(0)
CuHCO3+	1.233e-09	9.011e-10	-8.909	-9.045	-0.136	(0)
Cu(CO3)2-2	2.900e-10	8.262e-11	-9.538	-10.083	-0.545	(0)
UO2CO3	6.080e-11	6.626e-11	-10.216	-10.179	0.037	(0)
Ca	1.909e-02					
Ca+2	1.559e-02	4.886e-03	-1.807	-2.311	-0.504	(0)
CaSO4	3.016e-03	3.287e-03	-2.521	-2.483	0.037	(0)
CaHCO3+	4.444e-04	3.209e-04	-3.352	-3.494	-0.141	(0)
CaCO3	4.040e-05	4.403e-05	-4.394	-4.356	0.037	(0)
CaOH+	3.617e-08	2.612e-08	-7.442	-7.583	-0.141	(0)
Cl	4.587e-04					
Cl-	4.587e-04	2.968e-04	-3.339	-3.527	-0.189	(0)
MnCl+	2.094e-08	1.464e-08	-7.679	-7.835	-0.156	(0)
ZnCl+	2.539e-11	1.705e-11	-10.595	-10.768	-0.173	(0)
ZnOHCl	4.078e-12	4.444e-12	-11.390	-11.352	0.037	(0)
MnCl2	1.083e-12	1.180e-12	-11.965	-11.928	0.037	(0)
CuCl2-	6.612e-13	4.441e-13	-12.180	-12.353	-0.173	(0)
CuCl+	3.613e-13	2.426e-13	-12.442	-12.615	-0.173	(0)
ZnCl2	4.863e-15	5.300e-15	-14.313	-14.276	0.037	(0)
CuCl3-2	8.756e-16	2.089e-16	-15.058	-15.680	-0.622	(0)
MnCl3-	2.260e-16	1.579e-16	-15.646	-15.802	-0.156	(0)
FeCl+2	7.615e-17	1.817e-17	-16.118	-16.741	-0.622	(0)
CrCl+2	3.644e-17	1.038e-17	-16.438	-16.984	-0.545	(0)
CuCl2	3.549e-17	3.868e-17	-16.450	-16.413	0.037	(0)
ZnCl3-	2.628e-18	1.765e-18	-17.580	-17.753	-0.173	(0)
UO2Cl+	5.596e-19	4.088e-19	-18.252	-18.388	-0.136	(0)
FeCl2+	3.447e-20	2.409e-20	-19.463	-19.618	-0.156	(0)
CrOHCl2	2.354e-20	2.566e-20	-19.628	-19.591	0.037	(0)
ZnCl4-2	1.098e-21	2.620e-22	-20.959	-21.582	-0.622	(0)
CrCl2+	8.220e-22	6.005e-22	-21.085	-21.221	-0.136	(0)
CuCl3-	6.065e-23	4.073e-23	-22.217	-22.390	-0.173	(0)
FeCl3	6.561e-25	7.150e-25	-24.183	-24.146	0.037	(0)
CuCl4-2	2.540e-28	6.060e-29	-27.595	-28.218	-0.622	(0)
CrO3Cl-	4.842e-31	3.537e-31	-30.315	-30.451	-0.136	(0)
UCl+3	0.000e+00	0.000e+00	-44.140	-45.366	-1.227	(0)
Cr(2)	4.654e-24					
Cr+2	4.654e-24	1.326e-24	-23.332	-23.877	-0.545	(0)
Cr(3)	1.955e-08					
Cr(OH)3	9.687e-09	1.056e-08	-8.014	-7.976	0.037	(0)
Cr(OH)2+	9.202e-09	6.723e-09	-8.036	-8.172	-0.136	(0)
Cr(OH)+2	4.643e-10	1.323e-10	-9.333	-9.878	-0.545	(0)
CrOHSO4	1.813e-10	1.976e-10	-9.742	-9.704	0.037	(0)
CrO2-	7.556e-12	5.520e-12	-11.122	-11.258	-0.136	(0)
Cr(OH)4-	2.924e-12	2.136e-12	-11.534	-11.670	-0.136	(0)
Cr+3	1.053e-12	6.245e-14	-11.978	-13.204	-1.227	(0)

CrSO4+	6.254e-15	4.569e-15	-14.204	-14.340	-0.136	(0)
CrCl+2	3.644e-17	1.038e-17	-16.438	-16.984	-0.545	(0)
Cr2(OH)2SO4+2	1.668e-17	4.754e-18	-16.778	-17.323	-0.545	(0)
CrOHCl2	2.354e-20	2.566e-20	-19.628	-19.591	0.037	(0)
CrCl2+	8.220e-22	6.005e-22	-21.085	-21.221	-0.136	(0)
Cr2(OH)2(SO4)2	3.399e-22	3.705e-22	-21.469	-21.431	0.037	(0)
Cr(6)	1.917e-19					
CrO4-2	1.304e-19	2.652e-20	-18.885	-19.576	-0.692	(0)
NaCrO4-	5.493e-20	4.013e-20	-19.260	-19.397	-0.136	(0)
HCrO4-	5.480e-21	4.004e-21	-20.261	-20.398	-0.136	(0)
KCrO4-	8.657e-22	6.325e-22	-21.063	-21.199	-0.136	(0)
CrO3SO4-2	6.691e-28	1.906e-28	-27.175	-27.720	-0.545	(0)
H2CrO4	2.385e-29	2.600e-29	-28.622	-28.585	0.037	(0)
CrO3Cl-	4.842e-31	3.537e-31	-30.315	-30.451	-0.136	(0)
Cr2O7-2	1.966e-39	5.601e-40	-38.706	-39.252	-0.545	(0)
Cu(1)	2.637e-11					
Cu+	2.571e-11	1.594e-11	-10.590	-10.798	-0.208	(0)
CuCl2-	6.612e-13	4.441e-13	-12.180	-12.353	-0.173	(0)
CuCl3-2	8.756e-16	2.089e-16	-15.058	-15.680	-0.622	(0)
Cu(2)	1.597e-08					
CuCO3	9.492e-09	1.035e-08	-8.023	-7.985	0.037	(0)
Cu(OH)2	2.613e-09	2.847e-09	-8.583	-8.546	0.037	(0)
Cu+2	2.055e-09	3.037e-10	-8.687	-9.518	-0.830	(0)
CuHCO3+	1.233e-09	9.011e-10	-8.909	-9.045	-0.136	(0)
Cu(CO3)2-2	2.900e-10	8.262e-11	-9.538	-10.083	-0.545	(0)
CuSO4	1.879e-10	2.048e-10	-9.726	-9.689	0.037	(0)
CuOH+	9.580e-11	6.433e-11	-10.019	-10.192	-0.173	(0)
CuCl+	3.613e-13	2.426e-13	-12.442	-12.615	-0.173	(0)
Cu2(OH)2+2	6.356e-15	1.811e-15	-14.197	-14.742	-0.545	(0)
Cu(OH)3-	4.986e-15	3.643e-15	-14.302	-14.439	-0.136	(0)
CuCl2	3.549e-17	3.868e-17	-16.450	-16.413	0.037	(0)
Cu(OH)4-2	5.392e-20	1.536e-20	-19.268	-19.814	-0.545	(0)
CuCl3-	6.065e-23	4.073e-23	-22.217	-22.390	-0.173	(0)
CuCl4-2	2.540e-28	6.060e-29	-27.595	-28.218	-0.622	(0)
Fe(2)	9.223e-06					
Fe+2	8.026e-06	2.182e-06	-5.096	-5.661	-0.566	(0)
FeSO4	1.176e-06	1.282e-06	-5.930	-5.892	0.037	(0)
FeOH+	2.091e-08	1.462e-08	-7.680	-7.835	-0.156	(0)
Fe(OH)2	2.418e-12	2.635e-12	-11.617	-11.579	0.037	(0)
Fe(OH)3-	2.968e-15	2.074e-15	-14.528	-14.683	-0.156	(0)
Fe(3)	3.334e-06					
Fe(OH)2+	2.744e-06	1.945e-06	-5.562	-5.711	-0.150	(0)
Fe(OH)3	4.441e-07	4.840e-07	-6.353	-6.315	0.037	(0)
Fe(OH)4-	1.447e-07	1.025e-07	-6.840	-6.989	-0.150	(0)
FeOH+2	1.162e-09	2.772e-10	-8.935	-9.557	-0.622	(0)
FeSO4+	7.968e-14	5.569e-14	-13.099	-13.254	-0.156	(0)
Fe+3	2.025e-14	2.027e-15	-13.694	-14.693	-1.000	(0)
Fe(SO4)2-	7.961e-15	5.816e-15	-14.099	-14.235	-0.136	(0)
Fe2(OH)2+4	3.139e-16	2.069e-18	-15.503	-17.684	-2.181	(0)
FeCl+2	7.615e-17	1.817e-17	-16.118	-16.741	-0.622	(0)
Fe3(OH)4+5	2.150e-18	8.405e-22	-17.668	-21.075	-3.408	(0)
FeCl2+	3.447e-20	2.409e-20	-19.463	-19.618	-0.156	(0)
FeCl3	6.561e-25	7.150e-25	-24.183	-24.146	0.037	(0)
H(0)	2.842e-26					
H2	1.421e-26	1.549e-26	-25.847	-25.810	0.037	(0)
K	5.978e-03					
K+	5.854e-03	3.789e-03	-2.233	-2.422	-0.189	(0)
KSO4-	1.241e-04	8.793e-05	-3.906	-4.056	-0.150	(0)
KCrO4-	8.657e-22	6.325e-22	-21.063	-21.199	-0.136	(0)
Mg	5.142e-02					
Mg+2	4.201e-02	1.436e-02	-1.377	-1.843	-0.466	(0)
MgSO4	7.737e-03	8.433e-03	-2.111	-2.074	0.037	(0)
MgHCO3+	1.593e-03	1.070e-03	-2.798	-2.971	-0.173	(0)
MgCO3	7.974e-05	8.691e-05	-4.098	-4.061	0.037	(0)
MgOH+	6.821e-07	4.996e-07	-6.166	-6.301	-0.135	(0)
Mn(2)	5.365e-05					

Mn+2	4.484e-05	1.219e-05	-4.348	-4.914	-0.566	(0)
MnSO4	6.722e-06	7.326e-06	-5.173	-5.135	0.037	(0)
MnHCO3+	2.060e-06	1.440e-06	-5.686	-5.842	-0.156	(0)
MnCl+	2.094e-08	1.464e-08	-7.679	-7.835	-0.156	(0)
MnOH+	9.497e-09	6.637e-09	-8.022	-8.178	-0.156	(0)
MnCl2	1.083e-12	1.180e-12	-11.965	-11.928	0.037	(0)
MnCl3-	2.260e-16	1.579e-16	-15.646	-15.802	-0.156	(0)
Mn(OH)3-	2.628e-18	1.837e-18	-17.580	-17.736	-0.156	(0)
Mn(3)	3.789e-26					
Mn+3	3.789e-26	3.793e-27	-25.421	-26.421	-1.000	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-48.108	-48.730	-0.622	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-53.919	-54.114	-0.195	(0)
Na	4.332e-01					
Na+	4.251e-01	3.045e-01	-0.372	-0.516	-0.145	(0)
NaSO4-	7.114e-03	5.041e-03	-2.148	-2.297	-0.150	(0)
NaHCO3	9.966e-04	1.086e-03	-3.001	-2.964	0.037	(0)
NaCO3-	5.053e-05	3.580e-05	-4.296	-4.446	-0.150	(0)
NaCrO4-	5.493e-20	4.013e-20	-19.260	-19.397	-0.136	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-40.805	-40.768	0.037	(0)
S(6)	3.481e-02					
SO4-2	1.681e-02	3.303e-03	-1.774	-2.481	-0.707	(0)
MgSO4	7.737e-03	8.433e-03	-2.111	-2.074	0.037	(0)
NaSO4-	7.114e-03	5.041e-03	-2.148	-2.297	-0.150	(0)
CaSO4	3.016e-03	3.287e-03	-2.521	-2.483	0.037	(0)
KSO4-	1.241e-04	8.793e-05	-3.906	-4.056	-0.150	(0)
MnSO4	6.722e-06	7.326e-06	-5.173	-5.135	0.037	(0)
FeSO4	1.176e-06	1.282e-06	-5.930	-5.892	0.037	(0)
HSO4-	2.186e-08	1.499e-08	-7.660	-7.824	-0.164	(0)
ZnSO4	1.516e-08	1.653e-08	-7.819	-7.782	0.037	(0)
Zn(SO4)2-2	1.557e-09	4.437e-10	-8.808	-9.353	-0.545	(0)
CuSO4	1.879e-10	2.048e-10	-9.726	-9.689	0.037	(0)
CrOHSO4	1.813e-10	1.976e-10	-9.742	-9.704	0.037	(0)
AlSO4+	4.921e-13	3.375e-13	-12.308	-12.472	-0.164	(0)
Al(SO4)2-	1.291e-13	8.855e-14	-12.889	-13.053	-0.164	(0)
FeSO4+	7.968e-14	5.569e-14	-13.099	-13.254	-0.156	(0)
Fe(SO4)2-	7.961e-15	5.816e-15	-14.099	-14.235	-0.136	(0)
CrSO4+	6.254e-15	4.569e-15	-14.204	-14.340	-0.136	(0)
UO2SO4	1.287e-15	1.403e-15	-14.890	-14.853	0.037	(0)
UO2(SO4)2-2	4.843e-16	1.380e-16	-15.315	-15.860	-0.545	(0)
Cr2(OH)2SO4+2	1.668e-17	4.754e-18	-16.778	-17.323	-0.545	(0)
Cr2(OH)2(SO4)2	3.399e-22	3.705e-22	-21.469	-21.431	0.037	(0)
CrO3SO4-2	6.691e-28	1.906e-28	-27.175	-27.720	-0.545	(0)
U(SO4)2	3.736e-39	4.072e-39	-38.428	-38.390	0.037	(0)
USO4+2	2.229e-40	0.000e+00	-39.652	-40.197	-0.545	(0)
U(3)	0.000e+00					
U+3	0.000e+00	0.000e+00	-54.746	-55.973	-1.227	(0)
U(4)	2.951e-20					
U(OH)5-	2.947e-20	2.153e-20	-19.531	-19.667	-0.136	(0)
U(OH)4	3.905e-23	4.257e-23	-22.408	-22.371	0.037	(0)
U(OH)3+	1.005e-26	7.346e-27	-25.998	-26.134	-0.136	(0)
U(OH)2+2	5.627e-31	1.603e-31	-30.250	-30.795	-0.545	(0)
UOH+3	5.166e-36	3.064e-37	-35.287	-36.514	-1.227	(0)
U(SO4)2	3.736e-39	4.072e-39	-38.428	-38.390	0.037	(0)
USO4+2	2.229e-40	0.000e+00	-39.652	-40.197	-0.545	(0)
U+4	0.000e+00	0.000e+00	-40.996	-43.177	-2.181	(0)
UCl+3	0.000e+00	0.000e+00	-44.140	-45.366	-1.227	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-155.359	-166.401	-11.042	(0)
U(5)	6.924e-17					
UO2+	6.924e-17	5.059e-17	-16.160	-16.296	-0.136	(0)
U(6)	8.967e-08					
UO2(CO3)3-4	7.782e-08	5.129e-10	-7.109	-9.290	-2.181	(0)
UO2(CO3)2-2	1.178e-08	3.357e-09	-7.929	-8.474	-0.545	(0)
UO2CO3	6.080e-11	6.626e-11	-10.216	-10.179	0.037	(0)

UO2OH+	1.956e-13	1.429e-13	-12.709	-12.845	-0.136 (0)
UO2+2	2.913e-15	8.299e-16	-14.536	-15.081	-0.545 (0)
UO2SO4	1.287e-15	1.403e-15	-14.890	-14.853	0.037 (0)
UO2(SO4)2-2	4.843e-16	1.380e-16	-15.315	-15.860	-0.545 (0)
UO2Cl+	5.596e-19	4.088e-19	-18.252	-18.388	-0.136 (0)
(UO2)2(OH)2+2	2.457e-21	7.000e-22	-20.610	-21.155	-0.545 (0)
(UO2)3(OH)5+	8.521e-25	6.225e-25	-24.070	-24.206	-0.136 (0)
Zn	1.555e-07				
Zn+2	7.851e-08	2.134e-08	-7.105	-7.671	-0.566 (0)
ZnCO3	2.479e-08	2.702e-08	-7.606	-7.568	0.037 (0)
ZnHCO3+	2.177e-08	1.591e-08	-7.662	-7.798	-0.136 (0)
ZnSO4	1.516e-08	1.653e-08	-7.819	-7.782	0.037 (0)
Zn(CO3)2-2	1.286e-08	3.664e-09	-7.891	-8.436	-0.545 (0)
Zn(SO4)2-2	1.557e-09	4.437e-10	-8.808	-9.353	-0.545 (0)
ZnOH+	6.786e-10	4.958e-10	-9.168	-9.305	-0.136 (0)
Zn(OH)2	1.109e-10	1.209e-10	-9.955	-9.918	0.037 (0)
ZnCl+	2.539e-11	1.705e-11	-10.595	-10.768	-0.173 (0)
ZnOHCl	4.078e-12	4.444e-12	-11.390	-11.352	0.037 (0)
Zn(OH)3-	1.108e-14	8.097e-15	-13.955	-14.092	-0.136 (0)
ZnCl2	4.863e-15	5.300e-15	-14.313	-14.276	0.037 (0)
ZnCl3-	2.628e-18	1.765e-18	-17.580	-17.753	-0.173 (0)
Zn(OH)4-2	9.541e-20	2.719e-20	-19.020	-19.566	-0.545 (0)
ZnCl4-2	1.098e-21	2.620e-22	-20.959	-21.582	-0.622 (0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-1.41	8.97	10.38	Al(OH)3
Al2O3	-5.03	17.95	22.98	Al2O3
Al4(OH)10SO4	-3.96	18.74	22.70	Al4(OH)10SO4
AlOHSO4	-4.94	-8.17	-3.23	AlOHSO4
AlumK	-15.27	-20.44	-5.17	KAl(SO4)2:12H2O
Alunite	-1.11	-2.46	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-0.16	-4.79	-4.64	CaSO4
Antlerite	-10.02	-1.73	8.29	Cu3(OH)4SO4
Aragonite	0.83	-7.51	-8.34	CaCO3
Artinite	-3.84	5.76	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-7.92	-0.58	7.34	Cu2(OH)3Cl
Azurite	-7.38	-24.30	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.97	-0.43	5.54	UO2(OH)2
Bianchite	-8.41	-10.18	-1.76	ZnSO4:6H2O
Birnessite	-11.20	6.89	18.09	MnO2
Bixbyite	-8.26	-8.87	-0.61	Mn2O3
Boehmite	0.39	8.97	8.58	AlOOH
Brochantite	-11.94	3.40	15.34	Cu4(OH)6SO4
Brucite	-3.98	12.81	16.79	Mg(OH)2
CaCrO4	-19.62	-21.89	-2.27	CaCrO4
Calcite	0.97	-7.51	-8.47	CaCO3
CH4(g)	-70.39	-110.49	-40.10	CH4
Chalcanthite	-9.38	-12.02	-2.64	CuSO4:5H2O
CO2(g)	-1.69	-19.85	-18.16	CO2
Cr(OH)2	-20.04	-9.23	10.82	Cr(OH)2
Cr(OH)3(A)	-0.10	-0.85	-0.75	Cr(OH)3
Cr(OH)3(C)	-2.55	-0.85	1.70	Cr(OH)3
Cr2O3	1.71	-1.68	-3.39	Cr2O3
CrCl2	-46.80	-30.93	15.87	CrCl2
CrCl3	-46.91	-33.41	13.51	CrCl3
CrMetal	-64.12	-31.88	32.24	Cr
CrO3	-31.02	-34.23	-3.21	CrO3
Cu(OH)2	-3.51	5.13	8.64	Cu(OH)2
Cu2SO4	-22.13	-24.08	-1.95	Cu2SO4
CuCO3	-5.09	-14.72	-9.63	CuCO3
CuCrO4	-23.62	-29.09	-5.48	CuCrO4
CuMetal	-6.04	-14.80	-8.76	Cu
CuOCuSO4	-18.39	-6.86	11.53	CuO:CuSO4

CupricFerrite	13.84	19.72	5.88	CuFe2O4
Cuprite	-5.39	-6.94	-1.55	Cu2O
CuprousFerrite	12.74	3.82	-8.92	CuFeO2
CuSO4	-15.01	-12.00	3.01	CuSO4
Diaspore	2.10	8.97	6.87	AlOOH
Dolomite	2.45	-14.55	-17.00	CaMg(CO3)2
Epsomite	-2.21	-4.35	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	7.07	4.03	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-40.41	-36.83	3.58	Fe2(SO4)3
Fe3(OH)8	3.34	23.56	20.22	Fe3(OH)8
FeCr2O4	8.22	7.31	-0.90	FeCr2O4
Ferrihydrite	2.39	7.28	4.89	Fe(OH)3
Gibbsite(C)	0.20	8.97	8.77	Al(OH)3
Goethite	6.79	7.29	0.50	FeOOH
Goslarite	-8.22	-10.18	-1.96	ZnSO4:7H2O
Gummite	-10.83	-0.42	10.40	UO3
Gypsum	-0.19	-4.80	-4.61	CaSO4:2H2O
Halite	-5.63	-4.04	1.58	NaCl
Hausmannite	-9.66	51.88	61.54	Mn3O4
Hematite	18.59	14.58	-4.01	Fe2O3
Hercynite	-0.22	26.94	27.16	FeAl2O4
Huntite	1.34	-28.63	-29.97	CaMg3(CO3)4
Hydromagnesite	-6.60	-15.37	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-0.32	-12.42	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	7.29	-7.51	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	5.60	-5.60	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-42.98	-58.65	-15.67	K2Cr2O7
K2CrO4	-24.43	-24.42	0.01	K2CrO4
Langite	-13.39	3.40	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	5.92	7.29	1.37	FeOOH
Lime	-20.45	12.34	32.80	CaO
Maghemite	8.20	14.58	6.39	Fe2O3
Magnesite	0.99	-7.04	-8.03	MgCO3
Magnetite	19.84	23.58	3.74	Fe3O4
Malachite	-4.40	-9.58	-5.18	Cu2(OH)2CO3
Manganite	-4.20	-4.44	-0.24	MnOOH
Melanothallite	-20.30	-16.57	3.73	CuCl2
Melanterite	-5.70	-8.17	-2.47	FeSO4:7H2O
Mg-Ferrite	10.63	27.39	16.77	MgFe2O4
MgCr2O4	-0.95	11.13	12.08	MgCr2O4
MgCrO4	-26.80	-21.42	5.38	MgCrO4
Mirabilite	-2.44	-3.55	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-54.57	-60.29	-5.71	Mn2(SO4)3
MnCl2:4H2O	-14.69	-11.98	2.71	MnCl2:4H2O
MnSO4	-10.06	-7.40	2.67	MnSO4
Na2Cr2O7	-44.95	-54.84	-9.90	Na2Cr2O7
Na2CrO4	-23.87	-20.61	3.26	Na2CrO4
Nantokite	-7.57	-14.33	-6.76	CuCl
Natron	-4.96	-6.27	-1.31	Na2CO3:10H2O
Nesquehonite	-1.43	-7.05	-5.62	MgCO3:3H2O
Nsutite	-10.61	6.89	17.50	MnO2
O2(g)	-37.81	45.31	83.12	O2
Periclase	-8.70	12.81	21.51	MgO
Portlandite	-10.33	12.34	22.68	Ca(OH)2
Pyrocroite	-5.35	9.74	15.09	Mn(OH)2
Pyrolusite	-8.97	6.89	15.86	MnO2
Rhodochrosite	0.30	-10.11	-10.41	MnCO3
Rutherfordine	-5.82	-20.28	-14.46	UO2CO3
Schoepite	-5.84	-0.43	5.40	UO2(OH)2:H2O
Siderite	-0.31	-10.86	-10.55	FeCO3
Smithsonite	-2.87	-12.87	-10.00	ZnCO3
Spinel	-5.57	30.76	36.33	MgAl2O4
Tenorite	-2.48	5.14	7.62	CuO
Thenardite	-3.33	-3.51	-0.18	Na2SO4
Thermonatrite	-6.36	-6.23	0.13	Na2CO3:H2O
U3O8(C)	-17.39	3.72	21.11	U3O8

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  U4O9(C)          -29.42    -32.80   -3.38  U4O9
  UO2(am)          -14.80    -13.86    0.93  UO2
  UO3(C)            -8.14     -0.42    7.72  UO3
  Uraninite         -9.16    -13.86   -4.70  UO2
  Zincite           -4.15      6.99   11.14  ZnO
  Zincosite        -13.16    -10.15    3.01  ZnSO4
  Zn(BO2)2          -7.49      0.80    8.29  Zn(BO2)2
  Zn(OH)2(A)        -5.47      6.98   12.45  Zn(OH)2
  Zn(OH)2(B)        -4.77      6.98   11.75  Zn(OH)2
  Zn(OH)2(C)        -5.22      6.98   12.20  Zn(OH)2
  Zn(OH)2(E)        -4.52      6.98   11.50  Zn(OH)2
  Zn(OH)2(G)        -4.73      6.98   11.71  Zn(OH)2
  Zn2(OH)2SO4      -10.67     -3.17    7.50  Zn2(OH)2SO4
  Zn2(OH)3Cl       -12.09      3.11   15.20  Zn2(OH)3Cl
  Zn3O(SO4)2       -32.34    -13.32   19.02  Zn3O(SO4)2
  Zn4(OH)6SO4      -17.61     10.79   28.40  Zn4(OH)6SO4
  Zn5(OH)8Cl2      -25.30     13.20   38.50  Zn5(OH)8Cl2
  ZnCl2            -21.76    -14.73    7.03  ZnCl2
  ZnCO3:H2O         -2.61    -12.87  -10.26  ZnCO3:H2O
  ZnMetal          -41.43    -15.67   25.76  Zn
  ZnO(Active)       -4.32      6.99   11.31  ZnO
  ZnSO4:H2O         -9.59    -10.16   -0.57  ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 9.

-----------------------------Solution composition------------------------------

      Elements           Molality       Moles

      Al                7.070e-06   7.070e-06
      Alkalinity        2.995e-03   2.995e-03
      B                 7.059e-05   7.059e-05
      Ca                1.879e-03   1.879e-03
      Cl                4.645e-02   4.645e-02
      Cr                9.655e-09   9.655e-09
      Cu                3.160e-08   3.160e-08
      Fe                4.495e-07   4.495e-07
      K                 7.960e-04   7.960e-04
      Mg                6.277e-03   6.277e-03
      Mn                6.214e-07   6.214e-07
      Na                5.022e-02   5.022e-02
      S(6)              8.424e-03   8.424e-03
      U                 2.953e-08   2.953e-08
      Zn                3.840e-08   3.840e-08

----------------------------Description of solution----------------------------

                                    pH  =   8.020
                                    pe  =   4.000
                       Activity of water  =   0.998
                  Ionic strength (mol/kgw)  =   7.641e-02
                        Mass of water (kg)  =   1.000e+00
                   Total carbon (mol/kg)  =   2.937e-03
                      Total CO2 (mol/kg)  =   2.937e-03
                        Temperature (°C)  =  25.00
                  Electrical balance (eq)  =   1.067e-03
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   0.84
                               Iterations  =  11
                                  Total H  = 1.110156e+02
                                  Total O  = 5.554897e+01

---------------------------Distribution of species----------------------------
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Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
OH-	1.343e-06	1.050e-06	-5.872	-5.979	-0.107	(0)
H+	1.142e-08	9.550e-09	-7.942	-8.020	-0.078	0.00
H2O	5.551e+01	9.980e-01	1.744	-0.001	0.000	18.07
Al	7.070e-06					
Al(OH)4-	6.575e-06	5.222e-06	-5.182	-5.282	-0.100	(0)
Al(OH)3	4.909e-07	4.996e-07	-6.309	-6.301	0.008	(0)
Al(OH)2+	4.722e-09	3.797e-09	-8.326	-8.421	-0.095	(0)
AlOH+2	1.119e-11	4.681e-12	-10.951	-11.330	-0.378	(0)
Al+3	2.185e-14	4.377e-15	-13.661	-14.359	-0.698	(0)
AlSO4+	1.426e-14	1.132e-14	-13.846	-13.946	-0.100	(0)
Al(SO4)2-	2.798e-15	2.222e-15	-14.553	-14.653	-0.100	(0)
B	7.059e-05					
H3BO3	6.538e-05	6.654e-05	-4.185	-4.177	0.008	(0)
H2BO3-	5.213e-06	4.001e-06	-5.283	-5.398	-0.115	(0)
C(4)	2.937e-03					
HCO3-	2.681e-03	2.156e-03	-2.572	-2.666	-0.095	(0)
MgHCO3+	7.597e-05	5.987e-05	-4.119	-4.223	-0.103	(0)
NaHCO3	4.719e-05	4.803e-05	-4.326	-4.319	0.008	(0)
H2CO3	4.544e-05	4.624e-05	-4.343	-4.335	0.008	(0)
CO3-2	2.526e-05	1.057e-05	-4.598	-4.976	-0.378	(0)
MgCO3	2.340e-05	2.382e-05	-4.631	-4.623	0.008	(0)
CaHCO3+	1.858e-05	1.505e-05	-4.731	-4.822	-0.091	(0)
CaCO3	9.942e-06	1.012e-05	-5.003	-4.995	0.008	(0)
NaCO3-	9.640e-06	7.753e-06	-5.016	-5.111	-0.095	(0)
UO2(CO3)3-4	2.348e-08	6.173e-10	-7.629	-9.209	-1.580	(0)
ZnCO3	1.134e-08	1.154e-08	-7.946	-7.938	0.008	(0)
MnHCO3+	1.042e-08	8.332e-09	-7.982	-8.079	-0.097	(0)
Zn(CO3)2-2	6.475e-09	2.607e-09	-8.189	-8.584	-0.395	(0)
UO2(CO3)2-2	6.022e-09	2.425e-09	-8.220	-8.615	-0.395	(0)
CuCO3	5.534e-09	5.632e-09	-8.257	-8.249	0.008	(0)
ZnHCO3+	1.741e-09	1.387e-09	-8.759	-8.858	-0.099	(0)
Cu(CO3)2-2	1.861e-10	7.495e-11	-9.730	-10.125	-0.395	(0)
CuHCO3+	1.257e-10	1.002e-10	-9.901	-9.999	-0.099	(0)
UO2CO3	2.823e-11	2.873e-11	-10.549	-10.542	0.008	(0)
Ca	1.879e-03					
Ca+2	1.517e-03	6.739e-04	-2.819	-3.171	-0.352	(0)
CaSO4	3.332e-04	3.391e-04	-3.477	-3.470	0.008	(0)
CaHCO3+	1.858e-05	1.505e-05	-4.731	-4.822	-0.091	(0)
CaCO3	9.942e-06	1.012e-05	-5.003	-4.995	0.008	(0)
CaOH+	2.193e-08	1.777e-08	-7.659	-7.750	-0.091	(0)
Cl	4.645e-02					
Cl-	4.645e-02	3.608e-02	-1.333	-1.443	-0.110	(0)
MnCl+	3.784e-08	3.027e-08	-7.422	-7.519	-0.097	(0)
CuCl2-	2.721e-09	2.144e-09	-8.565	-8.669	-0.103	(0)
ZnCl+	6.742e-10	5.313e-10	-9.171	-9.275	-0.103	(0)
ZnOHCl	6.713e-10	6.832e-10	-9.173	-9.165	0.008	(0)
CuCl3-2	2.995e-10	1.226e-10	-9.524	-9.911	-0.388	(0)
MnCl2	2.915e-10	2.967e-10	-9.535	-9.528	0.008	(0)
ZnCl2	1.973e-11	2.008e-11	-10.705	-10.697	0.008	(0)
CuCl+	1.223e-11	9.637e-12	-10.913	-11.016	-0.103	(0)
MnCl3-	6.033e-12	4.826e-12	-11.219	-11.316	-0.097	(0)
ZnCl3-	1.031e-12	8.128e-13	-11.987	-12.090	-0.103	(0)
CuCl2	1.835e-13	1.867e-13	-12.736	-12.729	0.008	(0)
ZnCl4-2	3.582e-14	1.466e-14	-13.446	-13.834	-0.388	(0)
CuCl3-	3.034e-17	2.391e-17	-16.518	-16.621	-0.103	(0)
CrCl+2	2.074e-17	8.353e-18	-16.683	-17.078	-0.395	(0)
UO2Cl+	1.623e-17	1.293e-17	-16.790	-16.888	-0.099	(0)
FeCl+2	1.227e-17	5.025e-18	-16.911	-17.299	-0.388	(0)
CrOHCl2	1.216e-17	1.238e-17	-16.915	-16.907	0.008	(0)
FeCl2+	1.012e-18	8.099e-19	-17.995	-18.092	-0.097	(0)
CrCl2+	7.373e-20	5.873e-20	-19.132	-19.231	-0.099	(0)
CuCl4-2	1.056e-20	4.323e-21	-19.976	-20.364	-0.388	(0)
FeCl3	2.871e-21	2.922e-21	-20.542	-20.534	0.008	(0)

CrO3Cl-	5.039e-27	4.014e-27	-26.298	-26.396	-0.099	(0)
UCl+3	0.000e+00	0.000e+00	-45.744	-46.633	-0.889	(0)
Cr(2)	2.179e-26					
Cr+2	2.179e-26	8.776e-27	-25.662	-26.057	-0.395	(0)
Cr(3)	9.655e-09					
Cr(OH)3	8.243e-09	8.389e-09	-8.084	-8.076	0.008	(0)
Cr(OH)2+	1.359e-09	1.083e-09	-8.867	-8.965	-0.099	(0)
CrO2-	2.678e-11	2.133e-11	-10.572	-10.671	-0.099	(0)
Cr(OH)+2	1.073e-11	4.319e-12	-10.970	-11.365	-0.395	(0)
Cr(OH)4-	1.051e-11	8.373e-12	-10.978	-11.077	-0.099	(0)
CrOHSO4	4.742e-12	4.826e-12	-11.324	-11.316	0.008	(0)
Cr+3	3.200e-15	4.133e-16	-14.495	-15.384	-0.889	(0)
CrSO4+	2.839e-17	2.262e-17	-16.547	-16.646	-0.099	(0)
CrCl+2	2.074e-17	8.353e-18	-16.683	-17.078	-0.395	(0)
CrOHCl2	1.216e-17	1.238e-17	-16.915	-16.907	0.008	(0)
CrCl2+	7.373e-20	5.873e-20	-19.132	-19.231	-0.099	(0)
Cr2(OH)2SO4+2	9.412e-21	3.790e-21	-20.026	-20.421	-0.395	(0)
Cr2(OH)2(SO4)2	2.171e-25	2.209e-25	-24.663	-24.656	0.008	(0)
Cr(6)	1.724e-16					
CrO4-2	1.551e-16	5.982e-17	-15.809	-16.223	-0.414	(0)
NaCrO4-	1.477e-17	1.177e-17	-16.831	-16.929	-0.099	(0)
HCrO4-	2.315e-18	1.844e-18	-17.635	-17.734	-0.099	(0)
KCrO4-	2.875e-19	2.290e-19	-18.541	-18.640	-0.099	(0)
CrO3SO4-2	3.306e-26	1.331e-26	-25.481	-25.876	-0.395	(0)
CrO3Cl-	5.039e-27	4.014e-27	-26.298	-26.396	-0.099	(0)
H2CrO4	2.402e-27	2.444e-27	-26.619	-26.612	0.008	(0)
Cr2O7-2	2.929e-34	1.180e-34	-33.533	-33.928	-0.395	(0)
Cu(1)	3.027e-09					
CuCl2-	2.721e-09	2.144e-09	-8.565	-8.669	-0.103	(0)
CuCl3-2	2.995e-10	1.226e-10	-9.524	-9.911	-0.388	(0)
Cu+	6.785e-12	5.208e-12	-11.168	-11.283	-0.115	(0)
Cu(2)	2.857e-08					
Cu(OH)2	2.225e-08	2.264e-08	-7.653	-7.645	0.008	(0)
CuCO3	5.534e-09	5.632e-09	-8.257	-8.249	0.008	(0)
Cu+2	2.859e-10	9.923e-11	-9.544	-10.003	-0.460	(0)
Cu(CO3)2-2	1.861e-10	7.495e-11	-9.730	-10.125	-0.395	(0)
CuOH+	1.316e-10	1.037e-10	-9.881	-9.984	-0.103	(0)
CuHCO3+	1.257e-10	1.002e-10	-9.901	-9.999	-0.099	(0)
CuSO4	4.918e-11	5.005e-11	-10.308	-10.301	0.008	(0)
CuCl+	1.223e-11	9.637e-12	-10.913	-11.016	-0.103	(0)
CuCl2	1.835e-13	1.867e-13	-12.736	-12.729	0.008	(0)
Cu(OH)3-	1.794e-13	1.429e-13	-12.746	-12.845	-0.099	(0)
Cu2(OH)2+2	1.169e-14	4.706e-15	-13.932	-14.327	-0.395	(0)
CuCl3-	3.034e-17	2.391e-17	-16.518	-16.621	-0.103	(0)
Cu(OH)4-2	7.384e-18	2.973e-18	-17.132	-17.527	-0.395	(0)
CuCl4-2	1.056e-20	4.323e-21	-19.976	-20.364	-0.388	(0)
Fe(2)	1.385e-08					
Fe+2	1.150e-08	4.964e-09	-7.939	-8.304	-0.365	(0)
FeSO4	2.143e-09	2.181e-09	-8.669	-8.661	0.008	(0)
FeOH+	2.051e-10	1.641e-10	-9.688	-9.785	-0.097	(0)
Fe(OH)2	1.434e-13	1.459e-13	-12.843	-12.836	0.008	(0)
Fe(OH)3-	7.084e-16	5.666e-16	-15.150	-15.247	-0.097	(0)
Fe(3)	4.356e-07					
Fe(OH)4-	1.718e-07	1.382e-07	-6.765	-6.860	-0.095	(0)
Fe(OH)2+	1.339e-07	1.077e-07	-6.873	-6.968	-0.095	(0)
Fe(OH)3	1.299e-07	1.322e-07	-6.886	-6.879	0.008	(0)
FeOH+2	7.600e-12	3.112e-12	-11.119	-11.507	-0.388	(0)
FeSO4+	1.185e-16	9.476e-17	-15.926	-16.023	-0.097	(0)
Fe+3	2.302e-17	4.611e-18	-16.638	-17.336	-0.698	(0)
FeCl+2	1.227e-17	5.025e-18	-16.911	-17.299	-0.388	(0)
Fe(SO4)2-	9.294e-18	7.403e-18	-17.032	-17.131	-0.099	(0)
FeCl2+	1.012e-18	8.099e-19	-17.995	-18.092	-0.097	(0)
Fe2(OH)2+4	9.911e-21	2.606e-22	-20.004	-21.584	-1.580	(0)
FeCl3	2.871e-21	2.922e-21	-20.542	-20.534	0.008	(0)
Fe3(OH)4+5	1.726e-24	5.863e-27	-23.763	-26.232	-2.469	(0)
H(0)	1.269e-27					

H2	6.344e-28	6.457e-28	-27.198	-27.190	0.008	(0)
K	7.960e-04					
K+	7.829e-04	6.082e-04	-3.106	-3.216	-0.110	(0)
KSO4-	1.313e-05	1.056e-05	-4.882	-4.976	-0.095	(0)
KCrO4-	2.875e-19	2.290e-19	-18.541	-18.640	-0.099	(0)
Mg	6.277e-03					
Mg+2	5.158e-03	2.361e-03	-2.288	-2.627	-0.339	(0)
MgSO4	1.019e-03	1.037e-03	-2.992	-2.984	0.008	(0)
MgHCO3+	7.597e-05	5.987e-05	-4.119	-4.223	-0.103	(0)
MgCO3	2.340e-05	2.382e-05	-4.631	-4.623	0.008	(0)
MgOH+	4.971e-07	4.053e-07	-6.304	-6.392	-0.089	(0)
Mn(2)	6.214e-07					
Mn+2	4.805e-07	2.073e-07	-6.318	-6.683	-0.365	(0)
MnSO4	9.159e-08	9.322e-08	-7.038	-7.031	0.008	(0)
MnCl+	3.784e-08	3.027e-08	-7.422	-7.519	-0.097	(0)
MnHCO3+	1.042e-08	8.332e-09	-7.982	-8.079	-0.097	(0)
MnOH+	6.963e-10	5.570e-10	-9.157	-9.254	-0.097	(0)
MnCl2	2.915e-10	2.967e-10	-9.535	-9.528	0.008	(0)
MnCl3-	6.033e-12	4.826e-12	-11.219	-11.316	-0.097	(0)
Mn(OH)3-	4.689e-18	3.751e-18	-17.329	-17.426	-0.097	(0)
Mn(3)	3.220e-28					
Mn+3	3.220e-28	6.452e-29	-27.492	-28.190	-0.698	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-44.579	-44.967	-0.388	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-50.240	-50.351	-0.111	(0)
Na	5.022e-02					
Na+	4.956e-02	3.958e-02	-1.305	-1.403	-0.098	(0)
NaSO4-	6.093e-04	4.900e-04	-3.215	-3.310	-0.095	(0)
NaHCO3	4.719e-05	4.803e-05	-4.326	-4.319	0.008	(0)
NaCO3-	9.640e-06	7.753e-06	-5.016	-5.111	-0.095	(0)
NaCrO4-	1.477e-17	1.177e-17	-16.831	-16.929	-0.099	(0)
O(0)	1.957e-38					
O2	9.787e-39	9.961e-39	-38.009	-38.002	0.008	(0)
S(6)	8.424e-03					
SO4-2	6.449e-03	2.471e-03	-2.190	-2.607	-0.417	(0)
MgSO4	1.019e-03	1.037e-03	-2.992	-2.984	0.008	(0)
NaSO4-	6.093e-04	4.900e-04	-3.215	-3.310	-0.095	(0)
CaSO4	3.332e-04	3.391e-04	-3.477	-3.470	0.008	(0)
KSO4-	1.313e-05	1.056e-05	-4.882	-4.976	-0.095	(0)
MnSO4	9.159e-08	9.322e-08	-7.038	-7.031	0.008	(0)
ZnSO4	3.113e-09	3.169e-09	-8.507	-8.499	0.008	(0)
HSO4-	2.883e-09	2.289e-09	-8.540	-8.640	-0.100	(0)
FeSO4	2.143e-09	2.181e-09	-8.669	-8.661	0.008	(0)
Zn(SO4)2-2	1.580e-10	6.363e-11	-9.801	-10.196	-0.395	(0)
CuSO4	4.918e-11	5.005e-11	-10.308	-10.301	0.008	(0)
CrOHSO4	4.742e-12	4.826e-12	-11.324	-11.316	0.008	(0)
AlSO4+	1.426e-14	1.132e-14	-13.846	-13.946	-0.100	(0)
Al(SO4)2-	2.798e-15	2.222e-15	-14.553	-14.653	-0.100	(0)
UO2SO4	2.682e-16	2.730e-16	-15.571	-15.564	0.008	(0)
FeSO4+	1.185e-16	9.476e-17	-15.926	-16.023	-0.097	(0)
UO2(SO4)2-2	4.989e-17	2.009e-17	-16.302	-16.697	-0.395	(0)
CrSO4+	2.839e-17	2.262e-17	-16.547	-16.646	-0.099	(0)
Fe(SO4)2-	9.294e-18	7.403e-18	-17.032	-17.131	-0.099	(0)
Cr2(OH)2SO4+2	9.412e-21	3.790e-21	-20.026	-20.421	-0.395	(0)
Cr2(OH)2(SO4)2	2.171e-25	2.209e-25	-24.663	-24.656	0.008	(0)
CrO3SO4-2	3.306e-26	1.331e-26	-25.481	-25.876	-0.395	(0)
U(SO4)2	0.000e+00	0.000e+00	-42.001	-41.993	0.008	(0)
USO4+2	0.000e+00	0.000e+00	-43.279	-43.674	-0.395	(0)
U(3)	0.000e+00					
U+3	0.000e+00	0.000e+00	-58.435	-59.324	-0.889	(0)
U(4)	3.521e-20					
U(OH)5-	3.520e-20	2.804e-20	-19.453	-19.552	-0.099	(0)
U(OH)4	1.104e-23	1.124e-23	-22.957	-22.949	0.008	(0)
U(OH)3+	4.935e-28	3.931e-28	-27.307	-27.405	-0.099	(0)
U(OH)2+2	4.319e-33	1.739e-33	-32.365	-32.760	-0.395	(0)

UOH+3	5.216e-39	6.737e-40	-38.283	-39.172	-0.889 (0)
U(SO4)2	0.000e+00	0.000e+00	-42.001	-41.993	0.008 (0)
USO4+2	0.000e+00	0.000e+00	-43.279	-43.674	-0.395 (0)
U+4	0.000e+00	0.000e+00	-44.948	-46.528	-1.580 (0)
UCl+3	0.000e+00	0.000e+00	-45.744	-46.633	-0.889 (0)
U6(OH)15+9	0.000e+00	0.000e+00	-168.110	-176.109	-7.999 (0)
U(5)	1.652e-17				
UO2+	1.652e-17	1.316e-17	-16.782	-16.881	-0.099 (0)
U(6)	2.953e-08				
UO2(CO3)3-4	2.348e-08	6.173e-10	-7.629	-9.209	-1.580 (0)
UO2(CO3)2-2	6.022e-09	2.425e-09	-8.220	-8.615	-0.395 (0)
UO2CO3	2.823e-11	2.873e-11	-10.549	-10.542	0.008 (0)
UO2OH+	2.303e-13	1.834e-13	-12.638	-12.736	-0.099 (0)
UO2+2	5.363e-16	2.160e-16	-15.271	-15.666	-0.395 (0)
UO2SO4	2.682e-16	2.730e-16	-15.571	-15.564	0.008 (0)
UO2(SO4)2-2	4.989e-17	2.009e-17	-16.302	-16.697	-0.395 (0)
UO2Cl+	1.623e-17	1.293e-17	-16.790	-16.888	-0.099 (0)
(UO2)2(OH)2+2	2.865e-21	1.154e-21	-20.543	-20.938	-0.395 (0)
(UO2)3(OH)5+	4.023e-23	3.205e-23	-22.395	-22.494	-0.099 (0)
Zn	3.840e-08				
Zn+2	1.268e-08	5.471e-09	-7.897	-8.262	-0.365 (0)
ZnCO3	1.134e-08	1.154e-08	-7.946	-7.938	0.008 (0)
Zn(CO3)2-2	6.475e-09	2.607e-09	-8.189	-8.584	-0.395 (0)
ZnSO4	3.113e-09	3.169e-09	-8.507	-8.499	0.008 (0)
ZnHCO3+	1.741e-09	1.387e-09	-8.759	-8.858	-0.099 (0)
ZnOH+	7.870e-10	6.270e-10	-9.104	-9.203	-0.099 (0)
Zn(OH)2	7.409e-10	7.540e-10	-9.130	-9.123	0.008 (0)
ZnCl+	6.742e-10	5.313e-10	-9.171	-9.275	-0.103 (0)
ZnOHCl	6.713e-10	6.832e-10	-9.173	-9.165	0.008 (0)
Zn(SO4)2-2	1.580e-10	6.363e-11	-9.801	-10.196	-0.395 (0)
ZnCl2	1.973e-11	2.008e-11	-10.705	-10.697	0.008 (0)
ZnCl3-	1.031e-12	8.128e-13	-11.987	-12.090	-0.103 (0)
Zn(OH)3-	3.128e-13	2.492e-13	-12.505	-12.603	-0.099 (0)
ZnCl4-2	3.582e-14	1.466e-14	-13.446	-13.834	-0.388 (0)
Zn(OH)4-2	1.025e-17	4.127e-18	-16.989	-17.384	-0.395 (0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-0.68	9.70	10.38	Al(OH)3
Al2O3	-3.58	19.40	22.98	Al2O3
Al4(OH)10SO4	-2.55	20.15	22.70	Al4(OH)10SO4
AlOHSO4	-5.72	-8.95	-3.23	AlOHSO4
AlumK	-17.63	-22.80	-5.17	KAl(SO4)2:12H2O
Alunite	-2.05	-3.39	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-1.14	-5.78	-4.64	CaSO4
Antlerite	-8.83	-0.54	8.29	Cu3(OH)4SO4
Aragonite	0.19	-8.15	-8.34	CaCO3
Artinite	-3.79	5.81	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-4.73	2.61	7.34	Cu2(OH)3Cl
Azurite	-7.00	-23.92	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.17	0.37	5.54	UO2(OH)2
Bianchite	-9.11	-10.87	-1.76	ZnSO4:6H2O
Birnessite	-10.20	7.89	18.09	MnO2
Bixbyite	-7.65	-8.26	-0.61	Mn2O3
Boehmite	1.12	9.70	8.58	AlOOH
Brochantite	-9.85	5.49	15.34	Cu4(OH)6SO4
Brucite	-3.38	13.41	16.79	Mg(OH)2
CaCrO4	-17.13	-19.39	-2.27	CaCrO4
Calcite	0.33	-8.15	-8.47	CaCO3
CH4(g)	-77.07	-117.17	-40.10	CH4
Chalcanthite	-9.97	-12.61	-2.64	CuSO4:5H2O
CO2(g)	-2.86	-21.02	-18.16	CO2
Cr(OH)2	-20.84	-10.02	10.82	Cr(OH)2
Cr(OH)3(A)	-0.20	-0.95	-0.75	Cr(OH)3

Cr(OH)3(C)	-2.65	-0.95	1.70	Cr(OH)3
Cr2O3	1.50	-1.89	-3.39	Cr2O3
CrCl2	-44.81	-28.94	15.87	CrCl2
CrCl3	-42.84	-29.33	13.51	CrCl3
CrMetal	-66.30	-34.06	32.24	Cr
CrO3	-29.05	-32.26	-3.21	CrO3
Cu(OH)2	-2.61	6.03	8.64	Cu(OH)2
Cu2SO4	-23.22	-25.17	-1.95	Cu2SO4
CuCO3	-5.35	-14.98	-9.63	CuCO3
CuCrO4	-20.75	-26.23	-5.48	CuCrO4
CuMetal	-6.52	-15.28	-8.76	Cu
CuOCuSO4	-18.10	-6.57	11.53	CuO:CuSO4
CupricFerrite	13.60	19.48	5.88	CuFe2O4
Cuprite	-4.98	-6.53	-1.55	Cu2O
CuprousFerrite	12.38	3.46	-8.92	CuFeO2
CuSO4	-15.62	-12.61	3.01	CuSO4
Diaspore	2.83	9.70	6.87	AlOOH
Dolomite	1.25	-15.75	-17.00	CaMg(CO3)2
Epsomite	-3.10	-5.24	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	6.92	3.88	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-46.07	-42.49	3.58	Fe2(SO4)3
Fe3(OH)8	0.95	21.18	20.22	Fe3(OH)8
FeCr2O4	6.75	5.84	-0.90	FeCr2O4
Ferrihydrite	1.83	6.72	4.89	Fe(OH)3
Gibbsite(C)	0.93	9.70	8.77	Al(OH)3
Goethite	6.22	6.72	0.50	FeOOH
Goslarite	-8.92	-10.88	-1.96	ZnSO4:7H2O
Gummite	-10.03	0.37	10.40	UO3
Gypsum	-1.17	-5.78	-4.61	CaSO4:2H2O
Halite	-4.43	-2.85	1.58	NaCl
Hausmannite	-9.43	52.11	61.54	Mn3O4
Hematite	17.45	13.45	-4.01	Fe2O3
Hercynite	-0.03	27.13	27.16	FeAl2O4
Huntite	-0.99	-30.96	-29.97	CaMg3(CO3)4
Hydromagnesite	-8.24	-17.00	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-5.03	-17.13	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	2.48	-12.32	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	0.69	-10.51	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-39.25	-54.92	-15.67	K2Cr2O7
K2CrO4	-22.66	-22.66	0.01	K2CrO4
Langite	-11.30	5.49	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	5.35	6.72	1.37	FeOOH
Lime	-19.93	12.87	32.80	CaO
Maghemite	7.06	13.45	6.39	Fe2O3
Magnesite	0.43	-7.60	-8.03	MgCO3
Magnetite	17.44	21.18	3.74	Fe3O4
Malachite	-3.76	-8.94	-5.18	Cu2(OH)2CO3
Manganite	-3.89	-4.13	-0.24	MnOOH
Melanothallite	-16.62	-12.89	3.73	CuCl2
Melanterite	-8.45	-10.92	-2.47	FeSO4:7H2O
Mg-Ferrite	10.09	26.86	16.77	MgFe2O4
MgCr2O4	-0.56	11.52	12.08	MgCr2O4
MgCrO4	-24.23	-18.85	5.38	MgCrO4
Mirabilite	-4.31	-5.42	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-58.49	-64.20	-5.71	Mn2(SO4)3
MnCl2:4H2O	-12.28	-9.57	2.71	MnCl2:4H2O
MnSO4	-11.96	-9.29	2.67	MnSO4
Na2Cr2O7	-41.40	-51.29	-9.90	Na2Cr2O7
Na2CrO4	-22.29	-19.03	3.26	Na2CrO4
Nantokite	-5.97	-12.73	-6.76	CuCl
Natron	-6.48	-7.79	-1.31	Na2CO3:10H2O
Nesquehonite	-1.98	-7.61	-5.62	MgCO3:3H2O
Nsutite	-9.62	7.89	17.50	MnO2
O2(g)	-35.04	48.08	83.12	O2
Periclase	-8.10	13.41	21.51	MgO
Portlandite	-9.81	12.87	22.68	Ca(OH)2

Pyrocroite	-5.73	9.35	15.09	Mn(OH)2
Pyrolusite	-7.97	7.89	15.86	MnO2
Rhodochrosite	-1.25	-11.66	-10.41	MnCO3
Rutherfordine	-6.18	-20.64	-14.46	UO2CO3
Schoepite	-5.03	0.37	5.40	UO2(OH)2:H2O
Siderite	-2.73	-13.28	-10.55	FeCO3
Smithsonite	-3.24	-13.24	-10.00	ZnCO3
Spinel	-3.52	32.81	36.33	MgAl2O4
Tenorite	-1.58	6.04	7.62	CuO
Thenardite	-5.23	-5.41	-0.18	Na2SO4
Thermonatrite	-7.91	-7.78	0.13	Na2CO3:H2O
U3O8(C)	-16.38	4.73	21.11	U3O8
U4O9(C)	-30.38	-33.76	-3.38	U4O9
UO2(am)	-15.38	-14.45	0.93	UO2
UO3(C)	-7.35	0.37	7.72	UO3
Uraninite	-9.75	-14.45	-4.70	UO2
Zincite	-3.36	7.78	11.14	ZnO
Zincosite	-13.88	-10.87	3.01	ZnSO4
Zn(BO2)2	-8.86	-0.57	8.29	Zn(BO2)2
Zn(OH)2(A)	-4.67	7.78	12.45	Zn(OH)2
Zn(OH)2(B)	-3.97	7.78	11.75	Zn(OH)2
Zn(OH)2(C)	-4.42	7.78	12.20	Zn(OH)2
Zn(OH)2(E)	-3.72	7.78	11.50	Zn(OH)2
Zn(OH)2(G)	-3.93	7.78	11.71	Zn(OH)2
Zn2(OH)2SO4	-10.59	-3.09	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-9.11	6.09	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-32.98	-13.96	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-15.94	12.46	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-18.54	19.96	38.50	Zn5(OH)8Cl2
ZnCl2	-18.18	-11.15	7.03	ZnCl2
ZnCO3:H2O	-2.98	-13.24	-10.26	ZnCO3:H2O
ZnMetal	-42.02	-16.26	25.76	Zn
ZnO(Active)	-3.53	7.78	11.31	ZnO
ZnSO4:H2O	-10.30	-10.87	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 10.

-----------------------------Solution composition------------------------------

Elements	Molality	Moles
Al	1.863e-07	1.863e-07
Alkalinity	4.795e-03	4.795e-03
B	1.869e-04	1.869e-04
Ca	1.982e-03	1.982e-03
Cl	5.133e-02	5.133e-02
Cr	9.668e-09	9.668e-09
Cu	4.746e-08	4.746e-08
Fe	4.501e-07	4.501e-07
K	7.971e-04	7.971e-04
Mg	7.485e-03	7.485e-03
Mn	5.490e-08	5.490e-08
Na	6.691e-02	6.691e-02
S(6)	1.497e-02	1.497e-02
U	3.801e-08	3.801e-08
Zn	1.384e-07	1.384e-07

---------------------------Description of solution----------------------------

pH	=	8.020
pe	=	4.000
Activity of water	=	0.998
Ionic strength (mol/kgw)	=	9.890e-02

```
                    Mass of water (kg)  =   1.000e+00
                 Total carbon (mol/kg)  =   4.733e-03
                    Total CO2 (mol/kg)  =   4.733e-03
                      Temperature (°C)  =  25.00
                Electrical balance (eq)  =   5.854e-04
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =   0.36
                             Iterations  =  12
                                Total H  = 1.110177e+02
                                Total O  = 5.558085e+01

----------------------------Distribution of species----------------------------

                                                 Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma   cm³/mol

   OH-             1.376e-06   1.049e-06    -5.861    -5.979    -0.118     (0)
   H+              1.156e-08   9.550e-09    -7.937    -8.020    -0.083      0.00
   H2O             5.551e+01   9.975e-01     1.744    -0.001     0.000     18.07
Al              1.863e-07
   Al(OH)4-        1.736e-07   1.349e-07    -6.761    -6.870    -0.109     (0)
   Al(OH)3         1.262e-08   1.291e-08    -7.899    -7.889     0.010     (0)
   Al(OH)2+        1.245e-10   9.820e-11    -9.905   -10.008    -0.103     (0)
   AlOH+2          3.126e-13   1.211e-13   -12.505   -12.917    -0.412     (0)
   Al+3            6.343e-16   1.133e-16   -15.198   -15.946    -0.748     (0)
   AlSO4+          6.100e-16   4.740e-16   -15.215   -15.324    -0.109     (0)
   Al(SO4)2-       1.936e-16   1.505e-16   -15.713   -15.823    -0.109     (0)
B               1.869e-04
   H3BO3           1.727e-04   1.767e-04    -3.763    -3.753     0.010     (0)
   H2BO3-          1.425e-05   1.062e-05    -4.846    -4.974    -0.127     (0)
C(4)            4.733e-03
   HCO3-           4.299e-03   3.391e-03    -2.367    -2.470    -0.103     (0)
   MgHCO3+         1.261e-04   9.709e-05    -3.899    -4.013    -0.113     (0)
   NaHCO3          9.571e-05   9.791e-05    -4.019    -4.009     0.010     (0)
   H2CO3           7.110e-05   7.273e-05    -4.148    -4.138     0.010     (0)
   CO3-2           4.291e-05   1.662e-05    -4.367    -4.779    -0.412     (0)
   MgCO3           3.775e-05   3.862e-05    -4.423    -4.413     0.010     (0)
   CaHCO3+         2.683e-05   2.136e-05    -4.571    -4.670    -0.099     (0)
   NaCO3-          2.004e-05   1.581e-05    -4.698    -4.801    -0.103     (0)
   CaCO3           1.403e-05   1.436e-05    -4.853    -4.843     0.010     (0)
   ZnCO3           4.100e-08   4.194e-08    -7.387    -7.377     0.010     (0)
   Zn(CO3)2-2      3.990e-08   1.491e-08    -7.399    -7.827    -0.428     (0)
   UO2(CO3)3-4     3.362e-08   6.552e-10    -7.473    -9.184    -1.710     (0)
   CuCO3           1.153e-08   1.179e-08    -7.938    -7.928     0.010     (0)
   ZnHCO3+         6.450e-09   5.043e-09    -8.190    -8.297    -0.107     (0)
   UO2(CO3)2-2     4.380e-09   1.636e-09    -8.359    -8.786    -0.428     (0)
   MnHCO3+         1.270e-09   9.953e-10    -8.896    -9.002    -0.106     (0)
   Cu(CO3)2-2      6.605e-10   2.468e-10    -9.180    -9.608    -0.428     (0)
   CuHCO3+         2.682e-10   2.097e-10    -9.572    -9.678    -0.107     (0)
   UO2CO3          1.205e-11   1.233e-11   -10.919   -10.909     0.010     (0)
Ca              1.982e-03
   Ca+2            1.457e-03   6.078e-04    -2.836    -3.216    -0.380     (0)
   CaSO4           4.836e-04   4.947e-04    -3.316    -3.306     0.010     (0)
   CaHCO3+         2.683e-05   2.136e-05    -4.571    -4.670    -0.099     (0)
   CaCO3           1.403e-05   1.436e-05    -4.853    -4.843     0.010     (0)
   CaOH+           2.012e-08   1.602e-08    -7.696    -7.795    -0.099     (0)
Cl              5.133e-02
   Cl-             5.133e-02   3.885e-02    -1.290    -1.411    -0.121     (0)
   CuCl2-          4.297e-09   3.309e-09    -8.367    -8.480    -0.113     (0)
   MnCl+           3.158e-09   2.475e-09    -8.501    -8.606    -0.106     (0)
   ZnCl+           1.717e-09   1.322e-09    -8.765    -8.879    -0.113     (0)
   ZnOHCl          1.661e-09   1.699e-09    -8.780    -8.770     0.010     (0)
   CuCl3-2         5.396e-10   2.037e-10    -9.268    -9.691    -0.423     (0)
   ZnCl2           5.258e-11   5.379e-11   -10.279   -10.269     0.010     (0)
   MnCl2           2.553e-11   2.612e-11   -10.593   -10.583     0.010     (0)
   CuCl+           1.794e-11   1.381e-11   -10.746   -10.860    -0.113     (0)
   ZnCl3-          3.045e-12   2.345e-12   -11.516   -11.630    -0.113     (0)
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MnCl3-	5.837e-13	4.575e-13	-12.234	-12.340	-0.106	(0)
CuCl2	2.817e-13	2.882e-13	-12.550	-12.540	0.010	(0)
ZnCl4-2	1.207e-13	4.555e-14	-12.918	-13.342	-0.423	(0)
CuCl3-	5.159e-17	3.972e-17	-16.287	-16.401	-0.113	(0)
CrCl+2	2.417e-17	9.031e-18	-16.617	-17.044	-0.428	(0)
FeCl+2	1.414e-17	5.337e-18	-16.850	-17.273	-0.423	(0)
CrOHCl2	1.408e-17	1.440e-17	-16.851	-16.842	0.010	(0)
UO2Cl+	4.858e-18	3.798e-18	-17.314	-17.420	-0.107	(0)
FeCl2+	1.182e-18	9.263e-19	-17.928	-18.033	-0.106	(0)
CrCl2+	8.744e-20	6.836e-20	-19.058	-19.165	-0.107	(0)
CuCl4-2	2.049e-20	7.734e-21	-19.689	-20.112	-0.423	(0)
FeCl3	3.517e-21	3.599e-21	-20.454	-20.444	0.010	(0)
CrO3Cl-	5.543e-27	4.333e-27	-26.256	-26.363	-0.107	(0)
UCl+3	0.000e+00	0.000e+00	-46.202	-47.164	-0.962	(0)
Cr(2)	2.358e-26					
Cr+2	2.358e-26	8.811e-27	-25.627	-26.055	-0.428	(0)
Cr(3)	9.668e-09					
Cr(OH)3	8.221e-09	8.411e-09	-8.085	-8.075	0.010	(0)
Cr(OH)2+	1.389e-09	1.086e-09	-8.857	-8.964	-0.107	(0)
CrO2-	2.736e-11	2.139e-11	-10.563	-10.670	-0.107	(0)
Cr(OH)+2	1.160e-11	4.335e-12	-10.935	-11.363	-0.428	(0)
Cr(OH)4-	1.073e-11	8.390e-12	-10.969	-11.076	-0.107	(0)
CrOHSO4	7.657e-12	7.833e-12	-11.116	-11.106	0.010	(0)
Cr+3	3.802e-15	4.150e-16	-14.420	-15.382	-0.962	(0)
CrSO4+	4.698e-17	3.673e-17	-16.328	-16.435	-0.107	(0)
CrCl+2	2.417e-17	9.031e-18	-16.617	-17.044	-0.428	(0)
CrOHCl2	1.408e-17	1.440e-17	-16.851	-16.842	0.010	(0)
CrCl2+	8.744e-20	6.836e-20	-19.058	-19.165	-0.107	(0)
Cr2(OH)2SO4+2	1.652e-20	6.173e-21	-19.782	-20.209	-0.428	(0)
Cr2(OH)2(SO4)2	5.689e-25	5.820e-25	-24.245	-24.235	0.010	(0)
Cr(6)	1.927e-16					
CrO4-2	1.705e-16	5.995e-17	-15.768	-16.222	-0.454	(0)
NaCrO4-	1.955e-17	1.528e-17	-16.709	-16.816	-0.107	(0)
HCrO4-	2.363e-18	1.848e-18	-17.626	-17.733	-0.107	(0)
KCrO4-	2.836e-19	2.217e-19	-18.547	-18.654	-0.107	(0)
CrO3SO4-2	5.776e-26	2.158e-26	-25.238	-25.666	-0.428	(0)
CrO3Cl-	5.543e-27	4.333e-27	-26.256	-26.363	-0.107	(0)
H2CrO4	2.394e-27	2.449e-27	-26.621	-26.611	0.010	(0)
Cr2O7-2	3.171e-34	1.185e-34	-33.499	-33.926	-0.428	(0)
Cu(1)	4.846e-09					
CuCl2-	4.297e-09	3.309e-09	-8.367	-8.480	-0.113	(0)
CuCl3-2	5.396e-10	2.037e-10	-9.268	-9.691	-0.423	(0)
Cu+	9.297e-12	6.932e-12	-11.032	-11.159	-0.127	(0)
Cu(2)	4.262e-08					
Cu(OH)2	2.943e-08	3.011e-08	-7.531	-7.521	0.010	(0)
CuCO3	1.153e-08	1.179e-08	-7.938	-7.928	0.010	(0)
Cu(CO3)2-2	6.605e-10	2.468e-10	-9.180	-9.608	-0.428	(0)
Cu+2	4.273e-10	1.321e-10	-9.369	-9.879	-0.510	(0)
CuHCO3+	2.682e-10	2.097e-10	-9.572	-9.678	-0.107	(0)
CuOH+	1.792e-10	1.380e-10	-9.747	-9.860	-0.113	(0)
CuSO4	1.053e-10	1.078e-10	-9.977	-9.968	0.010	(0)
CuCl+	1.794e-11	1.381e-11	-10.746	-10.860	-0.113	(0)
CuCl2	2.817e-13	2.882e-13	-12.550	-12.540	0.010	(0)
Cu(OH)3-	2.430e-13	1.900e-13	-12.614	-12.721	-0.107	(0)
Cu2(OH)2+2	2.229e-14	8.330e-15	-13.652	-14.079	-0.428	(0)
CuCl3-	5.159e-17	3.972e-17	-16.287	-16.401	-0.113	(0)
Cu(OH)4-2	1.057e-17	3.950e-18	-16.976	-17.403	-0.428	(0)
CuCl4-2	2.049e-20	7.734e-21	-19.689	-20.112	-0.423	(0)
Fe(2)	1.580e-08					
Fe+2	1.219e-08	4.897e-09	-7.914	-8.310	-0.396	(0)
FeSO4	3.401e-09	3.480e-09	-8.468	-8.458	0.010	(0)
FeOH+	2.064e-10	1.618e-10	-9.685	-9.791	-0.106	(0)
Fe(OH)2	1.406e-13	1.438e-13	-12.852	-12.842	0.010	(0)
Fe(OH)3-	7.120e-16	5.581e-16	-15.147	-15.253	-0.106	(0)
Fe(3)	4.343e-07					
Fe(OH)4-	1.724e-07	1.360e-07	-6.763	-6.866	-0.103	(0)

Fe(OH)2+	1.345e-07	1.061e-07	-6.871	-6.974	-0.103	(0)
Fe(OH)3	1.273e-07	1.302e-07	-6.895	-6.885	0.010	(0)
FeOH+2	8.127e-12	3.068e-12	-11.090	-11.513	-0.423	(0)
FeSO4+	1.929e-16	1.512e-16	-15.715	-15.820	-0.106	(0)
Fe+3	2.547e-17	4.549e-18	-16.594	-17.342	-0.748	(0)
Fe(SO4)2-	2.443e-17	1.910e-17	-16.612	-16.719	-0.107	(0)
FeCl+2	1.414e-17	5.337e-18	-16.850	-17.273	-0.423	(0)
FeCl2+	1.182e-18	9.263e-19	-17.928	-18.033	-0.106	(0)
Fe2(OH)2+4	1.300e-20	2.534e-22	-19.886	-21.596	-1.710	(0)
FeCl3	3.517e-21	3.599e-21	-20.454	-20.444	0.010	(0)
Fe3(OH)4+5	2.641e-24	5.618e-27	-23.578	-26.250	-2.672	(0)
H(0)	1.262e-27					
H2	6.311e-28	6.457e-28	-27.200	-27.190	0.010	(0)
K	7.971e-04					
K+	7.762e-04	5.875e-04	-3.110	-3.231	-0.121	(0)
KSO4-	2.091e-05	1.649e-05	-4.680	-4.783	-0.103	(0)
KCrO4-	2.836e-19	2.217e-19	-18.547	-18.654	-0.107	(0)
Mg	7.485e-03					
Mg+2	5.630e-03	2.435e-03	-2.250	-2.614	-0.364	(0)
MgSO4	1.691e-03	1.730e-03	-2.772	-2.762	0.010	(0)
MgHCO3+	1.261e-04	9.709e-05	-3.899	-4.013	-0.113	(0)
MgCO3	3.775e-05	3.862e-05	-4.423	-4.413	0.010	(0)
MgOH+	5.210e-07	4.177e-07	-6.283	-6.379	-0.096	(0)
Mn(2)	5.490e-08					
Mn+2	3.920e-08	1.575e-08	-7.407	-7.803	-0.396	(0)
MnSO4	1.119e-08	1.145e-08	-7.951	-7.941	0.010	(0)
MnCl+	3.158e-09	2.475e-09	-8.501	-8.606	-0.106	(0)
MnHCO3+	1.270e-09	9.953e-10	-8.896	-9.002	-0.106	(0)
MnOH+	5.394e-11	4.228e-11	-10.268	-10.374	-0.106	(0)
MnCl2	2.553e-11	2.612e-11	-10.593	-10.583	0.010	(0)
MnCl3-	5.837e-13	4.575e-13	-12.234	-12.340	-0.106	(0)
Mn(OH)3-	3.629e-19	2.845e-19	-18.440	-18.546	-0.106	(0)
Mn(3)	2.743e-29					
Mn+3	2.743e-29	4.900e-30	-28.562	-29.310	-0.748	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-45.664	-46.087	-0.423	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-51.349	-51.471	-0.122	(0)
Na	6.691e-02					
Na+	6.549e-02	5.130e-02	-1.184	-1.290	-0.106	(0)
NaSO4-	1.302e-03	1.027e-03	-2.885	-2.988	-0.103	(0)
NaHCO3	9.571e-05	9.791e-05	-4.019	-4.009	0.010	(0)
NaCO3-	2.004e-05	1.581e-05	-4.698	-4.801	-0.103	(0)
NaCrO4-	1.955e-17	1.528e-17	-16.709	-16.816	-0.107	(0)
O(0)	1.945e-38					
O2	9.727e-39	9.951e-39	-38.012	-38.002	0.010	(0)
S(6)	1.497e-02					
SO4-2	1.147e-02	3.996e-03	-1.940	-2.398	-0.458	(0)
MgSO4	1.691e-03	1.730e-03	-2.772	-2.762	0.010	(0)
NaSO4-	1.302e-03	1.027e-03	-2.885	-2.988	-0.103	(0)
CaSO4	4.836e-04	4.947e-04	-3.316	-3.306	0.010	(0)
KSO4-	2.091e-05	1.649e-05	-4.680	-4.783	-0.103	(0)
ZnSO4	1.158e-08	1.184e-08	-7.936	-7.926	0.010	(0)
MnSO4	1.119e-08	1.145e-08	-7.951	-7.941	0.010	(0)
HSO4-	4.764e-09	3.703e-09	-8.322	-8.431	-0.109	(0)
FeSO4	3.401e-09	3.480e-09	-8.468	-8.458	0.010	(0)
Zn(SO4)2-2	1.030e-09	3.847e-10	-8.987	-9.415	-0.428	(0)
CuSO4	1.053e-10	1.078e-10	-9.977	-9.968	0.010	(0)
CrOHSO4	7.657e-12	7.833e-12	-11.116	-11.106	0.010	(0)
AlSO4+	6.100e-16	4.740e-16	-15.215	-15.324	-0.109	(0)
Al(SO4)2-	1.936e-16	1.505e-16	-15.713	-15.823	-0.109	(0)
FeSO4+	1.929e-16	1.512e-16	-15.715	-15.820	-0.106	(0)
UO2SO4	1.177e-16	1.204e-16	-15.929	-15.919	0.010	(0)
CrSO4+	4.698e-17	3.673e-17	-16.328	-16.435	-0.107	(0)
UO2(SO4)2-2	3.836e-17	1.433e-17	-16.416	-16.844	-0.428	(0)
Fe(SO4)2-	2.443e-17	1.910e-17	-16.612	-16.719	-0.107	(0)

Cr2(OH)2SO4+2	1.652e-20	6.173e-21	-19.782	-20.209	-0.428 (0)
Cr2(OH)2(SO4)2	5.689e-25	5.820e-25	-24.245	-24.235	0.010 (0)
CrO3SO4-2	5.776e-26	2.158e-26	-25.238	-25.666	-0.428 (0)
U(SO4)2	0.000e+00	0.000e+00	-42.149	-42.140	0.010 (0)
USO4+2	0.000e+00	0.000e+00	-43.602	-44.029	-0.428 (0)
U(3)	0.000e+00				
U+3	0.000e+00	0.000e+00	-58.926	-59.888	-0.962 (0)
U(4)	9.773e-21				
U(OH)5-	9.770e-21	7.638e-21	-20.010	-20.117	-0.107 (0)
U(OH)4	2.993e-24	3.062e-24	-23.524	-23.514	0.010 (0)
U(OH)3+	1.371e-28	1.072e-28	-27.863	-27.970	-0.107 (0)
U(OH)2+2	1.270e-33	4.745e-34	-32.896	-33.324	-0.428 (0)
UOH+3	1.685e-39	1.839e-40	-38.773	-39.735	-0.962 (0)
U(SO4)2	0.000e+00	0.000e+00	-42.149	-42.140	0.010 (0)
USO4+2	0.000e+00	0.000e+00	-43.602	-44.029	-0.428 (0)
U+4	0.000e+00	0.000e+00	-45.381	-47.092	-1.710 (0)
UCl+3	0.000e+00	0.000e+00	-46.202	-47.164	-0.962 (0)
U6(OH)15+9	0.000e+00	0.000e+00	-170.837	-179.495	-8.658 (0)
U(5)	4.593e-18				
UO2+	4.593e-18	3.591e-18	-17.338	-17.445	-0.107 (0)
U(6)	3.801e-08				
UO2(CO3)3-4	3.362e-08	6.552e-10	-7.473	-9.184	-1.710 (0)
UO2(CO3)2-2	4.380e-09	1.636e-09	-8.359	-8.786	-0.428 (0)
UO2CO3	1.205e-11	1.233e-11	-10.919	-10.909	0.010 (0)
UO2OH+	6.398e-14	5.002e-14	-13.194	-13.301	-0.107 (0)
UO2+2	1.577e-16	5.891e-17	-15.802	-16.230	-0.428 (0)
UO2SO4	1.177e-16	1.204e-16	-15.929	-15.919	0.010 (0)
UO2(SO4)2-2	3.836e-17	1.433e-17	-16.416	-16.844	-0.428 (0)
UO2Cl+	4.858e-18	3.798e-18	-17.314	-17.420	-0.107 (0)
(UO2)2(OH)2+2	2.295e-22	8.575e-23	-21.639	-22.067	-0.428 (0)
(UO2)3(OH)5+	8.301e-25	6.490e-25	-24.081	-24.188	-0.107 (0)
Zn	1.384e-07				
ZnCO3	4.100e-08	4.194e-08	-7.387	-7.377	0.010 (0)
Zn(CO3)2-2	3.990e-08	1.491e-08	-7.399	-7.827	-0.428 (0)
Zn+2	3.148e-08	1.265e-08	-7.502	-7.898	-0.396 (0)
ZnSO4	1.158e-08	1.184e-08	-7.936	-7.926	0.010 (0)
ZnHCO3+	6.450e-09	5.043e-09	-8.190	-8.297	-0.107 (0)
ZnOH+	1.852e-09	1.448e-09	-8.732	-8.839	-0.107 (0)
ZnCl+	1.717e-09	1.322e-09	-8.765	-8.879	-0.113 (0)
Zn(OH)2	1.702e-09	1.741e-09	-8.769	-8.759	0.010 (0)
ZnOHCl	1.661e-09	1.699e-09	-8.780	-8.770	0.010 (0)
Zn(SO4)2-2	1.030e-09	3.847e-10	-8.987	-9.415	-0.428 (0)
ZnCl2	5.258e-11	5.379e-11	-10.279	-10.269	0.010 (0)
ZnCl3-	3.045e-12	2.345e-12	-11.516	-11.630	-0.113 (0)
Zn(OH)3-	7.355e-13	5.751e-13	-12.133	-12.240	-0.107 (0)
ZnCl4-2	1.207e-13	4.555e-14	-12.918	-13.342	-0.423 (0)
Zn(OH)4-2	2.548e-17	9.520e-18	-16.594	-17.021	-0.428 (0)

-------------------------------Saturation indices-------------------------------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-2.27	8.11	10.38	Al(OH)3
Al2O3	-6.75	16.23	22.98	Al2O3
Al4(OH)10SO4	-8.69	14.01	22.70	Al4(OH)10SO4
AlOHSO4	-7.10	-10.33	-3.23	AlOHSO4
AlumK	-18.82	-23.99	-5.17	KAl(SO4)2:12H2O
Alunite	-6.41	-7.75	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-0.98	-5.61	-4.64	CaSO4
Antlerite	-8.25	0.04	8.29	Cu3(OH)4SO4
Aragonite	0.34	-8.00	-8.34	CaCO3
Artinite	-3.57	6.03	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-4.45	2.89	7.34	Cu2(OH)3Cl
Azurite	-6.24	-23.16	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.74	-0.19	5.54	UO2(OH)2
Bianchite	-8.54	-10.30	-1.76	ZnSO4:6H2O

Birnessite	-11.32	6.77	18.09	MnO2
Bixbyite	-9.89	-10.50	-0.61	Mn2O3
Boehmite	-0.47	8.11	8.58	AlOOH
Brochantite	-9.14	6.20	15.34	Cu4(OH)6SO4
Brucite	-3.37	13.42	16.79	Mg(OH)2
CaCrO4	-17.17	-19.44	-2.27	CaCrO4
Calcite	0.48	-8.00	-8.47	CaCO3
CH4(g)	-76.88	-116.98	-40.10	CH4
Chalcanthite	-9.64	-12.28	-2.64	CuSO4:5H2O
CO2(g)	-2.66	-20.82	-18.16	CO2
Cr(OH)2	-20.84	-10.02	10.82	Cr(OH)2
Cr(OH)3(A)	-0.20	-0.95	-0.75	Cr(OH)3
Cr(OH)3(C)	-2.65	-0.95	1.70	Cr(OH)3
Cr2O3	1.51	-1.89	-3.39	Cr2O3
CrCl2	-44.74	-28.88	15.87	CrCl2
CrCl3	-42.74	-29.23	13.51	CrCl3
CrMetal	-66.30	-34.05	32.24	Cr
CrO3	-29.05	-32.26	-3.21	CrO3
Cu(OH)2	-2.48	6.16	8.64	Cu(OH)2
Cu2SO4	-22.77	-24.72	-1.95	Cu2SO4
CuCO3	-5.03	-14.66	-9.63	CuCO3
CuCrO4	-20.63	-26.10	-5.48	CuCrO4
CuMetal	-6.40	-15.16	-8.76	Cu
CuOCuSO4	-17.65	-6.12	11.53	CuO:CuSO4
CupricFerrite	13.71	19.59	5.88	CuFe2O4
Cuprite	-4.73	-6.28	-1.55	Cu2O
CuprousFerrite	12.50	3.58	-8.92	CuFeO2
CuSO4	-15.29	-12.28	3.01	CuSO4
Diaspore	1.24	8.11	6.87	AlOOH
Dolomite	1.61	-15.39	-17.00	CaMg(CO3)2
Epsomite	-2.88	-5.02	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	6.93	3.89	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-45.46	-41.88	3.58	Fe2(SO4)3
Fe3(OH)8	0.94	21.16	20.22	Fe3(OH)8
FeCr2O4	6.74	5.84	-0.90	FeCr2O4
Ferrihydrite	1.82	6.71	4.89	Fe(OH)3
Gibbsite(C)	-0.66	8.11	8.77	Al(OH)3
Goethite	6.22	6.72	0.50	FeOOH
Goslarite	-8.34	-10.30	-1.96	ZnSO4:7H2O
Gummite	-10.59	-0.19	10.40	UO3
Gypsum	-1.01	-5.62	-4.61	CaSO4:2H2O
Halite	-4.28	-2.70	1.58	NaCl
Hausmannite	-12.79	48.75	61.54	Mn3O4
Hematite	17.44	13.43	-4.01	Fe2O3
Hercynite	-3.21	23.95	27.16	FeAl2O4
Huntite	-0.21	-30.17	-29.97	CaMg3(CO3)4
Hydromagnesite	-7.39	-16.15	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-4.63	-16.73	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	2.86	-11.94	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	1.20	-10.00	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-39.27	-54.95	-15.67	K2Cr2O7
K2CrO4	-22.69	-22.68	0.01	K2CrO4
Langite	-10.59	6.20	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	5.34	6.72	1.37	FeOOH
Lime	-19.97	12.82	32.80	CaO
Maghemite	7.05	13.43	6.39	Fe2O3
Magnesite	0.64	-7.39	-8.03	MgCO3
Magnetite	17.42	21.16	3.74	Fe3O4
Malachite	-3.32	-8.50	-5.18	Cu2(OH)2CO3
Manganite	-5.01	-5.25	-0.24	MnOOH
Melanothallite	-16.43	-12.70	3.73	CuCl2
Melanterite	-8.25	-10.72	-2.47	FeSO4:7H2O
Mg-Ferrite	10.09	26.86	16.77	MgFe2O4
MgCr2O4	-0.54	11.54	12.08	MgCr2O4
MgCrO4	-24.22	-18.84	5.38	MgCrO4
Mirabilite	-3.87	-4.99	-1.11	Na2SO4:10H2O

Mn2(SO4)3	-60.10	-65.81	-5.71	Mn2(SO4)3
MnCl2:4H2O	-13.34	-10.63	2.71	MnCl2:4H2O
MnSO4	-12.87	-10.20	2.67	MnSO4
Na2Cr2O7	-41.17	-51.06	-9.90	Na2Cr2O7
Na2CrO4	-22.06	-18.80	3.26	Na2CrO4
Nantokite	-5.81	-12.57	-6.76	CuCl
Natron	-6.06	-7.37	-1.31	Na2CO3:10H2O
Nesquehonite	-1.78	-7.40	-5.62	MgCO3:3H2O
Nsutite	-10.74	6.77	17.50	MnO2
O2(g)	-35.04	48.08	83.12	O2
Periclase	-8.08	13.43	21.51	MgO
Portlandite	-9.85	12.82	22.68	Ca(OH)2
Pyrocroite	-6.85	8.24	15.09	Mn(OH)2
Pyrolusite	-9.09	6.77	15.86	MnO2
Rhodochrosite	-2.17	-12.58	-10.41	MnCO3
Rutherfordine	-6.55	-21.01	-14.46	UO2CO3
Schoepite	-5.60	-0.19	5.40	UO2(OH)2:H2O
Siderite	-2.54	-13.09	-10.55	FeCO3
Smithsonite	-2.68	-12.68	-10.00	ZnCO3
Spinel	-6.68	29.65	36.33	MgAl2O4
Tenorite	-1.46	6.16	7.62	CuO
Thenardite	-4.80	-4.98	-0.18	Na2SO4
Thermonatrite	-7.49	-7.36	0.13	Na2CO3:H2O
U3O8(C)	-18.07	3.04	21.11	U3O8
U4O9(C)	-32.63	-36.02	-3.38	U4O9
UO2(am)	-15.95	-15.01	0.93	UO2
UO3(C)	-7.91	-0.19	7.72	UO3
Uraninite	-10.31	-15.01	-4.70	UO2
Zincite	-3.00	8.14	11.14	ZnO
Zincosite	-13.31	-10.30	3.01	ZnSO4
Zn(BO2)2	-7.65	0.64	8.29	Zn(BO2)2
Zn(OH)2(A)	-4.31	8.14	12.45	Zn(OH)2
Zn(OH)2(B)	-3.61	8.14	11.75	Zn(OH)2
Zn(OH)2(C)	-4.06	8.14	12.20	Zn(OH)2
Zn(OH)2(E)	-3.36	8.14	11.50	Zn(OH)2
Zn(OH)2(G)	-3.57	8.14	11.71	Zn(OH)2
Zn2(OH)2SO4	-9.66	-2.16	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-8.35	6.85	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-31.47	-12.45	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-14.28	14.12	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-16.66	21.84	38.50	Zn5(OH)8Cl2
ZnCl2	-17.75	-10.72	7.03	ZnCl2
ZnCO3:H2O	-2.42	-12.68	-10.26	ZnCO3:H2O
ZnMetal	-41.66	-15.90	25.76	Zn
ZnO(Active)	-3.17	8.14	11.31	ZnO
ZnSO4:H2O	-9.73	-10.30	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 11.

-----------------------------Solution composition------------------------------

Elements	Molality	Moles
Al	1.572e-03	1.572e-03
Alkalinity	8.236e-06	8.236e-06
B	4.686e-04	4.686e-04
Ca	6.269e-03	6.269e-03
Cl	5.386e-04	5.386e-04
Cr	1.933e-08	1.933e-08
Cu	1.060e-06	1.060e-06
Fe	8.512e-05	8.512e-05
K	5.063e-03	5.063e-03
Mg	4.671e-02	4.671e-02

Mn	2.140e-05	2.140e-05
Na	4.809e-04	4.809e-04
S(6)	3.494e-02	3.494e-02
U	3.336e-07	3.336e-07
Zn	3.229e-06	3.229e-06

----------Description of solution----------

pH	=	3.690
pe	=	4.000
Activity of water	=	0.997
Ionic strength (mol/kgw)	=	1.162e-01
Mass of water (kg)	=	1.000e+00
Total carbon (mol/kg)	=	1.160e-01
Total CO2 (mol/kg)	=	1.160e-01
Temperature (°C)	=	25.00
Electrical balance (eq)	=	4.601e-02
Percent error, 100*(Cat-|An|)/(Cat+|An|)	=	38.56
Iterations	=	13
Total H	=	1.112458e+02
Total O	=	5.599528e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	2.492e-04	2.042e-04	-3.603	-3.690	-0.087	0.00
OH-	6.538e-11	4.904e-11	-10.185	-10.309	-0.125	(0)
H2O	5.551e+01	9.967e-01	1.744	-0.001	0.000	18.07
Al	1.572e-03					
AlSO4+	7.017e-04	5.377e-04	-3.154	-3.269	-0.116	(0)
Al+3	5.374e-04	8.934e-05	-3.270	-4.049	-0.779	(0)
Al(SO4)2-	3.204e-04	2.455e-04	-3.494	-3.610	-0.116	(0)
AlOH+2	1.210e-05	4.463e-06	-4.917	-5.350	-0.433	(0)
Al(OH)2+	2.170e-07	1.691e-07	-6.664	-6.772	-0.108	(0)
Al(OH)3	1.012e-09	1.039e-09	-8.995	-8.983	0.012	(0)
Al(OH)4-	6.620e-13	5.073e-13	-12.179	-12.295	-0.116	(0)
B	4.686e-04					
H3BO3	4.686e-04	4.813e-04	-3.329	-3.318	0.012	(0)
H2BO3-	1.851e-09	1.354e-09	-8.733	-8.868	-0.136	(0)
C(4)	1.160e-01					
H2CO3	1.156e-01	1.187e-01	-0.937	-0.926	0.012	(0)
HCO3-	3.322e-04	2.589e-04	-3.479	-3.587	-0.108	(0)
MgHCO3+	5.524e-05	4.190e-05	-4.258	-4.378	-0.120	(0)
CaHCO3+	5.874e-06	4.623e-06	-5.231	-5.335	-0.104	(0)
NaHCO3	5.131e-08	5.270e-08	-7.290	-7.278	0.012	(0)
MnHCO3+	3.674e-08	2.843e-08	-7.435	-7.546	-0.111	(0)
CuHCO3+	3.411e-08	2.637e-08	-7.467	-7.579	-0.112	(0)
ZnHCO3+	3.075e-08	2.377e-08	-7.512	-7.624	-0.112	(0)
UO2CO3	3.057e-08	3.140e-08	-7.515	-7.503	0.012	(0)
MgCO3	7.590e-10	7.795e-10	-9.120	-9.108	0.012	(0)
CO3-2	1.610e-10	5.935e-11	-9.793	-10.227	-0.433	(0)
CaCO3	1.415e-10	1.454e-10	-9.849	-9.838	0.012	(0)
CuCO3	6.752e-11	6.935e-11	-10.171	-10.159	0.012	(0)
UO2(CO3)2-2	4.170e-11	1.488e-11	-10.380	-10.827	-0.447	(0)
ZnCO3	9.002e-12	9.246e-12	-11.046	-11.034	0.012	(0)
NaCO3-	5.107e-13	3.979e-13	-12.292	-12.400	-0.108	(0)
UO2(CO3)3-4	1.312e-15	2.127e-17	-14.882	-16.672	-1.790	(0)
Zn(CO3)2-2	3.288e-17	1.173e-17	-16.483	-16.931	-0.447	(0)
Cu(CO3)2-2	1.452e-17	5.182e-18	-16.838	-17.286	-0.447	(0)
Ca	6.269e-03					
Ca+2	4.298e-03	1.724e-03	-2.367	-2.764	-0.397	(0)
CaSO4	1.965e-03	2.018e-03	-2.707	-2.695	0.012	(0)
CaHCO3+	5.874e-06	4.623e-06	-5.231	-5.335	-0.104	(0)
CaCO3	1.415e-10	1.454e-10	-9.849	-9.838	0.012	(0)

CaOH+	2.698e-12	2.123e-12	-11.569	-11.673	-0.104	(0)
Cl	5.386e-04					
Cl-	5.386e-04	4.008e-04	-3.269	-3.397	-0.128	(0)
MnCl+	1.235e-08	9.553e-09	-7.908	-8.020	-0.111	(0)
ZnCl+	1.110e-09	8.422e-10	-8.955	-9.075	-0.120	(0)
CuCl2-	7.646e-10	5.799e-10	-9.117	-9.237	-0.120	(0)
CuCl+	3.094e-10	2.347e-10	-9.509	-9.630	-0.120	(0)
UO2Cl+	3.617e-11	2.795e-11	-10.442	-10.554	-0.112	(0)
CuCl3-2	1.028e-12	3.683e-13	-11.988	-12.434	-0.446	(0)
MnCl2	1.013e-12	1.040e-12	-11.995	-11.983	0.012	(0)
CrCl+2	9.399e-13	3.354e-13	-12.027	-12.474	-0.447	(0)
ZnCl2	3.441e-13	3.534e-13	-12.463	-12.452	0.012	(0)
ZnOHCl	4.924e-14	5.058e-14	-13.308	-13.296	0.012	(0)
CuCl2	4.918e-14	5.051e-14	-13.308	-13.297	0.012	(0)
FeCl+2	7.418e-16	2.658e-16	-15.130	-15.576	-0.446	(0)
MnCl3-	2.429e-16	1.879e-16	-15.615	-15.726	-0.111	(0)
ZnCl3-	2.095e-16	1.589e-16	-15.679	-15.799	-0.120	(0)
CrCl2+	3.389e-17	2.619e-17	-16.470	-16.582	-0.112	(0)
FeCl2+	6.149e-19	4.757e-19	-18.211	-18.323	-0.111	(0)
CrOHCl2	2.511e-19	2.579e-19	-18.600	-18.589	0.012	(0)
CuCl3-	9.469e-20	7.182e-20	-19.024	-19.144	-0.120	(0)
ZnCl4-2	8.889e-20	3.185e-20	-19.051	-19.497	-0.446	(0)
UCl+3	1.072e-22	1.055e-23	-21.970	-22.977	-1.007	(0)
FeCl3	1.856e-23	1.907e-23	-22.731	-22.720	0.012	(0)
CuCl4-2	4.026e-25	1.443e-25	-24.395	-24.841	-0.446	(0)
CrO3Cl-	0.000e+00	0.000e+00	-47.663	-47.774	-0.112	(0)
Cr(2)	8.890e-20					
Cr+2	8.890e-20	3.173e-20	-19.051	-19.499	-0.447	(0)
Cr(3)	1.933e-08					
Cr+3	1.518e-08	1.494e-09	-7.819	-8.826	-1.007	(0)
Cr(OH)+2	2.044e-09	7.294e-10	-8.690	-9.137	-0.447	(0)
CrOHSO4	1.846e-09	1.896e-09	-8.734	-8.722	0.012	(0)
CrSO4+	2.462e-10	1.903e-10	-9.609	-9.721	-0.112	(0)
Cr(OH)2+	1.105e-11	8.541e-12	-10.957	-11.068	-0.112	(0)
CrCl+2	9.399e-13	3.354e-13	-12.027	-12.474	-0.447	(0)
Cr(OH)3	3.009e-15	3.091e-15	-14.522	-14.510	0.012	(0)
Cr2(OH)2SO4+2	7.047e-16	2.515e-16	-15.152	-15.600	-0.447	(0)
CrCl2+	3.389e-17	2.619e-17	-16.470	-16.582	-0.112	(0)
CrOHCl2	2.511e-19	2.579e-19	-18.600	-18.589	0.012	(0)
Cr2(OH)2(SO4)2	3.320e-20	3.410e-20	-19.479	-19.467	0.012	(0)
CrO2-	4.762e-22	3.681e-22	-21.322	-21.434	-0.112	(0)
Cr(OH)4-	1.864e-22	1.441e-22	-21.729	-21.841	-0.112	(0)
Cr(6)	0.000e+00					
HCrO4-	0.000e+00	0.000e+00	-41.377	-41.488	-0.112	(0)
CrO4-2	0.000e+00	0.000e+00	-43.827	-44.307	-0.480	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-44.485	-44.933	-0.447	(0)
KCrO4-	0.000e+00	0.000e+00	-45.837	-45.949	-0.112	(0)
H2CrO4	0.000e+00	0.000e+00	-46.048	-46.036	0.012	(0)
NaCrO4-	0.000e+00	0.000e+00	-46.941	-47.053	-0.112	(0)
CrO3Cl-	0.000e+00	0.000e+00	-47.663	-47.774	-0.112	(0)
Cr2O7-2	0.000e+00	0.000e+00	-80.989	-81.436	-0.447	(0)
Cu(1)	1.638e-08					
Cu+	1.561e-08	1.142e-08	-7.807	-7.942	-0.136	(0)
CuCl2-	7.646e-10	5.799e-10	-9.117	-9.237	-0.120	(0)
CuCl3-2	1.028e-12	3.683e-13	-11.988	-12.434	-0.446	(0)
Cu(2)	1.043e-06					
Cu+2	7.602e-07	2.176e-07	-6.119	-6.662	-0.543	(0)
CuSO4	2.486e-07	2.554e-07	-6.604	-6.593	0.012	(0)
CuHCO3+	3.411e-08	2.637e-08	-7.467	-7.579	-0.112	(0)
CuCl+	3.094e-10	2.347e-10	-9.509	-9.630	-0.120	(0)
CuCO3	6.752e-11	6.935e-11	-10.171	-10.159	0.012	(0)
CuOH+	1.400e-11	1.062e-11	-10.854	-10.974	-0.120	(0)
Cu(OH)2	1.055e-13	1.083e-13	-12.977	-12.965	0.012	(0)
CuCl2	4.918e-14	5.051e-14	-13.308	-13.297	0.012	(0)
Cu2(OH)2+2	1.383e-16	4.936e-17	-15.859	-16.307	-0.447	(0)
Cu(CO3)2-2	1.452e-17	5.182e-18	-16.838	-17.286	-0.447	(0)

CuCl3-	9.469e-20	7.182e-20	-19.024	-19.144	-0.120	(0)
Cu(OH)3-	4.132e-23	3.194e-23	-22.384	-22.496	-0.112	(0)
CuCl4-2	4.026e-25	1.443e-25	-24.395	-24.841	-0.446	(0)
Cu(OH)4-2	8.696e-32	3.103e-32	-31.061	-31.508	-0.447	(0)
Fe(2)	8.512e-05					
Fe+2	6.160e-05	2.364e-05	-4.210	-4.626	-0.416	(0)
FeSO4	2.352e-05	2.416e-05	-4.628	-4.617	0.012	(0)
FeOH+	4.717e-11	3.649e-11	-10.326	-10.438	-0.111	(0)
Fe(OH)2	1.476e-18	1.516e-18	-17.831	-17.819	0.012	(0)
Fe(OH)3-	3.554e-25	2.750e-25	-24.449	-24.561	-0.111	(0)
Fe(3)	5.104e-12					
FeOH+2	1.932e-12	6.921e-13	-11.714	-12.160	-0.446	(0)
Fe(OH)2+	1.436e-12	1.119e-12	-11.843	-11.951	-0.108	(0)
FeSO4+	1.357e-12	1.050e-12	-11.867	-11.979	-0.111	(0)
Fe(SO4)2-	2.469e-13	1.908e-13	-12.607	-12.719	-0.112	(0)
Fe+3	1.321e-13	2.196e-14	-12.879	-13.658	-0.779	(0)
FeCl+2	7.418e-16	2.658e-16	-15.130	-15.576	-0.446	(0)
Fe(OH)3	6.247e-17	6.416e-17	-16.204	-16.193	0.012	(0)
FeCl2+	6.149e-19	4.757e-19	-18.211	-18.323	-0.111	(0)
Fe(OH)4-	4.020e-21	3.132e-21	-20.396	-20.504	-0.108	(0)
Fe2(OH)2+4	7.949e-22	1.289e-23	-21.100	-22.890	-1.790	(0)
FeCl3	1.856e-23	1.907e-23	-22.731	-22.720	0.012	(0)
Fe3(OH)4+5	1.888e-30	3.014e-33	-29.724	-32.521	-2.797	(0)
H(0)	5.747e-19					
H2	2.873e-19	2.951e-19	-18.542	-18.530	0.012	(0)
K	5.063e-03					
K+	4.875e-03	3.628e-03	-2.312	-2.440	-0.128	(0)
KSO4-	1.880e-04	1.465e-04	-3.726	-3.834	-0.108	(0)
KCrO4-	0.000e+00	0.000e+00	-45.837	-45.949	-0.112	(0)
Mg	4.671e-02					
Mg+2	3.296e-02	1.376e-02	-1.482	-1.861	-0.379	(0)
MgSO4	1.370e-02	1.407e-02	-1.863	-1.852	0.012	(0)
MgHCO3+	5.524e-05	4.190e-05	-4.258	-4.378	-0.120	(0)
MgCO3	7.590e-10	7.795e-10	-9.120	-9.108	0.012	(0)
MgOH+	1.391e-10	1.104e-10	-9.857	-9.957	-0.101	(0)
Mn(2)	2.140e-05					
Mn+2	1.535e-05	5.892e-06	-4.814	-5.230	-0.416	(0)
MnSO4	6.001e-06	6.163e-06	-5.222	-5.210	0.012	(0)
MnHCO3+	3.674e-08	2.843e-08	-7.435	-7.546	-0.111	(0)
MnCl+	1.235e-08	9.553e-09	-7.908	-8.020	-0.111	(0)
MnCl2	1.013e-12	1.040e-12	-11.995	-11.983	0.012	(0)
MnOH+	9.556e-13	7.393e-13	-12.020	-12.131	-0.111	(0)
MnCl3-	2.429e-16	1.879e-16	-15.615	-15.726	-0.111	(0)
Mn(OH)3-	1.404e-29	1.086e-29	-28.853	-28.964	-0.111	(0)
Mn(3)	1.103e-26					
Mn+3	1.103e-26	1.834e-27	-25.957	-26.737	-0.779	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-77.710	-78.155	-0.446	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-83.409	-83.539	-0.130	(0)
Na	4.809e-04					
Na+	4.675e-04	3.617e-04	-3.330	-3.442	-0.111	(0)
NaSO4-	1.337e-05	1.042e-05	-4.874	-4.982	-0.108	(0)
NaHCO3	5.131e-08	5.270e-08	-7.290	-7.278	0.012	(0)
NaCO3-	5.107e-13	3.979e-13	-12.292	-12.400	-0.108	(0)
NaCrO4-	0.000e+00	0.000e+00	-46.941	-47.053	-0.112	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-55.335	-55.323	0.012	(0)
S(6)	3.494e-02					
SO4-2	1.756e-02	5.748e-03	-1.756	-2.240	-0.485	(0)
MgSO4	1.370e-02	1.407e-02	-1.863	-1.852	0.012	(0)
CaSO4	1.965e-03	2.018e-03	-2.707	-2.695	0.012	(0)
AlSO4+	7.017e-04	5.377e-04	-3.154	-3.269	-0.116	(0)
Al(SO4)2-	3.204e-04	2.455e-04	-3.494	-3.610	-0.116	(0)
KSO4-	1.880e-04	1.465e-04	-3.726	-3.834	-0.108	(0)
HSO4-	1.486e-04	1.139e-04	-3.828	-3.944	-0.116	(0)

FeSO4	2.352e-05	2.416e-05	-4.628	-4.617	0.012	(0)
NaSO4-	1.337e-05	1.042e-05	-4.874	-4.982	-0.108	(0)
MnSO4	6.001e-06	6.163e-06	-5.222	-5.210	0.012	(0)
ZnSO4	1.024e-06	1.052e-06	-5.990	-5.978	0.012	(0)
CuSO4	2.486e-07	2.554e-07	-6.604	-6.593	0.012	(0)
Zn(SO4)2-2	1.378e-07	4.916e-08	-6.861	-7.308	-0.447	(0)
UO2SO4	1.204e-07	1.236e-07	-6.920	-6.908	0.012	(0)
UO2(SO4)2-2	5.931e-08	2.117e-08	-7.227	-7.674	-0.447	(0)
CrOHSO4	1.846e-09	1.896e-09	-8.734	-8.722	0.012	(0)
CrSO4+	2.462e-10	1.903e-10	-9.609	-9.721	-0.112	(0)
FeSO4+	1.357e-12	1.050e-12	-11.867	-11.979	-0.111	(0)
Fe(SO4)2-	2.469e-13	1.908e-13	-12.607	-12.719	-0.112	(0)
Cr2(OH)2SO4+2	7.047e-16	2.515e-16	-15.152	-15.600	-0.447	(0)
U(SO4)2	2.182e-16	2.241e-16	-15.661	-15.649	0.012	(0)
USO4+2	5.630e-18	2.009e-18	-17.250	-17.697	-0.447	(0)
Cr2(OH)2(SO4)2	3.320e-20	3.410e-20	-19.479	-19.467	0.012	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-44.485	-44.933	-0.447	(0)
U(3)	1.965e-33					
U+3	1.965e-33	1.934e-34	-32.707	-33.714	-1.007	(0)
U(4)	5.236e-15					
U(OH)4	2.124e-15	2.181e-15	-14.673	-14.661	0.012	(0)
U(OH)3+	2.113e-15	1.633e-15	-14.675	-14.787	-0.112	(0)
U(OH)2+2	4.336e-16	1.547e-16	-15.363	-15.810	-0.447	(0)
U(OH)5-	3.289e-16	2.542e-16	-15.483	-15.595	-0.112	(0)
U(SO4)2	2.182e-16	2.241e-16	-15.661	-15.649	0.012	(0)
UOH+3	1.304e-17	1.283e-18	-16.885	-17.892	-1.007	(0)
USO4+2	5.630e-18	2.009e-18	-17.250	-17.697	-0.447	(0)
U+4	7.455e-20	1.209e-21	-19.128	-20.918	-1.790	(0)
UCl+3	1.072e-22	1.055e-23	-21.970	-22.977	-1.007	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-78.344	-87.406	-9.062	(0)
U(5)	3.315e-09					
UO2+	3.315e-09	2.562e-09	-8.480	-8.591	-0.112	(0)
U(6)	3.302e-07					
UO2SO4	1.204e-07	1.236e-07	-6.920	-6.908	0.012	(0)
UO2+2	1.178e-07	4.203e-08	-6.929	-7.376	-0.447	(0)
UO2(SO4)2-2	5.931e-08	2.117e-08	-7.227	-7.674	-0.447	(0)
UO2CO3	3.057e-08	3.140e-08	-7.515	-7.503	0.012	(0)
UO2OH+	2.158e-09	1.668e-09	-8.666	-8.778	-0.112	(0)
UO2(CO3)2-2	4.170e-11	1.488e-11	-10.380	-10.827	-0.447	(0)
UO2Cl+	3.617e-11	2.795e-11	-10.442	-10.554	-0.112	(0)
(UO2)2(OH)2+2	2.671e-13	9.533e-14	-12.573	-13.021	-0.447	(0)
UO2(CO3)3-4	1.312e-15	2.127e-17	-14.882	-16.672	-1.790	(0)
(UO2)3(OH)5+	6.797e-20	5.254e-20	-19.168	-19.280	-0.112	(0)
Zn	3.229e-06					
Zn+2	2.035e-06	7.808e-07	-5.692	-6.107	-0.416	(0)
ZnSO4	1.024e-06	1.052e-06	-5.990	-5.978	0.012	(0)
Zn(SO4)2-2	1.378e-07	4.916e-08	-6.861	-7.308	-0.447	(0)
ZnHCO3+	3.075e-08	2.377e-08	-7.512	-7.624	-0.112	(0)
ZnCl+	1.110e-09	8.422e-10	-8.955	-9.075	-0.120	(0)
ZnCO3	9.002e-12	9.246e-12	-11.046	-11.034	0.012	(0)
ZnOH+	5.407e-12	4.179e-12	-11.267	-11.379	-0.112	(0)
ZnCl2	3.441e-13	3.534e-13	-12.463	-12.452	0.012	(0)
ZnOHCl	4.924e-14	5.058e-14	-13.308	-13.296	0.012	(0)
Zn(OH)2	2.286e-16	2.348e-16	-15.641	-15.629	0.012	(0)
ZnCl3-	2.095e-16	1.589e-16	-15.679	-15.799	-0.120	(0)
Zn(CO3)2-2	3.288e-17	1.173e-17	-16.483	-16.931	-0.447	(0)
ZnCl4-2	8.889e-20	3.185e-20	-19.051	-19.497	-0.446	(0)
Zn(OH)3-	4.689e-24	3.624e-24	-23.329	-23.441	-0.112	(0)
Zn(OH)4-2	7.857e-33	2.804e-33	-32.105	-32.552	-0.447	(0)

----------Saturation indices----------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-3.36	7.02	10.38	Al(OH)3
Al2O3	-8.94	14.04	22.98	Al2O3

Al4(OH)10SO4	-4.25	18.45	22.70	Al4(OH)10SO4
AlOHSO4	0.63	-2.60	-3.23	AlOHSO4
AlumK	-5.82	-10.99	-5.17	KAl(SO4)2:12H2O
Alunite	4.41	3.06	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-0.37	-5.00	-4.64	CaSO4
Antlerite	-15.76	-7.47	8.29	Cu3(OH)4SO4
Aragonite	-4.65	-12.99	-8.34	CaCO3
Artinite	-16.18	-6.58	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-13.00	-5.66	7.34	Cu2(OH)3Cl
Azurite	-16.14	-33.06	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.54	0.00	5.54	UO2(OH)2
Bianchite	-6.59	-8.36	-1.76	ZnSO4:6H2O
Birnessite	-26.07	-7.98	18.09	MnO2
Bixbyite	-30.73	-31.34	-0.61	Mn2O3
Boehmite	-1.56	7.02	8.58	AlOOH
Brochantite	-22.10	-6.76	15.34	Cu4(OH)6SO4
Brucite	-11.28	5.52	16.79	Mg(OH)2
CaCrO4	-44.81	-47.07	-2.27	CaCrO4
Calcite	-4.52	-12.99	-8.47	CaCO3
CH4(g)	-39.02	-79.12	-40.10	CH4
Chalcanthite	-6.27	-8.91	-2.64	CuSO4:5H2O
CO2(g)	0.55	-17.61	-18.16	CO2
Cr(OH)2	-22.94	-12.12	10.82	Cr(OH)2
Cr(OH)3(A)	-6.63	-7.38	-0.75	Cr(OH)3
Cr(OH)3(C)	-9.08	-7.38	1.70	Cr(OH)3
Cr2O3	-11.36	-14.76	-3.39	Cr2O3
CrCl2	-42.16	-26.29	15.87	CrCl2
CrCl3	-42.14	-28.64	13.51	CrCl3
CrMetal	-59.74	-27.50	32.24	Cr
CrO3	-48.48	-51.69	-3.21	CrO3
Cu(OH)2	-7.93	0.71	8.64	Cu(OH)2
Cu2SO4	-16.18	-18.13	-1.95	Cu2SO4
CuCO3	-7.26	-16.89	-9.63	CuCO3
CuCrO4	-45.49	-50.97	-5.48	CuCrO4
CuMetal	-3.18	-11.94	-8.76	Cu
CuOCuSO4	-19.72	-8.19	11.53	CuO:CuSO4
CupricFerrite	-10.34	-4.46	5.88	CuFe2O4
Cuprite	-6.96	-8.51	-1.55	Cu2O
CuprousFerrite	2.08	-6.84	-8.92	CuFeO2
CuSO4	-11.91	-8.90	3.01	CuSO4
Diaspore	0.15	7.02	6.87	AlOOH
Dolomite	-8.08	-25.08	-17.00	CaMg(CO3)2
Epsomite	-1.97	-4.11	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-1.68	-4.72	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-37.62	-34.04	3.58	Fe2(SO4)3
Fe3(OH)8	-22.66	-2.43	20.22	Fe3(OH)8
FeCr2O4	-11.10	-12.00	-0.90	FeCr2O4
Ferrihydrite	-7.48	-2.59	4.89	Fe(OH)3
Gibbsite(C)	-1.75	7.02	8.77	Al(OH)3
Goethite	-3.09	-2.59	0.50	FeOOH
Goslarite	-6.40	-8.36	-1.96	ZnSO4:7H2O
Gummite	-10.40	0.00	10.40	UO3
Gypsum	-0.40	-5.01	-4.61	CaSO4:2H2O
Halite	-8.42	-6.84	1.58	NaCl
Hausmannite	-39.71	21.83	61.54	Mn3O4
Hematite	-1.17	-5.18	-4.01	Fe2O3
Hercynite	-10.37	16.79	27.16	FeAl2O4
Huntite	-19.29	-49.25	-29.97	CaMg3(CO3)4
Hydromagnesite	-34.08	-42.84	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-14.92	-27.02	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-10.97	-25.77	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-15.57	-26.77	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-85.20	-100.87	-15.67	K2Cr2O7
K2CrO4	-49.20	-49.19	0.01	K2CrO4
Langite	-23.55	-6.76	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-3.96	-2.59	1.37	FeOOH

Lime	-28.18	4.62	32.80	CaO
Maghemite	-11.57	-5.18	6.39	Fe2O3
Magnesite	-4.06	-12.09	-8.03	MgCO3
Magnetite	-6.17	-2.43	3.74	Fe3O4
Malachite	-10.99	-16.17	-5.18	Cu2(OH)2CO3
Manganite	-15.43	-15.67	-0.24	MnOOH
Melanothallite	-17.19	-13.46	3.73	CuCl2
Melanterite	-4.41	-6.88	-2.47	FeSO4:7H2O
Mg-Ferrite	-16.43	0.34	16.77	MgFe2O4
MgCr2O4	-21.32	-9.24	12.08	MgCr2O4
MgCrO4	-51.55	-46.17	5.38	MgCrO4
Mirabilite	-8.02	-9.14	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-54.48	-60.19	-5.71	Mn2(SO4)3
MnCl2:4H2O	-14.74	-12.03	2.71	MnCl2:4H2O
MnSO4	-10.14	-7.47	2.67	MnSO4
Na2Cr2O7	-92.98	-102.88	-9.90	Na2Cr2O7
Na2CrO4	-54.45	-51.19	3.26	Na2CrO4
Nantokite	-4.58	-11.34	-6.76	CuCl
Natron	-15.81	-17.12	-1.31	Na2CO3:10H2O
Nesquehonite	-6.47	-12.09	-5.62	MgCO3:3H2O
Nsutite	-25.48	-7.98	17.50	MnO2
O2(g)	-52.36	30.76	83.12	O2
Periclase	-15.99	5.52	21.51	MgO
Portlandite	-18.06	4.61	22.68	Ca(OH)2
Pyrocroite	-12.94	2.15	15.09	Mn(OH)2
Pyrolusite	-23.84	-7.98	15.86	MnO2
Rhodochrosite	-5.05	-15.46	-10.41	MnCO3
Rutherfordine	-3.14	-17.60	-14.46	UO2CO3
Schoepite	-5.40	-0.00	5.40	UO2(OH)2:H2O
Siderite	-4.30	-14.85	-10.55	FeCO3
Smithsonite	-6.33	-16.33	-10.00	ZnCO3
Spinel	-16.78	19.56	36.33	MgAl2O4
Tenorite	-6.90	0.72	7.62	CuO
Thenardite	-8.94	-9.12	-0.18	Na2SO4
Thermonatrite	-17.24	-17.11	0.13	Na2CO3:H2O
U3O8(C)	-8.83	12.28	21.11	U3O8
U4O9(C)	-5.88	-9.26	-3.38	U4O9
UO2(am)	-7.09	-6.16	0.93	UO2
UO3(C)	-7.72	0.00	7.72	UO3
Uraninite	-1.46	-6.16	-4.70	UO2
Zincite	-9.87	1.27	11.14	ZnO
Zincosite	-11.36	-8.35	3.01	ZnSO4
Zn(BO2)2	-13.65	-5.36	8.29	Zn(BO2)2
Zn(OH)2(A)	-11.18	1.27	12.45	Zn(OH)2
Zn(OH)2(B)	-10.48	1.27	11.75	Zn(OH)2
Zn(OH)2(C)	-10.93	1.27	12.20	Zn(OH)2
Zn(OH)2(E)	-10.23	1.27	11.50	Zn(OH)2
Zn(OH)2(G)	-10.44	1.27	11.71	Zn(OH)2
Zn2(OH)2SO4	-14.58	-7.08	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-19.75	-4.55	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-34.44	-15.42	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-32.94	-4.54	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-46.32	-7.82	38.50	Zn5(OH)8Cl2
ZnCl2	-19.93	-12.90	7.03	ZnCl2
ZnCO3:H2O	-6.08	-16.34	-10.26	ZnCO3:H2O
ZnMetal	-39.86	-14.11	25.76	Zn
ZnO(Active)	-10.04	1.27	11.31	ZnO
ZnSO4:H2O	-7.78	-8.35	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 12.

-----------------------------Solution composition------------------------------

Elements	Molality	Moles
Al	6.410e-04	6.410e-04
Alkalinity	8.288e-06	8.288e-06
B	3.284e-04	3.284e-04
Ca	7.318e-04	7.318e-04
Cl	1.481e-01	1.481e-01
Cr	3.890e-08	3.890e-08
Cu	1.114e-07	1.114e-07
Fe	1.755e-04	1.755e-04
K	2.509e-03	2.509e-03
Mg	1.098e-02	1.098e-02
Mn	4.621e-06	4.621e-06
Na	1.531e-01	1.531e-01
S(6)	2.337e-02	2.337e-02
U	2.847e-07	2.847e-07
Zn	5.725e-07	5.725e-07

----------Description of solution----------

pH	= 4.460
pe	= 4.000
Activity of water	= 0.994
Ionic strength (mol/kgw)	= 2.060e-01
Mass of water (kg)	= 1.000e+00
Total carbon (mol/kg)	= 1.558e-03
Total CO2 (mol/kg)	= 1.558e-03
Temperature (°C)	= 25.00
Electrical balance (eq)	= -1.350e-02
Percent error, 100*(Cat-|An|)/(Cat+|An|)	= -3.77
Iterations	= 12
Total H	= 1.110166e+02
Total O	= 5.560542e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	4.354e-05	3.467e-05	-4.361	-4.460	-0.099	0.00
OH-	4.089e-10	2.881e-10	-9.388	-9.540	-0.152	(0)
H2O	5.551e+01	9.943e-01	1.744	-0.002	0.000	18.07
Al	6.410e-04					
Al+3	2.869e-04	3.698e-05	-3.542	-4.432	-0.890	(0)
AlSO4+	2.339e-04	1.700e-04	-3.631	-3.770	-0.139	(0)
Al(SO4)2-	8.156e-05	5.929e-05	-4.089	-4.227	-0.139	(0)
AlOH+2	3.536e-05	1.085e-05	-4.451	-4.964	-0.513	(0)
Al(OH)2+	3.246e-06	2.416e-06	-5.489	-5.617	-0.128	(0)
Al(OH)3	8.317e-08	8.721e-08	-7.080	-7.059	0.021	(0)
Al(OH)4-	3.441e-10	2.501e-10	-9.463	-9.602	-0.139	(0)
B	3.284e-04					
H3BO3	3.284e-04	3.444e-04	-3.484	-3.463	0.021	(0)
H2BO3-	8.410e-09	5.703e-09	-8.075	-8.244	-0.169	(0)
C(4)	1.558e-03					
H2CO3	1.528e-03	1.602e-03	-2.816	-2.795	0.021	(0)
HCO3-	2.765e-05	2.058e-05	-4.558	-4.687	-0.128	(0)
NaHCO3	1.228e-06	1.288e-06	-5.911	-5.890	0.021	(0)
MgHCO3+	1.082e-06	7.747e-07	-5.966	-6.111	-0.145	(0)
CaHCO3+	5.583e-08	4.214e-08	-7.253	-7.375	-0.122	(0)
UO2CO3	1.301e-08	1.365e-08	-7.886	-7.865	0.021	(0)
MnHCO3+	5.439e-10	4.007e-10	-9.265	-9.397	-0.133	(0)
ZnHCO3+	4.034e-10	3.007e-10	-9.394	-9.522	-0.128	(0)
CO3-2	9.052e-11	2.778e-11	-10.043	-10.556	-0.513	(0)
MgCO3	8.094e-11	8.488e-11	-10.092	-10.071	0.021	(0)
NaCO3-	7.691e-11	5.725e-11	-10.114	-10.242	-0.128	(0)
UO2(CO3)2-2	9.816e-12	3.028e-12	-11.008	-11.519	-0.511	(0)

CaCO3	7.440e-12	7.801e-12	-11.128	-11.108	0.021	(0)
CuHCO3+	4.105e-12	3.060e-12	-11.387	-11.514	-0.128	(0)
ZnCO3	6.569e-13	6.888e-13	-12.183	-12.162	0.021	(0)
CuCO3	4.519e-14	4.739e-14	-13.345	-13.324	0.021	(0)
UO2(CO3)3-4	2.238e-16	2.026e-18	-15.650	-17.693	-2.043	(0)
Zn(CO3)2-2	1.326e-18	4.091e-19	-17.877	-18.388	-0.511	(0)
Cu(CO3)2-2	5.373e-21	1.657e-21	-20.270	-20.781	-0.511	(0)
Ca	7.318e-04					
Ca+2	5.632e-04	1.977e-04	-3.249	-3.704	-0.455	(0)
CaSO4	1.686e-04	1.768e-04	-3.773	-3.753	0.021	(0)
CaHCO3+	5.583e-08	4.214e-08	-7.253	-7.375	-0.122	(0)
CaCO3	7.440e-12	7.801e-12	-11.128	-11.108	0.021	(0)
CaOH+	1.895e-12	1.430e-12	-11.722	-11.845	-0.122	(0)
Cl	1.481e-01					
Cl-	1.481e-01	1.032e-01	-0.830	-0.986	-0.157	(0)
MnCl+	5.920e-07	4.362e-07	-6.228	-6.360	-0.133	(0)
CuCl2-	7.836e-08	5.611e-08	-7.106	-7.251	-0.145	(0)
ZnCl+	4.819e-08	3.451e-08	-7.317	-7.462	-0.145	(0)
CuCl3-2	3.113e-08	9.176e-09	-7.507	-8.037	-0.531	(0)
MnCl2	1.166e-08	1.223e-08	-7.933	-7.913	0.021	(0)
UO2Cl+	8.967e-09	6.682e-09	-8.047	-8.175	-0.128	(0)
ZnCl2	3.555e-09	3.728e-09	-8.449	-8.429	0.021	(0)
MnCl3-	7.717e-10	5.687e-10	-9.113	-9.245	-0.133	(0)
ZnCl3-	6.027e-10	4.316e-10	-9.220	-9.365	-0.145	(0)
CrCl+2	2.478e-10	7.644e-11	-9.606	-10.117	-0.511	(0)
CuCl+	1.232e-10	8.820e-11	-9.910	-10.055	-0.145	(0)
ZnCl4-2	7.554e-11	2.227e-11	-10.122	-10.652	-0.531	(0)
ZnOHCl	1.161e-11	1.217e-11	-10.935	-10.915	0.021	(0)
CuCl2	4.661e-12	4.887e-12	-11.332	-11.311	0.021	(0)
CrCl2+	2.062e-12	1.537e-12	-11.686	-11.813	-0.128	(0)
FeCl+2	4.504e-13	1.328e-13	-12.346	-12.877	-0.531	(0)
CrOHCl2	8.476e-14	8.888e-14	-13.072	-13.051	0.021	(0)
FeCl2+	8.304e-14	6.119e-14	-13.081	-13.213	-0.133	(0)
CuCl3-	2.498e-15	1.789e-15	-14.602	-14.747	-0.145	(0)
FeCl3	6.021e-16	6.313e-16	-15.220	-15.200	0.021	(0)
CuCl4-2	3.139e-18	9.252e-19	-17.503	-18.034	-0.531	(0)
UCl+3	2.973e-23	2.108e-24	-22.527	-23.676	-1.149	(0)
CrO3Cl-	0.000e+00	0.000e+00	-40.672	-40.800	-0.128	(0)
Cr(2)	9.104e-20					
Cr+2	9.104e-20	2.808e-20	-19.041	-19.552	-0.511	(0)
Cr(3)	3.890e-08					
Cr+3	1.865e-08	1.323e-09	-7.729	-8.879	-1.149	(0)
Cr(OH)+2	1.230e-08	3.793e-09	-7.910	-8.421	-0.511	(0)
CrOHSO4	7.181e-09	7.530e-09	-8.144	-8.123	0.021	(0)
Cr(OH)2+	3.501e-10	2.609e-10	-9.456	-9.584	-0.128	(0)
CrCl+2	2.478e-10	7.644e-11	-9.606	-10.117	-0.511	(0)
CrSO4+	1.726e-10	1.286e-10	-9.763	-9.891	-0.128	(0)
CrCl2+	2.062e-12	1.537e-12	-11.686	-11.813	-0.128	(0)
Cr(OH)3	5.289e-13	5.546e-13	-12.277	-12.256	0.021	(0)
CrOHCl2	8.476e-14	8.888e-14	-13.072	-13.051	0.021	(0)
Cr2(OH)2SO4+2	1.683e-14	5.192e-15	-13.774	-14.285	-0.511	(0)
CrO2-	5.231e-19	3.898e-19	-18.281	-18.409	-0.128	(0)
Cr2(OH)2(SO4)2	5.129e-19	5.378e-19	-18.290	-18.269	0.021	(0)
Cr(OH)4-	2.038e-19	1.519e-19	-18.691	-18.819	-0.128	(0)
Cr(6)	9.663e-37					
HCrO4-	9.378e-37	6.989e-37	-36.028	-36.156	-0.128	(0)
CrO4-2	2.374e-38	6.244e-39	-37.624	-38.205	-0.580	(0)
NaCrO4-	4.629e-39	3.450e-39	-38.335	-38.462	-0.128	(0)
CrO3SO4-2	1.059e-40	0.000e+00	-39.975	-40.486	-0.511	(0)
KCrO4-	0.000e+00	0.000e+00	-40.048	-40.175	-0.128	(0)
CrO3Cl-	0.000e+00	0.000e+00	-40.672	-40.800	-0.128	(0)
H2CrO4	0.000e+00	0.000e+00	-41.494	-41.473	0.021	(0)
Cr2O7-2	0.000e+00	0.000e+00	-70.259	-70.769	-0.511	(0)
Cu(1)	1.095e-07					
CuCl2-	7.836e-08	5.611e-08	-7.106	-7.251	-0.145	(0)
CuCl3-2	3.113e-08	9.176e-09	-7.507	-8.037	-0.531	(0)

Cu+	2.458e-11	1.667e-11	-10.609	-10.778	-0.169	(0)
Cu(2)	1.905e-09					
Cu+2	1.501e-09	3.176e-10	-8.824	-9.498	-0.675	(0)
CuSO4	2.715e-10	2.847e-10	-9.566	-9.546	0.021	(0)
CuCl+	1.232e-10	8.820e-11	-9.910	-10.055	-0.145	(0)
CuCl2	4.661e-12	4.887e-12	-11.332	-11.311	0.021	(0)
CuHCO3+	4.105e-12	3.060e-12	-11.387	-11.514	-0.128	(0)
CuOH+	1.272e-13	9.108e-14	-12.896	-13.041	-0.145	(0)
CuCO3	4.519e-14	4.739e-14	-13.345	-13.324	0.021	(0)
Cu(OH)2	5.204e-15	5.457e-15	-14.284	-14.263	0.021	(0)
CuCl3-	2.498e-15	1.789e-15	-14.602	-14.747	-0.145	(0)
CuCl4-2	3.139e-18	9.252e-19	-17.503	-18.034	-0.531	(0)
Cu2(OH)2+2	1.177e-20	3.630e-21	-19.929	-20.440	-0.511	(0)
Cu(CO3)2-2	5.373e-21	1.657e-21	-20.270	-20.781	-0.511	(0)
Cu(OH)3-	1.268e-23	9.450e-24	-22.897	-23.025	-0.128	(0)
Cu(OH)4-2	1.749e-31	5.395e-32	-30.757	-31.268	-0.511	(0)
Fe(2)	1.755e-04					
Fe+2	1.413e-04	4.587e-05	-3.850	-4.338	-0.489	(0)
FeSO4	3.415e-05	3.581e-05	-4.467	-4.446	0.021	(0)
FeOH+	5.645e-10	4.159e-10	-9.248	-9.381	-0.133	(0)
Fe(OH)2	9.682e-17	1.015e-16	-16.014	-15.993	0.021	(0)
Fe(OH)3-	1.468e-22	1.082e-22	-21.833	-21.966	-0.133	(0)
Fe(3)	1.307e-10					
Fe(OH)2+	1.006e-10	7.491e-11	-9.997	-10.125	-0.128	(0)
FeOH+2	2.676e-11	7.889e-12	-10.572	-11.103	-0.531	(0)
FeSO4+	2.112e-12	1.556e-12	-11.675	-11.808	-0.133	(0)
FeCl+2	4.504e-13	1.328e-13	-12.346	-12.877	-0.531	(0)
Fe+3	3.305e-13	4.261e-14	-12.481	-13.370	-0.890	(0)
Fe(SO4)2-	2.898e-13	2.160e-13	-12.538	-12.666	-0.128	(0)
FeCl2+	8.304e-14	6.119e-14	-13.081	-13.213	-0.133	(0)
Fe(OH)3	2.407e-14	2.524e-14	-13.619	-13.598	0.021	(0)
FeCl3	6.021e-16	6.313e-16	-15.220	-15.200	0.021	(0)
Fe(OH)4-	9.724e-18	7.237e-18	-17.012	-17.140	-0.128	(0)
Fe2(OH)2+4	1.851e-19	1.675e-21	-18.733	-20.776	-2.043	(0)
Fe3(OH)4+5	4.086e-26	2.622e-29	-25.389	-28.581	-3.193	(0)
H(0)	1.623e-20					
H2	8.117e-21	8.511e-21	-20.091	-20.070	0.021	(0)
K	2.509e-03					
K+	2.439e-03	1.699e-03	-2.613	-2.770	-0.157	(0)
KSO4-	7.043e-05	5.242e-05	-4.152	-4.281	-0.128	(0)
KCrO4-	0.000e+00	0.000e+00	-40.048	-40.175	-0.128	(0)
Mg	1.098e-02					
Mg+2	8.598e-03	3.202e-03	-2.066	-2.495	-0.429	(0)
MgSO4	2.384e-03	2.499e-03	-2.623	-2.602	0.021	(0)
MgHCO3+	1.082e-06	7.747e-07	-5.966	-6.111	-0.145	(0)
MgOH+	1.977e-10	1.508e-10	-9.704	-9.822	-0.118	(0)
MgCO3	8.094e-11	8.488e-11	-10.092	-10.071	0.021	(0)
Mn(2)	4.621e-06					
Mn+2	3.220e-06	1.045e-06	-5.492	-5.981	-0.489	(0)
MnSO4	7.961e-07	8.348e-07	-6.099	-6.078	0.021	(0)
MnCl+	5.920e-07	4.362e-07	-6.228	-6.360	-0.133	(0)
MnCl2	1.166e-08	1.223e-08	-7.933	-7.913	0.021	(0)
MnCl3-	7.717e-10	5.687e-10	-9.113	-9.245	-0.133	(0)
MnHCO3+	5.439e-10	4.007e-10	-9.265	-9.397	-0.133	(0)
MnOH+	1.045e-12	7.702e-13	-11.981	-12.113	-0.133	(0)
Mn(OH)3-	5.300e-28	3.905e-28	-27.276	-27.408	-0.133	(0)
Mn(3)	2.522e-27					
Mn+3	2.522e-27	3.252e-28	-26.598	-27.488	-0.890	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-72.220	-72.751	-0.531	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-77.975	-78.135	-0.160	(0)
Na	1.531e-01					
Na+	1.498e-01	1.112e-01	-0.824	-0.954	-0.130	(0)
NaSO4-	3.286e-03	2.446e-03	-2.483	-2.612	-0.128	(0)
NaHCO3	1.228e-06	1.288e-06	-5.911	-5.890	0.021	(0)

NaCO3-	7.691e-11	5.725e-11	-10.114	-10.242	-0.128	(0)
NaCrO4-	4.629e-39	3.450e-39	-38.335	-38.462	-0.128	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-52.266	-52.245	0.021	(0)
S(6)	2.337e-02					
SO4-2	1.701e-02	4.390e-03	-1.769	-2.358	-0.588	(0)
NaSO4-	3.286e-03	2.446e-03	-2.483	-2.612	-0.128	(0)
MgSO4	2.384e-03	2.499e-03	-2.623	-2.602	0.021	(0)
AlSO4+	2.339e-04	1.700e-04	-3.631	-3.770	-0.139	(0)
CaSO4	1.686e-04	1.768e-04	-3.773	-3.753	0.021	(0)
Al(SO4)2-	8.156e-05	5.929e-05	-4.089	-4.227	-0.139	(0)
KSO4-	7.043e-05	5.242e-05	-4.152	-4.281	-0.128	(0)
FeSO4	3.415e-05	3.581e-05	-4.467	-4.446	0.021	(0)
HSO4-	2.032e-05	1.477e-05	-4.692	-4.831	-0.139	(0)
MnSO4	7.961e-07	8.348e-07	-6.099	-6.078	0.021	(0)
ZnSO4	1.220e-07	1.279e-07	-6.914	-6.893	0.021	(0)
UO2SO4	8.360e-08	8.766e-08	-7.078	-7.057	0.021	(0)
UO2(SO4)2-2	3.716e-08	1.146e-08	-7.430	-7.941	-0.511	(0)
Zn(SO4)2-2	1.479e-08	4.563e-09	-7.830	-8.341	-0.511	(0)
CrOHSO4	7.181e-09	7.530e-09	-8.144	-8.123	0.021	(0)
CuSO4	2.715e-10	2.847e-10	-9.566	-9.546	0.021	(0)
CrSO4+	1.726e-10	1.286e-10	-9.763	-9.891	-0.128	(0)
FeSO4+	2.112e-12	1.556e-12	-11.675	-11.808	-0.133	(0)
Fe(SO4)2-	2.898e-13	2.160e-13	-12.538	-12.666	-0.128	(0)
Cr2(OH)2SO4+2	1.683e-14	5.192e-15	-13.774	-14.285	-0.511	(0)
Cr2(OH)2(SO4)2	5.129e-19	5.378e-19	-18.290	-18.269	0.021	(0)
U(SO4)2	9.675e-20	1.015e-19	-19.014	-18.994	0.021	(0)
USO4+2	3.860e-21	1.191e-21	-20.413	-20.924	-0.511	(0)
CrO3SO4-2	1.059e-40	0.000e+00	-39.975	-40.486	-0.511	(0)
U(3)	2.117e-36					
U+3	2.117e-36	1.501e-37	-35.674	-36.824	-1.149	(0)
U(4)	4.132e-15					
U(OH)4	1.922e-15	2.016e-15	-14.716	-14.696	0.021	(0)
U(OH)5-	1.852e-15	1.380e-15	-14.732	-14.860	-0.128	(0)
U(OH)3+	3.448e-16	2.570e-16	-15.462	-15.590	-0.128	(0)
U(OH)2+2	1.343e-17	4.143e-18	-16.872	-17.383	-0.511	(0)
U(SO4)2	9.675e-20	1.015e-19	-19.014	-18.994	0.021	(0)
UOH+3	8.250e-20	5.849e-21	-19.084	-20.233	-1.149	(0)
USO4+2	3.860e-21	1.191e-21	-20.413	-20.924	-0.511	(0)
U+4	1.037e-22	9.382e-25	-21.984	-24.028	-2.043	(0)
UCl+3	2.973e-23	2.108e-24	-22.527	-23.676	-1.149	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-84.188	-94.532	-10.344	(0)
U(5)	3.192e-09					
UO2+	3.192e-09	2.379e-09	-8.496	-8.624	-0.128	(0)
U(6)	2.815e-07					
UO2+2	1.265e-07	3.903e-08	-6.898	-7.409	-0.511	(0)
UO2SO4	8.360e-08	8.766e-08	-7.078	-7.057	0.021	(0)
UO2(SO4)2-2	3.716e-08	1.146e-08	-7.430	-7.941	-0.511	(0)
UO2CO3	1.301e-08	1.365e-08	-7.886	-7.865	0.021	(0)
UO2OH+	1.221e-08	9.096e-09	-7.913	-8.041	-0.128	(0)
UO2Cl+	8.967e-09	6.682e-09	-8.047	-8.175	-0.128	(0)
UO2(CO3)2-2	9.816e-12	3.028e-12	-11.008	-11.519	-0.511	(0)
(UO2)2(OH)2+2	9.195e-12	2.836e-12	-11.036	-11.547	-0.511	(0)
(UO2)3(OH)5+	3.948e-16	2.942e-16	-15.404	-15.531	-0.128	(0)
UO2(CO3)3-4	2.238e-16	2.026e-18	-15.650	-17.693	-2.043	(0)
Zn	5.725e-07					
Zn+2	3.829e-07	1.243e-07	-6.417	-6.906	-0.489	(0)
ZnSO4	1.220e-07	1.279e-07	-6.914	-6.893	0.021	(0)
ZnCl+	4.819e-08	3.451e-08	-7.317	-7.462	-0.145	(0)
Zn(SO4)2-2	1.479e-08	4.563e-09	-7.830	-8.341	-0.511	(0)
ZnCl2	3.555e-09	3.728e-09	-8.449	-8.429	0.021	(0)
ZnCl3-	6.027e-10	4.316e-10	-9.220	-9.365	-0.145	(0)
ZnHCO3+	4.034e-10	3.007e-10	-9.394	-9.522	-0.128	(0)
ZnCl4-2	7.554e-11	2.227e-11	-10.122	-10.652	-0.531	(0)
ZnOHCl	1.161e-11	1.217e-11	-10.935	-10.915	0.021	(0)
ZnOH+	5.243e-12	3.907e-12	-11.280	-11.408	-0.128	(0)

ZnCO3	6.569e-13	6.888e-13	-12.183	-12.162	0.021	(0)
Zn(OH)2	1.230e-15	1.289e-15	-14.910	-14.890	0.021	(0)
Zn(CO3)2-2	1.326e-18	4.091e-19	-17.877	-18.388	-0.511	(0)
Zn(OH)3-	1.569e-22	1.169e-22	-21.804	-21.932	-0.128	(0)
Zn(OH)4-2	1.723e-30	5.314e-31	-29.764	-30.275	-0.511	(0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-1.44	8.94	10.38	Al(OH)3
Al2O3	-5.09	17.89	22.98	Al2O3
Al4(OH)10SO4	1.79	24.49	22.70	Al4(OH)10SO4
AlOHSO4	0.90	-2.33	-3.23	AlOHSO4
AlumK	-6.78	-11.95	-5.17	KAl(SO4)2:12H2O
Alunite	7.31	5.96	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-1.42	-6.06	-4.64	CaSO4
Antlerite	-21.31	-13.02	8.29	Cu3(OH)4SO4
Aragonite	-5.92	-14.26	-8.34	CaCO3
Artinite	-16.24	-6.64	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-13.95	-6.61	7.34	Cu2(OH)3Cl
Azurite	-23.77	-40.69	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-4.04	1.51	5.54	UO2(OH)2
Bianchite	-7.51	-9.28	-1.76	ZnSO4:6H2O
Birnessite	-23.74	-5.65	18.09	MnO2
Bixbyite	-27.61	-28.22	-0.61	Mn2O3
Boehmite	0.37	8.94	8.58	AlOOH
Brochantite	-28.94	-13.60	15.34	Cu4(OH)6SO4
Brucite	-10.37	6.42	16.79	Mg(OH)2
CaCrO4	-39.64	-41.91	-2.27	CaCrO4
Calcite	-5.79	-14.26	-8.47	CaCO3
CH4(g)	-47.05	-87.15	-40.10	CH4
Chalcanthite	-9.23	-11.87	-2.64	CuSO4:5H2O
CO2(g)	-1.31	-19.47	-18.16	CO2
Cr(OH)2	-21.46	-10.64	10.82	Cr(OH)2
Cr(OH)3(A)	-4.38	-5.13	-0.75	Cr(OH)3
Cr(OH)3(C)	-6.83	-5.13	1.70	Cr(OH)3
Cr2O3	-6.85	-10.24	-3.39	Cr2O3
CrCl2	-37.39	-21.52	15.87	CrCl2
CrCl3	-34.96	-21.46	13.51	CrCl3
CrMetal	-59.80	-27.55	32.24	Cr
CrO3	-43.91	-47.12	-3.21	CrO3
Cu(OH)2	-9.22	-0.58	8.64	Cu(OH)2
Cu2SO4	-21.96	-23.91	-1.95	Cu2SO4
CuCO3	-10.42	-20.05	-9.63	CuCO3
CuCrO4	-42.23	-47.70	-5.48	CuCrO4
CuMetal	-6.02	-14.78	-8.76	Cu
CuOCuSO4	-23.97	-12.44	11.53	CuO:CuSO4
CupricFerrite	-6.45	-0.57	5.88	CuFe2O4
Cuprite	-11.09	-12.64	-1.55	Cu2O
CuprousFerrite	2.61	-6.31	-8.92	CuFeO2
CuSO4	-14.87	-11.86	3.01	CuSO4
Diaspore	2.07	8.94	6.87	AlOOH
Dolomite	-10.31	-27.31	-17.00	CaMg(CO3)2
Epsomite	-2.73	-4.87	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	1.41	-1.63	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-37.39	-33.81	3.58	Fe2(SO4)3
Fe3(OH)8	-15.64	4.58	20.22	Fe3(OH)8
FeCr2O4	-4.76	-5.67	-0.90	FeCr2O4
Ferrihydrite	-4.89	0.00	4.89	Fe(OH)3
Gibbsite(C)	0.17	8.94	8.77	Al(OH)3
Goethite	-0.50	0.00	0.50	FeOOH
Goslarite	-7.32	-9.28	-1.96	ZnSO4:7H2O
Gummite	-8.89	1.51	10.40	UO3
Gypsum	-1.46	-6.07	-4.61	CaSO4:2H2O
Halite	-3.52	-1.94	1.58	NaCl

Hausmannite	-35.81	25.73	61.54	Mn3O4
Hematite	4.02	0.01	-4.01	Fe2O3
Hercynite	-4.69	22.47	27.16	FeAl2O4
Huntite	-23.44	-53.41	-29.97	CaMg3(CO3)4
Hydromagnesite	-37.03	-45.79	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-10.44	-22.54	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-6.05	-20.85	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-7.84	-19.04	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-75.19	-90.87	-15.67	K2Cr2O7
K2CrO4	-43.75	-43.74	0.01	K2CrO4
Langite	-30.40	-13.61	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-1.37	0.00	1.37	FeOOH
Lime	-27.58	5.21	32.80	CaO
Maghemite	-6.37	0.01	6.39	Fe2O3
Magnesite	-5.02	-13.05	-8.03	MgCO3
Magnetite	0.85	4.59	3.74	Fe3O4
Malachite	-15.46	-20.64	-5.18	Cu2(OH)2CO3
Manganite	-13.87	-14.11	-0.24	MnOOH
Melanothallite	-15.20	-11.47	3.73	CuCl2
Melanterite	-4.24	-6.71	-2.47	FeSO4:7H2O
Mg-Ferrite	-10.33	6.43	16.77	MgFe2O4
MgCr2O4	-15.90	-3.82	12.08	MgCr2O4
MgCrO4	-46.08	-40.70	5.38	MgCrO4
Mirabilite	-3.18	-4.29	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-56.34	-62.05	-5.71	Mn2(SO4)3
MnCl2:4H2O	-10.67	-7.96	2.71	MnCl2:4H2O
MnSO4	-11.01	-8.34	2.67	MnSO4
Na2Cr2O7	-77.34	-87.23	-9.90	Na2Cr2O7
Na2CrO4	-43.37	-40.11	3.26	Na2CrO4
Nantokite	-5.00	-11.76	-6.76	CuCl
Natron	-11.18	-12.49	-1.31	Na2CO3:10H2O
Nesquehonite	-7.44	-13.06	-5.62	MgCO3:3H2O
Nsutite	-23.16	-5.65	17.50	MnO2
O2(g)	-49.28	33.84	83.12	O2
Periclase	-15.09	6.42	21.51	MgO
Portlandite	-17.46	5.21	22.68	Ca(OH)2
Pyrocroite	-12.15	2.93	15.09	Mn(OH)2
Pyrolusite	-21.51	-5.65	15.86	MnO2
Rhodochrosite	-6.13	-16.54	-10.41	MnCO3
Rutherfordine	-3.50	-17.96	-14.46	UO2CO3
Schoepite	-3.90	1.50	5.40	UO2(OH)2:H2O
Siderite	-4.34	-14.89	-10.55	FeCO3
Smithsonite	-7.46	-17.46	-10.00	ZnCO3
Spinel	-12.02	24.31	36.33	MgAl2O4
Tenorite	-8.20	-0.58	7.62	CuO
Thenardite	-4.09	-4.27	-0.18	Na2SO4
Thermonatrite	-12.59	-12.47	0.13	Na2CO3:H2O
U3O8(C)	-5.85	15.26	21.11	U3O8
U4O9(C)	-4.47	-7.85	-3.38	U4O9
UO2(am)	-7.13	-6.19	0.93	UO2
UO3(C)	-6.21	1.51	7.72	UO3
Uraninite	-1.49	-6.19	-4.70	UO2
Zincite	-9.13	2.01	11.14	ZnO
Zincosite	-12.27	-9.26	3.01	ZnSO4
Zn(BO2)2	-13.20	-4.91	8.29	Zn(BO2)2
Zn(OH)2(A)	-10.44	2.01	12.45	Zn(OH)2
Zn(OH)2(B)	-9.74	2.01	11.75	Zn(OH)2
Zn(OH)2(C)	-10.19	2.01	12.20	Zn(OH)2
Zn(OH)2(E)	-9.49	2.01	11.50	Zn(OH)2
Zn(OH)2(G)	-9.70	2.01	11.71	Zn(OH)2
Zn2(OH)2SO4	-14.75	-7.25	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-16.63	-1.43	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-35.53	-16.51	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-31.64	-3.24	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-39.34	-0.84	38.50	Zn5(OH)8Cl2
ZnCl2	-15.91	-8.88	7.03	ZnCl2

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  ZnCO3:H2O        -7.20    -17.46  -10.26  ZnCO3:H2O
  ZnMetal         -40.66    -14.91   25.76  Zn
  ZnO(Active)      -9.30      2.01   11.31  ZnO
  ZnSO4:H2O        -8.70     -9.27   -0.57  ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

Initial solution 13.

-----------------------------Solution composition------------------------------

      Elements           Molality       Moles

      Al                1.747e-03   1.747e-03
      Alkalinity        8.251e-06   8.251e-06
      B                 3.894e-04   3.894e-04
      Ca                1.289e-02   1.289e-02
      Cl                7.952e-04   7.952e-04
      Cr                1.356e-07   1.356e-07
      Cu                5.229e-07   5.229e-07
      Fe                4.508e-07   4.508e-07
      K                 6.979e-03   6.979e-03
      Mg                7.331e-02   7.331e-02
      Mn                9.347e-05   9.347e-05
      Na                7.446e-04   7.446e-04
      S(6)              4.423e-02   4.423e-02
      U                 5.288e-07   5.288e-07
      Zn                3.358e-06   3.358e-06

----------------------------Description of solution----------------------------

                                    pH  =   4.170
                                    pe  =   4.000
                       Activity of water  =   0.998
                  Ionic strength (mol/kgw)  =   1.739e-01
                        Mass of water (kg)  =   1.000e+00
                   Total carbon (mol/kg)  =   8.053e-03
                      Total CO2 (mol/kg)  =   8.053e-03
                        Temperature (°C)  =  25.00
                  Electrical balance (eq)  =   9.628e-02
 Percent error, 100*(Cat-|An|)/(Cat+|An|)  =  54.15
                                Iterations  =  13
                                   Total H  = 1.110298e+02
                                   Total O  = 5.570853e+01

---------------------------Distribution of species----------------------------

                                                 Log       Log       Log    mole V
   Species          Molality    Activity  Molality  Activity     Gamma   cm³/mol

   H+               8.419e-05   6.761e-05    -4.075    -4.170    -0.095      0.00
   OH-              2.065e-10   1.483e-10    -9.685    -9.829    -0.144     (0)
   H2O              5.551e+01   9.979e-01     1.744    -0.001     0.000     18.07
Al            1.747e-03
   AlSO4+           7.193e-04   5.313e-04    -3.143    -3.275    -0.132     (0)
   Al+3             6.702e-04   9.310e-05    -3.174    -4.031    -0.857     (0)
   Al(SO4)2-        3.114e-04   2.300e-04    -3.507    -3.638    -0.132     (0)
   AlOH+2           4.336e-05   1.406e-05    -4.363    -4.852    -0.489     (0)
   Al(OH)2+         2.135e-06   1.611e-06    -5.671    -5.793    -0.122     (0)
   Al(OH)3          2.876e-08   2.994e-08    -7.541    -7.524     0.017     (0)
   Al(OH)4-         5.982e-11   4.418e-11   -10.223   -10.355    -0.132     (0)
B             3.894e-04
   H3BO3            3.894e-04   4.053e-04    -3.410    -3.392     0.017     (0)
   H2BO3-           4.958e-09   3.442e-09    -8.305    -8.463    -0.158     (0)
C(4)          8.053e-03
```

H2CO3	7.960e-03	8.285e-03	-2.099	-2.082	0.017	(0)
HCO3-	7.231e-05	5.457e-05	-4.141	-4.263	-0.122	(0)
MgHCO3+	1.827e-05	1.331e-05	-4.738	-4.876	-0.137	(0)
CaHCO3+	2.502e-06	1.912e-06	-5.602	-5.718	-0.117	(0)
MnHCO3+	3.270e-08	2.445e-08	-7.485	-7.612	-0.126	(0)
UO2CO3	3.055e-08	3.180e-08	-7.515	-7.498	0.017	(0)
NaHCO3	1.606e-08	1.672e-08	-7.794	-7.777	0.017	(0)
ZnHCO3+	6.590e-09	4.959e-09	-8.181	-8.305	-0.123	(0)
CuHCO3+	3.233e-09	2.433e-09	-8.490	-8.614	-0.123	(0)
MgCO3	7.186e-10	7.480e-10	-9.144	-9.126	0.017	(0)
CaCO3	1.744e-10	1.816e-10	-9.758	-9.741	0.017	(0)
CO3-2	1.165e-10	3.778e-11	-9.934	-10.423	-0.489	(0)
UO2(CO3)2-2	2.992e-11	9.595e-12	-10.524	-11.018	-0.494	(0)
CuCO3	1.856e-11	1.932e-11	-10.731	-10.714	0.017	(0)
ZnCO3	5.597e-12	5.826e-12	-11.252	-11.235	0.017	(0)
NaCO3-	5.052e-13	3.812e-13	-12.297	-12.419	-0.122	(0)
UO2(CO3)3-4	8.259e-16	8.732e-18	-15.083	-17.059	-1.976	(0)
Zn(CO3)2-2	1.468e-17	4.706e-18	-16.833	-17.327	-0.494	(0)
Cu(CO3)2-2	2.866e-18	9.192e-19	-17.543	-18.037	-0.494	(0)
Ca	1.289e-02					
Ca+2	9.278e-03	3.382e-03	-2.033	-2.471	-0.438	(0)
CaSO4	3.608e-03	3.755e-03	-2.443	-2.425	0.017	(0)
CaHCO3+	2.502e-06	1.912e-06	-5.602	-5.718	-0.117	(0)
CaCO3	1.744e-10	1.816e-10	-9.758	-9.741	0.017	(0)
CaOH+	1.648e-11	1.260e-11	-10.783	-10.900	-0.117	(0)
Cl	7.952e-04					
Cl-	7.952e-04	5.654e-04	-3.100	-3.248	-0.148	(0)
MnCl+	7.354e-08	5.499e-08	-7.133	-7.260	-0.126	(0)
ZnCl+	1.614e-09	1.176e-09	-8.792	-8.930	-0.137	(0)
CuCl2-	6.931e-10	5.052e-10	-9.159	-9.297	-0.137	(0)
CuCl+	1.988e-10	1.449e-10	-9.702	-9.839	-0.137	(0)
UO2Cl+	8.336e-11	6.273e-11	-10.079	-10.203	-0.123	(0)
MnCl2	8.114e-12	8.446e-12	-11.091	-11.073	0.017	(0)
CrCl+2	6.299e-12	2.020e-12	-11.201	-11.695	-0.494	(0)
CuCl3-2	1.448e-12	4.526e-13	-11.839	-12.344	-0.505	(0)
ZnCl2	6.688e-13	6.962e-13	-12.175	-12.157	0.017	(0)
ZnOHCl	2.052e-13	2.135e-13	-12.688	-12.671	0.017	(0)
CuCl2	4.227e-14	4.400e-14	-13.374	-13.357	0.017	(0)
MnCl3-	2.879e-15	2.153e-15	-14.541	-14.667	-0.126	(0)
ZnCl3-	6.060e-16	4.416e-16	-15.218	-15.355	-0.137	(0)
CrCl2+	2.957e-16	2.225e-16	-15.529	-15.653	-0.123	(0)
CrOHCl2	6.364e-18	6.624e-18	-17.196	-17.179	0.017	(0)
FeCl+2	5.921e-18	1.851e-18	-17.228	-17.733	-0.505	(0)
ZnCl4-2	3.993e-19	1.248e-19	-18.399	-18.904	-0.505	(0)
CuCl3-	1.211e-19	8.826e-20	-18.917	-19.054	-0.137	(0)
FeCl2+	6.252e-21	4.675e-21	-20.204	-20.330	-0.126	(0)
UCl+3	3.671e-24	2.840e-25	-23.435	-24.547	-1.111	(0)
CuCl4-2	7.998e-25	2.501e-25	-24.097	-24.602	-0.505	(0)
FeCl3	2.539e-25	2.643e-25	-24.595	-24.578	0.017	(0)
CrO3Cl-	0.000e+00	0.000e+00	-43.990	-44.113	-0.123	(0)
Cr(2)	4.223e-19					
Cr+2	4.223e-19	1.354e-19	-18.374	-18.868	-0.494	(0)
Cr(3)	1.356e-07					
Cr+3	8.243e-08	6.378e-09	-7.084	-8.195	-1.111	(0)
Cr(OH)+2	2.936e-08	9.414e-09	-7.532	-8.026	-0.494	(0)
CrOHSO4	2.229e-08	2.321e-08	-7.652	-7.634	0.017	(0)
CrSO4+	1.023e-09	7.700e-10	-8.990	-9.113	-0.123	(0)
Cr(OH)2+	4.429e-10	3.333e-10	-9.354	-9.477	-0.123	(0)
CrCl+2	6.299e-12	2.020e-12	-11.201	-11.695	-0.494	(0)
Cr(OH)3	3.504e-13	3.647e-13	-12.455	-12.438	0.017	(0)
Cr2(OH)2SO4+2	1.239e-13	3.972e-14	-12.907	-13.401	-0.494	(0)
CrCl2+	2.957e-16	2.225e-16	-15.529	-15.653	-0.123	(0)
CrOHCl2	6.364e-18	6.624e-18	-17.196	-17.179	0.017	(0)
Cr2(OH)2(SO4)2	4.907e-18	5.107e-18	-17.309	-17.292	0.017	(0)
CrO2-	1.741e-19	1.310e-19	-18.759	-18.883	-0.123	(0)
Cr(OH)4-	6.831e-20	5.141e-20	-19.165	-19.289	-0.123	(0)

Cr(6)	4.292e-38					
HCrO4-	4.240e-38	3.191e-38	-37.373	-37.496	-0.123	(0)
CrO4-2	5.183e-40	1.462e-40	-39.285	-39.835	-0.550	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-40.950	-41.444	-0.494	(0)
KCrO4-	0.000e+00	0.000e+00	-41.232	-41.356	-0.123	(0)
NaCrO4-	0.000e+00	0.000e+00	-42.279	-42.403	-0.123	(0)
H2CrO4	0.000e+00	0.000e+00	-42.541	-42.524	0.017	(0)
CrO3Cl-	0.000e+00	0.000e+00	-43.990	-44.113	-0.123	(0)
Cr2O7-2	0.000e+00	0.000e+00	-72.958	-73.452	-0.494	(0)
Cu(1)	7.892e-09					
Cu+	7.198e-09	4.998e-09	-8.143	-8.301	-0.158	(0)
CuCl2-	6.931e-10	5.052e-10	-9.159	-9.297	-0.137	(0)
CuCl3-2	1.448e-12	4.526e-13	-11.839	-12.344	-0.505	(0)
Cu(2)	5.150e-07					
Cu+2	4.097e-07	9.523e-08	-6.387	-7.021	-0.634	(0)
CuSO4	1.018e-07	1.060e-07	-6.992	-6.975	0.017	(0)
CuHCO3+	3.233e-09	2.433e-09	-8.490	-8.614	-0.123	(0)
CuCl+	1.988e-10	1.449e-10	-9.702	-9.839	-0.137	(0)
CuOH+	1.929e-11	1.406e-11	-10.715	-10.852	-0.137	(0)
CuCO3	1.856e-11	1.932e-11	-10.731	-10.714	0.017	(0)
Cu(OH)2	4.164e-13	4.334e-13	-12.380	-12.363	0.017	(0)
CuCl2	4.227e-14	4.400e-14	-13.374	-13.357	0.017	(0)
Cu2(OH)2+2	2.696e-16	8.645e-17	-15.569	-16.063	-0.494	(0)
Cu(CO3)2-2	2.866e-18	9.192e-19	-17.543	-18.037	-0.494	(0)
CuCl3-	1.211e-19	8.826e-20	-18.917	-19.054	-0.137	(0)
Cu(OH)3-	5.134e-22	3.864e-22	-21.290	-21.413	-0.123	(0)
CuCl4-2	7.998e-25	2.501e-25	-24.097	-24.602	-0.505	(0)
Cu(OH)4-2	3.540e-30	1.135e-30	-29.451	-29.945	-0.494	(0)
Fe(2)	4.508e-07					
Fe+2	3.421e-07	1.167e-07	-6.466	-6.933	-0.467	(0)
FeSO4	1.087e-07	1.131e-07	-6.964	-6.946	0.017	(0)
FeOH+	7.286e-13	5.448e-13	-12.138	-12.264	-0.126	(0)
Fe(OH)2	6.575e-20	6.844e-20	-19.182	-19.165	0.017	(0)
Fe(OH)3-	5.019e-26	3.753e-26	-25.299	-25.426	-0.126	(0)
Fe(3)	1.085e-13					
Fe(OH)2+	6.692e-14	5.050e-14	-13.174	-13.297	-0.122	(0)
FeOH+2	3.305e-14	1.033e-14	-13.481	-13.986	-0.505	(0)
FeSO4+	6.573e-15	4.915e-15	-14.182	-14.308	-0.126	(0)
Fe(SO4)2-	1.126e-15	8.472e-16	-14.949	-15.072	-0.123	(0)
Fe+3	7.806e-16	1.084e-16	-15.108	-15.965	-0.857	(0)
Fe(OH)3	8.414e-18	8.758e-18	-17.075	-17.058	0.017	(0)
FeCl+2	5.921e-18	1.851e-18	-17.228	-17.733	-0.505	(0)
FeCl2+	6.252e-21	4.675e-21	-20.204	-20.330	-0.126	(0)
Fe(OH)4-	1.713e-21	1.293e-21	-20.766	-20.889	-0.122	(0)
Fe2(OH)2+4	2.718e-25	2.874e-27	-24.566	-26.542	-1.976	(0)
FeCl3	2.539e-25	2.643e-25	-24.595	-24.578	0.017	(0)
Fe3(OH)4+5	3.707e-35	3.032e-38	-34.431	-37.518	-3.087	(0)
H(0)	6.218e-20					
H2	3.109e-20	3.236e-20	-19.507	-19.490	0.017	(0)
K	6.979e-03					
K+	6.736e-03	4.789e-03	-2.172	-2.320	-0.148	(0)
KSO4-	2.430e-04	1.834e-04	-3.614	-3.737	-0.122	(0)
KCrO4-	0.000e+00	0.000e+00	-41.232	-41.356	-0.123	(0)
Mg	7.331e-02					
Mg+2	5.397e-02	2.075e-02	-1.268	-1.683	-0.415	(0)
MgSO4	1.932e-02	2.011e-02	-1.714	-1.697	0.017	(0)
MgHCO3+	1.827e-05	1.331e-05	-4.738	-4.876	-0.137	(0)
MgCO3	7.186e-10	7.480e-10	-9.144	-9.126	0.017	(0)
MgOH+	6.516e-10	5.029e-10	-9.186	-9.298	-0.113	(0)
Mn(2)	9.347e-05					
Mn+2	7.046e-05	2.404e-05	-4.152	-4.619	-0.467	(0)
MnSO4	2.291e-05	2.384e-05	-4.640	-4.623	0.017	(0)
MnCl+	7.354e-08	5.499e-08	-7.133	-7.260	-0.126	(0)
MnHCO3+	3.270e-08	2.445e-08	-7.485	-7.612	-0.126	(0)
MnOH+	1.220e-11	9.121e-12	-10.914	-11.040	-0.126	(0)
MnCl2	8.114e-12	8.446e-12	-11.091	-11.073	0.017	(0)

MnCl3-	2.879e-15	2.153e-15	-14.541	-14.667	-0.126	(0)
Mn(OH)3-	1.639e-27	1.225e-27	-26.786	-26.912	-0.126	(0)
Mn(3)	5.386e-26					
Mn+3	5.386e-26	7.481e-27	-25.269	-26.126	-0.857	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-73.198	-73.703	-0.505	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-78.936	-79.087	-0.151	(0)
Na	7.446e-04					
Na+	7.249e-04	5.444e-04	-3.140	-3.264	-0.124	(0)
NaSO4-	1.970e-05	1.487e-05	-4.705	-4.828	-0.122	(0)
NaHCO3	1.606e-08	1.672e-08	-7.794	-7.777	0.017	(0)
NaCO3-	5.052e-13	3.812e-13	-12.297	-12.419	-0.122	(0)
NaCrO4-	0.000e+00	0.000e+00	-42.279	-42.403	-0.123	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-53.419	-53.402	0.017	(0)
S(6)	4.423e-02					
SO4-2	1.963e-02	5.450e-03	-1.707	-2.264	-0.557	(0)
MgSO4	1.932e-02	2.011e-02	-1.714	-1.697	0.017	(0)
CaSO4	3.608e-03	3.755e-03	-2.443	-2.425	0.017	(0)
AlSO4+	7.193e-04	5.313e-04	-3.143	-3.275	-0.132	(0)
Al(SO4)2-	3.114e-04	2.300e-04	-3.507	-3.638	-0.132	(0)
KSO4-	2.430e-04	1.834e-04	-3.614	-3.737	-0.122	(0)
HSO4-	4.841e-05	3.576e-05	-4.315	-4.447	-0.132	(0)
MnSO4	2.291e-05	2.384e-05	-4.640	-4.623	0.017	(0)
NaSO4-	1.970e-05	1.487e-05	-4.705	-4.828	-0.122	(0)
ZnSO4	9.486e-07	9.873e-07	-6.023	-6.006	0.017	(0)
UO2SO4	1.791e-07	1.865e-07	-6.747	-6.729	0.017	(0)
Zn(SO4)2-2	1.364e-07	4.374e-08	-6.865	-7.359	-0.494	(0)
FeSO4	1.087e-07	1.131e-07	-6.964	-6.946	0.017	(0)
CuSO4	1.018e-07	1.060e-07	-6.992	-6.975	0.017	(0)
UO2(SO4)2-2	9.439e-08	3.027e-08	-7.025	-7.519	-0.494	(0)
CrOHSO4	2.229e-08	2.321e-08	-7.652	-7.634	0.017	(0)
CrSO4+	1.023e-09	7.700e-10	-8.990	-9.113	-0.123	(0)
Cr2(OH)2SO4+2	1.239e-13	3.972e-14	-12.907	-13.401	-0.494	(0)
FeSO4+	6.573e-15	4.915e-15	-14.182	-14.308	-0.126	(0)
Fe(SO4)2-	1.126e-15	8.472e-16	-14.949	-15.072	-0.123	(0)
Cr2(OH)2(SO4)2	4.907e-18	5.107e-18	-17.309	-17.292	0.017	(0)
U(SO4)2	3.693e-18	3.844e-18	-17.433	-17.415	0.017	(0)
USO4+2	1.133e-19	3.634e-20	-18.946	-19.440	-0.494	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-40.950	-41.444	-0.494	(0)
U(3)	4.769e-35					
U+3	4.769e-35	3.690e-36	-34.322	-35.433	-1.111	(0)
U(4)	6.204e-15					
U(OH)4	3.341e-15	3.478e-15	-14.476	-14.459	0.017	(0)
U(OH)5-	1.629e-15	1.226e-15	-14.788	-14.912	-0.123	(0)
U(OH)3+	1.145e-15	8.615e-16	-14.941	-15.065	-0.123	(0)
U(OH)2+2	8.416e-17	2.699e-17	-16.075	-16.569	-0.494	(0)
U(SO4)2	3.693e-18	3.844e-18	-17.433	-17.415	0.017	(0)
UOH+3	9.567e-19	7.402e-20	-18.019	-19.131	-1.111	(0)
USO4+2	1.133e-19	3.634e-20	-18.946	-19.440	-0.494	(0)
U+4	2.182e-21	2.307e-23	-20.661	-22.637	-1.976	(0)
UCl+3	3.671e-24	2.840e-25	-23.435	-24.547	-1.111	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-80.512	-90.515	-10.003	(0)
U(5)	5.416e-09					
UO2+	5.416e-09	4.075e-09	-8.266	-8.390	-0.123	(0)
U(6)	5.234e-07					
UO2+2	2.085e-07	6.686e-08	-6.681	-7.175	-0.494	(0)
UO2SO4	1.791e-07	1.865e-07	-6.747	-6.729	0.017	(0)
UO2(SO4)2-2	9.439e-08	3.027e-08	-7.025	-7.519	-0.494	(0)
UO2CO3	3.055e-08	3.180e-08	-7.515	-7.498	0.017	(0)
UO2OH+	1.066e-08	8.021e-09	-7.972	-8.096	-0.123	(0)
UO2Cl+	8.336e-11	6.273e-11	-10.079	-10.203	-0.123	(0)
UO2(CO3)2-2	2.992e-11	9.595e-12	-10.524	-11.018	-0.494	(0)
(UO2)2(OH)2+2	6.878e-12	2.205e-12	-11.163	-11.657	-0.494	(0)
UO2(CO3)3-4	8.259e-16	8.732e-18	-15.083	-17.059	-1.976	(0)

(UO2)3(OH)5+	7.102e-17	5.344e-17	-16.149	-16.272	-0.123	(0)
Zn	3.358e-06					
Zn+2	2.265e-06	7.728e-07	-5.645	-6.112	-0.467	(0)
ZnSO4	9.486e-07	9.873e-07	-6.023	-6.006	0.017	(0)
Zn(SO4)2-2	1.364e-07	4.374e-08	-6.865	-7.359	-0.494	(0)
ZnHCO3+	6.590e-09	4.959e-09	-8.181	-8.305	-0.123	(0)
ZnCl+	1.614e-09	1.176e-09	-8.792	-8.930	-0.137	(0)
ZnOH+	1.662e-11	1.251e-11	-10.779	-10.903	-0.123	(0)
ZnCO3	5.597e-12	5.826e-12	-11.252	-11.235	0.017	(0)
ZnCl2	6.688e-13	6.962e-13	-12.175	-12.157	0.017	(0)
ZnOHCl	2.052e-13	2.135e-13	-12.688	-12.671	0.017	(0)
Zn(OH)2	2.041e-15	2.124e-15	-14.690	-14.673	0.017	(0)
ZnCl3-	6.060e-16	4.416e-16	-15.218	-15.355	-0.137	(0)
Zn(CO3)2-2	1.468e-17	4.706e-18	-16.833	-17.327	-0.494	(0)
ZnCl4-2	3.993e-19	1.248e-19	-18.399	-18.904	-0.505	(0)
Zn(OH)3-	1.318e-22	9.915e-23	-21.880	-22.004	-0.123	(0)
Zn(OH)4-2	7.233e-31	2.319e-31	-30.141	-30.635	-0.494	(0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-1.90	8.48	10.38	Al(OH)3
Al2O3	-6.02	16.96	22.98	Al2O3
Al4(OH)10SO4	0.60	23.30	22.70	Al4(OH)10SO4
AlOHSO4	1.10	-2.13	-3.23	AlOHSO4
AlumK	-5.72	-10.89	-5.17	KAl(SO4)2:12H2O
Alunite	7.42	6.07	-1.35	KAl3(SO4)2(OH)6
Anhydrite	-0.10	-4.73	-4.64	CaSO4
Antlerite	-14.94	-6.65	8.29	Cu3(OH)4SO4
Aragonite	-4.56	-12.89	-8.34	CaCO3
Artinite	-15.05	-5.45	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-12.12	-4.78	7.34	Cu2(OH)3Cl
Azurite	-16.65	-33.57	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-4.38	1.16	5.54	UO2(OH)2
Bianchite	-6.62	-8.38	-1.76	ZnSO4:6H2O
Birnessite	-23.54	-5.45	18.09	MnO2
Bixbyite	-26.62	-27.23	-0.61	Mn2O3
Boehmite	-0.10	8.48	8.58	AlOOH
Brochantite	-20.67	-5.33	15.34	Cu4(OH)6SO4
Brucite	-10.14	6.66	16.79	Mg(OH)2
CaCrO4	-40.04	-42.31	-2.27	CaCrO4
Calcite	-4.42	-12.89	-8.47	CaCO3
CH4(g)	-44.02	-84.12	-40.10	CH4
Chalcanthite	-6.65	-9.29	-2.64	CuSO4:5H2O
CO2(g)	-0.60	-18.76	-18.16	CO2
Cr(OH)2	-21.35	-10.53	10.82	Cr(OH)2
Cr(OH)3(A)	-4.56	-5.31	-0.75	Cr(OH)3
Cr(OH)3(C)	-7.01	-5.31	1.70	Cr(OH)3
Cr2O3	-7.22	-10.61	-3.39	Cr2O3
CrCl2	-41.23	-25.36	15.87	CrCl2
CrCl3	-41.07	-27.56	13.51	CrCl3
CrMetal	-59.11	-26.87	32.24	Cr
CrO3	-44.96	-48.17	-3.21	CrO3
Cu(OH)2	-7.32	1.32	8.64	Cu(OH)2
Cu2SO4	-16.92	-18.87	-1.95	Cu2SO4
CuCO3	-7.81	-17.44	-9.63	CuCO3
CuCrO4	-41.38	-46.86	-5.48	CuCrO4
CuMetal	-3.54	-12.30	-8.76	Cu
CuOCuSO4	-19.50	-7.97	11.53	CuO:CuSO4
CupricFerrite	-11.47	-5.59	5.88	CuFe2O4
Cuprite	-6.71	-8.26	-1.55	Cu2O
CuprousFerrite	1.33	-7.59	-8.92	CuFeO2
CuSO4	-12.29	-9.28	3.01	CuSO4
Diaspore	1.60	8.48	6.87	AlOOH
Dolomite	-8.00	-25.00	-17.00	CaMg(CO3)2

Epsomite	-1.81	-3.95	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-2.64	-5.68	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-42.30	-38.72	3.58	Fe2(SO4)3
Fe3(OH)8	-25.73	-5.51	20.22	Fe3(OH)8
FeCr2O4	-8.31	-9.21	-0.90	FeCr2O4
Ferrihydrite	-8.35	-3.46	4.89	Fe(OH)3
Gibbsite(C)	-0.29	8.48	8.77	Al(OH)3
Goethite	-3.96	-3.46	0.50	FeOOH
Goslarite	-6.42	-8.38	-1.96	ZnSO4:7H2O
Gummite	-9.24	1.16	10.40	UO3
Gypsum	-0.13	-4.74	-4.61	CaSO4:2H2O
Halite	-8.09	-6.51	1.58	NaCl
Hausmannite	-34.04	27.50	61.54	Mn3O4
Hematite	-2.90	-6.91	-4.01	Fe2O3
Hercynite	-8.80	18.36	27.16	FeAl2O4
Huntite	-19.24	-49.21	-29.97	CaMg3(CO3)4
Hydromagnesite	-33.01	-41.77	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-19.48	-31.58	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-14.93	-29.73	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-19.47	-30.67	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-76.98	-92.65	-15.67	K2Cr2O7
K2CrO4	-44.48	-44.47	0.01	K2CrO4
Langite	-22.12	-5.33	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-4.83	-3.46	1.37	FeOOH
Lime	-26.93	5.87	32.80	CaO
Maghemite	-13.30	-6.91	6.39	Fe2O3
Magnesite	-4.08	-12.11	-8.03	MgCO3
Magnetite	-9.24	-5.51	3.74	Fe3O4
Malachite	-10.95	-16.13	-5.18	Cu2(OH)2CO3
Manganite	-13.38	-13.62	-0.24	MnOOH
Melanothallite	-17.25	-13.52	3.73	CuCl2
Melanterite	-6.73	-9.20	-2.47	FeSO4:7H2O
Mg-Ferrite	-17.02	-0.26	16.77	MgFe2O4
MgCr2O4	-16.04	-3.96	12.08	MgCr2O4
MgCrO4	-46.90	-41.52	5.38	MgCrO4
Mirabilite	-7.69	-8.80	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-53.33	-59.04	-5.71	Mn2(SO4)3
MnCl2:4H2O	-13.83	-11.12	2.71	MnCl2:4H2O
MnSO4	-9.55	-6.88	2.67	MnSO4
Na2Cr2O7	-84.64	-94.54	-9.90	Na2Cr2O7
Na2CrO4	-49.62	-46.36	3.26	Na2CrO4
Nantokite	-4.79	-11.55	-6.76	CuCl
Natron	-15.65	-16.96	-1.31	Na2CO3:10H2O
Nesquehonite	-6.49	-12.11	-5.62	MgCO3:3H2O
Nsutite	-22.95	-5.45	17.50	MnO2
O2(g)	-50.44	32.68	83.12	O2
Periclase	-14.85	6.66	21.51	MgO
Portlandite	-16.81	5.87	22.68	Ca(OH)2
Pyrocroite	-11.37	3.72	15.09	Mn(OH)2
Pyrolusite	-21.31	-5.45	15.86	MnO2
Rhodochrosite	-4.63	-15.04	-10.41	MnCO3
Rutherfordine	-3.14	-17.60	-14.46	UO2CO3
Schoepite	-4.24	1.16	5.40	UO2(OH)2:H2O
Siderite	-6.81	-17.36	-10.55	FeCO3
Smithsonite	-6.53	-16.53	-10.00	ZnCO3
Spinel	-12.72	23.61	36.33	MgAl2O4
Tenorite	-6.30	1.32	7.62	CuO
Thenardite	-8.61	-8.79	-0.18	Na2SO4
Thermonatrite	-17.08	-16.95	0.13	Na2CO3:H2O
U3O8(C)	-6.31	14.80	21.11	U3O8
U4O9(C)	-4.11	-7.50	-3.38	U4O9
UO2(am)	-6.89	-5.96	0.93	UO2
UO3(C)	-6.55	1.16	7.72	UO3
Uraninite	-1.26	-5.96	-4.70	UO2
Zincite	-8.91	2.23	11.14	ZnO
Zincosite	-11.39	-8.38	3.01	ZnSO4

Zn(BO2)2	-12.84	-4.55	8.29	Zn(BO2)2
Zn(OH)2(A)	-10.22	2.23	12.45	Zn(OH)2
Zn(OH)2(B)	-9.52	2.23	11.75	Zn(OH)2
Zn(OH)2(C)	-9.97	2.23	12.20	Zn(OH)2
Zn(OH)2(E)	-9.27	2.23	11.50	Zn(OH)2
Zn(OH)2(G)	-9.48	2.23	11.71	Zn(OH)2
Zn2(OH)2SO4	-13.65	-6.15	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-18.16	-2.96	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-33.54	-14.52	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-30.10	-1.70	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-42.20	-3.70	38.50	Zn5(OH)8Cl2
ZnCl2	-19.64	-12.61	7.03	ZnCl2
ZnCO3:H2O	-6.28	-16.54	-10.26	ZnCO3:H2O
ZnMetal	-39.87	-14.11	25.76	Zn
ZnO(Active)	-9.08	2.23	11.31	ZnO
ZnSO4:H2O	-7.81	-8.38	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 14.

----------Solution composition----------

Elements	Molality	Moles
Al	1.760e-03	1.760e-03
Alkalinity	8.264e-06	8.264e-06
B	2.761e-04	2.761e-04
Ca	1.854e-02	1.854e-02
Cl	9.671e-04	9.671e-04
Cr	4.849e-08	4.849e-08
Cu	4.126e-07	4.126e-07
Fe	6.862e-06	6.862e-06
K	8.872e-03	8.872e-03
Mg	9.084e-02	9.084e-02
Mn	2.570e-07	2.570e-07
Na	9.212e-04	9.212e-04
S(6)	5.260e-02	5.260e-02
U	3.601e-07	3.601e-07
Zn	3.872e-06	3.872e-06

----------Description of solution----------

pH	=	4.170
pe	=	4.000
Activity of water	=	0.997
Ionic strength (mol/kgw)	=	2.149e-01
Mass of water (kg)	=	1.000e+00
Total carbon (mol/kg)	=	7.746e-03
Total CO2 (mol/kg)	=	7.746e-03
Temperature (°C)	=	25.00
Electrical balance (eq)	=	1.277e-01
Percent error, 100*(Cat-|An|)/(Cat+|An|)	=	58.09
Iterations	=	14
Total H	=	1.110288e+02
Total O	=	5.574071e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	8.506e-05	6.761e-05	-4.070	-4.170	-0.100	0.00
OH-	2.114e-10	1.482e-10	-9.675	-9.829	-0.154	(0)
H2O	5.551e+01	9.974e-01	1.744	-0.001	0.000	18.07

Al	1.760e-03				
AlSO4+	7.090e-04	5.133e-04	-3.149	-3.290	-0.140	(0)
Al+3	6.897e-04	8.730e-05	-3.161	-4.059	-0.898	(0)
Al(SO4)2-	3.162e-04	2.289e-04	-3.500	-3.640	-0.140	(0)
AlOH+2	4.354e-05	1.318e-05	-4.361	-4.880	-0.519	(0)
Al(OH)2+	2.035e-06	1.509e-06	-5.692	-5.821	-0.130	(0)
Al(OH)3	2.668e-08	2.803e-08	-7.574	-7.552	0.021	(0)
Al(OH)4-	5.712e-11	4.135e-11	-10.243	-10.383	-0.140	(0)
B	2.761e-04				
H3BO3	2.761e-04	2.901e-04	-3.559	-3.537	0.021	(0)
H2BO3-	3.656e-09	2.464e-09	-8.437	-8.608	-0.171	(0)
C(4)	7.746e-03				
H2CO3	7.650e-03	8.038e-03	-2.116	-2.095	0.021	(0)
HCO3-	7.137e-05	5.294e-05	-4.146	-4.276	-0.130	(0)
MgHCO3+	2.169e-05	1.546e-05	-4.664	-4.811	-0.147	(0)
CaHCO3+	3.410e-06	2.565e-06	-5.467	-5.591	-0.124	(0)
UO2CO3	1.914e-08	2.011e-08	-7.718	-7.697	0.021	(0)
NaHCO3	1.880e-08	1.975e-08	-7.726	-7.704	0.021	(0)
ZnHCO3+	7.077e-09	5.263e-09	-8.150	-8.279	-0.129	(0)
CuHCO3+	2.270e-09	1.688e-09	-8.644	-8.773	-0.129	(0)
MgCO3	8.270e-10	8.689e-10	-9.083	-9.061	0.021	(0)
CaCO3	2.318e-10	2.436e-10	-9.635	-9.613	0.021	(0)
CO3-2	1.211e-10	3.666e-11	-9.917	-10.436	-0.519	(0)
MnHCO3+	8.429e-11	6.188e-11	-10.074	-10.208	-0.134	(0)
UO2(CO3)2-2	1.926e-11	5.888e-12	-10.715	-11.230	-0.515	(0)
CuCO3	1.276e-11	1.341e-11	-10.894	-10.873	0.021	(0)
ZnCO3	5.885e-12	6.183e-12	-11.230	-11.209	0.021	(0)
NaCO3-	6.073e-13	4.504e-13	-12.217	-12.346	-0.130	(0)
UO2(CO3)3-4	5.949e-16	5.198e-18	-15.226	-17.284	-2.059	(0)
Zn(CO3)2-2	1.585e-17	4.846e-18	-16.800	-17.315	-0.515	(0)
Cu(CO3)2-2	2.024e-18	6.189e-19	-17.694	-18.208	-0.515	(0)
Ca	1.854e-02				
Ca+2	1.345e-02	4.677e-03	-1.871	-2.330	-0.459	(0)
CaSO4	5.091e-03	5.349e-03	-2.293	-2.272	0.021	(0)
CaHCO3+	3.410e-06	2.565e-06	-5.467	-5.591	-0.124	(0)
CaCO3	2.318e-10	2.436e-10	-9.635	-9.613	0.021	(0)
CaOH+	2.314e-11	1.741e-11	-10.636	-10.759	-0.124	(0)
Cl	9.671e-04				
Cl-	9.671e-04	6.705e-04	-3.015	-3.174	-0.159	(0)
ZnCl+	2.140e-09	1.526e-09	-8.670	-8.817	-0.147	(0)
CuCl2-	7.130e-10	5.083e-10	-9.147	-9.294	-0.147	(0)
MnCl+	2.318e-10	1.701e-10	-9.635	-9.769	-0.134	(0)
CuCl+	1.724e-10	1.230e-10	-9.763	-9.910	-0.147	(0)
UO2Cl+	6.524e-11	4.851e-11	-10.185	-10.314	-0.129	(0)
CrCl+2	2.588e-12	7.913e-13	-11.587	-12.102	-0.515	(0)
CuCl3-2	1.860e-12	5.402e-13	-11.731	-12.267	-0.537	(0)
ZnCl2	1.020e-12	1.071e-12	-11.992	-11.970	0.021	(0)
ZnOHCl	2.636e-13	2.769e-13	-12.579	-12.558	0.021	(0)
CuCl2	4.214e-14	4.427e-14	-13.375	-13.354	0.021	(0)
MnCl2	2.949e-14	3.099e-14	-13.530	-13.509	0.021	(0)
ZnCl3-	1.130e-15	8.060e-16	-14.947	-15.094	-0.147	(0)
CrCl2+	1.390e-16	1.034e-16	-15.857	-15.986	-0.129	(0)
FeCl+2	1.092e-16	3.171e-17	-15.962	-16.499	-0.537	(0)
MnCl3-	1.276e-17	9.368e-18	-16.894	-17.028	-0.134	(0)
CrOHCl2	2.928e-18	3.076e-18	-17.533	-17.512	0.021	(0)
ZnCl4-2	9.304e-19	2.702e-19	-18.031	-18.568	-0.537	(0)
CuCl3-	1.477e-19	1.053e-19	-18.831	-18.977	-0.147	(0)
FeCl2+	1.294e-19	9.498e-20	-18.888	-19.022	-0.134	(0)
FeCl3	6.061e-24	6.369e-24	-23.217	-23.196	0.021	(0)
UCl+3	3.163e-24	2.198e-25	-23.500	-24.658	-1.158	(0)
CuCl4-2	1.219e-24	3.540e-25	-23.914	-24.451	-0.537	(0)
CrO3Cl-	0.000e+00	0.000e+00	-44.392	-44.521	-0.129	(0)
Cr(2)	1.463e-19				
Cr+2	1.463e-19	4.473e-20	-18.835	-19.349	-0.515	(0)
Cr(3)	4.849e-08				
Cr+3	3.031e-08	2.107e-09	-7.518	-8.676	-1.158	(0)

Cr(OH)+2	1.017e-08	3.108e-09	-7.993	-8.508	-0.515	(0)
CrOHSO4	7.511e-09	7.892e-09	-8.124	-8.103	0.021	(0)
CrSO4+	3.524e-10	2.620e-10	-9.453	-9.582	-0.129	(0)
Cr(OH)2+	1.479e-10	1.100e-10	-9.830	-9.959	-0.129	(0)
CrCl+2	2.588e-12	7.913e-13	-11.587	-12.102	-0.515	(0)
Cr(OH)3	1.145e-13	1.203e-13	-12.941	-12.920	0.021	(0)
Cr2(OH)2SO4+2	1.459e-14	4.459e-15	-13.836	-14.351	-0.515	(0)
CrCl2+	1.390e-16	1.034e-16	-15.857	-15.986	-0.129	(0)
CrOHCl2	2.928e-18	3.076e-18	-17.533	-17.512	0.021	(0)
Cr2(OH)2(SO4)2	5.622e-19	5.907e-19	-18.250	-18.229	0.021	(0)
CrO2-	5.813e-20	4.323e-20	-19.236	-19.364	-0.129	(0)
Cr(OH)4-	2.279e-20	1.695e-20	-19.642	-19.771	-0.129	(0)
Cr(6)	1.433e-38					
HCrO4-	1.415e-38	1.052e-38	-37.849	-37.978	-0.129	(0)
CrO4-2	1.866e-40	0.000e+00	-39.729	-40.317	-0.588	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-41.398	-41.913	-0.515	(0)
KCrO4-	0.000e+00	0.000e+00	-41.616	-41.745	-0.129	(0)
NaCrO4-	0.000e+00	0.000e+00	-42.670	-42.799	-0.129	(0)
H2CrO4	0.000e+00	0.000e+00	-43.027	-43.006	0.021	(0)
CrO3Cl-	0.000e+00	0.000e+00	-44.392	-44.521	-0.129	(0)
Cr2O7-2	0.000e+00	0.000e+00	-73.901	-74.416	-0.515	(0)
Cu(1)	6.018e-09					
Cu+	5.303e-09	3.575e-09	-8.275	-8.447	-0.171	(0)
CuCl2-	7.130e-10	5.083e-10	-9.147	-9.294	-0.147	(0)
CuCl3-2	1.860e-12	5.402e-13	-11.731	-12.267	-0.537	(0)
Cu(2)	4.066e-07					
Cu+2	3.298e-07	6.813e-08	-6.482	-7.167	-0.685	(0)
CuSO4	7.433e-08	7.810e-08	-7.129	-7.107	0.021	(0)
CuHCO3+	2.270e-09	1.688e-09	-8.644	-8.773	-0.129	(0)
CuCl+	1.724e-10	1.230e-10	-9.763	-9.910	-0.147	(0)
CuOH+	1.410e-11	1.005e-11	-10.851	-10.998	-0.147	(0)
CuCO3	1.276e-11	1.341e-11	-10.894	-10.873	0.021	(0)
Cu(OH)2	2.948e-13	3.098e-13	-12.530	-12.509	0.021	(0)
CuCl2	4.214e-14	4.427e-14	-13.375	-13.354	0.021	(0)
Cu2(OH)2+2	1.446e-16	4.420e-17	-15.840	-16.355	-0.515	(0)
Cu(CO3)2-2	2.024e-18	6.189e-19	-17.694	-18.208	-0.515	(0)
CuCl3-	1.477e-19	1.053e-19	-18.831	-18.977	-0.147	(0)
Cu(OH)3-	3.712e-22	2.760e-22	-21.430	-21.559	-0.129	(0)
CuCl4-2	1.219e-24	3.540e-25	-23.914	-24.451	-0.537	(0)
Cu(OH)4-2	2.651e-30	8.106e-31	-29.577	-30.091	-0.515	(0)
Fe(2)	6.862e-06					
Fe+2	5.260e-06	1.686e-06	-5.279	-5.773	-0.494	(0)
FeSO4	1.602e-06	1.683e-06	-5.795	-5.774	0.021	(0)
FeOH+	1.071e-11	7.865e-12	-10.970	-11.104	-0.134	(0)
Fe(OH)2	9.399e-19	9.875e-19	-18.027	-18.005	0.021	(0)
Fe(OH)3-	7.373e-25	5.413e-25	-24.132	-24.267	-0.134	(0)
Fe(3)	1.626e-12					
Fe(OH)2+	9.824e-13	7.287e-13	-12.008	-12.137	-0.130	(0)
FeOH+2	5.135e-13	1.492e-13	-12.289	-12.826	-0.537	(0)
FeSO4+	9.962e-14	7.313e-14	-13.002	-13.136	-0.134	(0)
Fe(SO4)2-	1.746e-14	1.299e-14	-13.758	-13.887	-0.129	(0)
Fe+3	1.237e-14	1.566e-15	-13.908	-14.805	-0.898	(0)
Fe(OH)3	1.202e-16	1.263e-16	-15.920	-15.899	0.021	(0)
FeCl+2	1.092e-16	3.171e-17	-15.962	-16.499	-0.537	(0)
FeCl2+	1.294e-19	9.498e-20	-18.888	-19.022	-0.134	(0)
Fe(OH)4-	2.512e-20	1.863e-20	-19.600	-19.730	-0.130	(0)
Fe2(OH)2+4	6.854e-23	5.989e-25	-22.164	-24.223	-2.059	(0)
FeCl3	6.061e-24	6.369e-24	-23.217	-23.196	0.021	(0)
Fe3(OH)4+5	1.501e-31	9.118e-35	-30.824	-34.040	-3.217	(0)
H(0)	6.159e-20					
H2	3.080e-20	3.236e-20	-19.511	-19.490	0.021	(0)
K	8.872e-03					
K+	8.556e-03	5.932e-03	-2.068	-2.227	-0.159	(0)
KSO4-	3.155e-04	2.340e-04	-3.501	-3.631	-0.130	(0)
KCrO4-	0.000e+00	0.000e+00	-41.616	-41.745	-0.129	(0)
Mg	9.084e-02					

Mg+2	6.721e-02	2.484e-02	-1.173	-1.605	-0.432	(0)
MgSO4	2.360e-02	2.480e-02	-1.627	-1.606	0.021	(0)
MgHCO3+	2.169e-05	1.546e-05	-4.664	-4.811	-0.147	(0)
MgCO3	8.270e-10	8.689e-10	-9.083	-9.061	0.021	(0)
MgOH+	7.913e-10	6.019e-10	-9.102	-9.220	-0.119	(0)
Mn(2)	2.570e-07					
Mn+2	1.957e-07	6.272e-08	-6.708	-7.203	-0.494	(0)
MnSO4	6.098e-08	6.408e-08	-7.215	-7.193	0.021	(0)
MnCl+	2.318e-10	1.701e-10	-9.635	-9.769	-0.134	(0)
MnHCO3+	8.429e-11	6.188e-11	-10.074	-10.208	-0.134	(0)
MnOH+	3.240e-14	2.378e-14	-13.490	-13.624	-0.134	(0)
MnCl2	2.949e-14	3.099e-14	-13.530	-13.509	0.021	(0)
MnCl3-	1.276e-17	9.368e-18	-16.894	-17.028	-0.134	(0)
Mn(OH)3-	4.347e-30	3.192e-30	-29.362	-29.496	-0.134	(0)
Mn(3)	1.542e-28					
Mn+3	1.542e-28	1.952e-29	-27.812	-28.710	-0.898	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-75.750	-76.287	-0.537	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-81.509	-81.671	-0.162	(0)
Na	9.212e-04					
Na+	8.960e-04	6.630e-04	-3.048	-3.179	-0.131	(0)
NaSO4-	2.515e-05	1.866e-05	-4.599	-4.729	-0.130	(0)
NaHCO3	1.880e-08	1.975e-08	-7.726	-7.704	0.021	(0)
NaCO3-	6.073e-13	4.504e-13	-12.217	-12.346	-0.130	(0)
NaCrO4-	0.000e+00	0.000e+00	-42.670	-42.799	-0.129	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-53.424	-53.402	0.021	(0)
S(6)	5.260e-02					
MgSO4	2.360e-02	2.480e-02	-1.627	-1.606	0.021	(0)
SO4-2	2.216e-02	5.615e-03	-1.654	-2.251	-0.596	(0)
CaSO4	5.091e-03	5.349e-03	-2.293	-2.272	0.021	(0)
AlSO4+	7.090e-04	5.133e-04	-3.149	-3.290	-0.140	(0)
Al(SO4)2-	3.162e-04	2.289e-04	-3.500	-3.640	-0.140	(0)
KSO4-	3.155e-04	2.340e-04	-3.501	-3.631	-0.130	(0)
HSO4-	5.088e-05	3.684e-05	-4.293	-4.434	-0.140	(0)
NaSO4-	2.515e-05	1.866e-05	-4.599	-4.729	-0.130	(0)
FeSO4	1.602e-06	1.683e-06	-5.795	-5.774	0.021	(0)
ZnSO4	1.059e-06	1.113e-06	-5.975	-5.954	0.021	(0)
Zn(SO4)2-2	1.661e-07	5.078e-08	-6.780	-7.294	-0.515	(0)
UO2SO4	1.192e-07	1.252e-07	-6.924	-6.902	0.021	(0)
CuSO4	7.433e-08	7.810e-08	-7.129	-7.107	0.021	(0)
UO2(SO4)2-2	6.850e-08	2.094e-08	-7.164	-7.679	-0.515	(0)
MnSO4	6.098e-08	6.408e-08	-7.215	-7.193	0.021	(0)
CrOHSO4	7.511e-09	7.892e-09	-8.124	-8.103	0.021	(0)
CrSO4+	3.524e-10	2.620e-10	-9.453	-9.582	-0.129	(0)
FeSO4+	9.962e-14	7.313e-14	-13.002	-13.136	-0.134	(0)
Fe(SO4)2-	1.746e-14	1.299e-14	-13.758	-13.887	-0.129	(0)
Cr2(OH)2SO4+2	1.459e-14	4.459e-15	-13.836	-14.351	-0.515	(0)
U(SO4)2	2.534e-18	2.663e-18	-17.596	-17.575	0.021	(0)
Cr2(OH)2(SO4)2	5.622e-19	5.907e-19	-18.250	-18.229	0.021	(0)
USO4+2	7.992e-20	2.443e-20	-19.097	-19.612	-0.515	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-41.398	-41.913	-0.515	(0)
U(3)	3.464e-35					
U+3	3.464e-35	2.408e-36	-34.460	-35.618	-1.158	(0)
U(4)	4.045e-15					
U(OH)4	2.156e-15	2.266e-15	-14.666	-14.645	0.021	(0)
U(OH)5-	1.073e-15	7.981e-16	-14.969	-15.098	-0.129	(0)
U(OH)3+	7.550e-16	5.614e-16	-15.122	-15.251	-0.129	(0)
U(OH)2+2	5.755e-17	1.760e-17	-16.240	-16.755	-0.515	(0)
U(SO4)2	2.534e-18	2.663e-18	-17.596	-17.575	0.021	(0)
UOH+3	6.947e-19	4.829e-20	-18.158	-19.316	-1.158	(0)
USO4+2	7.992e-20	2.443e-20	-19.097	-19.612	-0.515	(0)
U+4	1.723e-21	1.505e-23	-20.764	-22.822	-2.059	(0)
UCl+3	3.163e-24	2.198e-25	-23.500	-24.658	-1.158	(0)
U6(OH)15+9	0.000e+00	0.000e+00	-81.208	-91.630	-10.422	(0)

U(5)	3.573e-09					
UO2+	3.573e-09	2.657e-09	-8.447	-8.576	-0.129	(0)
U(6)	3.565e-07					
UO2+2	1.426e-07	4.359e-08	-6.846	-7.361	-0.515	(0)
UO2SO4	1.192e-07	1.252e-07	-6.924	-6.902	0.021	(0)
UO2(SO4)2-2	6.850e-08	2.094e-08	-7.164	-7.679	-0.515	(0)
UO2CO3	1.914e-08	2.011e-08	-7.718	-7.697	0.021	(0)
UO2OH+	7.030e-09	5.228e-09	-8.153	-8.282	-0.129	(0)
UO2Cl+	6.524e-11	4.851e-11	-10.185	-10.314	-0.129	(0)
UO2(CO3)2-2	1.926e-11	5.888e-12	-10.715	-11.230	-0.515	(0)
(UO2)2(OH)2+2	3.064e-12	9.367e-13	-11.514	-12.028	-0.515	(0)
UO2(CO3)3-4	5.949e-16	5.198e-18	-15.226	-17.284	-2.059	(0)
(UO2)3(OH)5+	1.988e-17	1.478e-17	-16.702	-16.830	-0.129	(0)
Zn	3.872e-06					
Zn+2	2.638e-06	8.454e-07	-5.579	-6.073	-0.494	(0)
ZnSO4	1.059e-06	1.113e-06	-5.975	-5.954	0.021	(0)
Zn(SO4)2-2	1.661e-07	5.078e-08	-6.780	-7.294	-0.515	(0)
ZnHCO3+	7.077e-09	5.263e-09	-8.150	-8.279	-0.129	(0)
ZnCl+	2.140e-09	1.526e-09	-8.670	-8.817	-0.147	(0)
ZnOH+	1.839e-11	1.368e-11	-10.735	-10.864	-0.129	(0)
ZnCO3	5.885e-12	6.183e-12	-11.230	-11.209	0.021	(0)
ZnCl2	1.020e-12	1.071e-12	-11.992	-11.970	0.021	(0)
ZnOHCl	2.636e-13	2.769e-13	-12.579	-12.558	0.021	(0)
Zn(OH)2	2.210e-15	2.322e-15	-14.656	-14.634	0.021	(0)
ZnCl3-	1.130e-15	8.060e-16	-14.947	-15.094	-0.147	(0)
Zn(CO3)2-2	1.585e-17	4.846e-18	-16.800	-17.315	-0.515	(0)
ZnCl4-2	9.304e-19	2.702e-19	-18.031	-18.568	-0.537	(0)
Zn(OH)3-	1.457e-22	1.083e-22	-21.837	-21.965	-0.129	(0)
Zn(OH)4-2	8.283e-31	2.533e-31	-30.082	-30.596	-0.515	(0)

Saturation indices

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-1.93	8.45	10.38	Al(OH)3
Al2O3	-6.08	16.90	22.98	Al2O3
Al4(OH)10SO4	0.50	23.20	22.70	Al4(OH)10SO4
AlOHSO4	1.09	-2.14	-3.23	AlOHSO4
AlumK	-5.63	-10.80	-5.17	KAl(SO4)2:12H2O
Alunite	7.45	6.11	-1.35	KAl3(SO4)2(OH)6
Anhydrite	0.06	-4.58	-4.64	CaSO4
Antlerite	-15.37	-7.08	8.29	Cu3(OH)4SO4
Aragonite	-4.43	-12.77	-8.34	CaCO3
Artinite	-14.91	-5.31	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-12.34	-5.00	7.34	Cu2(OH)3Cl
Azurite	-17.11	-34.03	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-4.57	0.98	5.54	UO2(OH)2
Bianchite	-6.57	-8.33	-1.76	ZnSO4:6H2O
Birnessite	-26.12	-8.03	18.09	MnO2
Bixbyite	-31.79	-32.40	-0.61	Mn2O3
Boehmite	-0.13	8.45	8.58	AlOOH
Brochantite	-21.24	-5.90	15.34	Cu4(OH)6SO4
Brucite	-10.06	6.73	16.79	Mg(OH)2
CaCrO4	-40.38	-42.65	-2.27	CaCrO4
Calcite	-4.29	-12.77	-8.47	CaCO3
CH4(g)	-44.03	-84.13	-40.10	CH4
Chalcanthite	-6.78	-9.42	-2.64	CuSO4:5H2O
CO2(g)	-0.61	-18.77	-18.16	CO2
Cr(OH)2	-21.83	-11.01	10.82	Cr(OH)2
Cr(OH)3(A)	-5.04	-5.79	-0.75	Cr(OH)3
Cr(OH)3(C)	-7.49	-5.79	1.70	Cr(OH)3
Cr2O3	-8.18	-11.58	-3.39	Cr2O3
CrCl2	-41.56	-25.70	15.87	CrCl2
CrCl3	-41.32	-27.82	13.51	CrCl3
CrMetal	-59.59	-27.35	32.24	Cr
CrO3	-45.45	-48.66	-3.21	CrO3

Cu(OH)2	-7.47	1.17	8.64	Cu(OH)2
Cu2SO4	-17.19	-19.14	-1.95	Cu2SO4
CuCO3	-7.97	-17.60	-9.63	CuCO3
CuCrO4	-42.01	-47.48	-5.48	CuCrO4
CuMetal	-3.69	-12.45	-8.76	Cu
CuOCuSO4	-19.78	-8.25	11.53	CuO:CuSO4
CupricFerrite	-9.30	-3.42	5.88	CuFe2O4
Cuprite	-7.00	-8.55	-1.55	Cu2O
CuprousFerrite	2.35	-6.57	-8.92	CuFeO2
CuSO4	-12.43	-9.42	3.01	CuSO4
Diaspore	1.58	8.45	6.87	AlOOH
Dolomite	-7.81	-24.81	-17.00	CaMg(CO3)2
Epsomite	-1.72	-3.86	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-1.46	-4.50	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-39.94	-36.36	3.58	Fe2(SO4)3
Fe3(OH)8	-22.25	-2.03	20.22	Fe3(OH)8
FeCr2O4	-8.11	-9.01	-0.90	FeCr2O4
Ferrihydrite	-7.19	-2.30	4.89	Fe(OH)3
Gibbsite(C)	-0.32	8.45	8.77	Al(OH)3
Goethite	-2.80	-2.30	0.50	FeOOH
Goslarite	-6.37	-8.33	-1.96	ZnSO4:7H2O
Gummite	-9.42	0.98	10.40	UO3
Gypsum	0.03	-4.58	-4.61	CaSO4:2H2O
Halite	-7.93	-6.35	1.58	NaCl
Hausmannite	-41.79	19.75	61.54	Mn3O4
Hematite	-0.59	-4.59	-4.01	Fe2O3
Hercynite	-7.70	19.46	27.16	FeAl2O4
Huntite	-18.92	-48.89	-29.97	CaMg3(CO3)4
Hydromagnesite	-32.67	-41.43	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-15.97	-28.07	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-11.33	-26.13	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-15.88	-27.08	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-77.76	-93.43	-15.67	K2Cr2O7
K2CrO4	-44.78	-44.77	0.01	K2CrO4
Langite	-22.70	-5.91	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-3.67	-2.30	1.37	FeOOH
Lime	-26.79	6.01	32.80	CaO
Maghemite	-10.98	-4.59	6.39	Fe2O3
Magnesite	-4.01	-12.04	-8.03	MgCO3
Magnetite	-5.77	-2.03	3.74	Fe3O4
Malachite	-11.25	-16.43	-5.18	Cu2(OH)2CO3
Manganite	-15.96	-16.20	-0.24	MnOOH
Melanothallite	-17.24	-13.51	3.73	CuCl2
Melanterite	-5.56	-8.03	-2.47	FeSO4:7H2O
Mg-Ferrite	-14.62	2.14	16.77	MgFe2O4
MgCr2O4	-16.92	-4.84	12.08	MgCr2O4
MgCrO4	-47.30	-41.92	5.38	MgCrO4
Mirabilite	-7.50	-8.62	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-58.46	-64.17	-5.71	Mn2(SO4)3
MnCl2:4H2O	-16.26	-13.55	2.71	MnCl2:4H2O
MnSO4	-12.12	-9.45	2.67	MnSO4
Na2Cr2O7	-85.43	-95.33	-9.90	Na2Cr2O7
Na2CrO4	-49.94	-46.67	3.26	Na2CrO4
Nantokite	-4.86	-11.62	-6.76	CuCl
Natron	-15.49	-16.80	-1.31	Na2CO3:10H2O
Nesquehonite	-6.42	-12.04	-5.62	MgCO3:3H2O
Nsutite	-25.54	-8.03	17.50	MnO2
O2(g)	-50.44	32.68	83.12	O2
Periclase	-14.78	6.73	21.51	MgO
Portlandite	-16.67	6.01	22.68	Ca(OH)2
Pyrocroite	-13.95	1.14	15.09	Mn(OH)2
Pyrolusite	-23.89	-8.03	15.86	MnO2
Rhodochrosite	-7.23	-17.64	-10.41	MnCO3
Rutherfordine	-3.33	-17.80	-14.46	UO2CO3
Schoepite	-4.43	0.98	5.40	UO2(OH)2:H2O
Siderite	-5.66	-16.21	-10.55	FeCO3

Smithsonite	-6.51	-16.51	-10.00	ZnCO3
Spinel	-12.70	23.63	36.33	MgAl2O4
Tenorite	-6.45	1.17	7.62	CuO
Thenardite	-8.43	-8.61	-0.18	Na2SO4
Thermonatrite	-16.92	-16.79	0.13	Na2CO3:H2O
U3O8(C)	-6.86	14.24	21.11	U3O8
U4O9(C)	-4.86	-8.24	-3.38	U4O9
UO2(am)	-7.08	-6.14	0.93	UO2
UO3(C)	-6.74	0.98	7.72	UO3
Uraninite	-1.44	-6.14	-4.70	UO2
Zincite	-8.87	2.27	11.14	ZnO
Zincosite	-11.33	-8.32	3.01	ZnSO4
Zn(BO2)2	-13.10	-4.81	8.29	Zn(BO2)2
Zn(OH)2(A)	-10.19	2.26	12.45	Zn(OH)2
Zn(OH)2(B)	-9.49	2.26	11.75	Zn(OH)2
Zn(OH)2(C)	-9.94	2.26	12.20	Zn(OH)2
Zn(OH)2(E)	-9.24	2.26	11.50	Zn(OH)2
Zn(OH)2(G)	-9.45	2.26	11.71	Zn(OH)2
Zn2(OH)2SO4	-13.56	-6.06	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-18.01	-2.81	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-33.40	-14.38	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-29.93	-1.53	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-41.86	-3.36	38.50	Zn5(OH)8Cl2
ZnCl2	-19.45	-12.42	7.03	ZnCl2
ZnCO3:H2O	-6.25	-16.51	-10.26	ZnCO3:H2O
ZnMetal	-39.83	-14.07	25.76	Zn
ZnO(Active)	-9.04	2.27	11.31	ZnO
ZnSO4:H2O	-7.75	-8.32	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
For ideal gases, phi = 1.

Initial solution 15.

-----------------------------Solution composition-----------------------------

Elements	Molality	Moles
Al	4.256e-03	4.256e-03
Alkalinity	8.254e-06	8.254e-06
B	2.357e-04	2.357e-04
Ca	2.940e-02	2.940e-02
Cl	5.966e-04	5.966e-04
Cr	4.843e-07	4.843e-07
Cu	6.658e-07	6.658e-07
Fe	1.858e-05	1.858e-05
K	8.140e-03	8.140e-03
Mg	6.629e-02	6.629e-02
Mn	1.098e-05	1.098e-05
Na	4.820e-04	4.820e-04
S(6)	4.184e-02	4.184e-02
U	5.501e-07	5.501e-07
Zn	2.080e-06	2.080e-06

----------------------------Description of solution----------------------------

pH	=	3.630
pe	=	4.000
Activity of water	=	0.996
Ionic strength (mol/kgw)	=	1.971e-01
Mass of water (kg)	=	1.000e+00
Total carbon (mol/kg)	=	1.157e-01
Total CO2 (mol/kg)	=	1.157e-01
Temperature (°C)	=	25.00
Electrical balance (eq)	=	1.286e-01
Percent error, 100*(Cat-|An|)/(Cat+|An|)	=	64.19

Iterations = 14
Total H = 1.112447e+02
Total O = 5.602156e+01

----------Distribution of species----------

Species	Molality	Activity	Log Molality	Log Activity	Log Gamma	mole V cm³/mol
H+	2.937e-04	2.344e-04	-3.532	-3.630	-0.098	0.00
OH-	6.027e-11	4.268e-11	-10.220	-10.370	-0.150	(0)
H2O	5.551e+01	9.959e-01	1.744	-0.002	0.000	18.07
Al	4.256e-03					
Al+3	1.969e-03	2.589e-04	-2.706	-3.587	-0.881	(0)
AlSO4+	1.660e-03	1.212e-03	-2.780	-2.917	-0.137	(0)
Al(SO4)2-	5.895e-04	4.303e-04	-3.229	-3.366	-0.137	(0)
AlOH+2	3.614e-05	1.125e-05	-4.442	-4.949	-0.507	(0)
Al(OH)2+	4.968e-07	3.711e-07	-6.304	-6.430	-0.127	(0)
Al(OH)3	1.897e-09	1.985e-09	-8.722	-8.702	0.020	(0)
Al(OH)4-	1.155e-12	8.432e-13	-11.937	-12.074	-0.137	(0)
B	2.357e-04					
H3BO3	2.357e-04	2.467e-04	-3.628	-3.608	0.020	(0)
H2BO3-	8.855e-10	6.043e-10	-9.053	-9.219	-0.166	(0)
C(4)	1.157e-01					
H2CO3	1.153e-01	1.207e-01	-0.938	-0.918	0.020	(0)
HCO3-	3.069e-04	2.293e-04	-3.513	-3.640	-0.127	(0)
MgHCO3+	7.247e-05	5.214e-05	-4.140	-4.283	-0.143	(0)
CaHCO3+	2.496e-05	1.890e-05	-4.603	-4.723	-0.121	(0)
NaHCO3	4.327e-08	4.528e-08	-7.364	-7.344	0.020	(0)
UO2CO3	4.294e-08	4.494e-08	-7.367	-7.347	0.020	(0)
ZnHCO3+	1.786e-08	1.334e-08	-7.748	-7.875	-0.127	(0)
CuHCO3+	1.675e-08	1.252e-08	-7.776	-7.903	-0.127	(0)
MnHCO3+	1.658e-08	1.226e-08	-7.780	-7.911	-0.131	(0)
MgCO3	8.075e-10	8.450e-10	-9.093	-9.073	0.020	(0)
CaCO3	4.946e-10	5.176e-10	-9.306	-9.286	0.020	(0)
CO3-2	1.470e-10	4.578e-11	-9.833	-10.339	-0.507	(0)
UO2(CO3)2-2	5.275e-11	1.643e-11	-10.278	-10.784	-0.507	(0)
CuCO3	2.740e-11	2.867e-11	-10.562	-10.543	0.020	(0)
ZnCO3	4.321e-12	4.522e-12	-11.364	-11.345	0.020	(0)
NaCO3-	3.986e-13	2.978e-13	-12.399	-12.526	-0.127	(0)
UO2(CO3)3-4	1.925e-15	1.812e-17	-14.715	-16.742	-2.026	(0)
Zn(CO3)2-2	1.421e-17	4.426e-18	-16.847	-17.354	-0.507	(0)
Cu(CO3)2-2	5.306e-18	1.653e-18	-17.275	-17.782	-0.507	(0)
Ca	2.940e-02					
Ca+2	2.245e-02	7.958e-03	-1.649	-2.099	-0.451	(0)
CaSO4	6.925e-03	7.246e-03	-2.160	-2.140	0.020	(0)
CaHCO3+	2.496e-05	1.890e-05	-4.603	-4.723	-0.121	(0)
CaCO3	4.946e-10	5.176e-10	-9.306	-9.286	0.020	(0)
CaOH+	1.127e-11	8.531e-12	-10.948	-11.069	-0.121	(0)
Cl	5.966e-04					
Cl-	5.966e-04	4.180e-04	-3.224	-3.379	-0.155	(0)
MnCl+	6.561e-09	4.853e-09	-8.183	-8.314	-0.131	(0)
ZnCl+	7.740e-10	5.569e-10	-9.111	-9.254	-0.143	(0)
CuCl2-	4.700e-10	3.381e-10	-9.328	-9.471	-0.143	(0)
CuCl+	1.824e-10	1.312e-10	-9.739	-9.882	-0.143	(0)
UO2Cl+	7.241e-11	5.409e-11	-10.140	-10.267	-0.127	(0)
CrCl+2	2.258e-11	7.033e-12	-10.646	-11.153	-0.507	(0)
CuCl3-2	7.482e-13	2.240e-13	-12.126	-12.650	-0.524	(0)
MnCl2	5.266e-13	5.511e-13	-12.279	-12.259	0.020	(0)
ZnCl2	2.329e-13	2.437e-13	-12.633	-12.613	0.020	(0)
CuCl2	2.814e-14	2.945e-14	-13.551	-13.531	0.020	(0)
ZnOHCl	2.781e-14	2.910e-14	-13.556	-13.536	0.020	(0)
CrCl2+	7.667e-16	5.728e-16	-15.115	-15.242	-0.127	(0)
FeCl+2	1.914e-16	5.731e-17	-15.718	-16.242	-0.524	(0)
ZnCl3-	1.589e-16	1.143e-16	-15.799	-15.942	-0.143	(0)
MnCl3-	1.404e-16	1.038e-16	-15.853	-15.984	-0.131	(0)

CrOHCl2	4.690e-18	4.908e-18	-17.329	-17.309	0.020	(0)
FeCl2+	1.447e-19	1.070e-19	-18.840	-18.971	-0.131	(0)
ZnCl4-2	7.980e-20	2.389e-20	-19.098	-19.622	-0.524	(0)
CuCl3-	6.071e-20	4.368e-20	-19.217	-19.360	-0.143	(0)
UCl+3	4.905e-22	3.554e-23	-21.309	-22.449	-1.140	(0)
FeCl3	4.274e-24	4.473e-24	-23.369	-23.349	0.020	(0)
CuCl4-2	3.056e-25	9.149e-26	-24.515	-25.039	-0.524	(0)
CrO3Cl-	0.000e+00	0.000e+00	-46.687	-46.814	-0.127	(0)
Cr(2)	2.048e-18					
Cr+2	2.048e-18	6.378e-19	-17.689	-18.195	-0.507	(0)
Cr(3)	4.843e-07					
Cr+3	4.145e-07	3.004e-08	-6.382	-7.522	-1.140	(0)
Cr(OH)+2	4.097e-08	1.276e-08	-7.388	-7.894	-0.507	(0)
CrOHSO4	2.465e-08	2.580e-08	-7.608	-7.588	0.020	(0)
CrSO4+	3.981e-09	2.974e-09	-8.400	-8.527	-0.127	(0)
Cr(OH)2+	1.741e-10	1.300e-10	-9.759	-9.886	-0.127	(0)
CrCl+2	2.258e-11	7.033e-12	-10.646	-11.153	-0.507	(0)
Cr2(OH)2SO4+2	1.922e-13	5.985e-14	-12.716	-13.223	-0.507	(0)
Cr(OH)3	3.914e-14	4.095e-14	-13.407	-13.388	0.020	(0)
CrCl2+	7.667e-16	5.728e-16	-15.115	-15.242	-0.127	(0)
Cr2(OH)2(SO4)2	6.032e-18	6.312e-18	-17.220	-17.200	0.020	(0)
CrOHCl2	4.690e-18	4.908e-18	-17.329	-17.309	0.020	(0)
CrO2-	5.690e-21	4.251e-21	-20.245	-20.372	-0.127	(0)
Cr(OH)4-	2.224e-21	1.661e-21	-20.653	-20.780	-0.127	(0)
Cr(6)	0.000e+00					
HCrO4-	0.000e+00	0.000e+00	-40.480	-40.607	-0.127	(0)
CrO4-2	0.000e+00	0.000e+00	-42.914	-43.486	-0.572	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-43.593	-44.100	-0.507	(0)
KCrO4-	0.000e+00	0.000e+00	-44.816	-44.943	-0.127	(0)
H2CrO4	0.000e+00	0.000e+00	-45.114	-45.094	0.020	(0)
NaCrO4-	0.000e+00	0.000e+00	-46.117	-46.244	-0.127	(0)
CrO3Cl-	0.000e+00	0.000e+00	-46.687	-46.814	-0.127	(0)
Cr2O7-2	0.000e+00	0.000e+00	-79.166	-79.672	-0.507	(0)
Cu(1)	9.439e-09					
Cu+	8.968e-09	6.120e-09	-8.047	-8.213	-0.166	(0)
CuCl2-	4.700e-10	3.381e-10	-9.328	-9.471	-0.143	(0)
CuCl3-2	7.482e-13	2.240e-13	-12.126	-12.650	-0.524	(0)
Cu(2)	6.563e-07					
Cu+2	5.376e-07	1.166e-07	-6.270	-6.933	-0.664	(0)
CuSO4	1.017e-07	1.064e-07	-6.993	-6.973	0.020	(0)
CuHCO3+	1.675e-08	1.252e-08	-7.776	-7.903	-0.127	(0)
CuCl+	1.824e-10	1.312e-10	-9.739	-9.882	-0.143	(0)
CuCO3	2.740e-11	2.867e-11	-10.562	-10.543	0.020	(0)
CuOH+	6.886e-12	4.954e-12	-11.162	-11.305	-0.143	(0)
Cu(OH)2	4.202e-14	4.397e-14	-13.377	-13.357	0.020	(0)
CuCl2	2.814e-14	2.945e-14	-13.551	-13.531	0.020	(0)
Cu2(OH)2+2	3.448e-17	1.074e-17	-16.462	-16.969	-0.507	(0)
Cu(CO3)2-2	5.306e-18	1.653e-18	-17.275	-17.782	-0.507	(0)
CuCl3-	6.071e-20	4.368e-20	-19.217	-19.360	-0.143	(0)
Cu(OH)3-	1.510e-23	1.128e-23	-22.821	-22.948	-0.127	(0)
CuCl4-2	3.056e-25	9.149e-26	-24.515	-25.039	-0.524	(0)
Cu(OH)4-2	3.063e-32	9.541e-33	-31.514	-32.020	-0.507	(0)
Fe(2)	1.858e-05					
Fe+2	1.486e-05	4.888e-06	-4.828	-5.311	-0.483	(0)
FeSO4	3.713e-06	3.885e-06	-5.430	-5.411	0.020	(0)
FeOH+	8.877e-12	6.566e-12	-11.052	-11.183	-0.131	(0)
Fe(OH)2	2.269e-19	2.374e-19	-18.644	-18.624	0.020	(0)
Fe(OH)3-	5.066e-26	3.747e-26	-25.295	-25.426	-0.131	(0)
Fe(3)	9.455e-13					
FeOH+2	4.160e-13	1.245e-13	-12.381	-12.905	-0.524	(0)
Fe(OH)2+	2.345e-13	1.752e-13	-12.630	-12.756	-0.127	(0)
FeSO4+	2.282e-13	1.688e-13	-12.642	-12.773	-0.131	(0)
Fe+3	3.454e-14	4.541e-15	-13.462	-14.343	-0.881	(0)
Fe(SO4)2-	3.195e-14	2.387e-14	-13.496	-13.622	-0.127	(0)
FeCl+2	1.914e-16	5.731e-17	-15.718	-16.242	-0.524	(0)
Fe(OH)3	8.356e-18	8.744e-18	-17.078	-17.058	0.020	(0)

FeCl2+	1.447e-19	1.070e-19	-18.840	-18.971	-0.131	(0)
Fe(OH)4-	4.973e-22	3.715e-22	-21.303	-21.430	-0.127	(0)
Fe2(OH)2+4	4.437e-23	4.175e-25	-22.353	-24.379	-2.026	(0)
FeCl3	4.274e-24	4.473e-24	-23.369	-23.349	0.020	(0)
Fe3(OH)4+5	2.241e-32	1.528e-35	-31.650	-34.816	-3.166	(0)
H(0)	7.436e-19					
H2	3.718e-19	3.890e-19	-18.430	-18.410	0.020	(0)
K	8.140e-03					
K+	7.907e-03	5.540e-03	-2.102	-2.257	-0.155	(0)
KSO4-	2.329e-04	1.740e-04	-3.633	-3.759	-0.127	(0)
KCrO4-	0.000e+00	0.000e+00	-44.816	-44.943	-0.127	(0)
Mg	6.629e-02					
Mg+2	5.152e-02	1.934e-02	-1.288	-1.714	-0.426	(0)
MgSO4	1.469e-02	1.537e-02	-1.833	-1.813	0.020	(0)
MgHCO3+	7.247e-05	5.214e-05	-4.140	-4.283	-0.143	(0)
MgCO3	8.075e-10	8.450e-10	-9.093	-9.073	0.020	(0)
MgOH+	1.764e-10	1.350e-10	-9.754	-9.870	-0.116	(0)
Mn(2)	1.098e-05					
Mn+2	8.728e-06	2.870e-06	-5.059	-5.542	-0.483	(0)
MnSO4	2.231e-06	2.335e-06	-5.651	-5.632	0.020	(0)
MnHCO3+	1.658e-08	1.226e-08	-7.780	-7.911	-0.131	(0)
MnCl+	6.561e-09	4.853e-09	-8.183	-8.314	-0.131	(0)
MnCl2	5.266e-13	5.511e-13	-12.279	-12.259	0.020	(0)
MnOH+	4.237e-13	3.134e-13	-12.373	-12.504	-0.131	(0)
MnCl3-	1.404e-16	1.038e-16	-15.853	-15.984	-0.131	(0)
Mn(OH)3-	4.715e-30	3.487e-30	-29.327	-29.457	-0.131	(0)
Mn(3)	6.794e-27					
Mn+3	6.794e-27	8.931e-28	-26.168	-27.049	-0.881	(0)
Mn(6)	0.000e+00					
MnO4-2	0.000e+00	0.000e+00	-78.426	-78.949	-0.524	(0)
Mn(7)	0.000e+00					
MnO4-	0.000e+00	0.000e+00	-84.176	-84.333	-0.158	(0)
Na	4.820e-04					
Na+	4.714e-04	3.509e-04	-3.327	-3.455	-0.128	(0)
NaSO4-	1.052e-05	7.861e-06	-4.978	-5.105	-0.127	(0)
NaHCO3	4.327e-08	4.528e-08	-7.364	-7.344	0.020	(0)
NaCO3-	3.986e-13	2.978e-13	-12.399	-12.526	-0.127	(0)
NaCrO4-	0.000e+00	0.000e+00	-46.117	-46.244	-0.127	(0)
O(0)	0.000e+00					
O2	0.000e+00	0.000e+00	-55.583	-55.564	0.020	(0)
S(6)	4.184e-02					
SO4-2	1.699e-02	4.470e-03	-1.770	-2.350	-0.580	(0)
MgSO4	1.469e-02	1.537e-02	-1.833	-1.813	0.020	(0)
CaSO4	6.925e-03	7.246e-03	-2.160	-2.140	0.020	(0)
AlSO4+	1.660e-03	1.212e-03	-2.780	-2.917	-0.137	(0)
Al(SO4)2-	5.895e-04	4.303e-04	-3.229	-3.366	-0.137	(0)
KSO4-	2.329e-04	1.740e-04	-3.633	-3.759	-0.127	(0)
HSO4-	1.393e-04	1.017e-04	-3.856	-3.993	-0.137	(0)
NaSO4-	1.052e-05	7.861e-06	-4.978	-5.105	-0.127	(0)
FeSO4	3.713e-06	3.885e-06	-5.430	-5.411	0.020	(0)
MnSO4	2.231e-06	2.335e-06	-5.651	-5.632	0.020	(0)
ZnSO4	4.957e-07	5.187e-07	-6.305	-6.285	0.020	(0)
UO2SO4	1.705e-07	1.784e-07	-6.768	-6.749	0.020	(0)
CuSO4	1.017e-07	1.064e-07	-6.993	-6.973	0.020	(0)
UO2(SO4)2-2	7.625e-08	2.375e-08	-7.118	-7.624	-0.507	(0)
Zn(SO4)2-2	6.052e-08	1.885e-08	-7.218	-7.725	-0.507	(0)
CrOHSO4	2.465e-08	2.580e-08	-7.608	-7.588	0.020	(0)
CrSO4+	3.981e-09	2.974e-09	-8.400	-8.527	-0.127	(0)
FeSO4+	2.282e-13	1.688e-13	-12.642	-12.773	-0.131	(0)
Cr2(OH)2SO4+2	1.922e-13	5.985e-14	-12.716	-13.223	-0.507	(0)
Fe(SO4)2-	3.195e-14	2.387e-14	-13.496	-13.622	-0.127	(0)
U(SO4)2	4.183e-16	4.378e-16	-15.378	-15.359	0.020	(0)
USO4+2	1.620e-17	5.046e-18	-16.790	-17.297	-0.507	(0)
Cr2(OH)2(SO4)2	6.032e-18	6.312e-18	-17.220	-17.200	0.020	(0)
CrO3SO4-2	0.000e+00	0.000e+00	-43.593	-44.100	-0.507	(0)
U(3)	8.619e-33					

U+3	8.619e-33	6.246e-34	-32.065	-33.204	-1.140 (0)
U(4)	1.076e-14				
U(OH)3+	4.654e-15	3.477e-15	-14.332	-14.459	-0.127 (0)
U(OH)4	3.861e-15	4.040e-15	-14.413	-14.394	0.020 (0)
U(OH)2+2	1.215e-15	3.784e-16	-14.915	-15.422	-0.507 (0)
U(OH)5-	5.486e-16	4.098e-16	-15.261	-15.387	-0.127 (0)
U(SO4)2	4.183e-16	4.378e-16	-15.378	-15.359	0.020 (0)
UOH+3	4.977e-17	3.606e-18	-16.303	-17.443	-1.140 (0)
USO4+2	1.620e-17	5.046e-18	-16.790	-17.297	-0.507 (0)
U+4	4.150e-19	3.905e-21	-18.382	-20.408	-2.026 (0)
UCl+3	4.905e-22	3.554e-23	-21.309	-22.449	-1.140 (0)
U6(OH)15+9	0.000e+00	0.000e+00	-74.998	-85.256	-10.259 (0)
U(5)	6.363e-09				
UO2+	6.363e-09	4.753e-09	-8.196	-8.323	-0.127 (0)
U(6)	5.438e-07				
UO2+2	2.504e-07	7.798e-08	-6.601	-7.108	-0.507 (0)
UO2SO4	1.705e-07	1.784e-07	-6.768	-6.749	0.020 (0)
UO2(SO4)2-2	7.625e-08	2.375e-08	-7.118	-7.624	-0.507 (0)
UO2CO3	4.294e-08	4.494e-08	-7.367	-7.347	0.020 (0)
UO2OH+	3.605e-09	2.693e-09	-8.443	-8.570	-0.127 (0)
UO2Cl+	7.241e-11	5.409e-11	-10.140	-10.267	-0.127 (0)
UO2(CO3)2-2	5.275e-11	1.643e-11	-10.278	-10.784	-0.507 (0)
(UO2)2(OH)2+2	7.980e-13	2.485e-13	-12.098	-12.605	-0.507 (0)
UO2(CO3)3-4	1.925e-15	1.812e-17	-14.715	-16.742	-2.026 (0)
(UO2)3(OH)5+	2.242e-19	1.675e-19	-18.649	-18.776	-0.127 (0)
Zn	2.080e-06				
Zn+2	1.505e-06	4.950e-07	-5.822	-6.305	-0.483 (0)
ZnSO4	4.957e-07	5.187e-07	-6.305	-6.285	0.020 (0)
Zn(SO4)2-2	6.052e-08	1.885e-08	-7.218	-7.725	-0.507 (0)
ZnHCO3+	1.786e-08	1.334e-08	-7.748	-7.875	-0.127 (0)
ZnCl+	7.740e-10	5.569e-10	-9.111	-9.254	-0.143 (0)
ZnCO3	4.321e-12	4.522e-12	-11.364	-11.345	0.020 (0)
ZnOH+	3.086e-12	2.306e-12	-11.511	-11.637	-0.127 (0)
ZnCl2	2.329e-13	2.437e-13	-12.633	-12.613	0.020 (0)
ZnOHCl	2.781e-14	2.910e-14	-13.556	-13.536	0.020 (0)
ZnCl3-	1.589e-16	1.143e-16	-15.799	-15.942	-0.143 (0)
Zn(OH)2	1.077e-16	1.127e-16	-15.968	-15.948	0.020 (0)
Zn(CO3)2-2	1.421e-17	4.426e-18	-16.847	-17.354	-0.507 (0)
ZnCl4-2	7.980e-20	2.389e-20	-19.098	-19.622	-0.524 (0)
Zn(OH)3-	2.027e-24	1.514e-24	-23.693	-23.820	-0.127 (0)
Zn(OH)4-2	3.274e-33	1.020e-33	-32.485	-32.992	-0.507 (0)

----------Saturation indices----------

Phase	SI**	log IAP	log K(298 K, 1 atm)	
Al(OH)3(a)	-3.08	7.30	10.38	Al(OH)3
Al2O3	-8.38	14.60	22.98	Al2O3
Al4(OH)10SO4	-3.12	19.58	22.70	Al4(OH)10SO4
AlOHSO4	0.92	-2.31	-3.23	AlOHSO4
AlumK	-5.39	-10.56	-5.17	KAl(SO4)2:12H2O
Alunite	5.40	4.05	-1.35	KAl3(SO4)2(OH)6
Anhydrite	0.19	-4.45	-4.64	CaSO4
Antlerite	-16.93	-8.64	8.29	Cu3(OH)4SO4
Aragonite	-4.10	-12.44	-8.34	CaCO3
Artinite	-16.12	-6.52	9.60	MgCO3:Mg(OH)2:3H2O
Atacamite	-13.70	-6.36	7.34	Cu2(OH)3Cl
Azurite	-17.30	-34.22	-16.92	Cu3(OH)2(CO3)2
B_UO2(OH)2	-5.40	0.15	5.54	UO2(OH)2
Bianchite	-6.90	-8.67	-1.76	ZnSO4:6H2O
Birnessite	-26.62	-8.53	18.09	MnO2
Bixbyite	-31.71	-32.32	-0.61	Mn2O3
Boehmite	-1.28	7.30	8.58	AlOOH
Brochantite	-23.65	-8.31	15.34	Cu4(OH)6SO4
Brucite	-11.25	5.54	16.79	Mg(OH)2
CaCrO4	-43.32	-45.58	-2.27	CaCrO4

Calcite	-3.96	-12.44	-8.47	CaCO3
CH4(g)	-38.53	-78.63	-40.10	CH4
Chalcanthite	-6.65	-9.29	-2.64	CuSO4:5H2O
CO2(g)	0.56	-17.60	-18.16	CO2
Cr(OH)2	-21.76	-10.94	10.82	Cr(OH)2
Cr(OH)3(A)	-5.51	-6.26	-0.75	Cr(OH)3
Cr(OH)3(C)	-7.96	-6.26	1.70	Cr(OH)3
Cr2O3	-9.12	-12.51	-3.39	Cr2O3
CrCl2	-40.82	-24.95	15.87	CrCl2
CrCl3	-40.79	-27.28	13.51	CrCl3
CrMetal	-58.44	-26.20	32.24	Cr
CrO3	-47.53	-50.74	-3.21	CrO3
Cu(OH)2	-8.32	0.32	8.64	Cu(OH)2
Cu2SO4	-16.83	-18.78	-1.95	Cu2SO4
CuCO3	-7.64	-17.27	-9.63	CuCO3
CuCrO4	-44.94	-50.42	-5.48	CuCrO4
CuMetal	-3.45	-12.21	-8.76	Cu
CuOCuSO4	-20.49	-8.96	11.53	CuO:CuSO4
CupricFerrite	-12.47	-6.59	5.88	CuFe2O4
Cuprite	-7.62	-9.17	-1.55	Cu2O
CuprousFerrite	0.88	-8.04	-8.92	CuFeO2
CuSO4	-12.29	-9.28	3.01	CuSO4
Diaspore	0.43	7.30	6.87	AlOOH
Dolomite	-7.49	-24.49	-17.00	CaMg(CO3)2
Epsomite	-1.94	-4.08	-2.14	MgSO4:7H2O
Fe(OH)2.7Cl0.3	-2.52	-5.56	-3.04	Fe(OH)2.7Cl0.3
Fe2(SO4)3	-39.31	-35.73	3.58	Fe2(SO4)3
Fe3(OH)8	-25.19	-4.97	20.22	Fe3(OH)8
FeCr2O4	-9.66	-10.56	-0.90	FeCr2O4
Ferrihydrite	-8.35	-3.46	4.89	Fe(OH)3
Gibbsite(C)	-1.47	7.30	8.77	Al(OH)3
Goethite	-3.96	-3.46	0.50	FeOOH
Goslarite	-6.71	-8.67	-1.96	ZnSO4:7H2O
Gummite	-10.25	0.15	10.40	UO3
Gypsum	0.16	-4.45	-4.61	CaSO4:2H2O
Halite	-8.42	-6.83	1.58	NaCl
Hausmannite	-41.13	20.41	61.54	Mn3O4
Hematite	-2.90	-6.91	-4.01	Fe2O3
Hercynite	-10.61	16.55	27.16	FeAl2O4
Huntite	-18.63	-48.60	-29.97	CaMg3(CO3)4
Hydromagnesite	-33.91	-42.68	-8.77	Mg5(CO3)4(OH)2:4H2O
Jarosite-H	-17.49	-29.59	-12.10	(H3O)Fe3(SO4)2(OH)6
Jarosite-K	-13.42	-28.22	-14.80	KFe3(SO4)2(OH)6
Jarosite-Na	-18.21	-29.41	-11.20	NaFe3(SO4)2(OH)6
K2Cr2O7	-83.07	-98.74	-15.67	K2Cr2O7
K2CrO4	-48.01	-48.00	0.01	K2CrO4
Langite	-25.11	-8.32	16.79	Cu4(OH)6SO4:H2O
Lepidocrocite	-4.83	-3.46	1.37	FeOOH
Lime	-27.64	5.16	32.80	CaO
Maghemite	-13.30	-6.91	6.39	Fe2O3
Magnesite	-4.02	-12.05	-8.03	MgCO3
Magnetite	-8.70	-4.96	3.74	Fe3O4
Malachite	-11.77	-16.95	-5.18	Cu2(OH)2CO3
Manganite	-15.92	-16.16	-0.24	MnOOH
Melanothallite	-17.42	-13.69	3.73	CuCl2
Melanterite	-5.20	-7.67	-2.47	FeSO4:7H2O
Mg-Ferrite	-18.13	-1.37	16.77	MgFe2O4
MgCr2O4	-19.04	-6.97	12.08	MgCr2O4
MgCrO4	-50.58	-45.20	5.38	MgCrO4
Mirabilite	-8.16	-9.28	-1.11	Na2SO4:10H2O
Mn2(SO4)3	-55.44	-61.15	-5.71	Mn2(SO4)3
MnCl2:4H2O	-15.02	-12.31	2.71	MnCl2:4H2O
MnSO4	-10.56	-7.89	2.67	MnSO4
Na2Cr2O7	-91.24	-101.14	-9.90	Na2Cr2O7
Na2CrO4	-53.66	-50.40	3.26	Na2CrO4
Nantokite	-4.83	-11.59	-6.76	CuCl

Natron	-15.96	-17.27	-1.31	Na2CO3:10H2O
Nesquehonite	-6.44	-12.06	-5.62	MgCO3:3H2O
Nsutite	-26.04	-8.53	17.50	MnO2
O2(g)	-52.60	30.52	83.12	O2
Periclase	-15.97	5.54	21.51	MgO
Portlandite	-17.52	5.16	22.68	Ca(OH)2
Pyrocroite	-13.37	1.71	15.09	Mn(OH)2
Pyrolusite	-24.39	-8.53	15.86	MnO2
Rhodochrosite	-5.47	-15.88	-10.41	MnCO3
Rutherfordine	-2.99	-17.45	-14.46	UO2CO3
Schoepite	-5.26	0.15	5.40	UO2(OH)2:H2O
Siderite	-5.10	-15.65	-10.55	FeCO3
Smithsonite	-6.64	-16.64	-10.00	ZnCO3
Spinel	-16.19	20.15	36.33	MgAl2O4
Tenorite	-7.30	0.32	7.62	CuO
Thenardite	-9.08	-9.26	-0.18	Na2SO4
Thermonatrite	-17.38	-17.25	0.13	Na2CO3:H2O
U3O8(C)	-8.27	12.84	21.11	U3O8
U4O9(C)	-4.93	-8.31	-3.38	U4O9
UO2(am)	-6.83	-5.89	0.93	UO2
UO3(C)	-7.57	0.15	7.72	UO3
Uraninite	-1.19	-5.89	-4.70	UO2
Zincite	-10.19	0.95	11.14	ZnO
Zincosite	-11.67	-8.66	3.01	ZnSO4
Zn(BO2)2	-14.55	-6.26	8.29	Zn(BO2)2
Zn(OH)2(A)	-11.50	0.95	12.45	Zn(OH)2
Zn(OH)2(B)	-10.80	0.95	11.75	Zn(OH)2
Zn(OH)2(C)	-11.25	0.95	12.20	Zn(OH)2
Zn(OH)2(E)	-10.55	0.95	11.50	Zn(OH)2
Zn(OH)2(G)	-10.76	0.95	11.71	Zn(OH)2
Zn2(OH)2SO4	-15.20	-7.70	7.50	Zn2(OH)2SO4
Zn2(OH)3Cl	-20.31	-5.11	15.20	Zn2(OH)3Cl
Zn3O(SO4)2	-35.38	-16.36	19.02	Zn3O(SO4)2
Zn4(OH)6SO4	-34.20	-5.80	28.40	Zn4(OH)6SO4
Zn5(OH)8Cl2	-47.76	-9.26	38.50	Zn5(OH)8Cl2
ZnCl2	-20.09	-13.06	7.03	ZnCl2
ZnCO3:H2O	-6.39	-16.65	-10.26	ZnCO3:H2O
ZnMetal	-40.06	-14.31	25.76	Zn
ZnO(Active)	-10.36	0.95	11.31	ZnO
ZnSO4:H2O	-8.09	-8.66	-0.57	ZnSO4:H2O

**For a gas, SI = log10(fugacity). Fugacity = pressure * phi / 1 atm.
  For ideal gases, phi = 1.

End of simulation.

Reading input data for simulation 2.

End of Run after 0.23 Seconds.

Appendix E

SMR Process Plant PFDs and Layouts

E-1: SMR Crushing Plant Upgrade – Area Plan

E-2: SMR Crushing Plant Upgrade – Primary and Secondary Crushing – Process Flow Diagram

E-3: SMR Crushing Plant Upgrade – Tertiary Screening, Crushing and Stacking – Process Flow Diagram

E-4: SMR Ore Beneficiation Plant – Site Layout

E-5: SMR Ore Beneficiation Plant – Spiral Tower – Process Flow Diagram

E-6: SMR Ore Beneficiation Plant – Thickener – Process Flow Diagram

E-7: Project Magnet – Magnetite Concentrator – Concentrator Area and General Arrangement

E-8: SMR Magnetite Concentrator Expansion 2013 – Concentrator Layout

E-9: Project Magnet – Magnetite Concentrator – Process Flow Diagram – Overall

LAYDOWN AREA

CONSTRUCTION SITE OFFICES

UNDERGROUND CONNECTIONS WATER AND POWER TO TEMPORARY BUILDINGS (TYPICAL 175m)

UNDERGROUND POWER LINES

FENCE FOLLOWS CENTRE OF TRACKS

METPLANT SITE – BOUNDARY FENCE

SIGNAGE

PEDESTRIAN CHICANE

CHAIN & SIGNAGE

KOOLATAH TRAMWAY

PEDESTRIAN WALKWAY

TEMPORARY ACCESS ROAD

WATER TANK

OVERHEAD POWER LINES

LUMP STACKER CONVEYOR CC-08A/08B

3956.000 E
5105.000 N

EXISTING CONVEYOR STATION

GATE & SIGNAGE

SECONDARY CRUSHER CR-02

SCALPING AND SECONDARY CRUSHING STATION

MOVABLE FENCING

TERTIARY CRUSHING

CONVEYOR CC-02

CONVEYOR CC-07

CONVEYOR CV-202

3986.410 E
4972.283 N

3969.452 E
5110.409 N

LIVE TRAMWAY

WINDROW (EXISTING)

33KV TRANSFORMER

MCC

CONVEYOR CC-04

No 1 STACKER CONVEYOR

BELT FEEDER BF 01

FINES SAMPLING

EXISTING SECONDARY CRUSHING STATION

4000.000 E
5000.000 N

PEDESTRIAN CROSS-OVER

TRANSFORMER

CONTROL ROOM

CONVEYOR CV-101

4052.325 E
4924.403 N

PRIMARY CRUSHER CR-101

EXISTING CONVEYOR CC 01

EXISTING PRIMARY CRUSHING STATION

3900 E

3950 E

4000 E

4050 E

973-G-0003	LAYDOWN AREA AND SITE OFFICE –159053
973-G-4001	PRODUCT SCREENING AND STOCKPILE AREA PLAN –159086
973-G-3002	TERTIARY CRUSHING GA PLAN –159085
973-G-2002	SCALPING AND CRUSHING STATION GA PLAN –159072
973-G-	CONTROL ROOM ARRANGEMENT
973-G-1002	PRIMARY CRUSHING GA PLANS AT RL 203.100 AND RL 205.850 –159057
973-G-1001	PRIMARY CRUSHING GA PLANS AT RL 215.140 AND RL 211.718 –159056
DRAWING No	REFERENCE DRAWINGS

Metplant
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ACN 009 256 508

METPLANT REF. NO.

973-G-0002

No	REVISION	BY	DATE
B	SKID MOUNTED COMPRESSOR ADDED	NMc	06/02/09
A	ISSUED FOR ONESTEEL DRAWING REGISTRATION	OD	26/6/07
4	AS BUILT	RG	30.03.07
3	SECTION SYMBOLS ADDED ,EARTHWORKS AT PRIMARY CRUSHER AND STACKER UPDATED	JM	14.08.06
2	FINES SAMPLING ADDED	JM	03.08.06
1	FENCES & ACCESS ROADS REVISED	MJF	08.04.06
0	ISSUED FOR CONSTRUCTION	MJF	14.03.06
A	ISSUED FOR DESIGN	JWM	10.02.06

CAD REF Elec

LOCATION: 1 COLUMN; 29990 DR. REL; DR

SOUTH MIDDLEBACK RANGES CRUSHING PLANT UPGRADE AREA PLAN

onesteel whyalla steelworks

	NAME	SIGNATURE
DRAWN	J MORGAN	JWM
CHECKED	WAE	WAE
REVIEWED	AMc	AMc
C ENG	MBA /A.J.A.S.	MBA 14/6/07

DATE : 09.12.05 SCALE: 1:400

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159052 B

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159052B MODEL_1_PAGE 1 - 26/02/2009 6:02:03 AM

--R_PLANT DATA_PRINTED_DR_29996_X PAGE 1 - 9/07/2007 9:19:37 AM

B1

WATER 41

TRUCK OR LOADER

1

42

HT-101 CHAIN CURTAIN HOIST No.1

HT-102 CHAIN CURTAIN HOIST No.2

BN-101 ROM FEED BIN

2

AF-101 APRON FEEDER

CH-101 DRIBBLE CHUTE

4

RB-101 ROCK BREAKER

VG-101 GRIZZLY SCREEN

3

5

6

CR-101 PRIMARY CRUSHER

43

7

CV-102 DRIBBLE CONVEYOR

MD-101 CONVEYOR CV-101 METAL DETECTOR

CV-101 PRIMARY DISCHARGE CONVEYOR

BW-101 CONVEYOR CV-101 BELT WEIGHTOMETER

8

46

WATER 973-PFD-002

AREA 01

AREA 02

SC-201 SCALPING SCREEN

10

BN-201 SECONDARY CRUSHER SURGE BIN

9

10

VF-201 SECONDARY CRUSHER FEEDER

CR-201 SECONDARY CRUSHER

11

44

45

CV-201 SECONDARY DISCHARGE CONVEYOR No. 1

12

13

TO CONVEYOR CC-02 973-PFD-002

CV-202 SECONDARY DISCHARGE CONVEYOR No. 2

973-PFD-003

HR-01 FIRE HOSE REEL PRIMARY CRUSHING AREA

HR-02 FIRE HOSE REEL CONTROL ROOM AREA

HR-03 FIRE HOSE REEL CV-101 TAKE UP AREA

973-PFD-003

HR-05 FIRE HOSE REEL SECONDARY CRUSHING AREA

HR-04 FIRE HOSE REEL SECONDARY CRUSHING AREA

LEGEND

- NEW EQUIPMENT
- EXISTING EQUIPMENT
- E — EXISTING EQUIPMENT MODIFIED ELECTRICALLY
- M — EXISTING EQUIPMENT MODIFIED MECHANICALLY
- E / M — EXISTING EQUIPMENT MODIFIED ELECTRICALLY AND MECHANICALLY

NOTE

ALL EQUIPMENT NUMBERS ARE PREFIXED BY SMR-20-

SOUTH MIDDLEBACK RANGES CRUSHING PLANT UPGRADE PRIMARY AND SECONDARY CRUSHING PROCESS FLOW DIAGRAM

Metplant ENGINEERING SERVICES PTY LTD
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WEB SITE www.metplant.com.au
ACN 009 256 508

METPLANT REF. NO. 973-PFD-001

No	REVISION	BY	DATE
A	ISSUED FOR ONESTEEL DRAWING REGISTRATION	OD	26/6/07
1	AS BUILT	RG	02.04.07
0	ISSUED FOR CONSTRUCTION	RG	30.08.06

LOCATION 1 COLUMN

29996 DR DR. REL.

CAD REF Elect

onesteel whyalla steelworks

	NAME	SIGNATURE
DRAWN	RG	RG
CHECKED	LSH	LSH
REVIEWED	AS	AS
C ENG	RP /A.J.A.S.	RP 10/7/2007

DATE : 22.11.05 SCALE: NTS

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973-PFD-002 CRUSHING PLANT UPGRADE, TERTIARY SCREENING, CRUSHING & STACKING, PROCESS FLOW DIAGRAM -159237

DRAWING No REFERENCE DRAWINGS

159236 A

0 50 100

AREA 03

CH-19 TERTIARY CRUSHER FEED SPLITTER CHUTE

SPLIT STREAM

26

27

BW-02 CONVEYOR CC-07 BELT WEIGHTOMETER

BN-05 TERTIARY CRUSHER SURGE BIN

BN-04 TERTIARY CRUSHER SURGE BIN

FROM CONVEYOR CV-202

973-PFD-001

13

VF-05A/B TERTIARY CRUSHER FEEDER

VF-04A/B TERTIARY CRUSHER FEEDER

CR-05 TERTIARY CRUSHER

CR-04 TERTIARY CRUSHER

28

29

E CC-02 M TERTIARY SCREEN FEED CONVEYOR

14 TERTIARY SCREEN FEED SPLITTER CHUTE

CH-02

SPLIT STREAM

15

16

BN-02 TERTIARY SCREEN SURGE BIN

BN-03 TERTIARY SCREEN SURGE BIN

VF-02A/B TERTIARY SCREEN FEEDER

VF-03A/B TERTIARY SCREEN FEEDER

17

SC-02 TERTIARY SCREEN

18

SC-03 TERTIARY SCREEN

19

21

CH-05 TERTIARY SCREEN MIDSIZE CHUTE

DG-02 DIVERTER GATE

ALTERNATIVE STREAMS

19

19

20

22

CH-10 TERTIARY SCREEN MIDSIZE CHUTE

DG-03 DIVERTER GATE

ALTERNATIVE STREAMS

20

20

23

24

TERTIARY CRUSHER FEED CONVEYOR

E CC-07 M

MD-01 CONVEYOR CC-07 METAL DETECTOR

MG-02 TRAMP METAL MAGNET

25

CC-06 TERTIARY SCREEN OVERSIZE CONVEYOR

LEGEND

NEW EQUIPMENT

EXISTING EQUIPMENT

EXISTING EQUIPMENT MODIFIED ELECTRICALLY

EXISTING EQUIPMENT MODIFIED MECHANICALLY

EXISTING EQUIPMENT MODIFIED ELECTRICALLY AND MECHANICALLY

NOTE

ALL EQUIPMENT NUMBERS ARE PREFIXED BY SMR-20-

AREA 04

973-PFD-003

HR-06 FIRE HOSE REEL TERTIARY CRUSHING AREA

WATER

973-PFD-001

46

AREA 07

30

CC-03 MIXED PRODUCT CONVEYOR No.3

BW-03 CONVEYOR CC-04 BELT WEIGHTOMETER

CC-04 MIXED PRODUCT CONVEYOR No.4

E CC-08 M LUMP CONVEYOR

31

CC-05 MIXED PRODUCT CONVEYOR No.5

AREA 05

LUMP SAMPLING STATION

REFER TO DRG No. 0973-PFD-003

BW-04 CONVEYOR CC-09 BELT WEIGHTOMETER

CC-09A/B RADIAL STACKER CONVEYOR

32

RADIAL LUMP STOCKPILE

CV-03 No.1 STACKER CONVEYOR

FINES SAMPLING STATION

REFER TO DRG No. 0973-PFD-003

30

CV-04 No.1 STACKER BOOM CONVEYOR

LINEAR STOCKPILES

AREA 06

25BV00

HR-07 FIRE HOSE REEL RADIAL STACKER AREA

AREA 07

SOUTH MIDDLEBACK RANGES
CRUSHING PLANT UPGRADE
TERTIARY SCREENING, CRUSHING AND STACKING
PROCESS FLOW DIAGRAM

A	ISSUED FOR ONESTEEL DRAWING REGISTRATION	OD	26/6/07
1	AS BUILT	RG	02.04.07
0	ISSUED FOR CONSTRUCTION	RG	30.08.06
No	REVISION	BY	DATE

LOCATION: 1 COLUMN

DR DR. REL. 29996

CAD REF Elvis4

	NAME	SIGNATURE
DRAWN	RG	RG
CHECKED	LSH	LSH
REVIEWED	AS	AS
C ENG	RP /A.J.A.S.	RP 12/7/2007

DATE : 22.11.05 SCALE: NTS

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METPLANT REF. NO. 973-PFD-002

973-PFD-001 CRUSHING PLANT UPGRADE, PRIMARY & SECONDARY CRUSHING, PROCESS FLOW DIAGRAM -159236
DRAWING No REFERENCE DRAWINGS

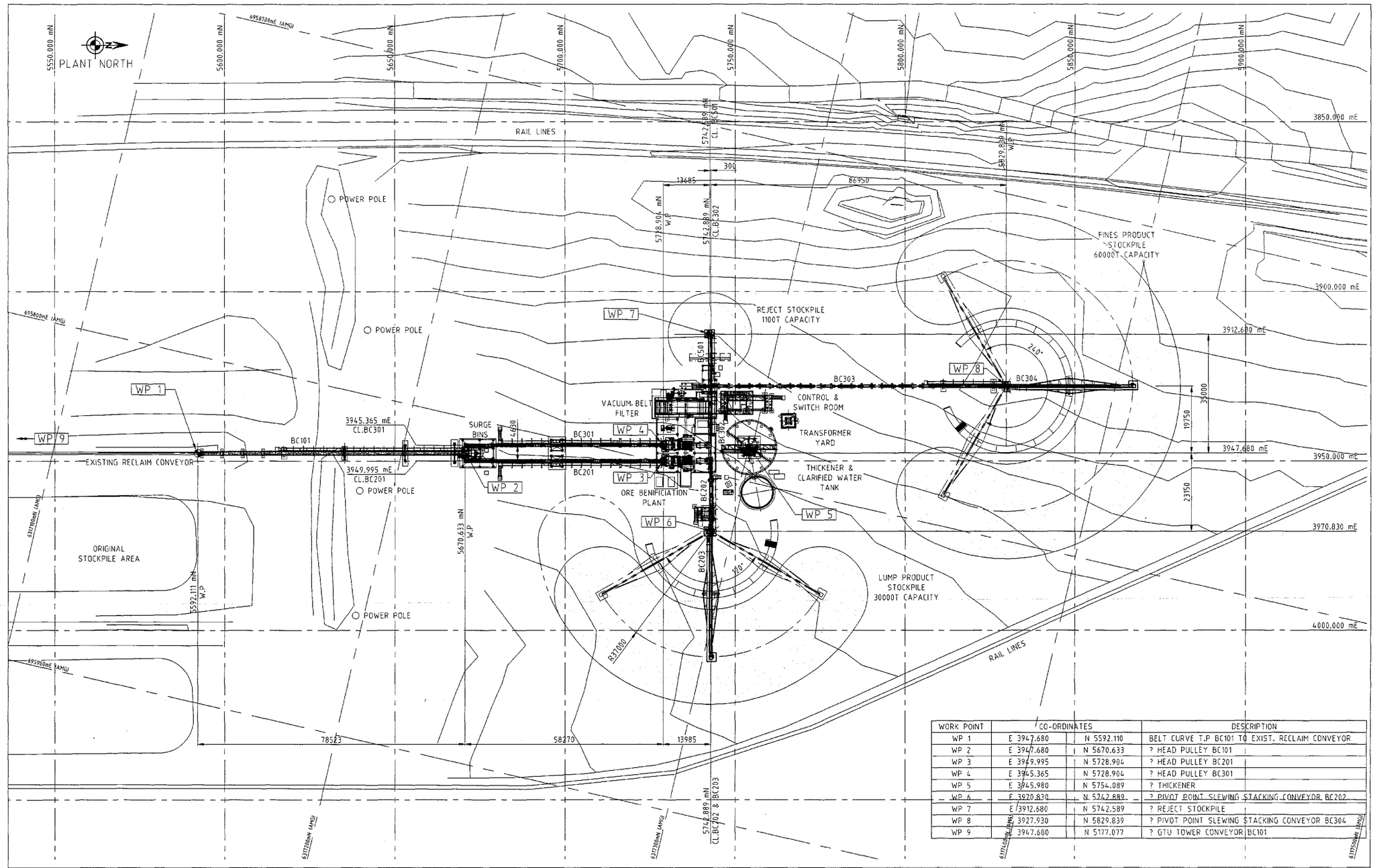
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159237 A

0 50 100

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No. OFF	ITEM	MARK No.	DESCRIPTION	MATERIAL



WORK POINT	CO-ORDINATES		DESCRIPTION
WP 1	E 3947.680	N 5592.110	BELT CURVE T.P BC101 TO EXIST. RECLAIM CONVEYOR
WP 2	E 3947.680	N 5670.633	? HEAD PULLEY BC101
WP 3	E 3949.995	N 5728.904	? HEAD PULLEY BC201
WP 4	E 3945.365	N 5728.904	? HEAD PULLEY BC301
WP 5	E 3945.980	N 5754.089	? THICKENER
WP 6	E 3970.830	N 5742.889	? PIVOT POINT SLEWING STACKING CONVEYOR BC202
WP 7	E 3912.680	N 5742.589	? REJECT STOCKPILE
WP 8	E 3927.930	N 5829.839	? PIVOT POINT SLEWING STACKING CONVEYOR BC304
WP 9	E 3947.680	N 5177.077	? GTU TOWER CONVEYOR BC101

REV	DATE		BY	CHK	APPROVED				REFERENCE	DRAWING NUMBER	TITLE
					CIV/STR	MECH	E/I	PROCESS			
1	08-12-04	AS BUILT	VL								
0	02-04-04	APPROVED FOR CONSTRUCTION	GG	BR							

AS BUILT

HWE HENRY WALKER ELTIN

CONTRACT No.	02-5488
ENG. DESIGN BY	B. ALLSOPP
DRAWN	N.P 17-11-03
CHECKED	BR 01.04.04
CIV. & STRUCT. DESIGN APPR.	
MECHANICAL DESIGN APPR.	
ELEC. & INSTR. DESIGN APPR.	
PROCESS DESIGN APPR.	
WEIGHTS CHECKED	

SIMON Engineering Australia

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A1

ONESTEEL PTY. LTD.- SOUTH MIDDLEBACK RANGES

ORE BENEFICIATION PLANT

SITE LAYOUT

Scale	SEA DRAWING No.	REV.
1:500	02-5488-81-501	1

REV CODE: SMR-OBP-LAY-MEC

AutoCAD

W.O. No. 31208 DR. REL.

onesteel whyalla steelworks

DATE : FEB 06	SCALE : 1:AS NOTED	
	NAME	SIGNATURE
DRAWN		
CHECKED		
REVIEWED	T.O'Brien	
C. ENG.	A.J.A.S.	AJAS 4/7/2006

Revisions

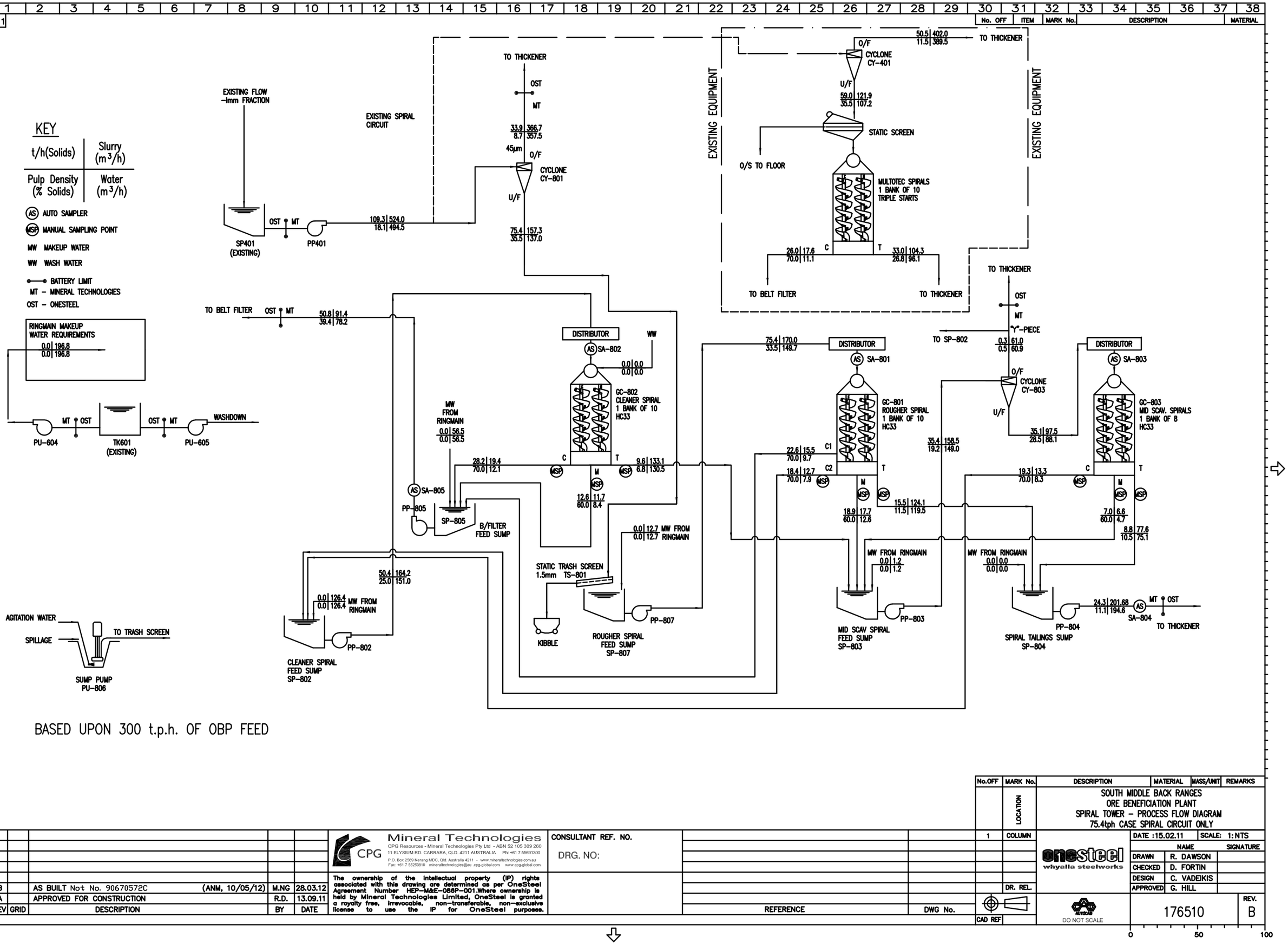
No. OFF	MARK No.	DESCRIPTION	MATERIAL	MASS/UNIT	REMARKS
	LOCATION	SOUTH MIDDLEBACK RANGES ORE BENEFICATION PLANT LAYOUT DRAWINGS SITE LAYOUT			

CAD. REF. C083

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189950

0 50 100



BASED UPON 300 t.p.h. OF OBP FEED

No. OFF	ITEM	MARK No.	DESCRIPTION	MATERIAL

No.OFF	MARK No.	DESCRIPTION	MATERIAL	MASS/UNIT	REMARKS
	LOCATION	SOUTH MIDDLE BACK RANGES ORE BENEFICIATION PLANT SPIRAL TOWER – PROCESS FLOW DIAGRAM 75.4tph CASE SPIRAL CIRCUIT ONLY			
1	COLUMN				
	DR. REL.				
	CAD REF				

Mineral Technologies
CPG Resources - Mineral Technologies Pty Ltd - ABN 52 105 309 260
11 ELYSIUM RD. CARRARA, QLD. 4211 AUSTRALIA Ph: +61 7 55691300
P.O. Box 2569 Nerang MDC, Qld. Australia 4211 - www.mineraltechnologies.com.au
Fax: +61 7 55253810 mineraltechnologies@au .cpg-global.com www.cpg-global.com

CONSULTANT REF. NO.
DRG. NO:

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REV	GRID	DESCRIPTION	BY	DATE
B		AS BUILT Not No. 90670572C (ANM, 10/05/12)	M.NG	28.03.12
A		APPROVED FOR CONSTRUCTION	R.D.	13.09.11

REFERENCE | DWG No.

onesteel whyalla steelworks

DATE :15.02.11	SCALE: 1:NTS	
	NAME	SIGNATURE
DRAWN	R. DAWSON	
CHECKED	D. FORTIN	
DESIGN	C. VADEIKIS	
APPROVED	G. HILL	

DO NOT SCALE

176510 REV. B

0 50 100

No. OFF	ITEM	MARK No.	DESCRIPTION	MATERIAL

180-ST-ID-SP-089-PE
PP-804
100-PW-073-ADA
MAKE-UP WATER
150-DR-026-FDA
GC-401 TO SP 402
255
256
350-DR-029-ADA
TK-201
350-DR-023-ADA
SC-303
200-DR-056-ADA
PP-701
300-DR-043-FDA
PP-403
300x80
350x300
600x350
FDA
ADA
EDB
500-ST-ID-SP-021-PE
CY-801
500x160
160-SF-ID-SP-060-PE
CY-803
600-DR-033-FDA
50 V402
053
054
VENDOR PACKAGE
HYDRAULIC UNIT
THICKNER CONTROL PANEL
TH601-CP
LI
RACK HEIGHT
LI
BED LEVEL
WI
RACK TORQUE
SW 3
BED MASS
FOR DETAILS OF PANEL CONTROLS & INDICATIONS REF OUTOKUMPU DWG'S T707021 TO 28
ST E/SP A/O/L
LCS 001
BREAK TANK TK201
258
SP-701
50V401
060
SP09 43
100V801
121
100x80
LCV 001
H L LL
AS
SP402
LT 001
252
253
VENT
257
FISHTAIL CYCLONE CE501
PROCESS WATER
BC-501
254
PIC 001
SC
VWF
PT 001
VS
CYCLONE FEED PUMP PP-402
OVERFLOW
SP402
250
251
SP401
SC-301
SC-201
SP-401
FLOCCULANT MIXING SYSTEM MCC-002C
xx
FOR DETAILS OF PANEL CONTROLS & INDICATION REF TRANSMIN DWG'S
E/ST
PT
LT
LE
LAUNDER
THICKNER TH-601
119
V601
120
200V102
097
101
200x100
600x450
450-RW-035-ADA
50-FL-083-EDB
50x40
600-RW-034-ADA
LT 002
FROM PUD10 CONCENTRATOR SEE DWG 124669 FOR DETAILS
630-DR-036-EDD
CLARIFIED WATER TANK TK-601
280m3
see also Drg. 176547 & 124669
SS
SP03 41
SP03 42
15V401 015
15V401 016
PI 001
600x300
600x302
600V801
004
006
600x400
400x300
150-RW-017-ADA
200-RW-009-ADA
80-RW-022-ADA
100-RW-007-ADA
GC-401 TO GC-408
JG-301
JG-201
300-RW-008-ADA
50-RW-006-ADA
125-RW-049-EDD
100V802
118
600V801
002
600x350
600-RW-004-ADA
600-RW-002-ADA
50V401
056
VA709
100
TO WELLTECH TANK SEE DWG.124669 FOR DETAILS
CLARIFIED WATER PUMP PP-603
VA704
50-PW-072-ADA
MAKE-UP WATER
PI
S
FSL
50
25
BAGS
FLOCCULANT STORAGE BIN BN-601
100W
FLOCCULANT FEEDER FE-601
FLOCCULANT BLOWER BL-601
FLOCCULANT MIXING TANK TK-602 1000 L
MX-601
LS
HH
H
L
LL
80
LSH
LSL
LSLL
FLOCCULANT DOSING TANK TK-603 2000 L
FLOCCULANT DOSING PUMPS PP-610
FI
V143
V141
V120
100-SL-045-ADB
50V601
102
SVO/C 001
ZSO 001
ZSC 001
CV 001
SP08 39
SP08 40
VVVF
PI 001
SVO/C 002
ZSO 002
ZSC 002
CV 002
100x50
100x80
THICKENER UNDERFLOW PUMP PP-601
103
V142
SP08 37
SP08 38
098
099
V140
THICKENER UNDERFLOW PUMP PP-602
100-SL-046-ADB
100-SL-047-ADB
50V601
107
108
FT 001
FI 001
PP-601
RADIO RD-003 TO CONT/ROOM
125x110
125-SL-048-EDE
125V103
115
LUGGED TYPE
ADB
EDE
12M
100V103
111
112
113
114
ø110
LSH 001
LSL 001
LSLL 001
100V801
116
100V302
117
110x90
TAILINGS DAM DM-601
DECANT SUMP SP-607
TAILINGS WATER RETURN PUMP PP-607
115462
CONCENTRATOR TSF
50-RW-006-ADA
VENDOR PACKAGE

△B REFERENCE DRAWINGS:
124669 WELLTECH TANK ROAD WATERING SYSTEM

△B REDRAWN FROM HWE DRAWING 02-5488-86-506 REV.1

No. OFF	MARK No.	DESCRIPTION	MATERIAL	MASS/UNIT	REMARKS
	LOCATION	SOUTH MIDDLEBACK RANGES ORE BENEFICATION PLANT THICKENER PROCESS FLOW DIAGRAM			

1	COL.	DATE : 4-4-10	SCALE : 1:N.T.S
		NAME	SIGNATURE
		DRAWN G.MUDGE	
		CHECKED	
		REVIEWED	
	W.O. No.	C. ENG.	
	DR. REL.		

onesteel whyalla

AutoCAD

SMR | OBP | FLO | 01

GM Drafting — GM Drafting WHYALLA Ph. 0417 896 453

Revisions			
D ADDED REFERENCES TO DRG. 124669 & 176547 UPDATED STREAM REFERENCES DR.40013604 NMc 18.10.2013	C UPDATE FLOW DIAGRAM. DR.90785072 NPM 29.10.2010	B REDRAWN ON CADD ADDED REF. DWG. DR.35090 GVM 5-4-10	A CORRECTED DR.29333 RS 7.10.06

CAD. REF.

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190199 D

0 50 100

CUTTING LINE

TRUE NORTH

PLANT NORTH
IRON DUKE STOCKPILE GRID

1–CC–010

1–CC–001

EXISTING INCLINE CONVEYOR TO BE DEMOLISHED

EXISTING TRAIN LOADOUT BINS TO BE DEMOLISHED

3900 E

3850 E

3800 E

3750 E

3700 E

5162.500 N
3869.000 E

RAW FEED BIN

NEW UNDERGROUND CABLE

33 KV POWER LINE

1–CC–002

5128.578 N
3834.850 E

SPACE FOR HVAC SYSTEMS

SWITCHROOM
2–BS–002

5147.100 N
3828.850 E

CONCENTRATOR BUILDING

HPGR 2

2–CC–205

5117.000 N
3819.300 E

2–CC–204

5066.000 N
3811.000 E

2–CC–003

PLANT FEED BIN

2–CC–105

2–CC–104

HPGR 1

5117.000 N
3802.700 E

RAW WATER PIPELINE FROM WHYALLA

CONCENTRATE SLURRY PUMP STATION

SLURRY PIPELINE

5298.297 N
3826.179 E

5194.506 N
3823.300 E

5293.400 N
3807.350 E

5215.500 N
3800.450 E

5229.082 N
3797.681 E

RAW WATER TANK

5250.000 N
3796.000 E

5298.000 N
3795.150 E

5265.900 N
3796.000 E

5263.506 N
3783.050 E

5292.105 N
3786.390 E

5243.490 N
3791.740 E

SERVICE WATER PUMPS

SWITCHROOM
3–BS–005

5185.806 N
3788.000 E

SWITCHROOM
2–BS–003

5132.156 N
3792.842 E

5089.000 N
3787.000 E

2–BA–003

2–BA–004

2–BA–005

2–BA–006

MAINTENANCE WORKSHOP

BALL MILL

5162.000 N
3775.000 E

5139.706 N
3786.642 E

5151.206 N
3786.642 E

LAB W/S

SWITCHROOM
2–BS–001

RAMP DOWN

PROCESS WATER PUMPS

5234.540 N
3756.000 E

CONCENTRATE THICKENER

PROCESS WATER TANK

RL 180.000

5254.850 N
3758.000 E

TAILINGS THICKENER

RAMP DOWN

5207.390 N
3744.758 E

5213.686 N
3722.595 E

COARSE TAILS COLLECTION

TO TAILINGS DAM

132/11/33 KV YARD

FINAL LOCATION & LAYOUT BY E.T.S.A.

N63168000

N5000

5350 N
5300 N
5250 N
5200 N
5150 N
5100 N
5050 N
5000 N

		No. OFF	MARK No.	DESCRIPTION	MATERIAL	MASS/UNIT	REMARKS
ISSUED FOR CONSTRUCTION			LOCATION	PROJECT MAGNET MAGNETITE CONCENTRATOR CONCENTRATOR AREA GENERAL ARRANGEMENT PLAN VIEW			

REF. DRAWING NUMBER	DESCRIPTION

THIESS PTY LTD
A.B.N. 87 010 221 486
LEVEL 13 / 225 ST. GEORGES TERRACE, PERTH WA 6000
PHONE (08) 9214 4200 FACSIMILE (08) 9214 4244

ProMet Engineers Pty Ltd
267 ST. GEORGES TERRACE, PERTH WA 6000
PHONE (08) 9476 5700
FACSIMILE (08) 9476 5710

THIESS REF. NO.
904006–10–M01–20501

CONSULTANT REF. NO.
–

REV	DESCRIPTION	BY	DATE
D	MEP AS–BUILT DR.MEX–00896	NMc	24–02–14
C	ISSUED FOR ONESTEEL DRAWING REGISTRATION	OD	4/10/07
B	GENERAL REVISIONS	MT	25/08/06
A	ISSUED FOR CONSTRUCTION	AFM	06.12.05

1 COLUMN

32941 DR. REL.

CAD REF

onesteel whyalla steelworks

DATE : 18/10/04 SCALE: 1:400

		SIGNATURE
DRAWN	A B BERRY	
CHECKED		
REVIEWED		
C ENG	A.J.A.S.	

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147101 D

0 50 100

TRUE NORTH

PLANT NORTH
IRON DUKE STOCKPILE GRID

3800.000 mE

3750.000 mE

3700.000 mE

5350.000 mN

5300.000 mN

5250.000 mN

5200.000 mN

CONCENTRATE SLURRY PUMP STATION (EXISTING)

2-BS-001 (EXISTING)

2-BS-007 (EXISTING)

EXISTING PIPERACK CO-ORDINATES
5263.506 N
3783.050 E

EXISTING PIPE/CABLE RACK

EXISTING BURIED WATER PIPE

EXISTING EARTH PIT

TRENCH-U/G LV CABLES

TRENCH-U/G HV CABLES

TRENCH-U/G LV CABLES

5326.756 N
3758.740 E

SWITCHROOM
2-BS-009

RL 181.600

5304.756 N
3756.800 E

CONTRACTOR TO ESTABLISH LOCATION OF ANODE BED

FUTURE

EXISTING U/G SERVICES

4000 CLEAR

FOR MEP PIPE RACK
REFER DRG 190736

5268.750 N
3745.300 E

5266.256 N
3736.000 E

FOR WATER SERVICES AREA
GENERAL ARRGT. DRG
REFER 190786

FOR RAW WATER AREA MODIFICATIONS REFER DRG 147183

2-TK-041
RAW WATER TANK
(EXISTING)

2-BS-005
(EXISTING)

FOR PROCESS WATER AREA MODIFICATIONS REFER DRG 190937

2-TR-002
CONCENTRATE THICKENER
(EXISTING)

2-TK-042
PROCESS WATER TANK
(EXISTING)

2-TR-003
TAILINGS THICKENER
(EXISTING)

FOR CMS TAILS TRANSFER TANK GA REFER DRG 190837

CMS

RMS

2x NEW RMS

DIMS

RMS

CONTROL ROOM (EXISTING)

FOR EXISTING MAGNETIC SEPERATION AREA REFER DRG 147147

NEW CYCLONE FEED PUMPS

FOR BALL MILL AREA GENERAL ARRG'T REFER DRG 147159

NEW THICKENER DEAERATION TANK & STRUCTURE (BY OTHERS)

EXTEND HARDSTAND FOR CYCLONE FEED PUMP ACCESS

MATCHLINE REFER DRG 147101

FINE GRINDING MEDIA STORAGE

FUTURE FINE GRINDING AREA

5338.756 N
3741.300 E

RL 180.000

5312.606 N
3739.800 E

FUTURE FINE SCREENING AREA

FOR FINE SCREENING AREA
GENERAL ARRGT. DRG
REFER 190752

FOR FINE GRINDING AREA
GENERAL ARRGT. DRG
REFER XSTRATA DRG
PM044-XT-0-402-2-0601
&ARRIUM DRGS 190828,
191140,191141

RAW/FIRE WATER O/FLOW DRAIN

EXISTING COARSE TAILINGS TOWER

FOR COARSE TAILS MODIFICATIONS DRG REFER 191031

No. OFF	ITEM	MARK No.	DESCRIPTION	MATERIAL

No. OFF	MARK No.	DESCRIPTION	MATERIAL	MASS/UNIT	REMARKS
	LOCATION	SOUTH MIDDLEBACK RANGES MAGNETITE CONCENTRATOR EXPANSION 2013 CONCENTRATOR LAYOUT PLOT PLAN			
1	COLUMN				

147101	CONCENTRATOR AREA GENERAL ARRANGEMENT
REF. DRAWING NUMBER	DESCRIPTION

GR ENGINEERING SERVICES LTD
ENGINEERING CONSULTANTS AND CONTRACTORS
179 Great Eastern Highway, Belmont ACN 121 542 738
Western Australia, 6104
Phone: (08) 6272 6000
Fax: (08) 6272 6001

LEIGHTON

LEIGHTON REF. NO.
V1576-GN-GN-DR-0002

CONSULTANTS REF. NO.
-

Issue	Description	Date	Drawn	Checked	Design	Eng. Approved	Project Approved
A	ISSUED FOR MEP REGISTRATION	24.7.13	KLL	PD	ADR	DST	SP

MEX-00896 DR. REL.

CAD REF

DATE :18.1.13 SCALE: 1:250

	NAME	SIGNATURE
DRAWN		
CHECKED		
REVIEWED		
AREA MANAGER		

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190745 A

0 50 100

CUTTING LINE

STOCKPILE

MOBILE FEED HOPPER

APRON FEEDER

RAW FEED BIN

101

PLANT FEED BIN

102

HIGH PRESSURE GRINDING ROLLS

PROCESS WATER

104

110

HPGR SCREEN

112

205

ROUGHER MAGNETIC SEPARATION (RMS)

207

RMS CONCENTRATE HOPPER

RMS CONCENTRATE PUMP

CYCLONE CLUSTERS

303

PROCESS WATER

402

403

DESLIME INTERMEDIATE MAGNETIC SEPARATION (DIMS)

DIMS CONCENTRATE TANK & AGITATOR

FINE GRINDING PRESCREEN

BYPASS

XXX

506

501

FINES GRINDING MILL

FINE SCREENING

610

614

TAILS CYCLONE

1006

1004

DEWATERING SCREEN

1011

1009

TRUCK TO TSF

304

301

816

PROCESS WATER

819

RAW WATER

818

CLEANER MAGNETIC SEPARATION (CMS)

CONCENTRATE THICKENER

901

TO PRODUCT STORAGE

902

MAKE-UP WATER

002

404

PROCESS WATER

302

817

TAILS THICKENER

1017

1016

TO TSF

003

RECYCLE TO PLANT

PROCESS WATER STORAGE TANK

BALL MILL

NOTES:
1. REFER TO DOCUMENT MEX – 00405 FOR STREAM NUMBERS

REF. DRAWING NUMBER	DESCRIPTION

THIESS PTY LTD
A.B.N. 87 010 221 486
LEVEL 13 / 225 ST. GEORGES TERRACE, PERTH WA 6000
PHONE (08) 9214 4200 FACSIMILE (08) 9214 4244

ProMet Engineers Pty Ltd
267 ST. GEORGES TERRACE, PERTH WA 6000
PHONE (08) 9476 5700
FACSIMILE (08) 9476 5710

THIESS REF. NO.
904006-10-G02-20001

CONSULTANT REF. NO.
V1576-GN-PR-DR-0002

REV	DESCRIPTION	BY	DATE
F	ISSUED FOR MEP REGISTRATION – MEX927	LJH	22.4.13
E	SCREEN ADDED (DR35503)	C.D.	7.5.09
D	ISSUED FOR ONESTEEL DRAWING REGISTRATION	D.M	24/9/07
C	MINOR TEXT CHANGE	JB	24.8.06
J	MEP AS BUILT	LJH	31.01.14
H	MODIFIED FOR FINE GRINDING PRESCREEN (MEP)	MK	17.01.14

Date	Drawn	Checked	Design	Eng Approval	Project Approval
17.1.14	MK	SON	SON	ADR	SP

No. OFF	MARK No.	DESCRIPTION	MATERIAL	MASS/UNIT	REMARKS
	LOCATION	PROJECT MAGNET MAGNETITE CONCENTRATOR PROCESS FLOW DIAGRAM OVERALL			
1	COLUMN				
32940	DR. REL.				
CAD REF					

onesteel whyalla steelworks

DATE : 15/10/04 SCALE: NTS

	NAME	SIGNATURE
DRAWN	JB	
CHECKED	RCP	
REVIEWED		
C ENG	AJAS	

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146601 F

0 50 100

Appendix F

TSF Master Plan construction sequence

Table F1 Magnetite TSF Master Plan Sequence and Strategy (Golder 2014a)

Year	Phase	Month	Tailings Deposition Location	Estimated Storage Volume at location (m3)	Estimated Months of Storage	Construction Zones	Dormant 'Drying' Tailings Area	Water Recovery Location
Year 1	Phase 2-6	1	Northern Embankment, Wing wall Voids and Southern Embankment	1,033,000	5		Southern Embankment	Southern Gravity Decant Tower
		2					Northern Embankment/ Wing wall Voids	Wing wall Void Decants
		3				Central Access Road		
		4				Northern Embankment		
		5				Western Embankment		
	Phase 7a	6	Northern Embankment	530,000	3		Southern Embankment	Central Causeway Decant
		7						
		8						
		9	Western Embankment	388,000	2		Northern Embankment	Wing wall Void Decants
		10				Southern Embankment		
Year 2		11	Southern Embankment	561,000	3	Northern Embankment and Central Access Road	Western Embankment	Central Causeway Decant
		12						
		13						
	Phase 7b	14	Northern Portion of Ring Main Embankment	683,000	4	Western Embankment	Southern Embankment	Central Causeway Decant
		15						
		16						

Year	Phase	Month	Tailings Deposition Location	Estimated Storage Volume at location (m3)	Estimated Months of Storage	Construction Zones	Dormant 'Drying' Tailings Area	Water Recovery Location
		17				Southern Embankment & Ring Main Embankment		
		18	Western Embankment	419,000	2	Central Access Road & Northern Embankment	Northern Embankment	Buttress Decant Towers
		19						
		20	Southern Embankment and Ring Main Embankment	315,000	2		Western Embankment	Central Causeway Decant
		21				Western Embankment		
	Phase 7c	22	Northern Embankment and Ring Main Embankment	373,000	2		Southern Embankment	Central Causeway Decant
		23						
		24	Western Embankment	940,000	5		Northern Embankment	Central Causeway Decant
		25						
		26						
Year 3		27						
		28				Southern Embankment		
		29	Southern Portion of Ring Main Embankment	611,000	3		Western Embankment	Central Causeway Decant
		30				North Western Embankment		
		31						
		32	North Western Embankment	566,000	3		Southern Embankment	Central Causeway Decant
	Phase 7d	33						
		34				South Western Embankment		
		35	South Western Embankment	673,000	4		North Western Embankment	Central Causeway Decant
		36						
		37				North Western Embankment		
Year 4		38						
		39	North Western Embankment	686,000	4		South Western Embankment	Central Causeway Decant
	Phase 7e	40						
		41				Southern Embankment		

Year	Phase	Month	Tailings Deposition Location	Estimated Storage Volume at location (m3)	Estimated Months of Storage	Construction Zones	Dormant 'Drying' Tailings Area	Water Recovery Location
		42	South Western Embankment	987,000	5		North Western Embankment	Central Causeway Decant
		43						
		44						
		45						
		46				North Western Embankment		
		47						
Year 5	Phase 7f	48	North Western Embankment	1,000,000	5		South Western Embankment	Central Causeway Decant
		49						
		50						
		51				South Western Embankment		
		52						
		53	South Western Embankment	1,300,000	8		North Western Embankment	Central Causeway Decant
		54						
		55						
		56						
		57						
		58						
		59				Next Stage of TSF Design		
		60						