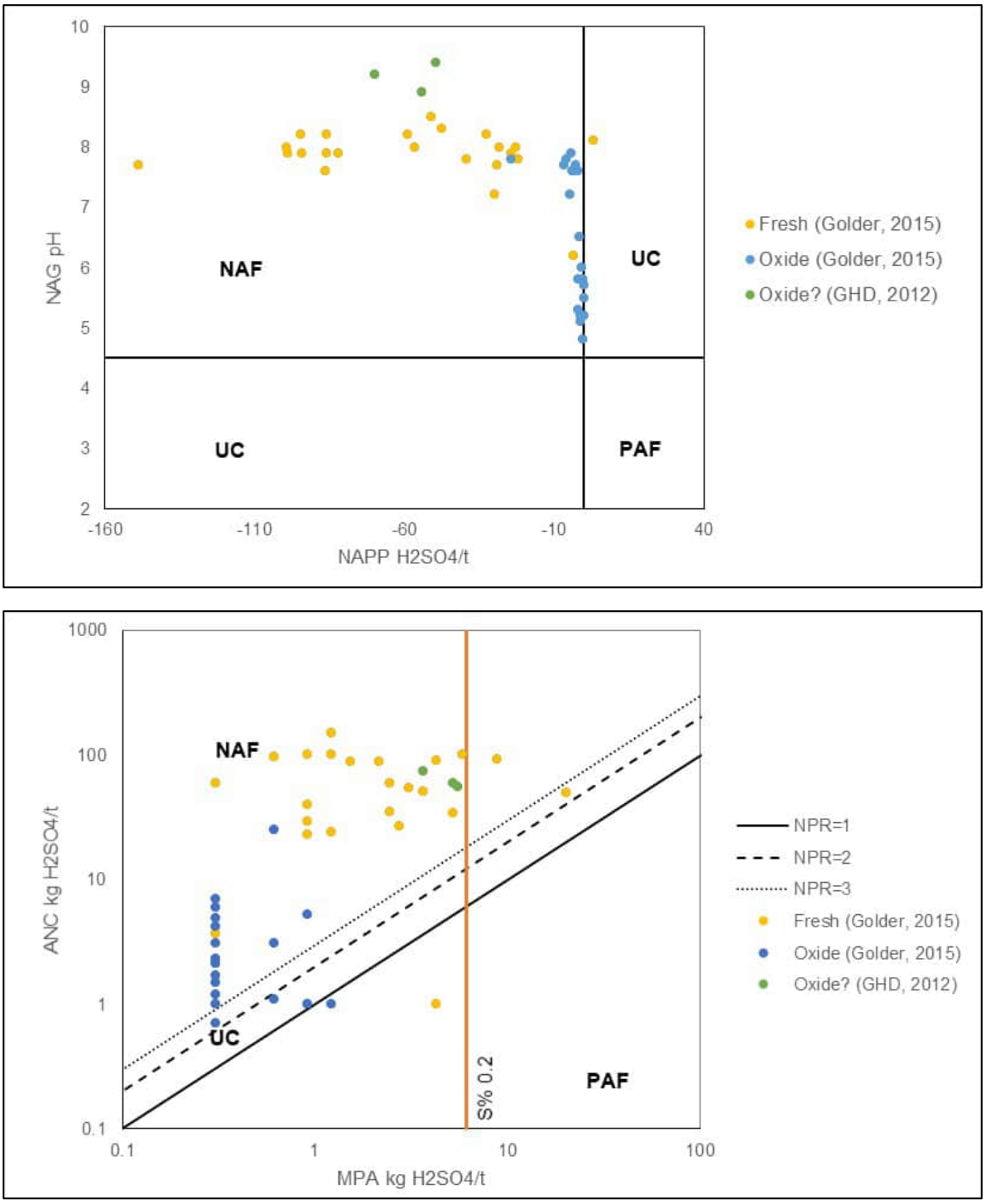


Figure 7-1: Tailings AMD classification according to AMIRA (top) and MEND (bottom)

7.5 Potential for contaminant leaching

7.5.1 Metal and metalloid content

A small number of samples have been submitted for elemental analyses; for each tailings category, selected results are presented in Table 7-4. Within the current datasets, GAI values for only cadmium and manganese are indicative of significant enrichment relative to average crustal abundance. As noted previously, high GAI values do not necessarily indicate high leachability (leachability is discussed in the next subsection).

Table 7-4: Tailings characterisation: Metal content and global abundance indices – selected elements only

Source	Average crustal abundance (ppm)[1]	Fresh	Oxide	Oxide?
		Golder (2015)	Golder (2015)	GHD (2012)
Count		3	3	3
		Maximum (ppm) (GAI in parentheses)		
As	1.5	10 (2)	<10 (1[2])	7 (1)
Cd	0.11	<0.5 (1[2])	<0.5 (1[2])	2 (3)
Cr	100	460 (0)	150 (0)	48 (0)
Cu	50	24 (0)	30 (0)	62 (0)
Mn	950	4,600 (1)	12,000 (3)	6,580 (2)
Ni	80	190 (0)	58 (0)	47 (0)
Pb	14	19 (0)	14 (0)	6 (0)
Zn	75	98 (0)	<50 (0)	30 (0)

GAI - Global Abundance Index

Notes:

[1] Crustal averages from Bowen, 1979.

[2] GAI was calculated on basis of the detection limit and is therefore an overestimate.

7.5.2 Contaminant leachability

Contact tests were performed using de-ionised water, acetic acid or peroxide as a leachant (GHD, 2012; Golder, 2015). One sample was submitted for kinetic (column) testing (GHD, 2014).

Irrespective of the leachant or methodology adopted, final leachate pH values were typically in the near-neutral to mildly alkaline range (consistent with the NAF classification of the tailings materials, Section 7.4). Dissolved concentrations of most metals and metalloids were at or close to method detection limits. Such an outcome is consistent with expectation for leaching under these pH conditions, due to the combination of low mineral solubility and strong adsorption to mineral surfaces.

For selected metals and metalloids, maximum dissolved concentrations are presented in Table 7-5, and generally remain low. Higher maximum concentrations are noted for leaching with acetic acid – particularly notable in the case of manganese – probably reflecting a combination of lower final pH values and formation of complexes with acetic acid ligands.

Table 7-5: Maximum dissolved concentrations (mg/L) in leach testing – by leachant

Parameter	DI leach	Column testing, first leach (DI)	Acetic acid	NAG liquor
Source	**GHD (2012) Golder (2015)**	**GHD (2014)**	**GHD (2012)**	**GHD (2012) Golder (2015)**
Tailings category	**Fresh and oxide**	**Oxide?**	**Oxide?**	**Fresh and oxide**
Count	**12**	**1**	**3**	**12**
pH range	7–9.85	9.9	5.4[2]	5.3–9.4
As	0.012	0.036	<0.005	0.004
Cd	<0.002	<0.0005	0.001	<0.002
Cr	0.01	0.003	<0.01	0.04
Cu	0.08	0.008	0.05	0.004
Mn	0.35	0.113	22.2	1
Ni	0.019	0.002	0.03	0.004
Pb	0.001	<0.0005	<0.01	0.011
Se	<0.01	0.013	<0.01	0.002
Zn	0.23	0.012	0.7	0.68

DI - de-ionised (water); NAG - net acid generation (test)

Notes:

[1] Dataset represents varied leach test conditions (e.g. test duration, solid: liquid ratio).

[2] All three tests gave the same pH in the final leachate.

8 Conclusions

IBO conducts ongoing geochemical characterisation of North Star mined materials. Available geochemical data and information has been reviewed herein and used to develop an understanding of the material properties and criteria for assessing the potential for AMD/NMD and contaminant leaching.

8.1 AMD potential

8.1.1 Waste rock and ore

The findings can be summarised as follows:

- Total sulfur content can be considered a reliable surrogate for acid potential within the materials. Sulfidic sulfur (pyrite, and small amounts of sphalerite) dominates sulfur speciation with little or no sulfate present.
- Measured ANC comprises a combination of carbonate and silicate mineral contributors. Readily available and effective carbonate-based ANC (calcium- and magnesium-bearing carbonates) is often less than 50% of the measured ANC. Ferrous carbonates (siderite, ankerite) are common but not considered effective neutralising minerals (under the oxidising conditions expected in waste rock dumps and ore stockpiles, ferrous iron is oxidised to ferric iron and precipitated to yield no net neutralising capacity).
- The calcium content (as CaO) is recommended as an approximate analytical surrogate for readily available ANC. Total inorganic carbon and magnesium are not considered reliable due to the presence of ferrous carbonates and magnesium silicates, respectively.
- Sulfur content and ANC are consistently lower in oxidised, weathered material than in fresh material.
- Acid-base accounting and NAG testing showed that a minority of samples (between 20% and 25% of waste rock, and less than 10% of ore) classified as PAF (i.e. based on positive NAPP values, NPRs <1, or measured acidity in NAG tests).
- A greater number of samples classed as PAF originated from the KCF lithological unit, known to host pyritic black shale horizons.
- The geochemical dataset for waste rock and ore was utilised to evaluate the AMIRA- and MEND-based approaches for AMD classification. Based on the combined classifications, a sulfur cut-off of 0.2% was shown to be effective in identifying NAF material.
- Both approaches were found to perform similarly; either could be applied to the waste rock. However, based on the available analytical data, the MEND approach can be more widely and easily implemented for forward planning.

8.1.2 Tailings products (wet and dry)

The conclusions based on the results for the tailings samples are as follows:

- Due to low total sulfur content, the tailings do not represent a significant potential source for AMD.
- The samples generated negligible acidity in NAG testing.

8.1.3 Recommended AMD classification criteria

The proposed approach and criteria for classifying waste rock are based on the MEND approach, as follows:

- Adopting an NPR threshold of greater than 3, or a sulfur cut-off of 0.2%, to indicate NAF material.
- NAF material with an NPR in excess of 3 and a sulfur content of greater than 0.2% may have the potential to generate NMD and should be identified as NAF_S.
- While an NPR of between 1 and 3 would conventionally be used to identify UC material, the UC material would be managed as PAF, thus negating the requirement for criteria to classify UC materials.

The NPR threshold and sulfur cut-off values are both conservative and will likely overestimate rather than underestimate the proportion of material to be handled as PAF. These threshold values should be verified, or re-evaluated, as more data become available, and the relationships between acid and neutralising potential become more established.

8.1.4 Block modelling and material management

Key conclusions from the block modelling results are as follows:

- Over a mining period 2021 to 2035, 171 Mbcm waste rock and 226 Mbcm ore will be mined.
- Using the recommended AMD classification approach:
  - 20% of the waste rock volume is classed as PAF, 6% as NAF_S, and 74% as NAF
  - 3% of the ore is PAF, 6% NAF_S and 91% NAF.
- The proportion of PAF and NAF_S waste rock to be mined may represent a risk of AMD and NMD, respectively, if not managed appropriately. IBO is therefore developing conceptual dump designs to mitigate those risks.

8.2 Contaminant leaching potential

The outcomes from leach extraction and column tests indicated the following:

- The main soluble mineral sources are inferred to be sodium- and magnesium-bearing salts. Carbonate minerals that are less soluble and less soluble silicate minerals also contribute solutes under neutral pH conditions. The major ions in leachates comprised Na, Mg and HCO_3.
- Leachate pH is considered a primary control on contaminant solubility and therefore leaching.
- Contaminant leaching under neutral pH conditions was found to be limited; in pH neutral leach extracts, the dissolved concentrations of most minor and trace elements were close to or below limits of detection.
- Contaminant leaching will increase with increasing acidic conditions that may result from sulfide mineral oxidation in PAF materials, confirming the need to manage these materials.

Project Number: FMG076

Report Title: North Star Magnetite Project Subsurface Materials Characterisation

Compiled by



Claire Linklater

Principal Geochemist

Peer reviewed by



John Chapman

Corporate Consultant

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Appendices

Appendix A: Detailed geochemical assessments

A1 Mineralogical Assessment

A2 Elemental Assays

A3 Acid-Base Accounting and Net Acid Generation Testing

A4 Short-term Leach Testing

A5 Kinetic (Column) Testing

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Source	Non-Ferrous Carbonates (ANC)	Calcite, syn	Calcite, magnesian	Magnesite	Dolomite	Ferrous Carbonates	Ankerite	Siderite	Iron Oxides (inc. ore minerals)	Goethite	Hematite	Hematite, syn	Magnetite	Magnetite, syn	Sulfates	Thenardite, syn	Other Oxides
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder	2.5%	2.5%				28%		28%	4.5%					4.5%	0.0%		0.0%
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder	2.6%	2.6%				29%		29%	6.8%					6.8%	0.0%		0.0%
AMD_6	NSRD0393	222.5	222.8	WP	Fresh	Golder	0.0%					28%	23%	5.2%	3.2%					3.2%	0.0%		0.0%
AMD_8	NSRD0393	226.7	227.1	WP	Fresh	Golder	0.0%					22%	8.3%	14%	0.0%						0.0%		0.0%
AMD # 015	NSRD0393	238.5	238.8	WP	Fresh	Golder	0.0%					1%	0.6%		0.0%						0.0%		0.0%
AMD # 023	NSRD0393	287.6	287.9	MP	Fresh	Golder	0.0%					5%	5.3%		0.0%						0.0%		0.0%
AMD # 029	NSRD0393	348.7	349	MP	Fresh	Golder	12%	4.9%		6.6%		20%	4.6%	16%	2.6%				2.6%		0.0%		0.0%
AMD # 033	NSRD0393	395.1	395.5	MP	Fresh	Golder	0.0%					0%			0.0%						0.0%		6.1%
AMD # 037	NSRD0393	422.7	423	MP	Fresh	Golder	0.0%					8.1%	4.9%	3.2%	0.0%						0.0%		0.0%
AMD # 043	NSRD0387	210.1	210.4	WP	Fresh	Golder	0.0%					26%	14%	13%	12%					12%	0.0%		0.0%
AMD # 049	NSRD0387	246.7	247	WP	Fresh	Golder	0.0%					19%		19%	9.2%					9.2%	0.0%		0.0%
AMD # 055	NSRD0387	306.9	307.3	WP	Fresh	Golder	0.0%					26%	6.5%	19%	17%					17%	0.0%		0.0%
AMD # 059	NSRD0387	340.2	340.6	WP	Fresh	Golder	0.0%					16%		16%	4.2%					4.2%	0.0%		0.0%
AMD66a	NSD0031	1	29.7	WP	Oxide	Golder	0.0%					0%			24%	19%		5.8%			0.0%		4.7%
AMD67a	NSD0031	37.48	63.08	WP	Fresh	Golder	0.0%					0%			24%	19%		5.8%			0.0%		4.7%
AMD79a	NSD0031	80.4	94.1	WP	Fresh	Golder	0.0%					13%		13%	8.0%					8.0%	0.0%		0.0%
AMD85	NSD0031	119	119.3	WP	Fresh	Golder	0.0%					25%		25%	1.0%					1.0%	0.0%		0.0%
AMD95	NSD0031	192.5	192.8	WP	Fresh	Golder	0.0%					3%		3.3%	19%					19%	0.0%		0.0%
AMD97	NSD0031	203	203.4	WP	Fresh	Golder	1.1%	1.1%				14%	2.7%	11%	8.7%					8.7%	0.0%		0.0%
AMD109a	NSD0032	35	68.3	WP	Fresh	Golder	0.0%					12%	7.7%	4.8%	21%		2.9%			18%	0.0%		0.0%
AMD118	NSD0032	112.8	113.2	WP	Fresh	Golder	1.2%			1.2%		1%		0.5%	0.0%						0.0%		0.0%
AMD121	NSD0032	126.8	127.2	WP	Fresh	Golder	0.0%					21%	16%	4.8%	2.3%					2.3%	0.0%		0.0%
AMD # 0131	NSD0031	298	298.3	WP	Fresh	Golder	0.0%					10%		10%	6.7%					6.7%	0.0%		0.0%
AMD # 0137	NSD0031	374.8	375.1	WP	Fresh	Golder	0.0%					11%	2.0%	9.2%	14%			6.2%	7.8%		0.0%		0.0%
AMD # 0143	NSD0031	437.8	438.1	WP	Fresh	Golder	0.0%					23%	3.3%	20%	14%				14%		0.0%		0.0%
AMD # 0151	NSD0032	255.7	256	WP	Fresh	Golder	0.0%					0%			8.7%				8.7%		3.3%	3.3%	0.0%
AMD # 0156	NSD0032	283.3	283.6	WP	Fresh	Golder	10%			5.5%	4.8%	12%		12%	6.3%				6.3%		0.0%		0.0%
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh	Golder	0.0%					29%		29%	4.9%				4.9%		0.0%		0.0%
AMD # 0167	NSD0032	343.7	344	WP	Fresh	Golder	0.0%					13%		13%	0.0%						0.0%		0.0%
AMD # 0169	NSD0032	356.5	356.8	WP	Fresh	Golder	0.0%					21%	5.4%	15%	0.0%						0.0%		0.0%
AMD # 0172	NSD0032	397.7	398	WP	Fresh	Golder	0.0%					55%		55%	0.0%						0.0%		0.0%
AMD # 0184	NS0572	42	48	KCF	Fresh	Golder	7.9%	7.9%				0%			0.0%						0.0%		0.0%
AMD # 0192	NS0572	90	96	KCF	Fresh	Golder	2.7%	2.7%				0%			0.0%						0.0%		0.0%
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder	0.0%					0%			0.0%						0.0%		0.0%
AMD # 0235	NS0576	18	24	KCF	Fresh	Golder	7.0%	7.0%				0.0%			0.0%						0.0%		0.0%
AMD # 0245	NS0576	78	84	KCF	Fresh	Golder	15.4%	15.4%				0.0%			0.0%						0.0%		0.0%
AMD # 0249	NS0576	102	108	KCF	Fresh	Golder	7.5%	7.5%				0.0%			0.0%						0.0%		0.0%
AMD # 0256	NS0576	144	150	KCF	Fresh	Golder	12.6%	12.6%				0.0%			0.0%						0.0%		0.0%
AMD # 0264	NS0576	192	198	KCF	Fresh	Golder	4.9%	3.6%	1.3%			0.0%			0.0%						0.0%		0.0%
AMD # 0271	NS0578	36	42	KCF	Fresh	Golder	12.6%	12.6%				0.0%			0.0%						0.0%		0.0%
AMD # 0277	NS0578	72	78	KCF	Fresh	Golder	0.0%					0.0%			1.9%			1.9%			0.0%		0.0%
AMD # 0285	NS0578	120	126	KCF	Fresh	Golder	0.0%					0.0%			0.0%						0.0%		0.0%
AMD # 0305	NS0580	42	48	KCF	Fresh	Golder	9.4%	9.4%				0.0%			0.0%						0.0%		0.0%
AMD # 0314	NS0580	96	102	KCF	Fresh	Golder	0.0%					0.0%			0.0%						0.0%		0.0%
AMD # 0322	NS0580	144	150	KCF	Fresh	Golder	0.0%					0.0%			0.0%						0.0%		0.0%
AMD # 0327	NS0580	174	180	KCF	Fresh	Golder	0.0%					13.9%		14%	0.0%						0.0%		0.0%
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder	0.0%					0.0%			0.0%						0.0%		0.0%

Italics denote a duplicate

ICDD=International Centre for Diffraction Data

ICDD Match probablity "Good"
ICDD Match probablity "Medium"
ICDD Match probablity "Poor"

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Source	Hollandite	Chromite, syn	Jacobsite, syn	Sulfides	Pyrite	Sphalerite, ferroan, syn	Silicates (ex. Quartz)	Albite	Actinolite	Almandine, manganoan	Andradite	Anorthite, sodian	Biotite	Biotite-1M	Braunite-1Q	Chamosite-1Mllb	Chamosite-1A, magnesian
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder				0.0%			7.9%										
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder				0.0%			7.9%										
AMD_6	NSRD0393	222.5	222.8	WP	Fresh	Golder				0.0%			28%										
AMD_8	NSRD0393	226.7	227.1	WP	Fresh	Golder				0.0%			27%										
AMD # 015	NSRD0393	238.5	238.8	WP	Fresh	Golder				0.0%			47%									32%	
AMD # 023	NSRD0393	287.6	287.9	MP	Fresh	Golder				0.0%			66%										
AMD # 029	NSRD0393	348.7	349	MP	Fresh	Golder				0.0%			31%							1.5%		17%	
AMD # 033	NSRD0393	395.1	395.5	MP	Fresh	Golder			6.1%	1.0%	1.0%		48%						3.8%			35%	
AMD # 037	NSRD0393	422.7	423	MP	Fresh	Golder				0.0%			60%										
AMD # 043	NSRD0387	210.1	210.4	WP	Fresh	Golder				0.0%			14%										
AMD # 049	NSRD0387	246.7	247	WP	Fresh	Golder				0.0%			18%			6.0%							
AMD # 055	NSRD0387	306.9	307.3	WP	Fresh	Golder				0.0%			17%										
AMD # 059	NSRD0387	340.2	340.6	WP	Fresh	Golder				0.0%			30%										
AMD66a	NSD0031	1	29.7	WP	Oxide	Golder		4.7%		0.0%			0%										
AMD67a	NSD0031	37.48	63.08	WP	Fresh	Golder		4.7%		0.0%			0%										
AMD79a	NSD0031	80.4	94.1	WP	Fresh	Golder				0.0%			32%									24%	
AMD85	NSD0031	119	119.3	WP	Fresh	Golder				0.0%			51%										
AMD95	NSD0031	192.5	192.8	WP	Fresh	Golder				0.0%			25%									8.4%	
AMD97	NSD0031	203	203.4	WP	Fresh	Golder				0.0%			9%										
AMD109a	NSD0032	35	68.3	WP	Fresh	Golder				0.0%			26%										
AMD118	NSD0032	112.8	113.2	WP	Fresh	Golder				0.0%			78%										
AMD121	NSD0032	126.8	127.2	WP	Fresh	Golder				0.0%			3%										
AMD # 0131	NSD0031	298	298.3	WP	Fresh	Golder				0.0%			41%									21%	
AMD # 0137	NSD0031	374.8	375.1	WP	Fresh	Golder				0.0%			9%	7.4%									
AMD # 0143	NSD0031	437.8	438.1	WP	Fresh	Golder				0.0%			11%	2.7%									
AMD # 0151	NSD0032	255.7	256	WP	Fresh	Golder				5.6%	5.6%		63%					2.1%					
AMD # 0156	NSD0032	283.3	283.6	WP	Fresh	Golder				0.0%			44%										
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh	Golder				0.0%			47%										
AMD # 0167	NSD0032	343.7	344	WP	Fresh	Golder				0.0%			47%										
AMD # 0169	NSD0032	356.5	356.8	WP	Fresh	Golder				0.0%			36%										
AMD # 0172	NSD0032	397.7	398	WP	Fresh	Golder				0.5%	0.5%		10%										3.5%
AMD # 0184	NS0572	42	48	KCF	Fresh	Golder				0.0%			77%	47%									
AMD # 0192	NS0572	90	96	KCF	Fresh	Golder				0.7%	0.7%		75%	35%									
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder				0.0%			62%	18%								19%	
AMD # 0235	NS0576	18	24	KCF	Fresh	Golder				1.2%	1.2%		75%	56%								17%	
AMD # 0245	NS0576	78	84	KCF	Fresh	Golder				0.0%			23%								2.9%	20%	
AMD # 0249	NS0576	102	108	KCF	Fresh	Golder				3.0%	3.0%		27%										
AMD # 0256	NS0576	144	150	KCF	Fresh	Golder				0.0%			65%	40%	8.0%								
AMD # 0264	NS0576	192	198	KCF	Fresh	Golder				0.0%			81%	46%	11%								
AMD # 0271	NS0578	36	42	KCF	Fresh	Golder				0.0%			65%	40%	8.0%								
AMD # 0277	NS0578	72	78	KCF	Fresh	Golder				0.0%			31%										
AMD # 0285	NS0578	120	126	KCF	Fresh	Golder				4.7%	4.7%		36%										
AMD # 0305	NS0580	42	48	KCF	Fresh	Golder				0.4%		0.4%	51%	31%									
AMD # 0314	NS0580	96	102	KCF	Fresh	Golder				0.0%			56%				1.1%						
AMD # 0322	NS0580	144	150	KCF	Fresh	Golder				1.5%	1.5%		60%				0.6%					52%	
AMD # 0327	NS0580	174	180	KCF	Fresh	Golder				1.5%	1.5%		29%										
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder				1.3%	1.3%		55%	20%									

Italics denote a duplicate

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ICDD Match probablity "Good"
ICDD Match probablity "Medium"
ICDD Match probablity "Poor"

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Source	Clinochlore-2Mlib	Clinochlore (ferroan)	Clinochlore-1Mlib, ferrian	Cronstedtite	Cronstedtite-1T	Dickite-2M1	Greenalite-1T	Grossular, manganoan	Grossmanite	Illite	Illite-2M2	Microcline	Microcline, intermediate	Muscovite 2M1, syn	Stilpnomelane	Clays
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder															7.9%	6.5%
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder															7.9%	2.8%
AMD_6	NSRD0393	222.5	222.8	WP	Fresh	Golder					7.0%										21%	0.0%
AMD_8	NSRD0393	226.7	227.1	WP	Fresh	Golder				13%											14%	0.0%
AMD # 015	NSRD0393	238.5	238.8	WP	Fresh	Golder													9.4%		5.3%	0.0%
AMD # 023	NSRD0393	287.6	287.9	MP	Fresh	Golder			45%										14%		7.0%	0.0%
AMD # 029	NSRD0393	348.7	349	MP	Fresh	Golder															12%	0.0%
AMD # 033	NSRD0393	395.1	395.5	MP	Fresh	Golder													10%			0.0%
AMD # 037	NSRD0393	422.7	423	MP	Fresh	Golder		53%											1.4%		5.5%	0.0%
AMD # 043	NSRD0387	210.1	210.4	WP	Fresh	Golder															14%	0.0%
AMD # 049	NSRD0387	246.7	247	WP	Fresh	Golder															12%	0.0%
AMD # 055	NSRD0387	306.9	307.3	WP	Fresh	Golder															17%	0.0%
AMD # 059	NSRD0387	340.2	340.6	WP	Fresh	Golder							10%								20%	18%
AMD66a	NSD0031	1	29.7	WP	Oxide	Golder																3.2%
AMD67a	NSD0031	37.48	63.08	WP	Fresh	Golder																3.2%
AMD79a	NSD0031	80.4	94.1	WP	Fresh	Golder															7.8%	0.0%
AMD85	NSD0031	119	119.3	WP	Fresh	Golder			42%												9.1%	0.0%
AMD95	NSD0031	192.5	192.8	WP	Fresh	Golder															17%	0.0%
AMD97	NSD0031	203	203.4	WP	Fresh	Golder															9%	2.5%
AMD109a	NSD0032	35	68.3	WP	Fresh	Golder	6.8%											6.0%			14%	0.0%
AMD118	NSD0032	112.8	113.2	WP	Fresh	Golder			59%					2.5%							17%	0.0%
AMD121	NSD0032	126.8	127.2	WP	Fresh	Golder															3.2%	0.0%
AMD # 0131	NSD0031	298	298.3	WP	Fresh	Golder															21%	0.0%
AMD # 0137	NSD0031	374.8	375.1	WP	Fresh	Golder												1.4%				0.0%
AMD # 0143	NSD0031	437.8	438.1	WP	Fresh	Golder														8.5%		0.0%
AMD # 0151	NSD0032	255.7	256	WP	Fresh	Golder		52%													9.1%	0.0%
AMD # 0156	NSD0032	283.3	283.6	WP	Fresh	Golder		19%													26%	0.0%
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh	Golder		23%													24%	0.0%
AMD # 0167	NSD0032	343.7	344	WP	Fresh	Golder		38%													9.1%	0.0%
AMD # 0169	NSD0032	356.5	356.8	WP	Fresh	Golder		18%													19%	0.0%
AMD # 0172	NSD0032	397.7	398	WP	Fresh	Golder														6.5%		0.0%
AMD # 0184	NS0572	42	48	KCF	Fresh	Golder		23%							2.4%						5.1%	0.0%
AMD # 0192	NS0572	90	96	KCF	Fresh	Golder			40%													0.0%
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder			24%													0.0%
AMD # 0235	NS0576	18	24	KCF	Fresh	Golder															2.1%	0.0%
AMD # 0245	NS0576	78	84	KCF	Fresh	Golder																0.0%
AMD # 0249	NS0576	102	108	KCF	Fresh	Golder			21%								6.3%					0.0%
AMD # 0256	NS0576	144	150	KCF	Fresh	Golder			17%													0.0%
AMD # 0264	NS0576	192	198	KCF	Fresh	Golder			23%													0.0%
AMD # 0271	NS0578	36	42	KCF	Fresh	Golder			17%													0.0%
AMD # 0277	NS0578	72	78	KCF	Fresh	Golder			16%			5.2%					9.7%					0.0%
AMD # 0285	NS0578	120	126	KCF	Fresh	Golder		23%												12%		0.0%
AMD # 0305	NS0580	42	48	KCF	Fresh	Golder			20%													0.0%
AMD # 0314	NS0580	96	102	KCF	Fresh	Golder			44%							2.9%				8.3%		0.0%
AMD # 0322	NS0580	144	150	KCF	Fresh	Golder														6.5%		0.0%
AMD # 0327	NS0580	174	180	KCF	Fresh	Golder			20%											9.0%		0.0%
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder			35%													0.0%

Italics denote a duplicate

ICDD=International Centre for Diffraction Data

ICDD Match probablity "Good"
ICDD Match probablity "Medium"
ICDD Match probablity "Poor"

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Source	Kaolinite-1A	Quartz	Quartz	Quartz, low	Quartz, syn	Total
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder	6.5%	51%	51%			100%
AMD_3	NSRD0393	203	203.2	WP	Fresh	Golder	2.8%	51%	51%			100%
AMD_6	NSRD0393	222.5	222.8	WP	Fresh	Golder		41%	41%			100%
AMD_8	NSRD0393	226.7	227.1	WP	Fresh	Golder		50%			50%	100%
AMD # 015	NSRD0393	238.5	238.8	WP	Fresh	Golder		53%			53%	100%
AMD # 023	NSRD0393	287.6	287.9	MP	Fresh	Golder		28%			28%	100%
AMD # 029	NSRD0393	348.7	349	MP	Fresh	Golder		34%			34%	100%
AMD # 033	NSRD0393	395.1	395.5	MP	Fresh	Golder		44%			44%	100%
AMD # 037	NSRD0393	422.7	423	MP	Fresh	Golder		32%		32%		100%
AMD # 043	NSRD0387	210.1	210.4	WP	Fresh	Golder		48%			48%	100%
AMD # 049	NSRD0387	246.7	247	WP	Fresh	Golder		44%			44%	91%
AMD # 055	NSRD0387	306.9	307.3	WP	Fresh	Golder		41%			41%	100%
AMD # 059	NSRD0387	340.2	340.6	WP	Fresh	Golder	18%	32%			32%	100%
AMD66a	NSD0031	1	29.7	WP	Oxide	Golder	3.2%	68%			68%	100%
AMD67a	NSD0031	37.48	63.08	WP	Fresh	Golder	3.2%	68%			68%	100%
AMD79a	NSD0031	80.4	94.1	WP	Fresh	Golder		47%			47%	100%
AMD85	NSD0031	119	119.3	WP	Fresh	Golder		23%			23%	100%
AMD95	NSD0031	192.5	192.8	WP	Fresh	Golder		52%			52%	100%
AMD97	NSD0031	203	203.4	WP	Fresh	Golder	2.5%	65%			65%	100%
AMD109a	NSD0032	35	68.3	WP	Fresh	Golder		40%			40%	100%
AMD118	NSD0032	112.8	113.2	WP	Fresh	Golder		20%	20%			100%
AMD121	NSD0032	126.8	127.2	WP	Fresh	Golder		74%			74%	100%
AMD # 0131	NSD0031	298	298.3	WP	Fresh	Golder		42%		42%		100%
AMD # 0137	NSD0031	374.8	375.1	WP	Fresh	Golder		66%			66%	100%
AMD # 0143	NSD0031	437.8	438.1	WP	Fresh	Golder		52%			52%	100%
AMD # 0151	NSD0032	255.7	256	WP	Fresh	Golder		20%			20%	100%
AMD # 0156	NSD0032	283.3	283.6	WP	Fresh	Golder		27%			27%	100%
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh	Golder		19%			19%	100%
AMD # 0167	NSD0032	343.7	344	WP	Fresh	Golder		40%			40%	100%
AMD # 0169	NSD0032	356.5	356.8	WP	Fresh	Golder		43%			43%	100%
AMD # 0172	NSD0032	397.7	398	WP	Fresh	Golder		35%			35%	100%
AMD # 0184	NS0572	42	48	KCF	Fresh	Golder		15%	15%			100%
AMD # 0192	NS0572	90	96	KCF	Fresh	Golder		21%	21%			100%
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder		38%	38%			100%
AMD # 0235	NS0576	18	24	KCF	Fresh	Golder		17%	17%			100%
AMD # 0245	NS0576	78	84	KCF	Fresh	Golder		61%	61%			100%
AMD # 0249	NS0576	102	108	KCF	Fresh	Golder		63%			63%	100%
AMD # 0256	NS0576	144	150	KCF	Fresh	Golder		22%	22%			100%
AMD # 0264	NS0576	192	198	KCF	Fresh	Golder		14%			14%	100%
AMD # 0271	NS0578	36	42	KCF	Fresh	Golder		22%	22%			100%
AMD # 0277	NS0578	72	78	KCF	Fresh	Golder		67%	67%			100%
AMD # 0285	NS0578	120	126	KCF	Fresh	Golder		60%	60%			100%
AMD # 0305	NS0580	42	48	KCF	Fresh	Golder		39%	39%			100%
AMD # 0314	NS0580	96	102	KCF	Fresh	Golder		44%	44%			100%
AMD # 0322	NS0580	144	150	KCF	Fresh	Golder		39%	39%			100%
AMD # 0327	NS0580	174	180	KCF	Fresh	Golder		56%			56%	100%
AMD # 0217	NS0574	42	48	KCF	Fresh	Golder		44%			44%	100%

Italics denote a duplicate

ICDD=International Centre for Diffraction Data

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Ag	Al	As	B	Ba	Be	Ca	Cd	Cl	Cr	Co	Cs	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
E391634	NS0028	130	132	WP	Fresh		Worley Parsons		15500	51	90	<10	1		7		188	13		15	194000	0.5				3760	<2		86
E391635	NS0028	132	134	WP	Fresh		Worley Parsons		34000	83	80	10	1		6		473	18		14	182000	0.4				2360	<2		132
E391651	NS0028	164	166	WP	Fresh		Worley Parsons		32600	35	70	<10	<1		5		387	20		46	160000	0.8				1370	<2		162
E391663-E391669	NS0028	188	202	WP	Fresh		Worley Parsons		27400	29	100	<10	2		8		354	16		24	206000	0.3				2540	<2		114
E391703	NS0028	266	268	KCF	Fresh		Worley Parsons		5410	10	80	20	1		6		57	5		6	183000	0.2				2620	<2		33
E392752-E392753	NS0039	110	114	MP	Fresh		Worley Parsons		19400	20	70	50	2		3		526	35		54	114000	1.3				1680	<2		198
E392781-E392784	NS0039	168	176	MP	Fresh		Worley Parsons		14000	13	80	80	2		5		182	15		26	152000	0.4				2750	<2		82
E395043	NS0050	82	84	MP	Fresh		Worley Parsons		43500	<5	70	<10	1		3		723	36		45	122000	0.3				618	<2		278
E396265	NS0057	88	90	MP	Fresh		Worley Parsons		5410	<5	70	50	1		3		42	7		16	112000	0.2				1860	<2		36
E396342	NS0057	240	242	MP	Fresh		Worley Parsons		9090	7	80	100	2		4		71	12		20	146000	0.4				2780	<2		61
E396454-E396456	NS0058	178	184	KCF	Fresh		Worley Parsons		21200	31	70	<10	<1		5		242	28		48	152000	0.7				1950	<2		170
E396459-E396460	NS0058	188	192	KCF	Fresh		Worley Parsons		17900	58	60	20	1		3		271	61		79	96800	1.1				574	<2		343
E889501	NS0077	0	4	WP	Oxide	Waste	GHD		4500	<5		<10	<1	290	2		49	<2		<5	111000	<0.1				36			13
E889505	NS0077	8	12	WP	Oxide	Waste	GHD		3630	<5		10	1	230	1		45	<2		<5	93800	<0.1				85			16
E889511	NS0077	20	24	WP	Oxide	Ore	GHD		2390	<5		290	<1	490	<1		12	15		<5	38700	<0.1				4840			18
E889515	NS0077	28	32	WP	Oxide	Ore	GHD		3320	<5		120	<1	1000	<1		9	7		<5	38000	<0.1				7830			30
E889591	NS0077	178	182	WP	Fresh	Waste	GHD		15500	35		60	1	2630	2		177	25		28	131000	0.6				3540			119
E889643	NS0078	0	4	WP	Oxide	Waste	GHD		4990	<5		20	<1	140	1		54	<2		<5	98500	<0.1				59			16
E889648	NS0078	8	12	WP	Oxide	Waste	GHD		2770	<5		<10	<1	120	<1		60	<2		<5	63900	<0.1				34			8
E889653	NS0078	18	24	WP	Oxide	Ore	GHD		11900	<5		90	1	3610	1		94	5		7	84400	<0.1				142			45
E889657	NS0078	26	32	WP	Oxide	Waste	GHD		10500	<5		60	<1	3150	<1		94	6		6	66500	<0.1				186			55
E889673	NS0078	58	64	WP	Fresh	Ore	GHD		2640	<5		30	0.5	11000	2		16	3		9	107000	0.3				2320			19
E889683	NS0078	78	80	WP	Fresh	Waste	GHD		2340	<5		20	0.5	3720	2		14	<2		6	93700	0.2				1810			16
E889697	NS0078	106	108	WP	Fresh	Waste	GHD		1130	<5		10	1	6110	3		12	<2		<5	154000	0.3				2300			10
E889723	NS0078	158	162	WP	Fresh	Waste	GHD		3120	13		40	1	4620	2		28	7		24	121000	0.4				2210			23
E889781	NS0078	274	278	WP	Fresh	Waste	GHD		11500	18		70	2	2040	2		137	13		19	132000	0.6				2940			72
E889809	NS0079	48	52	WP	Fresh	Ore	GHD		12200	7		20	1	3610	5		78	12		13	184000	0.2				3980			69
E889833	NS0079	94	98	WP	Fresh	Ore	GHD		8220	16		40	1	3130	4		82	12		16	219000	0.4				3800			56
X068310	NS0083	28	30	MP	Oxide	Waste	GHD		9710	<5		30	<1	3130	<1		243	6		14	52600	<0.1				73			72
X068342	NS0083	88	92	MP	Fresh	Waste	GHD		9160	8		60	2	13800	2		158	14		23	110000	0.1				1700			80
X068364	NS0083	130	134	MP	Fresh	Waste	GHD		12800	7		70	2	3030	2		272	17		26	117000	0.1				1760			106
X068378	NS0083	158	162	MP	Fresh	Waste	GHD		15300	6		60	2	7920	2		332	19		36	123000	0.1				1320			121
X068517	NS0084	140	144	WP	Fresh	Waste	GHD		6030	15		60	1	3860	2		28	13		12	116000	0.4				2810			44
X068527	NS0084	158	162	WP	Fresh	Waste	GHD		33100	22		<10	1	510	2		401	28		31	123000	0.4				1050			194
X068544	NS0084	190	194	WP	Fresh	Ore	GHD		4990	<5		30	<1	7150	1		21	6		8	102000	<0.1				4700			28
X068586	NS0084	270	274	WP	Fresh	Ore	GHD		12400	8		50	1	4200	2		66	14		24	141000	0.2				3890			70
X068592	NS0085	0	2	WP	Oxide		GHD		5430	<5		30	<1	300	2		143	2		7	110000	<0.1				253			8
X068597	NS0085	10	12	WP	Oxide	Waste	GHD		1170	<5		<10	<1	70	<1		14	<2		<5	37200	<0.1				92			4
X068601	NS0085	18	22	WP	Oxide	Ore	GHD		1340	<5		110	<1	260	<1		12	3		<5	35600	<0.1				1370			7
X068607	NS0085	30	34	WP	Oxide	Ore	GHD		2750	<5		80	<1	770	<1		10	9		<5	43500	<0.1				4690			21
X068621	NS0085	58	62	WP	Fresh	Ore	GHD		3980	6		10	<1	12500	1		20	9		8	89700	0.1				4680			26
X068638	NS0085	90	94	WP	Fresh	Ore	GHD		1580	<5		<10	<1	12800	<1		8	3		<5	76100	<0.1				4640			10
X068699	NS0085	208	212	WP	Fresh	Ore	GHD		2600	<5		50	<1	4580	2		14	3		<5	127000	<0.1				4830			13
X068741	NS0086	8	12	WP	Oxide	Waste	GHD		3390	<5		<10	<1	60	<1		156	<2		<5	78300	<0.1				10			6
X068751	NS0086	28	32	WP	Oxide	Waste	GHD		6040	<5		20	<1	1480	<1		35	<2		<5	47900	<0.1				45			20
X068843	NS0086	208	212	WP	Fresh	Ore	GHD		1370	<5		20	1	17000	2		12	2		9	113000	0.3				2580			11
X068863	NS0086	248	252	WP	Fresh	Waste	GHD		2790	7		40	2	14600	2		21	4		15	107000	0.2				1940			16
X068884	NS0087	8	12	WP	Oxide	Waste	GHD		1360	<5		<10	<1	120	<1		22	<2		<5	36700	<0.1				24			3
X068918-X068919	NS0087	74	78	WP	Fresh	Ore	Worley Parsons		3760	<5	80	40	1		4		24	5		10	136000	0.2				3590	<2		21
X068923	NS0087	84	88	WP	Fresh	Waste	GHD		7890	<5		410	2	3040	<1		16	28		<5	54500	<0.1				4820			49
X068925	NS0087	88	92	WP	Fresh	Waste	GHD		4760	8		60	1	7710	1		35	7		10	102000	0.3				2290			30
X068925-X068926	NS0087	88	92	WP	Fresh	Waste	Worley Parsons		10400	17	80	90	2		4		74	14		19	139000	0.8				2580	<2		65
X068967	NS0087	168	172	WP	Fresh	Ore	GHD		2980	<5		70	<1	10500	2		14	5		8	103000	0.1				3030			17
X068999	NS0087	230	234	WP	Fresh	Ore	GHD		3200	<5		40	<1	13100	1		12	4		8	79400	<0.1				3710			14
X070079	NS0087	380	384	WP	Fresh	Ore	GHD		1290	<5		10	<1	9470	2		9	3		<5	95400	<0.1				6110			10
X070083	NS0087	388	392	WP	Fresh	Ore	GHD		1990	<5		20	<1	13400	2		9	4		<5	94600	<0.1				5020			10
X070089	NS0088	0	2	WP	Oxide	Waste	GHD		3530	<5		<10	<1	370	<1		57	<2		<5	70000	<0.1				177			8
X070093	NS0088	8	12	WP	Oxide	Waste	GHD		790	<5		<10	<1	<50	<1		19	<2		<5	38300	<0.1				96			5
X070145	NS0088	108	112	WP	Fresh	Ore	GHD		1750	<5		<10	1	3100	3		13	4		6	173000	<0.1				3860			18
X070167	NS0088	150	154	WP	Fresh	Waste	GHD		15400	6		<10	1	2640	5		171	12		8	252000	0.1				3100			65
X070233	NS0088	280	284	WP	Fresh	Waste	GHD		7890	<5		<10	<1	4560	3		34	8		9	196000	<0.1				3000			42
X070267	NS0088	346	350	WP	Fresh	Ore	GHD		4020	<5		<10	<1	5030	3		24	6		8	169000	<0.1				4000			28
X070269	NS0089	0	4	WP	Oxide		GHD		2050	<5		60	<1	360	<1		113	<2		6	40900	<0.1				76			8
X070299	NS0089	60	64	WP	Oxide		GHD		6020	<5		20	<1	460	<1		36	7		6	42800	<0.1				2320			102
X070313	NS0089	88	92	WP	Fresh	Waste	GHD		10600	<5		10	1	6950	4		83	10		13	168000	<0.1				2780			61
X070333	NS0089	128	132	WP	Fresh	Waste	GHD		7340	6		<10	<1	3450	2		115	13		14	149000	0.2				2900			73

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Ag	Al	As	B	Ba	Be	Ca	Cd	Cl	Cr	Co	Cs	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
X070343	NS0089	148	158	WP	Fresh	Ore	Worley Parsons		6640	8	70	<10	<1		3		49	12		20	124000	0.3				1640	<2		74
X070359	NS0089	178	180	WP	Fresh	Waste	GHD		3950	7		<10	<1	3490	2		74	18		21	148000	0.2				3150			72
X070375	NS0089	210	214	WP	Fresh	Ore	GHD		910	<5		<10	<1	4350	3		12	5		6	177000	<0.1				4000			24
X070405	NS0089	268	272	WP	Fresh	Ore	GHD		1890	<5		<10	<1	3170	3		10	4		<5	180000	<0.1				3790			18
X070451	NS0089	360	364	WP	Fresh	Waste	GHD		2040	<5		<10	1	6810	5		12	3		<5	221000	<0.1				4620			24
X070473	NS0090	0	4	WP	Oxide	Waste	GHD		4390	<5		<10	<1	100	<1		102	<2		<5	71600	<0.1				21			7
X070477	NS0090	8	12	WP	Oxide	Waste	GHD		890	<5		<10	<1	80	<1		13	<2		<5	27100	<0.1				37			6
X070483	NS0090	20	24	WP	Oxide	Waste	GHD		790	<5		20	<1	<50	<1		10	<2		<5	36000	<0.1				628			5
X070537	NS0090	128	132	WP	Fresh	Ore	GHD		810	<5		<10	<1	10700	1		11	4		7	83900	<0.1				4700			11
X070569	NS0090	190	194	WP	Fresh	Ore	GHD		5640	<5		<10	<1	4710	2		26	10		10	116000	<0.1				3640			36
X070609	NS0090	268	272	WP	Fresh	Ore	GHD		280	<5		<10	<1	6760	3		9	3		<5	156000	<0.1				4380			14
X070696	NS0091	160	164	WP	Fresh	Waste	GHD		450	<5		<10	<1	6020	3		10	3		<5	149000	<0.1				2410			15
X070696	NS0091	160	164	WP	Fresh	Waste	GHD		450	<5		<10	<1	6020	3		10	3		<5	149000	<0.1				2410			15
X070716	NS0091	198	202	WP	Fresh	Waste	GHD		3400	<5		<10	2	5090	8		50	5		7	244000	<0.1				3830			37
X070779	NS0092	40	44	WP	Fresh	Waste	GHD		3950	<5		90	1	5970	2		16	6		17	161000	0.2				4550			23
X070783	NS0092	48	52	WP	Fresh	Ore	GHD		4150	<5		90	1	10300	2		18	5		14	152000	<0.1				3680			21
X070839	NS0092	158	162	WP	Fresh	Ore	GHD		2150	<5		30	<1	9590	2		11	4		<5	103000	<0.1				4690			11
X070947	NS0093	92	96	WP	Fresh	Ore	GHD		2740	<5		60	<1	11400	2		11	5		<5	122000	<0.1				5740			13
X071013	NS0093	216	220	WP	Fresh	Waste	GHD		1870	<5		50	2	8880	6		12	2		<5	269000	<0.1				3710			14
X071061	NS0094	28	32	WP	Oxide	Ore	GHD		5840	<5		340	1	1180	<1		17	17		6	54900	<0.1				5330			43
X071121	NS0094	148	152	WP	Fresh	Ore	GHD		660	<5		20	<1	14400	2		8	2		<5	87600	<0.1				5280			8
X071127	NS0094	160	164	WP	Fresh	Ore	GHD		950	7		20	<1	18800	1		9	4		<5	98500	<0.1				5750			9
X071205	NS0095	30	34	WP	Oxide	Waste	GHD		1320	<5		170	1	370	<1		18	10		<5	53000	<0.1				6770			22
X071209	NS0095	38	42	WP	Oxide	Waste	GHD		970	<5		<10	<1	1040	<1		14	4		<5	46200	<0.1				4940			20
X071328	NS0096	20	24	WP	Oxide	Ore	GHD		1950	<5		180	<1	390	<1		11	3		<5	44000	<0.1				2760			9
X071353	NS0096	70	74	WP	Fresh	Ore	GHD		2580	<5		80	<1	9010	1		11	4		8	102000	<0.1				4790			12
X071379	NS0096	120	124	WP	Fresh	Ore	GHD		4910	6		40	<1	7120	<1		21	8		12	98700	<0.1				4130			30
X071435	NS0096	230	234	WP	Fresh	Waste	GHD		13800	24		70	<1	3900	1		87	18		20	104000	0.2				3900			90
X071447	NS0096	254	258	WP	Fresh	Ore	GHD		1940	<5		20	<1	16800	2		10	4		6	93800	<0.1				5660			11
X071476	NS0097	28	32	WP	Oxide	Waste	GHD		1660	<5		150	<1	360	<1		17	9		<5	47900	<0.1				4680			39
X071482	NS0097	40	44	WP	Fresh	Waste	GHD		23500	20		20	1	980	<1		278	24		31	82300	0.3				1870			182
X071606	NS0098	0	4	WP	Oxide	Waste	GHD		3150	<5		20	<1	320	<1		77	<2		7	58200	<0.1				48			5
X071616	NS0098	20	24	WP	Oxide	Waste	GHD		530	<5		<10	<1	100	<1		12	<2		<5	38100	<0.1				48			3
X071634	NS0098	56	58	WP	Fresh	Waste	GHD		2810	12		20	<1	2260	2		25	5		10	114000	0.2				4380			23
X071635	NS0098	58	62	WP	Fresh	Ore	GHD		2250	7		20	<1	3150	1		23	5		11	118000	0.1				5780			23
X071661	NS0098	108	112	WP	Fresh	Ore	GHD		250	<5		<10	<1	4770	2		9	3		<5	103000	<0.1				3680			8
X071697	NS0098	180	184	WP	Fresh	Ore	GHD		2420	5		20	<1	4530	1		14	3		<5	128000	0.1				2390			13
X071933	NS0100	78	82	WP	Fresh	Waste	GHD		15000	5		80	2	3350	2		119	8		10	111000	0.3				1880			66
X073003	NS0106	2	4	WP	Oxide		GHD		2460	<5		10	<1	340	<1		161	<2		<5	48700	<0.1				90			4
X073027	NS0106	48	52	WP	Fresh	Ore	GHD		1320	6		20	<1	14200	<1		8	7		5	76200	0.1				5920			11
X073049	NS0106	92	96	WP	Fresh	Ore	GHD		6890	22		60	<1	5000	2		42	10		14	98800	0.4				3530			54
X073089	NS0106	170	172	WP	Fresh	Ore	GHD		540	<5		<10	<1	15700	<1		12	<2		<5	65900	<0.1				5880			5
X073202-X073203	NS0107	112	116	KCF	Fresh	Waste	Worley Parsons		15800	30	<50	20	<1		1		220	32		71	62100	1.3				299	<2		174
X073204-X073205	NS0107	116	120	KCF	Fresh	Waste	Worley Parsons		22400	31	<50	20	<1		2		304	47		61	75600	1.1				435	<2		265
X073206	NS0107	120	124	KCF	Fresh	Waste	GHD		16300	37		10	<1	360	1		276	44		60	92300	1.5				1850			281
X073210	NS0107	128	132	KCF	Fresh	Waste	GHD		14800	17		<10	<1	290	<1		285	46		49	67700	0.8				1080			236
X073210-X073211	NS0107	128	132	KCF	Fresh	Waste	Worley Parsons		29500	18	70	10	<1		4		542	43		46	141000	0.8				3000	<2		298
X073216	NS0107	140	142	KCF	Fresh	Waste	GHD		17600	12		<10	<1	3370	<1		370	66		97	51000	1				2440			254
X073216-X073217	NS0107	140	144	KCF	Fresh	Waste	Worley Parsons		30500	10	<50	10	<1		2		779	63		106	74700	0.6				1620	<2		458
X073219-X073220	NS0107	146	150	KCF	Fresh	Waste	Worley Parsons		30000	15	<50	20	<1		2		728	74		86	70700	1.5				485	<2		532
X073220	NS0107	148	152	KCF	Fresh	Waste	GHD		18400	14		<10	<1	270	<1		394	63		72	45400	1.4				346			347
X073224-X073225	NS0107	156	160	KCF	Fresh	Waste	Worley Parsons		27400	14	<50	20	<1		2		582	72		77	63600	1.5				630	<2		470
X073226	NS0107	160	164	KCF	Fresh	Waste	GHD		18600	12		<10	<1	300	<1		436	67		83	48700	1				1280			311
X073231	NS0107	170	174	KCF	Fresh	Waste	GHD		19400	12		10	<1	10400	<1		439	65		91	52900	1				1120			326
X073231-X073232	NS0107	170	174	KCF	Fresh	Waste	Worley Parsons		24600	15	<50	20	<1		2		595	77		93	67400	1.6				739	<2		450
X073242	NS0107	192	194	KCF	Fresh	Waste	Worley Parsons		26200	15	<50	20	<1		2		610	69		77	63100	1.6				670	<2		432
X073245-X073247	NS0107	198	202	KCF	Fresh	Waste	Worley Parsons		29100	13	<50	20	<1		2		707	65		82	67000	1				1180	<2		430
X073329	NS0108	160	162	WP	Fresh	Ore	GHD		4280	9		10	<1	7020	2		16	10		11	95600	<0.1				4240			36
X073338	NS0108	178	180	WP	Fresh	Ore	GHD		7490	<5		<10	<1	3880	3		73	9		12	169000	0.2				5160			51
X073715	NS0111	188	192	WP	Fresh	Waste	GHD		1430	<5		<10	<1	3460	2		34	3		<5	118000	<0.1				1110			17
X073741	NS0111	240	244	WP	Fresh	Ore	GHD		100	<5		<10	<1	5030	2		14	<2		<5	108000	<0.1				2660			6
X073767	NS0111	290	294	WP	Fresh	Waste	GHD		1000	<5		<10	2	6430	7		24	<2		<5	207000	0.1				2950			14
X073988	NS0113	128	132	MP	Fresh	Ore	GHD		7240	<5		20	1	4220	3		73	10		15	142000	0.2				2220			48
X073994	NS0113	140	142	MP	Fresh	Waste	GHD		9880	6		40	1	2260	2		164	18		23	158000	0.3				3090			88
X074004	NS0113	158	162	MP	Fresh	Waste	GHD		15600	6		<10	1	3020	3		250	16		28	163000	0.1				2230			104
X074024	NS0113	198	202	MP	Fresh	Waste	GHD		4280	<5		20	1	3610	2		56	12		19	168000	0.1				2860			60

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Ag	Al	As	B	Ba	Be	Ca	Cd	Cl	Cr	Co	Cs	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
X074347	NS0116	108	112	MP	Fresh	Waste	GHD		17000	8		40	2	4250	2		254	18		28	151000	0.4				1860			103
X074359	NS0116	130	132	MP	Fresh	Waste	GHD		19800	9		30	2	6570	2		313	18		31	146000	0.3				1860			113
X074532	NS0117	190	194	MP	Fresh	Ore	GHD		11200	6		40	2	12100	3		128	14		20	170000	0.2				2260			66
X074649	NS0118	140	144	WP	Fresh	Waste	GHD		4530	30		<10	1	4200	3		59	12		31	191000	0.7				3020			43
X074866	NS0120	206	210	WP	Fresh	Waste	GHD		15800	6		30	1	1790	1		317	19		24	120000	0.1				1870			121
X075124	NS0122	150	154	WP	Fresh	Waste	GHD		7640	5		50	1	8630	2		74	11		36	111000	0.2				1490			56
X075393	NS0124	118	122	MP	Fresh	Ore	GHD		1690	<5		20	1	14900	3		20	3		8	129000	<0.1				1730			14
X075399	NS0124	130	134	MP	Fresh	Waste	GHD		26000	21		100	2	1940	1		441	33		30	119000	0.4				355			160
X138071	NS0128	150	154	WP	Fresh	Waste	GHD		24300	10		<10	2	3240	3		307	29		38	178000	0.4				2860			175
X072252	NS0152	78	82	MP	Fresh	Waste	GHD		33200	15		<10	1	5220	2		570	33		54	146000	0.2				1370			211
X072273	NS0152	120	124	WP	Fresh	Ore	GHD		4150	<5		30	1	12000	1		32	9		14	109000	0.2				2400			35
X072287	NS0152	148	152	WP	Fresh	Ore	GHD		4610	7		30	<1	28900	2		36	7		12	80400	0.2				1500			32
X072335	NS0152	244	248	WP	Fresh	Waste	GHD		5760	6		50	2	24200	2		42	9		15	119000	0.2				2860			38
X072404	NS0153	98	102	WP	Fresh	Waste	GHD		5810	14		30	<1	6350	3		82	6		9	160000	0.3				5050			35
X072439	NS0153	168	172	WP	Fresh	Ore	GHD		4430	<5		20	<1	4450	2		41	5		<5	147000	<0.1				3900			30
X072455	NS0153	200	204	WP	Fresh	Waste	GHD		5420	86		<10	<1	400	<1		97	75		57	81300	1.9				584			439
X072465	NS0153	220	224	WP	Fresh	Waste	GHD		5680	7		<10	<1	9740	4		76	11		10	195000	0.2				4020			56
X072493	NS0154	18	22	WP	Oxide	Ore	GHD		2030	<5		270	<1	470	<1		9	10		<5	40600	<0.1				5640			19
X072499	NS0154	30	34	WP	Fresh	Ore	GHD		1910	<5		10	<1	4700	1		10	4		6	110000	<0.1				5940			14
X072503	NS0154	38	42	WP	Fresh	Ore	GHD		4390	<5		10	<1	8760	<1		20	7		8	90800	<0.1				4190			28
X072585	NS0154	200	204	WP	Fresh	Waste	GHD		9470	6		60	2	5820	3		161	10		19	164000	0.3				2190			58
X072677	NS0155	100	104	WP	Fresh	Waste	GHD		17100	13		60	2	8480	2		278	17		22	142000	0.4				1970			105
X072681	NS0155	108	112	WP	Fresh	Waste	GHD		3430	<5		40	2	6490	4		46	4		14	190000	0.2				2630			29
X072733	NS0155	210	214	WP	Fresh	Ore	GHD		2960	<5		40	2	9380	2		23	5		9	118000	0.1				2280			20
X072921	NS0157	130	134	WP	Fresh	Ore	GHD		7620	<5		<10	1	2050	3		81	11		10	186000	0.1				3750			50
X141514	NS0158	66	70	MP	Fresh	Waste	GHD		7700	<5		30	<1	8810	2		72	8		10	146000	0.2				5200			46
X141536	NS0158	110	114	MP	Fresh	Ore	GHD		5260	<5		<10	<1	10100	<1		36	9		14	87800	0.1				3320			42
X141571	NS0158	178	182	MP	Fresh	Ore	GHD		2160	<5		<10	<1	17100	<1		15	4		<5	75700	<0.1				4110			15
X141643	NS0159	116	118	WP	Fresh	Ore	GHD		2280	8		40	1	4340	4		12	8		6	142000	0.7				4470			18
X141776	NS0160	58	62	WP	Fresh	Waste	GHD		19400	<5		110	2	7920	3		306	20		24	158000	0.3				2940			161
X121052	NS0165	100	104	WP	Fresh	Ore	GHD		1610	<5		<10	<1	4340	1		10	3		<5	126000	0.3				1480			12
AMD # 0178	NS0572	6	12	KCF	Oxide		Golder	<0.10	32600	1.8	<50	270	0.51	9100	0.2	42	410		3.7		99000	0.23	220	13	30000	1900		930	280
AMD # 0181	NS0572	24	30	KCF	Fresh		Golder	<0.10	32700	4	<50	240	<0.50	17000	<0.10	9	350		9.4		86000	0.12	2000	15	36000	1300		1400	190
AMD # 0184	NS0572	42	48	KCF	Fresh		Golder	<0.10	33200	<0.4	<50	230	<0.50	34000	0.11	14	510		9.1		88000	0.14	1800	15	37000	1400		1400	260
AMD # 0187	NS0572	60	66	KCF	Fresh		Golder	<0.10	37300	9	<50	91	<0.50	37000	<0.10	12	380		3.9		82000	0.09	770	18	39000	1400		830	200
AMD # 0189	NS0572	72	78	KCF	Fresh		Golder	<0.10	36300	0.7	<50	21	<0.50	17000	<0.10	14	410		1.1		82000	0.13	210	18	35000	1200		490	230
AMD # 0192	NS0572	90	96	KCF	Fresh		Golder	<0.10	35200	3.1	<50	4.2	<0.50	20000	0.15	22	740		0.19		88000	0.11	88	18	30000	1400		510	370
AMD # 0195	NS0572	108	114	KCF	Fresh		Golder	<0.10	57500	2.7	<50	20	0.89	1100	0.32	19	430		0.16		150000	0.06	<50	23	32000	1300		<100	240
AMD # 0198	NS0572	126	132	KCF	Fresh		Golder	<0.10	58400	5.5	<50	12	0.51	160	0.27	15	510		0.14		130000	0.27	1100	48	35000	700		<100	290
AMD # 0201	NS0572	144	150	KCF	Fresh		Golder	<0.10	54400	5.2	<50	41	0.74	3000	0.17	22	620		0.53		120000	0.47	5200	54	39000	2500		<100	400
AMD # 0204	NS0572	162	168	KCF	Fresh		Golder	<0.10	44900	11	<50	58	0.67	7400	0.18	13	930		1.8		76000	1.2	8900	34	27000	930		<100	650
AMD # 0207	NS0572	180	186	KCF	Fresh		Golder	<0.10	39700	22	<50	39	0.68	10000	0.19	23	900		1.6		97000	1.2	5100	34	24000	1800		<100	620
AMD # 0210	NS0574	0	6	KCF	Oxide		Golder	<0.10	44300	3.7	<50	14	<0.50	23000	0.12	58	250		0.48		88000	0.24	2000	26	36000	1700		690	150
AMD # 0213	NS0574	18	24	KCF	Fresh		Golder	<0.10	45200	1.7	<50	1.5	<0.50	4900	0.19	12	310		0.25		89000	0.43	190	28	35000	1800		470	300
AMD # 0217	NS0574	42	48	KCF	Fresh		Golder	<0.10	62700	1.7	<50	1.9	<0.50	1500	<0.10	7	220		0.25		100000	0.06	120	49	50000	910		140	200
AMD # 0220	NS0574	60	66	KCF	Fresh		Golder	<0.10	50500	7.6	<50	30	<0.50	420	0.31	10	500		0.38		100000	0.53	2600	54	38000	240		<100	360
AMD # 0225	NS0574	90	96	KCF	Fresh		Golder	<0.10	49600	9.3	<50	36	0.63	1100	0.21	13	960		0.64		110000	0.85	3200	52	34000	1700		<100	560
AMD # 0227	NS0574	102	108	KCF	Fresh		Golder	<0.10	48300	11	<50	30	0.5	8500	0.31	14	960		0.8		98000	1.2	2800	52	37000	970		<100	560
AMD # 0230	NS0574	120	126	KCF	Fresh		Golder	<0.10	46100	8.6	<50	28	<0.50	8900	0.19	14	1000		1.1		85000	0.75	3100	51	38000	1100		<100	620
AMD # 0232	NS0576	0	6	KCF	Oxide		Golder	<0.10	41800	3.8	<50	38	<0.50	3400	<0.10	12	500		0.26		88000	0.17	400	18	31000	1100		230	250
AMD # 0235	NS0576	18	24	KCF	Fresh		Golder	<0.10	38200	1.4	<50	150	<0.50	27000	0.16	14	190		4.8		91000	0.05	710	11	40000	1500		580	140
AMD # 0238	NS0576	36	42	KCF	Fresh		Golder	<0.10	35700	3	<50	29	<0.50	18000	0.1	18	390		0.67		82000	0.05	120	14	36000	1500		450	250
AMD # 0241	NS0576	54	60	KCF	Fresh		Golder	<0.10	50500	0.4	<50	4.8	<0.50	27000	<0.10	<5	210		0.46		85000	<0.04	59	25	52000	1400		240	140
AMD # 0245	NS0576	78	84	KCF	Fresh		Golder	<0.10	47800	3.9	<50	1.5	<0.50	47000	0.52	10	2200		0.11		76000	0.19	170	29	56000	1100		<100	880
AMD # 0249	NS0576	102	108	KCF	Fresh		Golder	<0.10	46200	6.3	<50	11	<0.50	34000	0.15	17	330		0.5		77000	0.76	1700	34	45000	950		<100	190
AMD # 0252	NS0576	120	126	KCF	Fresh		Golder	<0.10	44700	1.2	<50	15	<0.50	28000	<0.10	14	450		0.22		77000	0.08	430	29	42000	1400		190	220
AMD # 0256	NS0576	144	150	KCF	Fresh		Golder	<0.10	40800	3.1	<50	9.5	<0.50	37000	<0.10	11	160		0.53		78000	<0.04	170	19	41000	1700		340	140
AMD # 0259	NS0576	162	168	KCF	Fresh		Golder	<0.10	29600	1.7	<50	6.6	<0.50	12000	<0.10	14	120		0.47		65000	<0.04	74	14	27000	1000		620	100
AMD # 0261	NS0576	174	180	KCF	Fresh		Golder	<0.10	25900	1.2	<50	7.5	<0.50	11000	<0.10	<5	220		0.26		58000	0.05	120	14	23000	870		710	160
AMD # 0264	NS0576	192	198	KCF	Fresh		Golder	<0.10	33700	1.8	<50	7.9	<0.50	16000	<0.10	7	320		0.17		72000	0.05	150	21	32000	830		580	190
AMD # 0268	NS0578	18	24	KCF	Oxide		Golder	<0.10	15000	12	<50	28	<0.50	550	<0.10	17	420		0.34		78000	0.81	2400	6	720	90		<100	52
AMD # 0271	NS0578	36	42	KCF	Fresh		Golder	<0.10	29600	8.4	<50	20	0.51	<100	<0.10	19	990		0.44		110000	1.7	2000	29	12000	310		<100	400
AMD # 0274	NS0578	54	60	KCF	Fresh		Golder	<0.10	43800	11	<50	30	<0.50	<100	<0.10	9	920		0.89		96000	1	3000	49	30000	250		<100	640
AMD # 0277	NS0578	72	78	KCF	Fresh		Golder	<0.10	42600	14	<50	51	0.65	310	0.12	13	830		1.3		93000	2	5100	44	28000	1200		<100	640
AMD # 0280	NS0578	90	96	KCF	Fresh		Golder	<0.10	48100	13	<50	62	1	380	0.21	13	940		1.8		97000	1.4	6300	45	28000	2100		<100	670
AMD # 0283	NS0578	108	114	KCF	Fresh		Golder	<0.10	31000	7.3	<50	26	1	1800	<0.10	16	500		0.65		180000	0.55	2500	24	22000	4400		<100	320

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Ag	Al	As	B	Ba	Be	Ca	Cd	Cl	Cr	Co	Cs	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
AMD # 0285	NS0578	120	126	KCF	Fresh		Golder	<0.10	37500	12	<50	44	0.83	410	0.18	19	650		1.2		110000	1.4	4900	32	21000	2400		<100	500
AMD # 0289	NS0578	144	150	KCF	Fresh		Golder	<0.10	5230	23	<50	22	2.1	5300	<0.10	25	81		0.62		240000	0.44	2700	<2.0	23000	4200		<100	80
AMD # 0293	NS0578	168	174	WP	Fresh		Golder	<0.10	5800	29	<50	23	1.3	4300	<0.10	26	72		1.9		260000	0.63	1400	3.3	15000	3500		200	47
AMD # 0296	NS0578	186	192	WP	Fresh		Golder	<0.10	4580	3.2	<50	38	1.1	6800	<0.10	11	45		7.8		280000	0.14	2100	3.1	13000	1900		870	27
AMD # 0298	NS0580	0	6	KCF	Oxide		Golder	<0.10	37900	4.2	<50	15	<0.50	8700	<0.10	227	420		1.2		110000	0.09	640	42	21000	1800		520	270
AMD # 0301	NS0580	18	24	KCF	Fresh		Golder	<0.10	52100	2.1	<50	2.5	<0.50	6800	<0.10	19	680		0.22		94000	0.06	66	30	42000	2200		320	340
AMD # 0305	NS0580	42	48	KCF	Fresh		Golder	<0.10	47300	2.2	<50	6.4	<0.50	30000	<0.10	7	570		0.11		89000	0.07	200	30	41000	1500		250	280
AMD # 0308	NS0580	60	66	KCF	Fresh		Golder	<0.10	50000	1.9	<50	1.3	0.98	340	0.29	10	440		<0.10		120000	0.09	<50	26	25000	700		<100	240
AMD # 0311	NS0580	78	84	KCF	Fresh		Golder	<0.10	62200	2.1	<50	35	<0.50	<100	<0.10	7	560		0.38		110000	0.06	2400	46	40000	700		<100	300
AMD # 0314	NS0580	96	102	KCF	Fresh		Golder	<0.10	57100	4.7	<50	47	<0.50	<100	<0.10	11	820		0.4		91000	0.16	3600	43	38000	670		<100	380
AMD # 0317	NS0580	114	120	KCF	Fresh		Golder	<0.10	59700	2.1	<50	18	<0.50	<100	<0.10	11	420		0.32		110000	0.11	1700	48	44000	640		<100	260
AMD # 0319	NS0580	126	132	KCF	Fresh		Golder	<0.10	54800	6.6	<50	31	0.52	<100	<0.10	14	810		0.42		91000	0.47	2700	53	44000	530		<100	410
AMD # 0322	NS0580	144	150	KCF	Fresh		Golder	<0.10	58100	7.1	<50	28	<0.50	<100	<0.10	16	770		0.49		97000	0.59	2700	58	44000	600		<100	440
AMD # 0324	NS0580	156	162	KCF	Fresh		Golder	<0.10	57700	7	<50	29	0.56	<100	0.26	8	990		0.67		97000	0.79	2900	60	43000	660		<100	520
AMD # 0327	NS0580	174	180	KCF	Fresh		Golder	<0.10	50700	9	<50	18	0.72	450	0.3	15	910		0.46		130000	0.84	2000	53	35000	3600		<100	530
AMD66a	NSD0031	1	29.7	WP	Oxide		Golder	0.11	3620	2.1	<50	12	-	150	<0.10	17	76		<0.10		150000	1.5	<50	<2.0	270	560		<100	24
AMD67a	NSD0031	37.48	63.08	WP	Fresh		Golder	<0.10	5710	2.9	<50	83	-	11000	<0.10	14	45		2.9		210000	1.7	1200	6.1	9600	3700		260	72
AMD77a	NSD0031	73.24	80	WP	Fresh		Golder	<0.10	9110	2.8	<50	57	-	10000	<0.10	<5	55		3.7		220000	1.5	2500	7.8	18000	4100		630	45
AMD79a	NSD0031	80.38	94.1	WP	Fresh		Golder	<0.10	29800	11	<50	35	-	1300	<0.10	9	210		2.1		230000	0.72	1300	29	30000	3000		430	180
AMD83	NSD0031	103.17	103.43	WP	Fresh		Golder	<0.10	2720	1.9	<50	21	-	2300	<0.10	<5	23		1		230000	2.4	780	3.4	13000	5100		270	19
AMD85	NSD0031	119	119.33	WP	Fresh		Golder	<0.10	46200	18	<50	94	-	710	<0.10	7	390		5.9		250000	0.44	3000	44	38000	1700		1000	280
AMD87	NSD0031	127.7	128	WP	Fresh		Golder	<0.10	59100	13	<50	89	-	350	<0.10	6	510		6.1		240000	0.29	2900	57	40000	480		1000	330
AMD89	NSD0031	144.77	145.06	WP	Fresh		Golder	<0.10	14900	22	<50	190	-	1900	<0.10	11	130		11		240000	1.5	5600	13	22000	5000		2000	100
AMD91	NSD0031	156	156.34	WP	Fresh		Golder	<0.10	583	2	<50	6.9	-	940	<0.10	11	9.8		0.64		83000	7.9	260	<2.0	1400	340		150	<10
AMD93	NSD0031	171.06	171.42	WP	Fresh		Golder	<0.10	5770	3.5	<50	88	-	12000	<0.10	8	56		5		190000	3	3000	5.6	15000	2900		1100	39
AMD95	NSD0031	192.53	192.82	WP	Fresh		Golder	<0.10	8160	2.6	<50	65	-	2600	<0.10	8	43		3.7		160000	1.4	2300	7.9	13000	1900		780	39
AMD97	NSD0031	203	203.36	WP	Fresh		Golder	<0.10	3280	1.7	<50	41	-	9700	<0.10	<5	26		2.1		130000	4.1	1300	3.5	11000	2600		430	21
AMD99	NSD0031	231.48	231.82	WP	Fresh		Golder	<0.10	5710	1.9	<50	85	-	2800	<0.10	<5	62		3.7		250000	2.5	2100	5.8	13000	3100		720	33
AMD102a	NSD0031	259.38	276.55	WP	Fresh		Golder	<0.10	5860	1.8	<50	53	-	15000	0.11	<5	46		1.7		260000	2.2	1000	6.4	12000	3100		350	34
AMD # 0129	NSD0031	280.4	280.7	WP	Fresh		Golder	<0.10	5070	1.9	<50	56	-	22000	0.1	<5	33		1.8		170000	4.5	1100	5.6	11000	1700		380	28
AMD # 0131	NSD0031	297.96	298.26	WP	Fresh		Golder	<0.10	25200	4.6	<50	110	-	7500	<0.10	5	180		3.5		210000	0.74	2000	25	29000	4200		750	140
AMD # 0133	NSD0031	321.98	322.38	WP	Fresh		Golder	<0.10	5050	2.2	<50	22	-	7600	<0.10	<5	34		0.59		240000	1.9	320	6.4	15000	7700		130	31
AMD # 0135	NSD0031	363.98	364.29	WP	Fresh		Golder	<0.10	218	6.9	<50	4	-	2900	<0.10	<5	44		<0.10		290000	0.97	96	<2.0	9900	6300		<100	35
AMD # 0137	NSD0031	374.83	375.12	WP	Fresh		Golder	<0.10	346	10	<50	15	-	5700	<0.10	<5	24		0.12		160000	3.5	260	2.1	7400	5200		<100	23
AMD # 0139	NSD0031	392.48	392.79	WP	Fresh		Golder	<0.10	1820	2	<50	7.4	-	5500	<0.10	<5	23		0.23		200000	0.86	210	8.9	14000	6000		<100	20
AMD # 0141	NSD0031	416.93	417.25	WP	Fresh		Golder	<0.10	5020	2	<50	3.1	-	4100	0.11	<5	58		<0.10		290000	0.66	<50	28	17000	5800		<100	49
AMD # 0143	NSD0031	437.77	438.09	WP	Fresh		Golder	<0.10	394	2.9	<50	14	-	6500	<0.10	<5	23		<0.10		270000	0.5	300	2.2	14000	4800		<100	23
AMD # 0145	NSD0031	457.91	458.2	WP	Fresh		Golder	<0.10	4920	3	<50	3.6	-	5400	<0.10	<5	33		0.1		230000	1.3	<50	8.7	11000	5500		<100	33
AMD104a	NSD0032	6.47	30.16	WP	Oxide		Golder	<0.10	7460	3.6	<50	71	-	660	<0.10	35	82		2.6		270000	0.55	680	<2.0	1300	1500		190	40
AMD109a	NSD0032	35	68.32	WP	Fresh		Golder	<0.10	3450	2.7	<50	33	-	15000	0.1	<5	41		1.9		270000	1.6	1000	3.5	12000	6600		240	31
AMD113	NSD0032	76.52	76.84	WP	Fresh		Golder	<0.10	4860	2.1	<50	36	-	16000	0.1	<5	38		2.6		270000	1.1	1000	5.7	13000	5300		330	32
AMD115	NSD0032	95.75	96.18	WP	Fresh		Golder	<0.10	2830	1.7	<50	37	-	15000	<0.10	<5	14		2.2		120000	1.4	980	4.4	10000	5600		390	16
AMD118	NSD0032	112.8	113.15	WP	Fresh		Golder	<0.10	54200	17	<50	120	-	670	<0.10	8	650		11		200000	0.6	3200	72	33000	600		1400	310
AMD119	NSD0032	117.35	117.71	WP	Fresh		Golder	<0.10	2820	6.7	<50	35	-	23000	<0.10	<5	17		2.4		160000	1.9	970	4.2	9400	4900		410	14
AMD121	NSD0032	126.79	127.15	WP	Fresh		Golder	<0.10	833	0.8	<50	17	-	23000	<0.10	<5	17		0.97		95000	4	410	<2.0	7200	3300		180	<10
AMD127	NSD0032	186.12	186.32	WP	Fresh		Golder	<0.10	2850	1.1	<50	23	-	4600	<0.10	<5	16		1.8		240000	1.5	640	3.9	8300	3300		290	12
AMD # 0146	NSD0032	200.68	200.98	WP	Fresh		Golder	<0.10	3070	2.1	<50	39	-	5100	<0.10	<5	15		3.3		230000	0.69	1200	4.2	15000	6700		550	17
AMD # 0148	NSD0032	224.19	224.56	WP	Fresh		Golder	<0.10	4190	1.9	<50	22	-	6200	<0.10	<5	23		1.9		200000	1.1	640	5.6	11000	4900		300	20
AMD # 0150	NSD0032	249.64	249.99	WP	Fresh		Golder	<0.10	6490	1.7	<50	49	-	1800	<0.10	<5	23		4		220000	0.69	1300	7.5	13000	5600		610	24
AMD # 0151	NSD0032	255.68	256.03	WP	Fresh		Golder	<0.10	42800	38	<50	230	-	690	<0.10	16	310		20		270000	1.8	5300	49	32000	840		2800	230
AMD # 0154	NSD0032	273.79	274.07	WP	Fresh		Golder	<0.10	38200	25	<50	110	-	3500	<0.10	9	300		16		270000	0.61	3700	41	26000	2100		1700	200
AMD # 0156	NSD0032	283.31	283.61	WP	Fresh		Golder	<0.10	16300	16	<50	240	-	13000	<0.10	5	130		19		280000	0.7	6200	14	24000	4900		3300	78
AMD # 0158	NSD0032	289.44	289.8	WP	Fresh		Golder	<0.10	17700	18	<50	230	-	7300	0.11	7	150		17		320000	0.57	5500	16	26000	4900		2900	89
AMD # 0160	NSD0032	311.87	312.26	WP	Fresh		Golder	<0.10	8350	14	<50	80	-	16000	0.11	8	76		5.5		300000	0.95	1800	8.9	15000	3500		880	49
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh		Golder	<0.10	15100	7.1	<50	180	-	2800	0.15	6	110		9.8		330000	0.32	3200	14	26000	6200		1600	78
AMD # 0164	NSD0032	329.11	329.52	WP	Fresh		Golder	<0.10	3590	1.3	<50	56	-	1500	<0.10	<5	31		3		310000	1.2	1200	3.4	11000	3900		570	19
AMD # 0167	NSD0032	343.73	344.04	WP	Fresh		Golder	<0.10	16800	21	<50	9.9	-	7200	<0.10	8	160		0.35		220000	1.5	110	21	14000	3800		<100	78
AMD # 0168	NSD0032	349.2	349.53	WP	Fresh		Golder	<0.10	3570	1.4	<50	58	-	5600	<0.10	<5	25		3.8		310000	0.92	1300	3.5	11000	4300		630	17
AMD # 0169	NSD0032	356.45	356.8	WP	Fresh		Golder	<0.10	17200	17	<50	37	-	8100	<0.10	<5	220		2.4		220000	0.99	810	14	23000	4000		410	94
AMD # 0174	NSD0032	421.98	422.39	WP	Fresh		Golder	<0.10	2350	0.7	<50	3.4	-	8300	<0.10	<5	28		<0.10		290000	0.52	110	3.2	28000	4900		<100	18
AMD # 0176	NSD0032	449.04	449.4	WP	Fresh		Golder	<0.10	2160	12	<50	6.8	-	7500	<0.10	10	37		0.11		300000	0.45	570	2.2	30000	4400		<100	46
AMD # 039	NSRD0387	184.65	184.96	WP	Fresh		Golder	<0.10	9970	2.8	<50	120	-	1700	0.1	<5	75		6.2		270000	0.1	7100	12	16000	4000		1800	50
AMD # 041	NSRD0387	201.93	202.24	WP	Fresh		Golder	<0.10	7920	3	<50	58	-	5400	<0.10	8	70		5.2		270000	0.17	6000	9.4	16000	3600		1500	48
AMD # 043	NSRD0387	210.08	210.43	WP	Fresh		Golder	<0.10	4720	2.2	<50	28	-	23000	<0.10	<5	39		2.6		190000	0.27	4100	6.9	12000	2800		1100	27
AMD # 045	NSRD0387	221.94	222.3	WP	Fresh		Golder	<0.10	6220	4.6	<50	39	-	6000	<0.10	7	78		4.8		230000	0.3	4800	7.5	11000	2900		1200	40
AMD # 047	NSRD0387	233.78	234.13	WP	Fresh		Golder	<0.10	19400	18	77	170	-	1400	<0.10	11	160		15		270000	0.28	12000	17	16000	930		2800	110

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Ag	Al	As	B	Ba	Be	Ca	Cd	Cl	Cr	Co	Cs	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
AMD # 049	NSRD0387	246.67	247	WP	Fresh		Golder	<0.10	7980	5.7	66	46	-	3000	<0.10	<5	65		5.9		240000	0.26	6100	10	14000	2800		1500	50
AMD # 051	NSRD0387	259.19	259.56	WP	Fresh		Golder	<0.10	9110	4.6	66	55	-	2300	<0.10	<5	74		6.1		280000	0.36	6900	11	15000	3100		1700	60
AMD # 053	NSRD0387	279.3	279.62	WP	Fresh		Golder	<0.10	5790	1.9	<50	36	-	4300	<0.10	<5	50		3.4		300000	0.33	4600	6.5	12000	2600		1100	33
AMD # 055	NSRD0387	306.92	307.32	WP	Fresh		Golder	<0.10	5920	2	<50	29	-	7600	<0.10	<5	49		3.3		280000	0.13	5000	7.7	12000	3200		1200	33
AMD # 057	NSRD0387	322.68	323.07	WP	Fresh		Golder	<0.10	7980	7.5	79	48	-	3600	<0.10	<5	63		5.3		300000	0.18	5800	8.8	15000	3600		1300	48
AMD # 059	NSRD0387	340.23	340.57	WP	Fresh		Golder	<0.10	11000	7	120	57	-	3800	<0.10	<5	96		7.5		290000	1.9	7700	13	16000	2200		1700	79
AMD # 061	NSRD0387	356.08	356.46	WP	Fresh		Golder	<0.10	12300	10	68	90	-	3500	<0.10	8	110		8.7		290000	0.45	8800	12	19000	2000		2000	94
AMD # 063	NSRD0387	373.42	373.83	MP	Fresh		Golder	<0.10	6700	2.7	<50	110	-	10000	<0.10	7	61		4.2		220000	0.07	5000	7.9	14000	2100		1200	40
AMD # 065	NSRD0387	401.48	401.85	MP	Fresh		Golder	<0.10	11400	2.3	<50	39	-	20000	<0.10	9	170		1.4		250000	0.1	1900	4	19000	2400		490	75
AMD_1	NSRD0393	181.1	181.45	WP	Fresh		Golder	<0.10	25100	9.4	<50	160	-	10000	0.11	<5	220		10		230000	0.59	8700	21	20000	1400		2100	150
AMD_3	NSRD0393	202.96	203.23	WP	Fresh		Golder	<0.10	7400	2.7	<50	79	-	6600	0.11	6	100		4.7		280000	<0.04	4200	6.3	12000	2500		990	43
AMD_6	NSRD0393	222.46	222.75	WP	Fresh		Golder	<0.10	27600	15	<50	230	-	13000	<0.10	<5	240		14		240000	0.35	11000	31	22000	1900		2700	170
AMD_7	NSRD0393	223.45	223.78	WP	Fresh		Golder	<0.10	27900	9.4	<50	180	-	22000	0.11	<5	240		11		230000	0.3	9300	29	22000	1200		2200	150
AMD_8	NSRD0393	226.74	227.08	WP	Fresh		Golder	<0.10	35200	12	<50	130	-	7600	0.13	7	470		8.2		210000	0.47	7500	36	20000	2300		2000	200
AMD_11	NSRD0393	231.44	231.8	WP	Fresh		Golder	<0.10	22300	7.3	<50	160	-	8200	<0.10	6	320		8.6		260000	0.11	8000	21	21000	4600		2100	120
AMD_13	NSRD0393	234.67	234.94	WP	Fresh		Golder	<0.10	14900	3.7	<50	120	-	7500	0.12	6	180		7.1		240000	0.08	6600	13	16000	3000		1600	85
AMD # 015	NSRD0393	238.46	238.82	WP	Fresh		Golder	<0.10	41800	5.7	<50	4.4	-	420	<0.10	7	990		0.16		120000	0.09	320	45	19000	340		<100	330
AMD # 017	NSRD0393	248.88	249.17	WP	Fresh		Golder	<0.10	53400	12	<50	2.9	-	640	<0.10	9	790		0.16		170000	0.3	120	24	21000	620		<100	300
AMD # 019	NSRD0393	255.02	255.37	WP	Fresh		Golder	<0.10	10400	17	<50	56	-	4700	0.29	<5	310		1.6		81000	0.53	1800	4.8	6000	1300		380	120
AMD # 021	NSRD0393	270.45	270.8	WP	Fresh		Golder	<0.10	33500	9.3	<50	220	-	14000	0.13	<5	540		7.9		220000	0.21	7300	12	23000	1600		1600	250
AMD # 023	NSRD0393	287.6	287.92	MP	Fresh		Golder	<0.10	37400	49	<50	26	-	9800	1.2	<5	1200		0.85		120000	0.26	1300	19	21000	990		220	410
AMD # 025	NSRD0393	299.6	299.97	MP	Fresh		Golder	<0.10	16100	3.2	<50	170	-	2400	<0.10	7	260		6.1		290000	0.07	7600	12	20000	5000		1900	100
AMD # 027	NSRD0393	328.83	329.19	MP	Fresh		Golder	<0.10	1200	<0.4	<50	9.1	-	15000	<0.10	<5	83		0.27		33000	0.13	380	<2.0	1600	480		<100	11
AMD # 029	NSRD0393	348.67	349	MP	Fresh		Golder	<0.10	23100	3	<50	150	-	9700	0.14	<5	210		11		270000	0.1	11000	11	18000	2200		2200	130
AMD # 031	NSRD0393	378.65	379.06	MP	Fresh		Golder	<0.10	51000	21	<50	5.2	-	690	0.43	<5	1000		0.21		140000	0.19	350	33	27000	420		<100	420
AMD # 033	NSRD0393	395.11	395.52	MP	Fresh		Golder	0.1	29900	19	<50	11	-	900	0.33	<5	450		0.63		68000	0.31	2000	32	20000	480		<100	330
AMD # 035	NSRD0393	410.72	411	MP	Fresh		Golder	0.12	49900	14	<50	5	-	2400	0.24	<5	1000		0.11		130000	0.12	230	32	29000	780		<100	340
AMD # 037	NSRD0393	422.71	423.02	MP	Fresh		Golder	<0.10	43300	0.6	<50	84	-	10000	0.15	7	740		2		180000	0.08	1900	12	25000	2800		510	240

Tailings samples

Sample ID	Type	Description	Source	Ag	Al	As	B	Ba	Be	Ca	Cd	Cl	Cr	Co	Cs	Cu	Fe	Hg	K	Li	Mg	Mn	Mo	Na	Ni
				(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
(3283 - Year 1-7Tailings)			GHD		4430	7		50	1	13900	2		17	8		24	110000	0.1				6580			24
(3283 Tails) 1			GHD		5800	6		50	1	11800	2		48	9		62	112000	0.2				4280			46
(3283 Tails) 2			GHD		5840	6		50	1	12100	2		48	9		58	112000	0.2				4230			47
Batch Plant Fresh Coarse Cobing Non Mags (A1	Dry-Fresh	Stage 2 Process Plant Dry rejects	Golder	<5.0	8700	<10	<50	55	1.1	13000	<0.50	6	150	12	3.3	30	180000	0.2	2500	8.9	16000	4700	<5.0	620	58
Batch Plant Oxide Coarse Cobing Non Mags (A1	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	<5.0	22300	<10	<50	22	1	590	<0.50	14	230	8.8	0.18	5.7	270000	<0.02	130	4.3	310	220	<5.0	<100	25
VARFR01 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	<5.0	25700	10	<50	59	1.7	7900	<0.50	<5	460	30	3.2	24	170000	0.26	3200	32	15000	2600	<5.0	630	190
VARFR09 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	<5.0	3950	<10	<50	42	1.2	10000	<0.50	<5	67	9.1	1.4	2	210000	0.03	910	4.6	17000	4600	<5.0	250	28
VAROX03 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	<5.0	6460	<10	<50	16	0.81	340	<0.50	16	78	7.6	<0.05	1.5	230000	0.03	<50	<2.0	230	340	<5.0	<100	20
VAROX09 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	<5.0	2990	<10	<50	280	2.9	1300	<0.50	8	57	23	1.1	12	170000	0.02	690	<2.0	1400	12000	<5.0	120	52

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	P	Pb	Rb	S	Sb	Se	SiO2_Si	Sn	Sr	Th	U	V	Zn
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
E391634	NS0028	130	132	WP	Fresh		Worley Parsons		<5			<5	<5		<5				40	29
E391635	NS0028	132	134	WP	Fresh		Worley Parsons		<5			<5	<5		<5				80	43
E391651	NS0028	164	166	WP	Fresh		Worley Parsons		<5			<5	<5		<5				82	31
E391663-E391669	NS0028	188	202	WP	Fresh		Worley Parsons		<5			<5	<5		<5				70	38
E391703	NS0028	266	268	KCF	Fresh		Worley Parsons		<5			<5	<5		<5				17	11
E392752-E392753	NS0039	110	114	MP	Fresh		Worley Parsons		11			<5	<5		<5				94	74
E392781-E392784	NS0039	168	176	MP	Fresh		Worley Parsons		<5			<5	<5		<5				40	34
E395043	NS0050	82	84	MP	Fresh		Worley Parsons		9			<5	<5		<5				133	131
E396265	NS0057	88	90	MP	Fresh		Worley Parsons		<5			<5	<5		<5				12	14
E396342	NS0057	240	242	MP	Fresh		Worley Parsons		<5			<5	<5		<5				22	27
E396454-E396456	NS0058	178	184	KCF	Fresh		Worley Parsons		<5			<5	<5		<5				50	71
E396459-E396460	NS0058	188	192	KCF	Fresh		Worley Parsons		8			<5	<5		<5				38	134
E889501	NS0077	0	4	WP	Oxide	Waste	GHD		<5				<5						12	<5
E889505	NS0077	8	12	WP	Oxide	Waste	GHD		<5				<5						10	<5
E889511	NS0077	20	24	WP	Oxide	Ore	GHD		<5				<5						<5	8
E889515	NS0077	28	32	WP	Oxide	Ore	GHD		<5				<5						<5	11
E889591	NS0077	178	182	WP	Fresh	Waste	GHD		<5				<5						38	32
E889643	NS0078	0	4	WP	Oxide	Waste	GHD		<5				<5						11	<5
E889648	NS0078	8	12	WP	Oxide	Waste	GHD		<5				<5						15	<5
E889653	NS0078	18	24	WP	Oxide	Ore	GHD		<5				<5						18	9
E889657	NS0078	26	32	WP	Oxide	Waste	GHD		<5				<5						10	14
E889673	NS0078	58	64	WP	Fresh	Ore	GHD		<5				<5						<5	7
E889683	NS0078	78	80	WP	Fresh	Waste	GHD		<6				<5						<5	7
E889697	NS0078	106	108	WP	Fresh	Waste	GHD		<5				<5						<5	6
E889723	NS0078	158	162	WP	Fresh	Waste	GHD		<5				<5						9	10
E889781	NS0078	274	278	WP	Fresh	Waste	GHD		<5				<5						32	25
E889809	NS0079	48	52	WP	Fresh	Ore	GHD		<5				<5						26	24
E889833	NS0079	94	98	WP	Fresh	Ore	GHD		<5				<5						20	15
X068310	NS0083	28	30	MP	Oxide	Waste	GHD		<5				<5						21	23
X068342	NS0083	88	92	MP	Fresh	Waste	GHD		<5				<5						32	36
X068364	NS0083	130	134	MP	Fresh	Waste	GHD		<5				<5						50	50
X068378	NS0083	158	162	MP	Fresh	Waste	GHD		<5				<5						56	45
X068517	NS0084	140	144	WP	Fresh	Waste	GHD		<5				<5						11	11
X068527	NS0084	158	162	WP	Fresh	Waste	GHD		<5				<5						92	55
X068544	NS0084	190	194	WP	Fresh	Ore	GHD		<5				<5						7	10
X068586	NS0084	270	274	WP	Fresh	Ore	GHD		<5				<5						26	26
X068592	NS0085	0	2	WP	Oxide		GHD		<5				<5						49	<5
X068597	NS0085	10	12	WP	Oxide	Waste	GHD		<5				<5						<5	<5
X068601	NS0085	18	22	WP	Oxide	Ore	GHD		<5				<5						<5	<5
X068607	NS0085	30	34	WP	Oxide	Ore	GHD		<5				<5						<5	10
X068621	NS0085	58	62	WP	Fresh	Ore	GHD		<5				<5						6	12
X068638	NS0085	90	94	WP	Fresh	Ore	GHD		<5				<5						<5	6
X068699	NS0085	208	212	WP	Fresh	Ore	GHD		<5				<5						<5	8
X068741	NS0086	8	12	WP	Oxide	Waste	GHD		<5				<5						27	<5
X068751	NS0086	28	32	WP	Oxide	Waste	GHD		<5				<5						6	<5
X068843	NS0086	208	212	WP	Fresh	Ore	GHD		<5				<5						<5	<5
X068863	NS0086	248	252	WP	Fresh	Waste	GHD		<5				<5						10	<5
X068884	NS0087	8	12	WP	Oxide	Waste	GHD		<5				<5						<5	<5
X068918-X068919	NS0087	74	78	WP	Fresh	Ore	Worley Parsons		<5			<5	<5		<5				8	11
X068923	NS0087	84	88	WP	Fresh	Waste	GHD		<5				<5						<5	14
X068925	NS0087	88	92	WP	Fresh	Waste	GHD		<5				<5						11	11
X068925-X068926	NS0087	88	92	WP	Fresh	Waste	Worley Parsons		<5			<5	<5		<5				22	22
X068967	NS0087	168	172	WP	Fresh	Ore	GHD		<5				<5						<5	9
X068999	NS0087	230	234	WP	Fresh	Ore	GHD		<5				<5						<5	5
X070079	NS0087	380	384	WP	Fresh	Ore	GHD		<5				<5						<5	6
X070083	NS0087	388	392	WP	Fresh	Ore	GHD		<5				<5						<5	6
X070089	NS0088	0	2	WP	Oxide	Waste	GHD		<5				<5						16	<5
X070093	NS0088	8	12	WP	Oxide	Waste	GHD		<5				<5						<5	<5
X070145	NS0088	108	112	WP	Fresh	Ore	GHD		<5				<5						<5	10
X070167	NS0088	150	154	WP	Fresh	Waste	GHD		<5				<5						38	19
X070233	NS0088	280	284	WP	Fresh	Waste	GHD		<5				<5						13	21
X070267	NS0088	346	350	WP	Fresh	Ore	GHD		<5				<5						8	12
X070269	NS0089	0	4	WP	Oxide		GHD		<5				<5						20	<5
X070299	NS0089	60	64	WP	Oxide		GHD		<5				<5						12	27
X070313	NS0089	88	92	WP	Fresh	Waste	GHD		<5				<5						26	30
X070333	NS0089	128	132	WP	Fresh	Waste	GHD		<5				<5						22	23

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	P	Pb	Rb	S	Sb	Se	SiO2_Si	Sn	Sr	Th	U	V	Zn
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
X070343	NS0089	148	158	WP	Fresh	Ore	Worley Parsons		<5			<5	<5		<5				13	19
X070359	NS0089	178	180	WP	Fresh	Waste	GHD		<5				<5						16	23
X070375	NS0089	210	214	WP	Fresh	Ore	GHD		<5				<5						<5	12
X070405	NS0089	268	272	WP	Fresh	Ore	GHD		<5				<5						<5	12
X070451	NS0089	360	364	WP	Fresh	Waste	GHD		<5				<5						<5	16
X070473	NS0090	0	4	WP	Oxide	Waste	GHD		<5				<5						21	<5
X070477	NS0090	8	12	WP	Oxide	Waste	GHD		<5				<5						<5	<5
X070483	NS0090	20	24	WP	Oxide	Waste	GHD		<5				<5						<5	<5
X070537	NS0090	128	132	WP	Fresh	Ore	GHD		<5				<5						<5	6
X070569	NS0090	190	194	WP	Fresh	Ore	GHD		<5				<5						9	17
X070609	NS0090	268	272	WP	Fresh	Ore	GHD		<5				<5						<5	9
X070696	NS0091	160	164	WP	Fresh	Waste	GHD		<5				<5						<5	5
X070696	NS0091	160	164	WP	Fresh	Waste	GHD		<5				<5						<5	5
X070716	NS0091	198	202	WP	Fresh	Waste	GHD		<5				<5						12	15
X070779	NS0092	40	44	WP	Fresh	Waste	GHD		<5				<5						6	10
X070783	NS0092	48	52	WP	Fresh	Ore	GHD		<5				<5						6	10
X070839	NS0092	158	162	WP	Fresh	Ore	GHD		<5				<5						<5	6
X070947	NS0093	92	96	WP	Fresh	Ore	GHD		<5				<5						<5	8
X071013	NS0093	216	220	WP	Fresh	Waste	GHD		<5				<5						<5	6
X071061	NS0094	28	32	WP	Oxide	Ore	GHD		<5				<5						<5	16
X071121	NS0094	148	152	WP	Fresh	Ore	GHD		<5				<5						<5	<5
X071127	NS0094	160	164	WP	Fresh	Ore	GHD		<5				<5						<5	6
X071205	NS0095	30	34	WP	Oxide	Waste	GHD		<5				<5						<5	11
X071209	NS0095	38	42	WP	Oxide	Waste	GHD		<5				<5						<5	7
X071328	NS0096	20	24	WP	Oxide	Ore	GHD		<5				<5						<5	<5
X071353	NS0096	70	74	WP	Fresh	Ore	GHD		<5				<5						<5	7
X071379	NS0096	120	124	WP	Fresh	Ore	GHD		<5				<5						8	12
X071435	NS0096	230	234	WP	Fresh	Waste	GHD		<5				<5						27	25
X071447	NS0096	254	258	WP	Fresh	Ore	GHD		<5				<5						<5	8
X071476	NS0097	28	32	WP	Oxide	Waste	GHD		<5				<5						<5	12
X071482	NS0097	40	44	WP	Fresh	Waste	GHD		<5				<5						50	67
X071606	NS0098	0	4	WP	Oxide	Waste	GHD		<5				<5						23	<5
X071616	NS0098	20	24	WP	Oxide	Waste	GHD		<5				<5						<5	<5
X071634	NS0098	56	58	WP	Fresh	Waste	GHD		<5				<5						5	11
X071635	NS0098	58	62	WP	Fresh	Ore	GHD		<5				<5						5	14
X071661	NS0098	108	112	WP	Fresh	Ore	GHD		<5				<5						<5	<5
X071697	NS0098	180	184	WP	Fresh	Ore	GHD		<5				<5						<5	6
X071933	NS0100	78	82	WP	Fresh	Waste	GHD		<5				<5						36	19
X073003	NS0106	2	4	WP	Oxide		GHD		<5				<5						42	<5
X073027	NS0106	48	52	WP	Fresh	Ore	GHD		<5				<5						<5	8
X073049	NS0106	92	96	WP	Fresh	Ore	GHD		<5				<5						8	13
X073089	NS0106	170	172	WP	Fresh	Ore	GHD		<5				<5						<5	7
X073202-X073203	NS0107	112	116	KCF	Fresh	Waste	Worley Parsons		<5			<5	<5		<5				39	39
X073204-X073205	NS0107	116	120	KCF	Fresh	Waste	Worley Parsons		<5			<5	<5		<5				45	70
X073206	NS0107	120	124	KCF	Fresh	Waste	GHD		6				<5						35	83
X073210	NS0107	128	132	KCF	Fresh	Waste	GHD		5				<5						35	45
X073210-X073211	NS0107	128	132	KCF	Fresh	Waste	Worley Parsons		<5			<5	<5		<5				75	84
X073216	NS0107	140	142	KCF	Fresh	Waste	GHD		7				<5						51	86
X073216-X073217	NS0107	140	144	KCF	Fresh	Waste	Worley Parsons		<5			<5	<5		<5				99	108
X073219-X073220	NS0107	146	150	KCF	Fresh	Waste	Worley Parsons		7			<5	<5		<5				72	111
X073220	NS0107	148	152	KCF	Fresh	Waste	GHD		7				<5						42	65
X073224-X073225	NS0107	156	160	KCF	Fresh	Waste	Worley Parsons		8			<5	<5		<5				65	113
X073226	NS0107	160	164	KCF	Fresh	Waste	GHD		8				<5						46	81
X073231	NS0107	170	174	KCF	Fresh	Waste	GHD		8				<5						48	84
X073231-X073232	NS0107	170	174	KCF	Fresh	Waste	Worley Parsons		11			<5	<5		<5				60	119
X073242	NS0107	192	194	KCF	Fresh	Waste	Worley Parsons		9			<5	<5		<5				62	113
X073245-X073247	NS0107	198	202	KCF	Fresh	Waste	Worley Parsons		6			<5	<5		<5				72	112
X073329	NS0108	160	162	WP	Fresh	Ore	GHD		<5				<5						<5	14
X073338	NS0108	178	180	WP	Fresh	Ore	GHD		<5				<5						11	22
X073715	NS0111	188	192	WP	Fresh	Waste	GHD		<5				<5						<5	10
X073741	NS0111	240	244	WP	Fresh	Ore	GHD		<5				<5						<5	<5
X073767	NS0111	290	294	WP	Fresh	Waste	GHD		<5				<5						6	13
X073988	NS0113	128	132	MP	Fresh	Ore	GHD		<5				<5						18	24
X073994	NS0113	140	142	MP	Fresh	Waste	GHD		<5				<5						39	34
X074004	NS0113	158	162	MP	Fresh	Waste	GHD		<5				<5						50	44
X074024	NS0113	198	202	MP	Fresh	Waste	GHD		<5				<5						17	30

Appendix A2: Total elements

Drill hole samples																			
Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	P	Pb	Rb	S	Sb	Se	SiO2_Si	Sn	Sr	Th	U	V	Zn
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
X074347	NS0116	108	112	MP	Fresh	Waste	GHD		<5				<5						50	46
X074359	NS0116	130	132	MP	Fresh	Waste	GHD		<5				<5						62	54
X074532	NS0117	190	194	MP	Fresh	Ore	GHD		<5				<5						30	32
X074649	NS0118	140	144	WP	Fresh	Waste	GHD		<5				<5						14	13
X074866	NS0120	206	210	WP	Fresh	Waste	GHD		9				<5						50	55
X075124	NS0122	150	154	WP	Fresh	Waste	GHD		<5				<5						22	20
X075393	NS0124	118	122	MP	Fresh	Ore	GHD		<5				<5						<5	6
X075399	NS0124	130	134	MP	Fresh	Waste	GHD		6				<5						82	73
X138071	NS0128	150	154	WP	Fresh	Waste	GHD		<5				<5						66	49
X072252	NS0152	78	82	MP	Fresh	Waste	GHD		<5				<5						101	94
X072273	NS0152	120	124	WP	Fresh	Ore	GHD		<5				<5						11	14
X072287	NS0152	148	152	WP	Fresh	Ore	GHD		<5				<5						11	13
X072335	NS0152	244	248	WP	Fresh	Waste	GHD		<5				<5						14	14
X072404	NS0153	98	102	WP	Fresh	Waste	GHD		<5				<5						17	15
X072439	NS0153	168	172	WP	Fresh	Ore	GHD		<5				<5						13	12
X072455	NS0153	200	204	WP	Fresh	Waste	GHD		17				<5						11	88
X072465	NS0153	220	224	WP	Fresh	Waste	GHD		<5				<5						16	16
X072493	NS0154	18	22	WP	Oxide	Ore	GHD		<5				<5						<5	7
X072499	NS0154	30	34	WP	Fresh	Ore	GHD		<5				<5						<5	9
X072503	NS0154	38	42	WP	Fresh	Ore	GHD		<5				<5						7	13
X072585	NS0154	200	204	WP	Fresh	Waste	GHD		<5				<5						29	37
X072677	NS0155	100	104	WP	Fresh	Waste	GHD		<5				<5						54	59
X072681	NS0155	108	112	WP	Fresh	Waste	GHD		<5				<5						11	17
X072733	NS0155	210	214	WP	Fresh	Ore	GHD		<5				<5						6	8
X072921	NS0157	130	134	WP	Fresh	Ore	GHD		<5				<5						29	15
X141514	NS0158	66	70	MP	Fresh	Waste	GHD		<5				<5						13	15
X141536	NS0158	110	114	MP	Fresh	Ore	GHD		<5				<5						10	12
X141571	NS0158	178	182	MP	Fresh	Ore	GHD		<5				<5						<5	7
X141643	NS0159	116	118	WP	Fresh	Ore	GHD		<5				<5						<5	7
X141776	NS0160	58	62	WP	Fresh	Waste	GHD		<5				<5						60	67
X121052	NS0165	100	104	WP	Fresh	Ore	GHD		<5				<5						<5	<5
AMD # 0178	NS0572	6	12	KCF	Oxide		Golder	360	2.4	1.8	<50	<0.10	0.13	358		30	<1.0	0.1	250	140
AMD # 0181	NS0572	24	30	KCF	Fresh		Golder	280	1.5	9.3	3900	<0.10	0.49	633		14	<1.0	0.09	260	110
AMD # 0184	NS0572	42	48	KCF	Fresh		Golder	260	2	8.9	4600	<0.10	0.59	405		28	<1.0	0.14	260	120
AMD # 0187	NS0572	60	66	KCF	Fresh		Golder	320	1.3	3.6	1800	<0.10	0.25	342		32	<1.0	0.07	290	100
AMD # 0189	NS0572	72	78	KCF	Fresh		Golder	280	2.6	0.91	4500	<0.10	0.52	466		15	<1.0	0.07	280	100
AMD # 0192	NS0572	90	96	KCF	Fresh		Golder	210	5	0.21	9500	<0.10	0.55	303		31	<1.0	0.2	250	150
AMD # 0195	NS0572	108	114	KCF	Fresh		Golder	140	1.2	0.17	3700	<0.10	0.43	367		11	<1.0	0.11	240	140
AMD # 0198	NS0572	126	132	KCF	Fresh		Golder	62	2.2	4.9	5100	0.15	0.53	436		7.2	<1.0	0.1	210	130
AMD # 0201	NS0572	144	150	KCF	Fresh		Golder	280	2.4	23	6600	0.16	0.43	420		17	<1.0	0.06	180	190
AMD # 0204	NS0572	162	168	KCF	Fresh		Golder	81	6.9	41	17000	0.31	0.71	437		11	1.2	0.2	110	160
AMD # 0207	NS0572	180	186	KCF	Fresh		Golder	110	7.5	23	26000	0.44	0.51	470		19	1.5	0.26	100	170
AMD # 0210	NS0574	0	6	KCF	Oxide		Golder	210	1.1	5.3	890	0.12	0.24	396		79	<1.0	0.1	250	89
AMD # 0213	NS0574	18	24	KCF	Fresh		Golder	270	<1.0	2.6	430	<0.10	0.54	369		31	<1.0	0.09	300	130
AMD # 0217	NS0574	42	48	KCF	Fresh		Golder	320	<1.0	0.79	1000	<0.10	0.27	308		5.5	<1.0	0.02	320	130
AMD # 0220	NS0574	60	66	KCF	Fresh		Golder	170	2.8	12	8400	0.14	0.51	393		3.3	<1.0	0.07	160	170
AMD # 0225	NS0574	90	96	KCF	Fresh		Golder	170	6.1	16	18000	0.24	0.68	421		8.5	<1.0	0.13	140	200
AMD # 0227	NS0574	102	108	KCF	Fresh		Golder	160	8.1	15	19000	0.37	0.96	548		13	<1.0	0.16	130	210
AMD # 0230	NS0574	120	126	KCF	Fresh		Golder	89	6.9	16	11000	0.25	0.47	379		15	1	0.18	110	150
AMD # 0232	NS0576	0	6	KCF	Oxide		Golder	130	2.8	1.9	1300	<0.10	0.33	239		21	<1.0	0.12	210	110
AMD # 0235	NS0576	18	24	KCF	Fresh		Golder	370	<1.0	5.5	2400	<0.10	0.3	351		43	<1.0	0.04	300	110
AMD # 0238	NS0576	36	42	KCF	Fresh		Golder	270	2	0.52	2700	<0.10	0.57	414		22	<1.0	0.1	230	120
AMD # 0241	NS0576	54	60	KCF	Fresh		Golder	210	<1.0	0.18	230	<0.10	0.12	425		19	<1.0	<0.02	240	91
AMD # 0245	NS0576	78	84	KCF	Fresh		Golder	190	1.2	0.73	11000	<0.10	1.8	384		17	<1.0	0.03	190	130
AMD # 0249	NS0576	102	108	KCF	Fresh		Golder	290	2.2	6.8	17000	0.23	0.8	430		18	<1.0	0.03	160	100
AMD # 0252	NS0576	120	126	KCF	Fresh		Golder	320	1.4	1.1	5700	<0.10	0.5	486		23	<1.0	0.09	230	110
AMD # 0256	NS0576	144	150	KCF	Fresh		Golder	240	<1.0	0.49	1100	<0.10	0.17	668		36	<1.0	0.02	220	92
AMD # 0259	NS0576	162	168	KCF	Fresh		Golder	300	<1.0	0.28	750	<0.10	0.14	868		13	<1.0	0.03	180	82
AMD # 0261	NS0576	174	180	KCF	Fresh		Golder	260	1.3	0.26	2500	<0.10	0.42	844		11	<1.0	0.06	160	83
AMD # 0264	NS0576	192	198	KCF	Fresh		Golder	260	1.6	0.27	3800	<0.10	0.5	777		11	<1.0	0.08	200	97
AMD # 0268	NS0578	18	24	KCF	Oxide		Golder	<50	6.1	11	140	0.35	0.16	329		2.8	<1.0	0.14	110	<50
AMD # 0271	NS0578	36	42	KCF	Fresh		Golder	85	5	8.9	290	0.31	0.65	278		<2.0	<1.0	0.16	130	120
AMD # 0274	NS0578	54	60	KCF	Fresh		Golder	<50	8.2	14	14000	0.36	0.5	283		<2.0	1	0.18	100	130
AMD # 0277	NS0578	72	78	KCF	Fresh		Golder	63	8.4	24	32000	0.27	1	587		<2.0	1.4	0.24	97	160
AMD # 0280	NS0578	90	96	KCF	Fresh		Golder	90	7.8	31	26000	0.22	0.55	557		2.7	1.7	0.23	110	190
AMD # 0283	NS0578	108	114	KCF	Fresh		Golder	340	4.5	12	14000	0.11	0.31	653		7.9	1.1	0.22	71	120

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	P	Pb	Rb	S	Sb	Se	SiO2_Si	Sn	Sr	Th	U	V	Zn
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
AMD # 0285	NS0578	120	126	KCF	Fresh		Golder	66	7	25	25000	0.19	0.54	595		3.2	2.2	0.33	75	140
AMD # 0289	NS0578	144	150	KCF	Fresh		Golder	780	2.6	12	12000	1.6	0.28	995		11	<1.0	0.13	19	50
AMD # 0293	NS0578	168	174	WP	Fresh		Golder	730	1.8	12	22000	4.5	0.32	1030		11	<1.0	0.08	17	<50
AMD # 0296	NS0578	186	192	WP	Fresh		Golder	800	<1.0	38	650	0.66	<0.10	973		11	<1.0	0.06	12	<50
AMD # 0298	NS0580	0	6	KCF	Oxide		Golder	130	1	7.5	300	<0.10	0.44	316		27	<1.0	0.07	260	130
AMD # 0301	NS0580	18	24	KCF	Fresh		Golder	180	1.4	0.64	1400	<0.10	0.28	366		11	<1.0	0.14	220	120
AMD # 0305	NS0580	42	48	KCF	Fresh		Golder	250	1	0.79	4800	<0.10	0.53	373		22	<1.0	0.06	250	110
AMD # 0308	NS0580	60	66	KCF	Fresh		Golder	150	1.2	0.24	7800	<0.10	1.3	416		<2.0	<1.0	0.07	240	100
AMD # 0311	NS0580	78	84	KCF	Fresh		Golder	61	1	11	830	<0.10	0.19	377		<2.0	<1.0	0.05	260	120
AMD # 0314	NS0580	96	102	KCF	Fresh		Golder	51	2.8	18	3000	0.14	0.4	407		<2.0	<1.0	0.04	200	120
AMD # 0317	NS0580	114	120	KCF	Fresh		Golder	<50	1.4	7.6	3600	<0.10	0.39	642		<2.0	<1.0	0.06	210	120
AMD # 0319	NS0580	126	132	KCF	Fresh		Golder	92	3.6	13	8900	0.28	0.71	473		<2.0	<1.0	0.08	170	140
AMD # 0322	NS0580	144	150	KCF	Fresh		Golder	<50	4.1	12	12000	0.18	0.59	436		<2.0	<1.0	0.06	180	140
AMD # 0324	NS0580	156	162	KCF	Fresh		Golder	<50	4	14	14000	0.19	0.49	455		<2.0	<1.0	0.08	180	150
AMD # 0327	NS0580	174	180	KCF	Fresh		Golder	74	6.1	8.8	21000	0.22	0.69	524		7.2	<1.0	0.1	160	260
AMD66a	NSD0031	1	29.7	WP	Oxide		Golder	58	1.7	0.2	86	0.15	<0.10	590		<2.0	<1.0	0.12	19	<50
AMD67a	NSD0031	37.48	63.08	WP	Fresh		Golder	1600	1.2	20	590	<0.10	<0.10	554		20	<1.0	0.11	12	<50
AMD77a	NSD0031	73.24	80	WP	Fresh		Golder	1500	1.2	26	630	<0.10	<0.10	582		11	<1.0	0.12	14	<50
AMD79a	NSD0031	80.38	94.1	WP	Fresh		Golder	290	3.7	16	3600	<0.10	0.29	1070		2.3	1.7	0.24	64	71
AMD83	NSD0031	103.17	103.43	WP	Fresh		Golder	580	<1.0	8.7	260	<0.10	<0.10	913		3.1	<1.0	0.02	6.2	<50
AMD85	NSD0031	119	119.33	WP	Fresh		Golder	71	4.4	39	3700	0.12	0.25	632		3.1	2.8	0.46	110	100
AMD87	NSD0031	127.7	128	WP	Fresh		Golder	77	2.5	37	2500	<0.10	0.2	926		3.5	3.3	0.54	140	130
AMD89	NSD0031	144.77	145.06	WP	Fresh		Golder	310	6.8	74	8200	0.23	0.63	493		4.7	<1.0	0.28	33	63
AMD91	NSD0031	156	156.34	WP	Fresh		Golder	130	1.4	3	140	<0.10	<0.10	690		<2.0	<1.0	<0.02	2.3	<50
AMD93	NSD0031	171.06	171.42	WP	Fresh		Golder	1200	<1.0	35	380	0.1	<0.10	861		10	<1.0	0.09	14	<50
AMD95	NSD0031	192.53	192.82	WP	Fresh		Golder	270	<1.0	26	370	<0.10	<0.10	367		3.4	<1.0	0.1	10	<50
AMD97	NSD0031	203	203.36	WP	Fresh		Golder	85	<1.0	16	230	<0.10	<0.10	594		6.1	<1.0	0.04	7.5	<50
AMD99	NSD0031	231.48	231.82	WP	Fresh		Golder	160	<1.0	25	320	<0.10	<0.10	856		3.1	<1.0	0.07	15	<50
AMD102a	NSD0031	259.38	276.55	WP	Fresh		Golder	670	7.7	12	270	<0.10	0.11	801		16	<1.0	0.07	12	<50
AMD # 0129	NSD0031	280.4	280.7	WP	Fresh		Golder	280	<1.0	13	240	<0.10	<0.10	882		17	<1.0	0.06	8.4	<50
AMD # 0131	NSD0031	297.96	298.26	WP	Fresh		Golder	3000	1.5	17	950	0.12	0.11	904		14	1.4	0.31	47	67
AMD # 0133	NSD0031	321.98	322.38	WP	Fresh		Golder	1100	2	3.5	260	<0.10	0.14	551		12	<1.0	0.07	10	<50
AMD # 0135	NSD0031	363.98	364.29	WP	Fresh		Golder	470	<1.0	0.6	200	0.58	<0.10	817		5.3	<1.0	0.05	11	<50
AMD # 0137	NSD0031	374.83	375.12	WP	Fresh		Golder	1200	<1.0	2.3	<50	1.4	<0.10	695		9	<1.0	0.07	5.2	<50
AMD # 0139	NSD0031	392.48	392.79	WP	Fresh		Golder	1600	1.3	1.2	270	0.13	<0.10	727		10	<1.0	0.05	6.1	<50
AMD # 0141	NSD0031	416.93	417.25	WP	Fresh		Golder	210	<1.0	0.39	930	<0.10	<0.10	1070		4.7	<1.0	0.03	12	<50
AMD # 0143	NSD0031	437.77	438.09	WP	Fresh		Golder	660	<1.0	2.6	200	0.48	<0.10	785		9.2	<1.0	0.05	6.4	<50
AMD # 0145	NSD0031	457.91	458.2	WP	Fresh		Golder	760	<1.0	0.3	270	0.15	<0.10	797		9.5	<1.0	0.04	9.1	<50
AMD104a	NSD0032	6.47	30.16	WP	Oxide		Golder	290	1.2	20	61	0.11	0.22	511		10	<1.0	0.17	18	<50
AMD109a	NSD0032	35	68.32	WP	Fresh		Golder	700	1.1	14	380	0.15	0.11	789		29	<1.0	0.08	12	<50
AMD113	NSD0032	76.52	76.84	WP	Fresh		Golder	350	1.9	18	230	0.25	0.11	641		31	<1.0	0.13	12	<50
AMD115	NSD0032	95.75	96.18	WP	Fresh		Golder	580	<1.0	17	190	<0.10	<0.10	342		29	<1.0	0.05	4.4	<50
AMD118	NSD0032	112.8	113.15	WP	Fresh		Golder	<50	6.2	67	8500	0.31	1.1	695		4	2.8	0.42	120	120
AMD119	NSD0032	117.35	117.71	WP	Fresh		Golder	880	<1.0	17	340	0.17	<0.10	711		41	<1.0	0.05	6.8	<50
AMD121	NSD0032	126.79	127.15	WP	Fresh		Golder	780	<1.0	7.2	81	0.11	<0.10	538		37	<1.0	<0.02	3.5	<50
AMD127	NSD0032	186.12	186.32	WP	Fresh		Golder	560	<1.0	12	130	0.13	<0.10	848		8.8	<1.0	0.04	7.1	<50
AMD # 0146	NSD0032	200.68	200.98	WP	Fresh		Golder	1100	<1.0	23	240	0.15	<0.10	751		11	<1.0	0.06	7	<50
AMD # 0148	NSD0032	224.19	224.56	WP	Fresh		Golder	1100	1.8	12	310	0.17	<0.10	916		13	<1.0	0.05	5.7	<50
AMD # 0150	NSD0032	249.64	249.99	WP	Fresh		Golder	350	<1.0	25	210	0.17	<0.10	882		4	<1.0	0.05	7.5	<50
AMD # 0151	NSD0032	255.68	256.03	WP	Fresh		Golder	<50	20	110	24000	1.1	1.6	778		7	2.4	0.44	58	83
AMD # 0154	NSD0032	273.79	274.07	WP	Fresh		Golder	600	7	77	3500	0.52	0.22	1010		7.9	2	0.38	95	76
AMD # 0156	NSD0032	283.31	283.61	WP	Fresh		Golder	3100	4.5	120	4400	0.41	0.49	1020		32	<1.0	0.19	19	59
AMD # 0158	NSD0032	289.44	289.8	WP	Fresh		Golder	2100	5.1	110	4700	0.56	0.43	1290		20	1	0.21	20	62
AMD # 0160	NSD0032	311.87	312.26	WP	Fresh		Golder	160	2.5	34	1600	0.63	0.16	1120		32	<1.0	0.1	18	<50
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh		Golder	170	1.6	61	1300	0.39	<0.10	863		7.4	<1.0	0.17	33	60
AMD # 0164	NSD0032	329.11	329.52	WP	Fresh		Golder	100	<1.0	20	130	0.46	<0.10	1280		3.6	<1.0	0.04	11	<50
AMD # 0167	NSD0032	343.73	344.04	WP	Fresh		Golder	2500	2.5	1.6	4300	1.2	0.18	1670		19	<1.0	0.23	42	<50
AMD # 0168	NSD0032	349.2	349.53	WP	Fresh		Golder	860	<1.0	21	120	0.56	<0.10	1300		19	<1.0	0.04	7.5	<50
AMD # 0169	NSD0032	356.45	356.8	WP	Fresh		Golder	250	2.4	13	2400	1.1	0.11	575		20	<1.0	0.14	42	<50
AMD # 0174	NSD0032	421.98	422.39	WP	Fresh		Golder	970	<1.0	0.46	300	<0.10	<0.10	1200		11	<1.0	0.03	6.8	<50
AMD # 0176	NSD0032	449.04	449.4	WP	Fresh		Golder	620	2.7	2.5	10000	2	0.2	1350		10	<1.0	0.06	8.9	<50
AMD # 039	NSRD0387	184.65	184.96	WP	Fresh		Golder	230	<1.0	78	400	<0.10	<0.10	437		6.5	<1.0	0.14	22	52
AMD # 041	NSRD0387	201.93	202.24	WP	Fresh		Golder	820	<1.0	65	430	<0.10	<0.10	424		8	<1.0	0.13	17	<50
AMD # 043	NSRD0387	210.08	210.43	WP	Fresh		Golder	3800	1.3	39	920	<0.10	<0.10	385		19	<1.0	0.07	6.9	<50
AMD # 045	NSRD0387	221.94	222.3	WP	Fresh		Golder	470	1.2	56	1600	<0.10	0.11	475		6.5	<1.0	0.09	16	<50
AMD # 047	NSRD0387	233.78	234.13	WP	Fresh		Golder	460	1.6	160	610	<0.10	0.11	808		13	1.3	0.27	45	62

Appendix A2: Total elements

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	P	Pb	Rb	S	Sb	Se	SiO2_Si	Sn	Sr	Th	U	V	Zn
		From	to					(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
AMD # 049	NSRD0387	246.67	247	WP	Fresh		Golder	630	<1.0	70	1300	<0.10	0.15	390		5.8	<1.0	0.13	17	<50
AMD # 051	NSRD0387	259.19	259.56	WP	Fresh		Golder	520	2.1	84	1200	<0.10	0.19	395		6.6	<1.0	0.16	20	52
AMD # 053	NSRD0387	279.3	279.62	WP	Fresh		Golder	770	<1.0	52	300	<0.10	<0.10	476		5.5	<1.0	0.09	13	<50
AMD # 055	NSRD0387	306.92	307.32	WP	Fresh		Golder	660	<1.0	54	83	<0.10	<0.10	494		7.9	<1.0	0.09	12	<50
AMD # 057	NSRD0387	322.68	323.07	WP	Fresh		Golder	700	2	69	550	<0.10	0.1	527		7	<1.0	0.15	18	<50
AMD # 059	NSRD0387	340.23	340.57	WP	Fresh		Golder	680	2.6	100	3000	<0.10	0.28	397		9.9	<1.0	0.2	28	50
AMD # 061	NSRD0387	356.08	356.46	WP	Fresh		Golder	640	2.7	110	3600	<0.10	0.22	603		11	<1.0	0.2	31	63
AMD # 063	NSRD0387	373.42	373.83	MP	Fresh		Golder	550	1.7	58	410	<0.10	<0.10	439		26	<1.0	0.13	11	<50
AMD # 065	NSRD0387	401.48	401.85	MP	Fresh		Golder	2800	2.7	16	2300	<0.10	0.17	1060		21	<1.0	0.19	30	66
AMD_1	NSRD0393	181.1	181.45	WP	Fresh		Golder	260	5.3	110	3400	<0.10	0.22	485		27	1.5	0.36	61	79
AMD_3	NSRD0393	202.96	203.23	WP	Fresh		Golder	1900	<1.0	47	1000	<0.10	<0.10	704		14	<1.0	0.1	19	<50
AMD_6	NSRD0393	222.46	222.75	WP	Fresh		Golder	1200	5.9	150	3700	0.15	0.28	438		47	1.7	0.49	69	88
AMD_7	NSRD0393	223.45	223.78	WP	Fresh		Golder	1400	6	120	2800	<0.10	0.22	486		58	1.7	0.42	67	88
AMD_8	NSRD0393	226.74	227.08	WP	Fresh		Golder	1000	9.1	88	5800	0.17	0.43	713		28	2	0.33	86	110
AMD_11	NSRD0393	231.44	231.8	WP	Fresh		Golder	1800	4.6	88	3400	<0.10	0.27	266		29	1.2	0.25	53	86
AMD_13	NSRD0393	234.67	234.94	WP	Fresh		Golder	990	2.7	79	1600	<0.10	0.17	377		22	<1.0	0.21	38	60
AMD # 015	NSRD0393	238.46	238.82	WP	Fresh		Golder	120	3.2	1.8	2600	<0.10	0.12	854		2.8	3.8	0.55	130	120
AMD # 017	NSRD0393	248.88	249.17	WP	Fresh		Golder	100	9.4	1.3	8700	<0.10	0.21	919		<2.0	2.9	0.36	140	170
AMD # 019	NSRD0393	255.02	255.37	WP	Fresh		Golder	90	6.8	20	21000	0.62	0.24	766		9.5	<1.0	0.15	28	57
AMD # 021	NSRD0393	270.45	270.8	WP	Fresh		Golder	1500	2.6	83	2500	<0.10	0.18	660		42	1.7	0.3	94	140
AMD # 023	NSRD0393	287.6	287.92	MP	Fresh		Golder	69	17	10	1700	0.12	0.26	732		23	3.2	0.42	160	170
AMD # 025	NSRD0393	299.6	299.97	MP	Fresh		Golder	370	2.7	80	11000	0.11	0.39	511		26	<1.0	0.16	44	92
AMD # 027	NSRD0393	328.83	329.19	MP	Fresh		Golder	<50	<1.0	3.8	460	<0.10	<0.10	502		28	<1.0	<0.02	4	<50
AMD # 029	NSRD0393	348.67	349	MP	Fresh		Golder	230	1.3	140	1200	<0.10	0.11	385		45	1.7	0.31	55	87
AMD # 031	NSRD0393	378.65	379.06	MP	Fresh		Golder	96	24	1.4	2300	0.18	0.24	728		2.7	4	0.51	180	210
AMD # 033	NSRD0393	395.11	395.52	MP	Fresh		Golder	140	13	12	7500	1.1	0.24	511		2.2	4.3	0.62	66	190
AMD # 035	NSRD0393	410.72	411	MP	Fresh		Golder	100	30	0.96	6100	0.44	0.26	692		5	4.5	0.61	140	180
AMD # 037	NSRD0393	422.71	423.02	MP	Fresh		Golder	290	3.2	20	1600	<0.10	0.14	577		25	3.2	0.36	100	130

Tailings samples

Sample ID	Type	Description	Source	P	Pb	Rb	S	Sb	Se	SiO2_Si	Sn	Sr	Th	U	V	Zn
				(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
(3283 - Year 1-7Tailings)			GHD		<5				<5						<5	20
(3283 Tails) 1			GHD		<5				<5						13	28
(3283 Tails) 2			GHD		6				<5						13	30
Batch Plant Fresh Coarse Cobing Non Mags (A1	Dry-Fresh	Stage 2 Process Plant Dry rejects	Golder	1200	12	33	2200	<20	<20	220		22	<100	0.21	21	<50
Batch Plant Oxide Coarse Cobing Non Mags (A1	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	200	19	1.4	120	<20	<20	380		5.2	<100	0.81	55	<50
VARFR01 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	1100	13	43	5900	<20	<20	150		14	<100	0.37	76	98
VARFR09 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	950	14	11	690	<20	<20	290		15	<100	0.06	8	<50
VAROX03 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	430	14	0.14	88	<20	<20	340		3.7	<100	0.14	13	<50
VAROX09 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	550	12	9.2	67	<20	<20	240		48	<100	0.31	5.4	<50

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
		From	to					pH units	µS/cm	wt%	wt%	wt%	wt%	wt%	pH units	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t		kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t
E391634	NS0028	130	132	WP	Fresh		Worley Parsons			1.94	1.82	0.35			3.3	4.6	17.2	21.91	0.63	59.41	37.5	
E391635	NS0028	132	134	WP	Fresh		Worley Parsons			1.37	1.33	0.14			3	7.7	16.7	24.76	0.41	41.96	17.2	6.13
E391651	NS0028	164	166	WP	Fresh		Worley Parsons			1.69	1.56	0.41			2.8	21.4	33.2	37.56	0.27	51.76	14.2	
E391663-E391669	NS0028	188	202	WP	Fresh		Worley Parsons			0.52	0.5	0.06			7	<0.1	<0.1	-18.18	2.14	15.93	34.1	
E391703	NS0028	266	268	KCF	Fresh		Worley Parsons			0.13	0.12	0.03			9	<0.1	<0.1	-34.32	9.62	3.98	38.3	
E392752-E392753	NS0039	110	114	MP	Fresh		Worley Parsons			1.5	1.46	0.11			3.4	4.2	8.4	8.94	0.81	45.94	37	
E392781-E392784	NS0039	168	176	MP	Fresh		Worley Parsons			0.93	0.92	0.02			4.2	0.5	3.6	-9.52	1.33	28.48	38	14.7
E395043	NS0050	82	84	MP	Fresh		Worley Parsons			0.34	0.33	0.02			8.5	<0.1	<0.1	-6.99	1.67	10.41	17.4	
E396265	NS0057	88	90	MP	Fresh		Worley Parsons			0.08	0.08	0.01			9	<0.1	<0.1	-51.35	21.96	2.45	53.8	
E396342	NS0057	240	242	MP	Fresh		Worley Parsons			0.31	0.31	0.01			8.7	<0.1	<0.1	-28.51	4	9.49	38	
E396454-E396456	NS0058	178	184	KCF	Fresh		Worley Parsons			2.28	2.09	0.55			3	13.2	24	33.03	0.53	69.83	36.8	
E396459-E396460	NS0058	188	192	KCF	Fresh		Worley Parsons			3.69	3.24	1.36			2.4	60.4	76.7	100.91	0.11	113.01	12.1	4.5
E889501	NS0077	0	4	WP	Oxide	Waste	GHD								7.2	0.1	0.1	-1.7	3.85	0.6	2.3	
E889505	NS0077	8	12	WP	Oxide	Waste	GHD								7.3	0.1	0.1	-3.2	20	0.2	3.37	
E889511	NS0077	20	24	WP	Oxide	Ore	GHD								7.7	0.1	0.1			0.1		
E889515	NS0077	28	32	WP	Oxide	Ore	GHD								7.8	0.1	0.1			0.3		
E889521	NS0077	40	44	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.8		
E889525	NS0077	48	52	WP	Fresh	Ore	GHD								8.4	0.1	0.1			1.1		
E889531	NS0077	60	64	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1		
E889535	NS0077	68	72	WP	Fresh	Ore	GHD								8.8	0.1	0.1			4.7		
E889541	NS0077	80	84	WP	Fresh	Ore	GHD								8.4	0.1	0.1			1.1		
E889545	NS0077	88	92	WP	Fresh	Ore	GHD								8.5	0.1	0.1			3		
E889555	NS0077	108	112	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.1		
E889561	NS0077	120	124	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2.5		
E889565	NS0077	128	132	WP	Fresh	Ore	GHD								8.3	0.1	0.1			0.6		
E889571	NS0077	140	144	WP	Fresh	Ore	GHD								7.9	0.1	0.1			1.1		
E889575	NS0077	148	152	WP	Fresh	Ore	GHD								8.7	0.1	0.1			4.1		
E889581	NS0077	158	162	WP	Fresh	Waste	GHD								8.7	0.1	0.1			3.9		
E889587	NS0077	170	174	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1		
E889591	NS0077	178	182	WP	Fresh	Waste	GHD			1.6					3.4	3.2	15.3			49		
E889597	NS0077	190	194	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.6		
E889601	NS0077	198	202	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.8		
E889607	NS0077	210	214	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.8		
E889609	NS0077	214	218	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.3		
E889611	NS0077	218	222	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.7		
E889617	NS0077	230	234	WP	Fresh	Ore	GHD								9	0.1	0.1			0.9		
E889621	NS0077	238	242	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1		
E889622	NS0077	240	244	WP	Fresh	Ore	GHD								7.3	0.1	0.1			1		
E889627	NS0077	250	254	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1		
E889631	NS0077	258	262	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.2		
E889637	NS0077	270	274	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.9		
E889641	NS0077	278	282	WP	Fresh	Ore	GHD								8.8	0.1	0.1			3.6		
E889643	NS0078	0	4	WP	Oxide	Waste	GHD								7.3	0.1	0.1			1.1		
E889648	NS0078	8	12	WP	Oxide	Waste	GHD								6.7	0.1	0.6	-2.33	5.12	0.6	2.9	0.7
E889653	NS0078	18	24	WP	Oxide	Ore	GHD								6.8	0.1	0.2	-4.4	16.39	0.3	4.69	
E889654	NS0078	20	22	WP	Oxide	Ore	GHD			0.01					6.5	0.1	0.1	-3.7	13.08	0.3	4.01	
E889657	NS0078	26	32	WP	Oxide	Waste	GHD								7.4	0.1	0.1	-3.3	18.01	0.2	3.49	
E889658	NS0078	28	30	WP	Oxide	Waste	GHD								7.2	0.1	0.1	-3.3	22.55	0.2	3.45	
E889663	NS0078	38	40	WP	Oxide	Waste	GHD								7	0.1	0.1			0.2		
E889664	NS0078	40	42	WP	Oxide	Waste	GHD								7.5	0.1	0.1			0.2		
E889667	NS0078	46	48	WP	Oxide	Waste	GHD								7.7	0.1	0.1			0.6		
E889668	NS0078	48	50	WP	Fresh	Waste	GHD								8.7	0.1	0.1			1.2		
E889673	NS0078	58	64	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-55	44.45	1.3	56.27	
E889674	NS0078	60	62	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-38.1	32.1	1.2	39.33	
E889677	NS0078	66	72	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-35.4	9.94	4	39.36	
E889678	NS0078	68	70	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-41.3	33.11	1.3	42.59	
E889683	NS0078	78	80	WP	Fresh	Waste	GHD								8.7	0.1	0.1			1.5		
E889684	NS0078	80	82	WP	Fresh	Waste	GHD								8.3	0.1	0.1			32.5		
E889687	NS0078	86	88	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.8		
E889688	NS0078	88	90	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1		
E889697	NS0078	106	108	WP	Fresh	Waste	GHD								8.5	0.1	0.1	-29.79	17.49	1.8	31.6	18
E889698	NS0078	108	110	WP	Fresh	Waste	GHD								8.4	0.1	0.1			4.6		
E889703	NS0078	118	124	WP	Fresh	Waste	GHD								8.6	0.1	0.1			3.6		
E889704	NS0078	120	122	WP	Fresh	Waste	GHD								8.2	0.1	0.1			4.7		
E889707	NS0078	126	132	WP	Fresh	Waste	GHD								8.6	0.1	0.1			3.2		
E889708	NS0078	128	130	WP	Fresh	Waste	GHD								8.7	0.1	0.1			1.8		
E889713	NS0078	138	144	WP	Fresh	Waste	GHD								8.6	0.1	0.1			2.9		
E889714	NS0078	140	142	WP	Fresh	Waste	GHD								8.3	0.1	0.1			2.8		
E889717	NS0078	146	148	WP	Fresh	Waste	GHD								8.6	0.1	0.1			5.1		
E889718	NS0078	148	150	WP	Fresh	Waste	GHD								8.4	0.1	0.1			2		
E889723	NS0078	158	162	WP	Fresh	Waste	GHD								8.7	0.1	0.1			5.3		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
E889727	NS0078	166	170	WP	Fresh	Waste	GHD								8.8	0.1	0.1			2.5		
E889733	NS0078	178	182	WP	Fresh	Waste	GHD								7.3	0.1	0.1			1.7		
E889737	NS0078	186	190	WP	Fresh	Waste	GHD								7.9	0.1	0.1			2.7		
E889743	NS0078	198	202	WP	Fresh	Ore	GHD								7.8	0.1	0.1			2.1		
E889747	NS0078	206	210	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.5		
E889753	NS0078	218	222	WP	Fresh	Ore	GHD								8.7	0.1	0.1			3		
E889757	NS0078	226	228	WP	Fresh	Waste	GHD								8.8	0.1	0.1			3.6		
E889759	NS0078	230	232	WP	Fresh	Waste	GHD								8.5	0.1	0.1			4.3		
E889763	NS0078	238	242	WP	Fresh	Ore	GHD								8.2	0.1	0.1			2.3		
E889767	NS0078	246	250	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.2		
E889773	NS0078	258	262	WP	Fresh	Waste	GHD								8.4	0.1	0.1			8.5		
E889777	NS0078	266	270	WP	Fresh	Waste	GHD			0.21					8.7	0.1	0.1			6.4		
E889781	NS0078	274	278	WP	Fresh	Waste	GHD								7.4	0.1	0.1			16.7		
E889785	NS0079	0	4	WP	Oxide	Waste	GHD								7.3	0.1	0.1	-2.9	5.21	0.7	3.59	
E889795	NS0079	20	24	WP	Oxide	Ore	GHD								7.8	0.1	0.1	-2.1	23.86	0.1	2.19	
E889799	NS0079	28	32	WP	Oxide	Ore	GHD								8	0.1	0.1	-6.2	102.22	0.1	6.26	
E889805	NS0079	40	44	WP	Oxide	Ore	GHD								8.2	0.1	0.1	-28.4	25.73	1.1	29.55	
E889809	NS0079	48	52	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-45.5	6.92	7.7	53.19	
E889815	NS0079	60	62	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.9		
E889816	NS0079	62	64	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.9		
E889821	NS0079	70	74	WP	Fresh	Ore	GHD								8.6	0.1	0.1			2.1		
E889825	NS0079	78	82	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.9		
E889831	NS0079	90	94	WP	Fresh	Ore	GHD								9	0.1	0.1			0.9		
E889833	NS0079	94	98	WP	Fresh	Ore	GHD								7.5	0.1	0.1			17.3		
E889835	NS0079	98	102	WP	Fresh	Waste	GHD								9	0.1	0.1			4.1		
E889841	NS0079	110	112	WP	Fresh	Ore	GHD								9	0.1	0.1			2		
E889842	NS0079	112	114	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.6		
E889847	NS0079	120	124	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-31.1	17.93	1.8	32.94	
E889851	NS0079	128	132	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-31.3	7.29	5	36.28	
E889857	NS0079	140	142	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.7		
E889858	NS0079	142	144	WP	Fresh	Ore	GHD								8.8	0.1	0.1			3.2		
X068296	NS0083	0	4	MP	Oxide	Waste	GHD								7.7	0.1	0.1			0.7		
X068300	NS0083	8	12	MP	Oxide	Waste	GHD								7.6	0.1	0.1			0.4		
X068306	NS0083	20	24	MP	Oxide	Waste	GHD								7	0.1	0.1	-3.8	28.57	0.1	3.94	
X068310	NS0083	28	30	MP	Oxide	Waste	GHD								7.1	0.1	0.1	-2	8.26	0.3	2.28	
X068311	NS0083	30	32	MP	Oxide	Waste	GHD								7.5	0.1	0.1			0.4		
X068316	NS0083	40	42	MP	Oxide	Waste	GHD								7.7	0.1	0.1			0.2		
X068317	NS0083	42	44	MP	Oxide	Waste	GHD								7.2	0.1	0.1			0.1		
X068326	NS0083	58	60	MP	Oxide	Waste	GHD								7.8	0.1	0.1			1.2		
X068327	NS0083	60	62	MP	Fresh	Waste	GHD								8.2	0.1	0.1			8.8		
X068332	NS0083	68	72	MP	Fresh	Waste	GHD								7.9	0.1	0.1			4.6		
X068338	NS0083	80	82	MP	Fresh	Waste	GHD								8.2	0.1	0.1			19.8		
X068339	NS0083	82	84	MP	Fresh	Waste	GHD								8.2	0.1	0.1			9.2		
X068342	NS0083	88	92	MP	Fresh	Waste	GHD								8.1	0.1	0.1	-35.79	4.84	9.3	45.1	19
X068349	NS0083	100	102	MP	Fresh	Waste	GHD								8.1	0.1	0.1			2.5		
X068354	NS0083	110	112	MP	Fresh	Waste	GHD								8.5	0.1	0.1			9.7		
X068355	NS0083	112	114	MP	Fresh	Waste	GHD								7.7	0.1	0.1			9.8		
X068358	NS0083	118	120	MP	Fresh	Waste	GHD								8.1	0.1	0.1			10		
X068359	NS0083	120	122	MP	Fresh	Waste	GHD								8.5	0.1	0.1			13.6		
X068364	NS0083	130	134	MP	Fresh	Waste	GHD								8.4	0.1	0.1	-6.06	1.45	13.3	19.4	2.5
X068368	NS0083	138	142	MP	Fresh	Waste	GHD								9	0.1	0.1			10.8		
X068374	NS0083	150	154	MP	Fresh	Waste	GHD								8.9	0.1	0.1			11.8		
X068378	NS0083	158	162	MP	Fresh	Waste	GHD								8.7	0.1	0.1			10.2		
X068384	NS0083	170	172	MP	Fresh	Waste	GHD								8.9	0.1	0.1			10.2		
X068385	NS0083	172	174	MP	Fresh	Waste	GHD								8.9	0.1	0.1			14.1		
X068388	NS0083	178	182	MP	Fresh	Waste	GHD								8.7	0.1	0.1			12.1		
X068394	NS0083	190	194	MP	Fresh	Waste	GHD								8.4	0.1	0.1			16		
X068398	NS0083	198	202	MP	Fresh	Waste	GHD								8.2	0.1	0.1			20.1		
X068406	NS0083	210	214	MP	Fresh	Waste	GHD								8.8	0.1	0.1			3.3		
X068410	NS0083	218	222	MP	Fresh	Waste	GHD								8.7	0.1	0.1			8.7		
X068416	NS0083	230	234	MP	Fresh	Waste	GHD								8.4	0.1	0.1			6.8		
X068420	NS0083	238	242	MP	Fresh	Waste	GHD								8.8	0.1	0.1			10.9		
X068426	NS0083	250	254	MP	Fresh	Waste	GHD								8.8	0.1	0.1			9.7		
X068438	NS0083	268	272	MP	Fresh	Waste	GHD								8.8	0.1	0.1			6		
X068444	NS0083	280	282	MP	Fresh	Waste	GHD								8.6	0.1	0.1			5.4		
X068446	NS0084	2	4	WP	Oxide	Waste	GHD								8.1	0.1	0.1			0.6		
X068451	NS0084	10	12	WP	Oxide		GHD								8.2	0.1	0.1			0.3		
X068455	NS0084	18	22	WP	Oxide	Ore	GHD								8	0.1	0.1			0.1		
X068461	NS0084	30	34	WP	Oxide	Ore	GHD								7.8	0.1	0.1			0.1		
X068465	NS0084	38	42	WP	Oxide	Ore	GHD								8.1	0.1	0.1			7.2		
X068471	NS0084	50	54	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.2		
X068475	NS0084	58	62	WP	Fresh	Ore	GHD								9	0.1	0.1			1.3		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples																					
Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X068481	NS0084	70	74	WP	Fresh	Waste	GHD								8.9	0.1	0.1			3.4		
X068485	NS0084	78	82	WP	Fresh	Waste	GHD								8.7	0.1	0.1			5.1		
X068492	NS0084	90	92	WP	Fresh	Waste	GHD								8.8	0.1	0.1			12.2		
X068497	NS0084	100	104	WP	Fresh	Waste	GHD			0.44					7.8	0.1	0.1			13.5		
X068501	NS0084	108	112	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.2		
X068507	NS0084	120	124	WP	Fresh	Waste	GHD								8.7	0.1	0.1			7.5		
X068511	NS0084	128	132	WP	Fresh	Waste	GHD								8.7	0.1	0.1			6.2		
X068517	NS0084	140	144	WP	Fresh	Waste	GHD								8.2	0.1	0.1			23.3		
X068523	NS0084	150	154	WP	Fresh	Waste	GHD								8.3	0.1	0.1			11.6		
X068527	NS0084	158	162	WP	Fresh	Waste	GHD			0.77					3.4	11.8	22			23.6		
X068533	NS0084	170	174	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.4		
X068539	NS0084	180	182	WP	Fresh		GHD								8.5	0.1	0.1			1.1		
X068544	NS0084	190	194	WP	Fresh	Ore	GHD								8.2	0.1	0.1			6.4		
X068548	NS0084	198	202	WP	Fresh	Waste	GHD								8.2	0.1	0.1			8.9		
X068554	NS0084	210	214	WP	Fresh	Waste	GHD								8.9	0.1	0.1			16.8		
X068556	NS0084	214	218	WP	Fresh	Ore	GHD								9.3	0.1	0.1			2.9		
X068564	NS0084	228	232	WP	Fresh	Ore	GHD								9	0.1	0.1			2.3		
X068574	NS0084	248	252	WP	Fresh	Waste	GHD								9.2	0.1	0.1			2.1		
X068580	NS0084	258	262	WP	Fresh	Waste	GHD								8.9	0.1	0.1			6.2		
X068586	NS0084	270	274	WP	Fresh	Ore	GHD								8.4	0.1	0.1			7.5		
X068591	NS0084	280	282	WP	Fresh	Waste	GHD								9.1	0.1	0.1			1.3		
X068592	NS0085	0	2	WP	Oxide		GHD								7.8	0.1	0.1			0.3		
X068597	NS0085	10	12	WP	Oxide	Waste	GHD								6.9	0.1	0.1	-0.75	5.88	0.2	0.9	0.5
X068598	NS0085	12	14	WP	Oxide	Waste	GHD								8.4	0.1	0.1			0.2		
X068601	NS0085	18	22	WP	Oxide	Ore	GHD								7.5	0.1	0.1			0.1		
X068607	NS0085	30	34	WP	Oxide	Ore	GHD								8.2	0.1	0.1	-7.3	120.18	0.1	7.36	
X068611	NS0085	38	42	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-41.8	36	1.2	42.99	
X068617	NS0085	50	54	WP	Fresh	Ore	GHD								8.5	0.1	0.1	-52.2	40.64	1.3	53.52	
X068621	NS0085	58	62	WP	Fresh	Ore	GHD								8.5	0.1	0.1	-57.4	22.42	2.7	60.08	
X068627	NS0085	70	74	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-48	21.09	2.4	50.39	
X068632	NS0085	78	82	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-42	6.92	7.1	49.09	
X068638	NS0085	90	94	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-64.9	118.82	0.6	65.5	59
X068642	NS0085	98	102	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-63.3	94.95	0.7	63.97	
X068648	NS0085	110	112	WP	Fresh	Ore	GHD								8.3	0.1	0.1			0.6		
X068653	NS0085	118	122	WP	Fresh	Ore	GHD								8.1	0.1	0.1			1.9		
X068659	NS0085	130	132	WP	Fresh	Ore	GHD								9	0.1	0.1			0.8		
X068665	NS0085	140	144	WP	Fresh	Ore	GHD								9	0.1	0.1			0.6		
X068669	NS0085	148	152	WP	Fresh	Ore	GHD								8.5	0.1	0.1	-52.9	72.97	0.7	53.64	
X068675	NS0085	160	164	WP	Fresh	Ore	GHD								8.5	0.1	0.1	-43.6	106.46	0.4	44.01	
X068679	NS0085	168	172	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-55.8	42.41	1.3	57.15	
X068685	NS0085	180	184	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-55.5	55.92	1	56.51	
X068695	NS0085	200	204	WP	Fresh	Waste	GHD								8	0.1	0.1	-34.4	4.52	9.8	44.18	
X068699	NS0085	208	212	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-52.9	58.56	0.9	53.8	20.5
X068708	NS0085	224	228	WP	Fresh	Waste	GHD								8.5	0.1	0.1	-37.2	68.48	0.6	37.75	
X068711	NS0085	230	234	WP	Fresh	Waste	GHD								8.4	0.1	0.1	-59.6	29.41	2.1	61.7	
X068715	NS0085	238	242	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-51.6	85.24	0.6	52.21	
X068721	NS0085	250	254	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-40	30.68	1.3	41.35	
X068725	NS0085	258	262	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-43.3	84.17	0.5	43.82	
X068731	NS0085	270	274	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-40	10.78	4.1	44.09	
X068741	NS0086	8	12	WP	Oxide	Waste	GHD			0.01					6.2	0.1	1.1			0.3		
X068747	NS0086	20	24	WP	Oxide	Waste	GHD								7.1	0.1	0.1			0.3		
X068751	NS0086	28	32	WP	Oxide	Waste	GHD			0.01					6.5	0.1	1.3			0.3		
X068757	NS0086	40	44	WP	Oxide	Waste	GHD								7.6	0.1	0.1			0.3		
X068761	NS0086	48	52	WP	Fresh	Waste	GHD								8.4	0.1	0.1			9		
X068767	NS0086	60	64	WP	Fresh	Waste	GHD								8.6	0.1	0.1			1.9		
X068771	NS0086	68	72	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2		
X068777	NS0086	80	84	WP	Fresh	Waste	GHD								8.7	0.1	0.1			7		
X068781	NS0086	88	92	WP	Fresh	Waste	GHD								8.6	0.1	0.1	-24.3	2.8	13.5	37.79	
X068793	NS0086	110	114	WP	Fresh	Waste	GHD								8	0.1	0.1	-20	2.06	18.9	38.87	
X068797	NS0086	118	122	WP	Fresh	Waste	GHD								8.5	0.1	0.1	-27.4	3.39	11.5	38.87	
X068803	NS0086	128	132	WP	Fresh	Waste	GHD								8.7	0.1	0.1	-32	4.63	8.8	40.82	
X068809	NS0086	140	144	WP	Fresh	Waste	GHD								8.6	0.1	0.1	-38.7	13.27	3.2	41.85	
X068813	NS0086	148	152	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-38.4	21.06	1.9	40.31	
X068819	NS0086	160	164	WP	Fresh	Waste	GHD								8.6	0.1	0.1	-44.3	26.16	1.8	46.06	
X068823	NS0086	168	172	WP	Fresh	Waste	GHD								8.7	0.1	0.1	-24.4	5.93	4.9	29.35	
X068829	NS0086	180	182	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-42.2	17.4	2.6	44.77	
X068833	NS0086	188	192	WP	Fresh	Waste	GHD								9	0.1	0.1	-45.2	16.7	2.9	48.08	
X068839	NS0086	200	204	WP	Fresh	Waste	GHD								9	0.1	0.1	-43.2	15.85	2.9	46.11	
X068843	NS0086	208	212	WP	Fresh	Ore	GHD								9.2	0.1	0.1	-62.9	31.86	2	64.4	49
X068849	NS0086	220	224	WP	Fresh	Waste	GHD								9.3	0.1	0.1	-47.1	34.8	1.4	48.49	
X068853	NS0086	228	232	WP	Fresh	Ore	GHD								9.2	0.1	0.1	-42.6	19.07	2.4	44.96	
X068863	NS0086	248	252	WP	Fresh	Waste	GHD								9.2	0.1	0.1	-58.4	45.26	1.3	59.6	36

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X068869	NS0086	260	264	WP	Fresh	Waste	GHD								9.3	0.1	0.1	-35.8	5.57	7.8	43.64	
X068873	NS0086	268	272	WP	Fresh	Waste	GHD								9.1	0.1	0.1	-22.5	6.27	4.3	26.77	
X068879	NS0086	280	282	WP	Fresh	Waste	GHD								9.2	0.1	0.1	-47.4	13.58	3.8	51.17	
X068880	NS0087	0	4	WP	Oxide	Waste	GHD								7.1	0.1	0.1			0.9		
X068884	NS0087	8	12	WP	Oxide	Waste	GHD								7	0.1	0.1	-0.99	2.22	0.8	1.8	0.7
X068895	NS0087	30	34	WP	Oxide	Waste	GHD								8.1	0.1	0.1			0.2		
X068905	NS0087	50	54	WP	Fresh	Ore	GHD								9	0.1	0.1			2		
X068911	NS0087	60	64	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.3		
X068918-X068919	NS0087	74	78	WP	Fresh	Ore	Worley Parsons			0.06	0.06	0.01			8.9	<0.1	<0.1	-47.66	26.94	1.84	49.5	
X068921	NS0087	80	84	WP	Fresh	Ore	GHD								8.6	0.1	0.1			1.2		
X068923	NS0087	84	88	WP	Fresh	Waste	GHD								8.3	0.1	0.1			2.7		
X068925	NS0087	88	92	WP	Fresh	Waste	GHD								8.8	0.1	0.1			10.4		
X068925-X068926	NS0087	88	92	WP	Fresh	Waste	Worley Parsons			0.52	0.52	0.01			8.5	<0.1	<0.1	-22.28	2.4	15.93	38.2	
X068931	NS0087	98	102	WP	Fresh	Ore	GHD								9	0.1	0.1			6.5		
X068937	NS0087	110	114	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1		
X068941	NS0087	118	122	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-48.3	34.56	1.4	49.74	
X068947	NS0087	130	134	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-32.8	25.91	1.3	34.12	
X068951	NS0087	138	142	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-48.9	30.57	1.7	50.55	
X068957	NS0087	148	152	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-50	22.62	2.3	52.31	
X068963	NS0087	160	164	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-44.8	23.68	2	46.78	
X068967	NS0087	168	172	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-43.6	28.64	1.6	45.18	
X068973	NS0087	180	184	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-44.4	31.52	1.5	45.85	
X068977	NS0087	188	192	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-34.8	10.92	3.5	38.31	
X068983	NS0087	198	202	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-47.5	35.09	1.4	48.89	
X068989	NS0087	210	212	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-37.6	12.69	3.2	40.82	
X068993	NS0087	218	222	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.8		
X068999	NS0087	230	234	WP	Fresh	Ore	GHD								9	0.1	0.1	-51.3	27.17	2	53.26	
X070005	NS0087	240	244	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-45	46.21	1	46	
X070009	NS0087	248	252	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-35.2	16.33	2.3	37.5	
X070015	NS0087	260	264	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-48.5	61.91	0.8	49.3	
X070019	NS0087	268	272	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-28.2	4.98	7.1	35.29	
X070025	NS0087	280	284	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-38.1	9.35	4.6	42.66	
X070031	NS0087	290	292	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1		
X070032	NS0087	292	294	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.3		
X070037	NS0087	300	304	WP	Fresh	Ore	GHD								9	0.1	0.1	-34.8	33.47	1.1	35.87	
X070041	NS0087	308	312	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.5		
X070047	NS0087	320	324	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-43.2	22.54	2	45.21	
X070053	NS0087	330	334	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-43.3	9.13	5.3	48.63	
X070057	NS0087	338	342	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-49.6	19.51	2.7	52.28	
X070063	NS0087	350	354	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.7		
X070067	NS0087	358	362	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-52.6	59.22	0.9	53.5	
X070073	NS0087	368	372	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-72.6	81.36	0.9	73.5	
X070079	NS0087	380	384	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-59.3	95.45	0.6	59.93	
X070083	NS0087	388	392	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-77.4	79.98	1	78.38	
X070087	NS0087	396	400	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-65.8	77.73	0.9	66.66	
X070089	NS0088	0	2	WP	Oxide	Waste	GHD								6.8	0.1	0.5			0.6		
X070093	NS0088	8	12	WP	Oxide	Waste	GHD			0.01					6.5	0.1	2.3			0.3		
X070099	NS0088	20	24	WP	Oxide	Waste	GHD								8.2	0.1	0.1			0.4		
X070105	NS0088	30	34	WP	Oxide	Waste	GHD								9.7	0.1	0.1			0.3		
X070109	NS0088	38	42	WP	Oxide	Waste	GHD								8.4	0.1	0.1			0.3		
X070115	NS0088	50	54	WP	Oxide	Waste	GHD								8.9	0.1	0.1			0.2		
X070121	NS0088	60	64	WP	Oxide	Waste	GHD								8.7	0.1	0.1			1		
X070125	NS0088	68	72	WP	Oxide	Ore	GHD								8.6	0.1	0.1			1.1		
X070131	NS0088	80	84	WP	Oxide	Ore	GHD								8.8	0.1	0.1			3.6		
X070135	NS0088	88	92	WP	Fresh	Waste	GHD								9.8	0.1	0.1			1.6		
X070141	NS0088	100	104	WP	Fresh	Waste	GHD								8.7	0.1	0.1			1.6		
X070145	NS0088	108	112	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.6		
X070152	NS0088	120	122	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.4		
X070157	NS0088	130	134	WP	Fresh	Waste	GHD								8.9	0.1	0.1			1.8		
X070161	NS0088	138	142	WP	Fresh	Waste	GHD								8.8	0.1	0.1			0.1		
X070167	NS0088	150	154	WP	Fresh	Waste	GHD								7.7	0.1	0.1			8.2		
X070171	NS0088	158	160	WP	Fresh	Waste	GHD								8.6	0.1	0.1			0.1		
X070172	NS0088	160	162	WP	Fresh	Waste	GHD								8.5	0.1	0.1			0.3		
X070177	NS0088	170	174	WP	Fresh	Waste	GHD								8.9	0.1	0.1			0.1		
X070181	NS0088	178	182	WP	Fresh	Waste	GHD								8.7	0.1	0.1			0.2		
X070187	NS0088	190	194	WP	Fresh	Waste	GHD								9	0.1	0.1			0.1		
X070191	NS0088	198	202	WP	Fresh	Ore	GHD								8.8	0.1	0.1			6		
X070197	NS0088	210	214	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.2		
X070207	NS0088	228	232	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.1		
X070213	NS0088	240	244	WP	Fresh	Waste	GHD								8.8	0.1	0.1			0.9		
X070217	NS0088	248	252	WP	Fresh	Waste	GHD								8.7	0.1	0.1			0.4		
X070223	NS0088	260	264	WP	Fresh	Waste	GHD								8.5	0.1	0.1			12.6		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X070227	NS0088	268	272	WP	Fresh	Waste	GHD								8.8	0.1	0.1			2.4		
X070233	NS0088	280	284	WP	Fresh	Waste	GHD								8.6	0.1	0.1			2.6		
X070237	NS0088	288	292	WP	Fresh	Waste	GHD								8.8	0.1	0.1			8		
X070243	NS0088	300	304	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.1		
X070247	NS0088	308	312	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.8		
X070253	NS0088	318	322	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.3		
X070259	NS0088	330	332	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.3		
X070263	NS0088	338	342	WP	Fresh	Waste	GHD								9.1	0.1	0.1			0.8		
X070267	NS0088	346	350	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.2		
X070269	NS0089	0	4	WP	Oxide	#N/A	GHD			0.02					6.6	0.1	2.4					
X070273	NS0089	8	12	WP	Oxide	#N/A	GHD								8.1	0.1	0.1					
X070279	NS0089	20	24	WP	Oxide	#N/A	GHD								7.6	0.1	0.1					
X070283	NS0089	28	32	WP	Oxide	#N/A	GHD								8	0.1	0.1					
X070289	NS0089	40	42	WP	Oxide	#N/A	GHD								7.7	0.1	0.1					
X070293	NS0089	48	52	WP	Oxide	#N/A	GHD								7.6	0.1	0.1					
X070299	NS0089	60	64	WP	Oxide	#N/A	GHD								8	0.1	0.1					
X070303	NS0089	68	72	WP	Fresh	Waste	GHD								8.4	0.1	0.1			7.7		
X070309	NS0089	80	84	WP	Fresh	Waste	GHD								8.7	0.1	0.1			5.2		
X070313	NS0089	88	92	WP	Fresh	Waste	GHD								8.8	0.1	0.1	-16.82	4.18	5.3	22.1	5.2
X070319	NS0089	100	104	WP	Fresh	Ore	GHD			0.44					8.9	0.1	0.1			13.5		
X070323	NS0089	108	112	WP	Fresh	Waste	GHD								8	0.1	0.1			5.6		
X070329	NS0089	120	122	WP	Fresh	Waste	GHD								8.4	0.1	0.1			11.8		
X070333	NS0089	128	132	WP	Fresh	Waste	GHD								8.3	0.1	0.1			12.5		
X070339	NS0089	140	144	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.9		
X070341	NS0089	144	148	WP	Fresh	Ore	GHD								8.8	0.1	0.1			13		
X070343	NS0089	148	152	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.9		
X070343	NS0089	148	158	WP	Fresh	Ore	Worley Parsons			0.69	0.68	0.02			6.5	<0.1	0.2	4.23	0.8	21.13	16.9	
X070349	NS0089	160	162	WP	Fresh	Ore	GHD								9	0.1	0.1			3.8		
X070355	NS0089	170	174	WP	Fresh	Waste	GHD								8.9	0.1	0.1			4.9		
X070359	NS0089	178	180	WP	Fresh	Waste	GHD								7.6	0.1	0.1			42		
X070365	NS0089	190	194	WP	Fresh	Ore	GHD								9.1	0.1	0.1			2.2		
X070369	NS0089	198	202	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.6		
X070375	NS0089	210	214	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.5		
X070379	NS0089	218	222	WP	Fresh	Waste	GHD								8.4	0.1	0.1			7.3		
X070385	NS0089	230	234	WP	Fresh	Waste	GHD								8.7	0.1	0.1			3.7		
X070395	NS0089	250	254	WP	Fresh	Waste	GHD								9.2	0.1	0.1			1		
X070401	NS0089	260	264	WP	Fresh	Ore	GHD								7.5	0.1	0.1			0.8		
X070405	NS0089	268	272	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1		
X070411	NS0089	280	284	WP	Fresh	Waste	GHD								8.5	0.1	0.1			0.3		
X070415	NS0089	288	292	WP	Fresh	Waste	GHD								7.8	0.1	0.1			6.5		
X070421	NS0089	300	304	WP	Fresh	Waste	GHD								7.6	0.1	0.1			2.3		
X070425	NS0089	308	312	WP	Fresh	Waste	GHD								9.3	0.1	0.1			0.8		
X070431	NS0089	320	324	WP	Fresh	Waste	GHD								8.3	0.1	0.1			0.5		
X070432	NS0089	320	324	WP	Fresh	Waste	GHD								8.2	0.1	0.1			0.5		
X070435	NS0089	328	332	WP	Fresh	Ore	GHD								8.4	0.1	0.1			0.9		
X070445	NS0089	348	352	WP	Fresh	Ore	GHD								9.3	0.1	0.1	-24.83	33.44	0.8	25.6	11
X070451	NS0089	360	364	WP	Fresh	Waste	GHD								8.8	0.1	0.1			0.7		
X070455	NS0089	368	372	WP	Fresh	Waste	GHD								8.3	0.1	0.1			0.4		
X070461	NS0089	380	384	WP	Fresh	#N/A	GHD								8.4	0.1	0.1					
X070465	NS0089	388	392	WP	Fresh	#N/A	GHD								8.5	0.1	0.1					
X070471	NS0089	398	402	WP	Fresh	#N/A	GHD								9.4	0.1	0.1					
X070473	NS0090	0	4	WP	Oxide	Waste	GHD			0.01					6.4	0.1	1.5			0.3		
X070477	NS0090	8	12	WP	Oxide	Waste	GHD			0.01					6.5	0.1	4			0.3		
X070483	NS0090	20	24	WP	Oxide	Waste	GHD								6.6	0.1	4			0.1		
X070487	NS0090	28	32	WP	Oxide	Waste	GHD								8	0.1	0.1			0.1		
X070493	NS0090	40	44	WP	Oxide	Ore	GHD								8.5	0.1	0.1			0.1		
X070497	NS0090	48	52	WP	Fresh	Ore	GHD								8.1	0.1	0.1			4.4		
X070503	NS0090	60	64	WP	Fresh	Ore	GHD								8	0.1	0.1			3.5		
X070507	NS0090	68	72	WP	Fresh	Waste	GHD								8.7	0.1	0.1			1.1		
X070511	NS0090	76	80	WP	Fresh	Waste	GHD								8.8	0.1	0.1			3.6		
X070517	NS0090	88	92	WP	Fresh	Ore	GHD								8.7	0.1	0.1			0.9		
X070523	NS0090	100	104	WP	Fresh	Ore	GHD								8.6	0.1	0.1			3.8		
X070527	NS0090	108	112	WP	Fresh	Ore	GHD								8	0.1	0.1			5.5		
X070533	NS0090	120	124	WP	Fresh	Ore	GHD								9	0.1	0.1			0.9		
X070537	NS0090	128	132	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-49.24	52.04	1	50.2	33
X070543	NS0090	140	144	WP	Fresh	Ore	GHD								8.8	0.1	0.1			4		
X070547	NS0090	148	152	WP	Fresh	Ore	GHD								8.5	0.1	0.1			6.1		
X070553	NS0090	158	162	WP	Fresh	Ore	GHD								8.2	0.1	0.1			6.6		
X070559	NS0090	170	172	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.4		
X070563	NS0090	178	182	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.8		
X070569	NS0090	190	194	WP	Fresh	Ore	GHD								9.3	0.1	0.1	-23.58	12.67	2	25.6	6.5
X070573	NS0090	198	202	WP	Fresh	Waste	GHD								9.1	0.1	0.1			9.4		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X070579	NS0090	210	214	WP	Fresh	Waste	GHD								7.9	0.1	0.1			8.3		
X070583	NS0090	218	222	WP	Fresh	Waste	GHD								9.2	0.1	0.1			0.6		
X070589	NS0090	230	232	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.3		
X070593	NS0090	238	242	WP	Fresh	Waste	GHD								9.3	0.1	0.1			2.5		
X070599	NS0090	250	254	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2.6		
X070605	NS0090	260	264	WP	Fresh	Ore	GHD								9	0.1	0.1			2.6		
X070609	NS0090	268	272	WP	Fresh	Ore	GHD								8.1	0.1	0.1			0.9		
X070615	NS0090	280	282	WP	Fresh	Ore	GHD								8.6	0.1	0.1			5.9		
X070646	NS0091	60	64	WP	Oxide	Waste	GHD								8	0.1	0.1			0.1		
X070650	NS0091	68	72	WP	Oxide	Waste	GHD								7.8	0.1	0.1			0.2		
X070656	NS0091	80	84	WP	Fresh	Waste	GHD								8.4	0.1	0.1			10		
X070661	NS0091	90	92	WP	Fresh	Waste	GHD								8.4	0.1	0.1			6		
X070666	NS0091	100	102	WP	Fresh	Waste	GHD								8.8	0.1	0.1			5.6		
X070670	NS0091	108	112	WP	Fresh	Waste	GHD								9	0.1	0.1			2		
X070676	NS0091	120	122	WP	Fresh	Ore	GHD								8.4	0.1	0.1			0.6		
X070680	NS0091	128	132	WP	Fresh	Ore	GHD								8.9	0.1	0.1			5.3		
X070691	NS0091	150	152	WP	Fresh	Waste	GHD								8.7	0.1	0.1	34.8	-10.25	3.1	-31.71	
X070696	NS0091	160	164	WP	Fresh	Waste	GHD								8.8	0.1	0.1	-35.3	9.9	4	39.27	
X070696	NS0091	160	164	WP	Fresh	Waste	GHD								9	0.1	0.1	-50.9	13.83	4	54.87	
X070702	NS0091	170	174	WP	Fresh	Waste	GHD								8.8	0.1	0.1	38.1	-21.22	1.7	-36.39	
X070706	NS0091	178	182	WP	Fresh	Waste	GHD								8.8	0.1	0.1			1.5		
X070712	NS0091	190	194	WP	Fresh	Ore	GHD								8.6	0.1	0.1			2.9		
X070716	NS0091	198	202	WP	Fresh	Waste	GHD								8.9	0.1	0.1	-16.4	3.24	7.3	23.7	4.9
X070722	NS0091	210	214	WP	Fresh	Waste	GHD								8.8	0.1	0.1			0.2		
X070726	NS0091	218	222	WP	Fresh	Waste	GHD								8.9	0.1	0.1			0.1		
X070732	NS0091	230	234	WP	Fresh	Waste	GHD								8.8	0.1	0.1			5.3		
X070736	NS0091	238	242	WP	Fresh	Waste	GHD								8.9	0.1	0.1			2.2		
X070742	NS0091	250	254	WP	Fresh	Waste	GHD								8.8	0.1	0.1			0.7		
X070746	NS0091	258	262	WP	Fresh	Waste	GHD								9	0.1	0.1			1.5		
X070752	NS0091	268	272	WP	Fresh	Waste	GHD								8.6	0.1	0.1			9.5		
X070758	NS0091	280	282	WP	Fresh	Waste	GHD								9.1	0.1	0.1			1.3		
X070774	NS0092	30	32	WP	Oxide	Ore	GHD								8	0.1	0.1			0.1		
X070779	NS0092	40	44	WP	Fresh	Waste	GHD								8.8	0.1	0.1	-42.95	9.68	4.9	47.9	15
X070783	NS0092	48	52	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-49.38	31.42	1.6	51	22
X070789	NS0092	60	62	WP	Fresh	Ore	GHD								8.8	0.1	0.1			3.1		
X070793	NS0092	68	72	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1		
X070799	NS0092	80	82	WP	Fresh	Waste	GHD								8.8	0.1	0.1			4.2		
X070805	NS0092	90	94	WP	Fresh	Ore	GHD								9	0.1	0.1			2		
X070809	NS0092	98	102	WP	Fresh	Ore	GHD								9	0.1	0.1			1.4		
X070815	NS0092	110	114	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2.3		
X070819	NS0092	118	122	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2.5		
X070825	NS0092	130	134	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.3		
X070835	NS0092	150	154	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.7		
X070839	NS0092	158	162	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-38.4	49.23	0.8	39.2	42
X070845	NS0092	170	174	WP	Fresh	Ore	GHD								9	0.1	0.1			0.7		
X070849	NS0092	178	182	WP	Fresh	Ore	GHD								9	0.1	0.1			1.3		
X070855	NS0092	188	192	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.2		
X070861	NS0092	200	204	WP	Fresh	Ore	GHD								9	0.1	0.1			6.1		
X070865	NS0092	208	212	WP	Fresh	Ore	GHD								8.1	0.1	0.1			4.8		
X070872	NS0092	222	224	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.6		
X070875	NS0092	228	232	WP	Fresh	Ore	GHD								8.3	0.1	0.1			0.9		
X070881	NS0092	240	244	WP	Fresh	Ore	GHD								9	0.1	0.1			0.8		
X070882	NS0092	242	244	WP	Fresh	Ore	GHD								9	0.1	0.1			1.1		
X070885	NS0092	248	252	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.6		
X070891	NS0092	260	264	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.5		
X070895	NS0092	268	272	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.8		
X070901	NS0092	280	282	WP	Fresh	Ore	GHD								9	0.1	0.1			0.3		
X070922	NS0093	40	44	WP	Oxide	Ore	GHD								7.7	0.1	0.1			0.1		
X070926	NS0093	48	52	WP	Oxide	Ore	GHD								8.3	0.1	0.1			0.9		
X070931	NS0093	58	62	WP	Oxide	Ore	GHD								8.1	0.1	0.1			0.9		
X070937	NS0093	70	74	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.5		
X070941	NS0093	78	82	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.5		
X070947	NS0093	92	96	WP	Fresh	Ore	GHD								9.1	0.1	0.1	-66.44	78.48	0.9	67.3	39
X070951	NS0093	98	102	WP	Fresh	Ore	GHD								8.8	0.1	0.1			3.1		
X070957	NS0093	108	112	WP	Fresh	Waste	GHD								9	0.1	0.1			1.9		
X070963	NS0093	120	124	WP	Fresh	Ore	GHD								8.9	0.1	0.1			6.2		
X070967	NS0093	128	132	WP	Fresh	Ore	GHD								7.6	0.1	0.1			4.8		
X070973	NS0093	140	144	WP	Fresh	Waste	GHD								9	0.1	0.1			2.6		
X070977	NS0093	148	152	WP	Fresh	Ore	GHD								8.9	0.1	0.1			4.5		
X070981	NS0093	156	160	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.2		
X070983	NS0093	160	162	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.8		
X070989	NS0093	170	172	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.5		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples																					
Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X070993	NS0093	178	182	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.5		
X070999	NS0093	190	194	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.6		
X071009	NS0093	210	214	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.3		
X071013	NS0093	216	220	WP	Fresh	Waste	GHD								9	0.1	0.1			1		
X071017	NS0093	224	228	WP	Fresh	Waste	GHD								8.8	0.1	0.1			25.5		
X071025	NS0093	240	244	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.6		
X071035	NS0093	260	264	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.7		
X071039	NS0093	268	272	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.5		
X071045	NS0093	280	282	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.6		
X071061	NS0094	28	32	WP	Oxide	Ore	GHD								7.9	0.1	0.1	-6.48	53.88	0.1	6.6	2.5
X071067	NS0094	40	44	WP	Fresh	Ore	GHD								8.4	0.1	0.1			0.9		
X071071	NS0094	48	52	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1.3		
X071077	NS0094	60	64	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1		
X071081	NS0094	68	72	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.4		
X071087	NS0094	80	84	WP	Fresh	Ore	GHD								8.9	0.1	0.1			9.5		
X071091	NS0094	90	94	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.5		
X071095	NS0094	98	102	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.1		
X071102	NS0094	110	112	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.3		
X071107	NS0094	120	124	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.7		
X071111	NS0094	128	132	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.8		
X071117	NS0094	140	144	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.5		
X071119	NS0094	144	148	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.5		
X071121	NS0094	148	152	WP	Fresh	Ore	GHD								9.1	0.1	0.1	-75.03	133.44	0.6	75.6	48
X071125	NS0094	156	160	WP	Fresh	Ore	GHD								9	0.1	0.1			0.6		
X071127	NS0094	160	164	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-72.77	116.91	0.6	73.4	47
X071131	NS0094	168	172	WP	Fresh	Ore	GHD								9	0.1	0.1			0.7		
X071137	NS0094	180	184	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.7		
X071141	NS0094	188	192	WP	Fresh	Ore	GHD								9.1	0.1	0.1			0.8		
X071147	NS0094	200	204	WP	Fresh	Ore	GHD								9	0.1	0.1			0.6		
X071151	NS0094	208	212	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.8		
X071157	NS0094	218	222	WP	Fresh	Ore	GHD								8.3	0.1	0.1			1		
X071163	NS0094	230	232	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.6		
X071167	NS0094	238	242	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.7		
X071173	NS0094	250	254	WP	Fresh	Ore	GHD								8.2	0.1	0.1			1.7		
X071187	NS0094	278	282	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.6		
X071205	NS0095	30	34	WP	Oxide	Waste	GHD								7.6	0.1	0.1	-4.39	41.98	0.1	4.5	0.8
X071209	NS0095	38	42	WP	Oxide	Waste	GHD								7.8	0.1	0.1	-6.91	6.38	1.3	8.2	1.5
X071215	NS0095	50	54	WP	Fresh	Ore	GHD								8.4	0.1	0.1			1.7		
X071219	NS0095	58	62	WP	Fresh	Ore	GHD								8.6	0.1	0.1			1.1		
X071225	NS0095	70	74	WP	Fresh	Ore	GHD								8.5	0.1	0.1			2.3		
X071235	NS0095	90	94	WP	Fresh	Ore	GHD								8.5	0.1	0.1			2.2		
X071239	NS0095	98	102	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1.8		
X071245	NS0095	110	114	WP	Fresh	Ore	GHD								8.6	0.1	0.1			4.1		
X071249	NS0095	118	122	WP	Fresh	Ore	GHD								8.6	0.1	0.1			2.7		
X071256	NS0095	130	134	WP	Fresh	Ore	GHD								8.4	0.1	0.1			2.1		
X071261	NS0095	140	144	WP	Fresh	Waste	GHD								8.3	0.1	0.1			5.5		
X071265	NS0095	148	152	WP	Fresh	Waste	GHD								8.4	0.1	0.1			16		
X071271	NS0095	160	164	WP	Fresh	Waste	GHD								8.9	0.1	0.1			7.1		
X071275	NS0095	168	172	WP	Fresh	Waste	GHD								8.2	0.1	0.1			4.5		
X071281	NS0095	180	184	WP	Fresh	Ore	GHD								8.6	0.1	0.1			3.3		
X071285	NS0095	188	192	WP	Fresh	Waste	GHD								8.9	0.1	0.1			6.8		
X071291	NS0095	200	204	WP	Fresh	Waste	GHD								8.5	0.1	0.1			7.4		
X071295	NS0095	208	212	WP	Fresh	Ore	GHD								8.9	0.1	0.1			4.9		
X071301	NS0095	218	222	WP	Fresh	Waste	GHD								7.8	0.1	0.1			10.4		
X071307	NS0095	230	234	WP	Fresh	Waste	GHD								8.8	0.1	0.1			3.6		
X071312	NS0095	240	242	MP	Fresh	Waste	GHD								8.5	0.1	0.1			8.6		
X071317	NS0095	250	252	MP	Fresh	Waste	GHD								8.4	0.1	0.1			12.5		
X071328	NS0096	20	24	WP	Oxide	Ore	GHD								7.9	0.1	0.1			0.1		
X071333	NS0096	30	34	WP	Oxide	Ore	GHD								7.9	0.1	0.1			0		
X071337	NS0096	38	42	WP	Oxide	Ore	GHD								8	0.1	0.1			0		
X071343	NS0096	50	54	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.8		
X071347	NS0096	58	62	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.5		
X071349	NS0096	62	66	WP	Fresh	Ore	GHD								8.9	0.1	0.1			4.1		
X071353	NS0096	70	74	WP	Fresh	Ore	GHD								9.3	0.1	0.1	-35.2	16.33	2.3	37.5	23
X071357	NS0096	78	82	WP	Fresh	Ore	GHD								9.4	0.1	0.1			0.7		
X071363	NS0096	90	94	WP	Fresh	Ore	GHD								9.4	0.1	0.1			1.3		
X071369	NS0096	100	104	WP	Fresh	Ore	GHD								9.3	0.1	0.1			3.4		
X071373	NS0096	108	112	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1		
X071379	NS0096	120	124	WP	Fresh	Ore	GHD								9.2	0.1	0.1			3.1		
X071383	NS0096	128	132	WP	Fresh	Ore	GHD								9.4	0.1	0.1			1.2		
X071389	NS0096	140	142	WP	Fresh	Ore	GHD								9.4	0.1	0.1			1		
X071394	NS0096	150	152	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.3		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X071399	NS0096	160	164	WP	Fresh	Ore	GHD								9	0.1	0.1			1.4		
X071405	NS0096	170	174	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.8		
X071409	NS0096	178	182	WP	Fresh	Ore	GHD								9.3	0.1	0.1			0.7		
X071415	NS0096	190	194	WP	Fresh	Ore	GHD								8.8	0.1	0.1			5.3		
X071419	NS0096	198	202	WP	Fresh	Ore	GHD								9	0.1	0.1			0.9		
X071435	NS0096	230	234	WP	Fresh	Waste	GHD			0.98					4.2	0.8	5.4			30		
X071437	NS0096	234	238	WP	Fresh	Ore	GHD								8.9	0.1	0.1			17.5		
X071439	NS0096	238	242	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1		
X071445	NS0096	250	252	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.5		
X071447	NS0096	254	258	WP	Fresh	Ore	GHD								9.3	0.1	0.1	-79.62	102.95	0.8	80.4	58
X071451	NS0096	260	264	WP	Fresh	Ore	GHD								9.4	0.1	0.1			3.8		
X071455	NS0096	268	272	WP	Fresh	Ore	GHD								9.4	0.1	0.1			1		
X071461	NS0096	280	282	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.5		
X071473	NS0097	22	24	WP	Oxide	Ore	GHD								7.7	0.1	0.1			0.1		
X071476	NS0097	28	32	WP	Oxide	Waste	GHD								7.9	0.1	0.1	-6.99	66.24	0.1	7.1	2
X071482	NS0097	40	44	WP	Fresh	Waste	GHD			0.04					3.5	3.8	11			1.3		
X071486	NS0097	48	52	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.8		
X071491	NS0097	58	62	WP	Fresh	Ore	GHD								8.6	0.1	0.1			1.5		
X071497	NS0097	70	74	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.1		
X071503	NS0097	80	84	WP	Fresh	Ore	GHD								8.7	0.1	0.1			0.8		
X071507	NS0097	88	92	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.7		
X071513	NS0097	100	104	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1.3		
X071517	NS0097	108	112	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.6		
X071523	NS0097	120	124	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.7		
X071527	NS0097	128	132	WP	Fresh	Ore	GHD								8.7	0.1	0.1			0.7		
X071533	NS0097	140	144	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.8		
X071537	NS0097	148	152	WP	Fresh	Ore	GHD			0.01					6.4	0.1	0.1			0.4		
X071543	NS0097	160	164	WP	Fresh	Ore	GHD								9	0.1	0.1			0.3		
X071547	NS0097	168	172	WP	Fresh	Ore	GHD								8.7	0.1	0.1			0.7		
X071553	NS0097	178	182	WP	Fresh	Ore	GHD								9	0.1	0.1			0.2		
X071559	NS0097	190	192	WP	Fresh	Ore	GHD								8.7	0.1	0.1			0.7		
X071563	NS0097	198	202	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.8		
X071569	NS0097	210	214	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.9		
X071573	NS0097	218	222	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.6		
X071579	NS0097	230	234	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1		
X071583	NS0097	238	242	WP	Fresh	Ore	GHD								8.7	0.1	0.1			0.9		
X071589	NS0097	250	252	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.7		
X071593	NS0097	258	262	WP	Fresh	Ore	GHD								8.5	0.1	0.1			2.1		
X071599	NS0097	270	272	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.9		
X071605	NS0097	280	282	WP	Fresh	Ore	GHD								8.1	0.1	0.1			7.9		
X071606	NS0098	0	4	WP	Oxide	Waste	GHD								6.7	0.1	0.6	-1.85	6.25	0.4	2.2	1.8
X071610	NS0098	8	12	WP	Oxide	Waste	GHD								7.5	0.1	0.1			0.4		
X071616	NS0098	20	24	WP	Oxide	Waste	GHD			0					6.3	0.1	1.4			0.1		
X071620	NS0098	28	32	WP	Oxide	Waste	GHD								8	0.1	0.1			0.2		
X071626	NS0098	40	44	WP	Oxide	Waste	GHD								7.9	0.1	0.1			0.2		
X071631	NS0098	50	54	WP	Fresh	Waste	GHD			0.23					6.4	0.1	0.1			7		
X071633	NS0098	54	56	WP	Fresh	Waste	GHD			0.31					7.8	0.1	0.1			9.5		
X071634	NS0098	56	58	WP	Fresh	Waste	GHD			0.94					6	0.1	3.5			28.8		
X071635	NS0098	58	62	WP	Fresh	Ore	GHD								6.7	0.1	0.1	-5.09	1.35	14.6	19.7	2
X071641	NS0098	70	74	WP	Fresh	Ore	GHD								8	0.1	0.1			10.5		
X071645	NS0098	78	82	WP	Fresh	Ore	GHD								7.9	0.1	0.1			4.3		
X071651	NS0098	88	92	WP	Fresh	Waste	GHD								8.1	0.1	0.1			12.4		
X071657	NS0098	100	104	WP	Fresh	Ore	GHD								9.1	0.1	0.1			2.3		
X071661	NS0098	108	112	WP	Fresh	Ore	GHD								9.1	0.1	0.1	-28.64	34.4	0.9	29.5	12
X071667	NS0098	120	124	WP	Fresh	Ore	GHD								9	0.1	0.1			2.3		
X071671	NS0098	128	132	WP	Fresh	Ore	GHD								8.4	0.1	0.1			2.2		
X071677	NS0098	140	144	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.7		
X071681	NS0098	148	150	WP	Fresh	Ore	GHD								9	0.1	0.1			0.6		
X071682	NS0098	150	152	WP	Fresh	Ore	GHD								9	0.1	0.1			3.3		
X071687	NS0098	160	164	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.5		
X071691	NS0098	168	172	WP	Fresh	Waste	GHD								8.5	0.1	0.1			1.5		
X071697	NS0098	180	184	WP	Fresh	Ore	GHD								8.4	0.1	0.1			14		
X071703	NS0098	190	194	WP	Fresh	Ore	GHD								8.6	0.1	0.1			8.1		
X071707	NS0098	198	202	WP	Fresh	Ore	GHD								9	0.1	0.1			1		
X071713	NS0098	210	214	WP	Fresh	Waste	GHD								8	0.1	0.1			18.9		
X071765	NS0099	30	34	WP	Oxide	Ore	GHD								8.1	0.1	0.1			0.1		
X071769	NS0099	38	42	WP	Oxide	Waste	GHD								8.5	0.1	0.1			0.1		
X071775	NS0099	50	54	WP	Oxide	Waste	GHD								8	0.1	0.1			0.1		
X071779	NS0099	58	62	WP	Fresh	Ore	GHD								8.1	0.1	0.1			3		
X071785	NS0099	70	74	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.6		
X071790	NS0099	80	82	WP	Fresh		GHD								8.5	0.1	0.1			1.8		
X071795	NS0099	90	96	WP	Fresh	Ore	GHD								8.4	0.1	0.1			1		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X071801	NS0099	100	104	WP	Fresh	Ore	GHD								9	0.1	0.1	-57.3	94.55	0.6	57.91	
X071811	NS0099	120	124	WP	Fresh	Ore	GHD								9	0.1	0.1	-62.4	29.3	2.2	64.61	
X071821	NS0099	140	144	WP	Fresh	Ore	GHD								9	0.1	0.1	-58	48.95	1.2	59.21	
X071825	NS0099	148	152	WP	Fresh	Ore	GHD								9	0.1	0.1	-63.2	85.23	0.8	63.95	
X071831	NS0099	160	164	WP	Fresh	Ore	GHD								8.4	0.1	0.1			0.7		
X071835	NS0099	168	172	WP	Fresh	Ore	GHD								8.4	0.1	0.1			0.8		
X071841	NS0099	180	184	WP	Fresh	Ore	GHD								8.6	0.1	0.1			1		
X071845	NS0099	188	192	WP	Fresh	Ore	GHD								8.3	0.1	0.1			1.6		
X071851	NS0099	198	202	WP	Fresh	Ore	GHD								8.3	0.1	0.1			2.6		
X071867	NS0099	230	234	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.6		
X071871	NS0099	238	242	WP	Fresh	Ore	GHD								8.2	0.1	0.1			0.8		
X071877	NS0099	250	254	WP	Fresh	Ore	GHD								8.2	0.1	0.1			3.9		
X071881	NS0099	258	262	WP	Fresh	Ore	GHD								8	0.1	0.1			0.6		
X071887	NS0099	270	274	WP	Fresh	Ore	GHD								8.2	0.1	0.1			2.3		
X071899	NS0100	12	16	WP	Oxide	Waste	GHD								7.7	0.1	0.1			0.4		
X071907	NS0100	28	32	WP	Oxide	Ore	GHD								8.2	0.1	0.1			0.1		
X071913	NS0100	38	42	WP	Oxide	Ore	GHD								7.8	0.1	0.1			0.1		
X071919	NS0100	50	54	WP	Fresh	Ore	GHD								8.3	0.1	0.1			2.5		
X071923	NS0100	58	62	WP	Fresh	Ore	GHD								8.4	0.1	0.1			1.1		
X071929	NS0100	70	72	WP	Fresh		GHD								8.7	0.1	0.1			1.4		
X071933	NS0100	78	82	WP	Fresh	Waste	GHD								8.3	0.1	0.1			7.5		
X071949	NS0100	110	112	WP	Fresh	Waste	GHD								8.3	0.1	0.1			0.9		
X071955	NS0100	120	124	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.5		
X071965	NS0100	140	144	WP	Fresh	Ore	GHD								8.5	0.1	0.1			2.4		
X071969	NS0100	148	152	WP	Fresh	Ore	GHD								8.4	0.1	0.1			8.8		
X071983	NS0100	176	180	WP	Fresh	Ore	GHD								9	0.1	0.1			1.9		
X073003	NS0106	2	4	WP	Oxide	#N/A	GHD			0.02					6.4	0.1	1.6					
X073006	NS0106	8	12	WP	Oxide	#N/A	GHD								8.1	0.1	0.1					
X073012	NS0106	20	24	WP	Oxide	Ore	GHD								8.3	0.1	0.1			0.6		
X073016	NS0106	28	32	WP	Oxide	Ore	GHD								8.4	0.1	0.1	-7.33	13.94	0.6	7.9	2.5
X073022	NS0106	40	44	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1.3		
X073027	NS0106	48	52	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-53.93	71.44	0.8	54.7	57
X073033	NS0106	60	64	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.8		
X073037	NS0106	68	72	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.4		
X073043	NS0106	80	84	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.6		
X073047	NS0106	88	92	WP	Fresh	Ore	GHD								9	0.1	0.1			1.5		
X073049	NS0106	92	96	WP	Fresh	Ore	GHD								8.7	0.1	0.1			17.4		
X073054	NS0106	100	104	WP	Fresh	Ore	GHD								8.5	0.1	0.1			2.7		
X073058	NS0106	108	112	WP	Fresh	Ore	GHD								9	0.1	0.1			0.7		
X073073	NS0106	138	142	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.8		
X073079	NS0106	150	154	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.6		
X073083	NS0106	158	162	WP	Fresh	Ore	GHD								8.4	0.1	0.1			0.6		
X073089	NS0106	170	172	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-74.19	122.12	0.6	74.8	64
X073093	NS0106	178	182	WP	Fresh	Ore	GHD								9.1	0.1	0.1			0.8		
X073099	NS0106	190	194	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.6		
X073104	NS0106	198	202	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.6		
X073110	NS0106	210	214	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.5		
X073114	NS0106	218	222	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.5		
X073120	NS0106	230	234	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.7		
X073135	NS0106	260	264	WP	Fresh	Ore	GHD								8.6	0.1	0.1			1		
X073139	NS0106	268	272	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.7		
X073143	NS0106	276	280	WP	Fresh	Ore	GHD								9	0.1	0.1			0.8		
X073145	NS0107	0	4	WP	Oxide	#N/A	GHD								7.3	0.1	0.1					
X073149	NS0107	8	12	WP	Oxide	#N/A	GHD								7.1	0.1	0.1					
X073155	NS0107	20	22	WP	Oxide	Waste	GHD								7.9	0.1	0.1			0.5		
X073165	NS0107	40	44	WP	Oxide	Waste	GHD								8.2	0.1	0.1	-2.6	20.32	0.1	2.8	3
X073169	NS0107	48	52	WP	Oxide	Waste	GHD								7.9	0.1	0.1	-4.2	31.48	0.1	4.34	
X073175	NS0107	60	64	WP	Fresh	Ore	GHD								8	0.1	0.1	-18.9	5.29	4.4	23.31	
X073179	NS0107	68	72	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-40.5	17.13	2.5	43.01	
X073185	NS0107	80	84	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-39	23.62	1.7	40.5	3.5
X073197	NS0107	102	104	KCF	Fresh	Waste	GHD								7.9	0.1	0.1			1.9		
X073200	NS0107	108	112	KCF	Fresh	Waste	GHD								7.9	0.1	0.1	-5.6	3.24	2.5	8.1	
X073202-X073203	NS0107	112	116	KCF	Fresh	Waste	Worley Parsons			2.04	1.99	0.16			2.5	46.3	55.1	57.18	0.08	62.48	5.3	
X073204-X073205	NS0107	116	120	KCF	Fresh	Waste	Worley Parsons			2.49	2.45	0.14			2.4	54.2	65	66.86	0.12	76.26	9.4	
X073206	NS0107	120	124	KCF	Fresh	Waste	GHD			3.09					2.3	45.7	60.8	80.1	0.15	94.6	14.53	
X073210	NS0107	128	132	KCF	Fresh	Waste	GHD			2.58					2.5	38.9	52.2	69.3	0.12	79	9.71	
X073210-X073211	NS0107	128	132	KCF	Fresh	Waste	Worley Parsons			2.3	2.26	0.1			2.8	23.1	34.4	38.04	0.46	70.44	32.4	0.74
X073214	NS0107	136	140	KCF	Fresh	Waste	GHD								8.3	0.1	0.1	-64.2	2.75	36.6	100.8	
X073216	NS0107	140	142	KCF	Fresh	Waste	GHD			1.89					2.6	17.8	24.7	18.9	0.67	57.9	38.98	
X073216-X073217	NS0107	140	144	KCF	Fresh	Waste	Worley Parsons			1.17	1.15	0.07			8.6	<0.1	<0.1	-70.17	2.96	35.83	106	
X073219-X073220	NS0107	146	150	KCF	Fresh	Waste	Worley Parsons			1.75	1.71	0.13			2.8	30.5	40.2	34.09	0.36	53.59	19.5	
X073220	NS0107	148	152	KCF	Fresh	Waste	GHD			1.91					2.6	30.2	40.8	41.1	0.3	58.5	17.39	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X073224-X073225	NS0107	156	160	KCF	Fresh	Waste	Worley Parsons			1.77	1.76	0.04			2.9	10.4	15.9	18.81	0.65	54.21	35.4	
X073226	NS0107	160	164	KCF	Fresh	Waste	GHD			1.63					2.5	40.2	53.8	31.4	0.37	49.9	18.52	
X073231	NS0107	170	174	KCF	Fresh	Waste	GHD			1.86					3	11	18.1	15.3	0.73	57	41.66	
X073231-X073232	NS0107	170	174	KCF	Fresh	Waste	Worley Parsons			2.61	2.59	0.06			2.6	34	45.3	44.33	0.45	79.93	35.6	
X073235	NS0107	178	182	KCF	Fresh	Waste	GHD			2.11					6.4	0.1	0.8	1.7	0.97	64.6	62.92	
X073241	NS0107	190	194	KCF	Fresh	Waste	GHD								7.4	0.1	0.1	6.3	0.89	56.2	49.9	
X073242	NS0107	192	194	KCF	Fresh	Waste	Worley Parsons			1.92	1.89	0.08			3	7.9	13.7	13.5	0.77	58.8	45.3	
X073245-X073247	NS0107	198	202	KCF	Fresh	Waste	Worley Parsons			1.32	1.3	0.07			8.4	<0.1	<0.1	-35.48	1.88	40.43	75.9	
X073247	NS0107	200	202	KCF	Fresh	Waste	GHD								8.1	0.1	0.1	-22	1.59	37.4	59.36	
X073248	NS0108	0	4	WP	Oxide	Waste	GHD								7.8	0.1	0.1			0.8		
X073252	NS0108	8	12	WP	Oxide	Waste	GHD								7.1	0.1	0.1			0.8		
X073258	NS0108	20	24	WP	Oxide	Waste	GHD								7.4	0.1	0.1			0.3		
X073263	NS0108	30	34	WP	Oxide	Ore	GHD								8.7	0.1	0.1			0.9		
X073265	NS0108	34	38	WP	Oxide	Ore	GHD								7.7	0.1	0.1			2.8		
X073267	NS0108	38	42	WP	Oxide	Waste	GHD								8.4	0.1	0.1			0.2		
X073273	NS0108	50	54	WP	Oxide	Waste	GHD								8.8	0.1	0.1			1.1		
X073277	NS0108	58	62	WP	Oxide	Waste	GHD								8.3	0.1	0.1			0.3		
X073283	NS0108	70	72	WP	Oxide	Waste	GHD								9.3	0.1	0.1			0.1		
X073284	NS0108	72	74	WP	Oxide	Waste	GHD								8.6	0.1	0.1			0.1		
X073288	NS0108	80	82	WP	Fresh	Ore	GHD								9	0.1	0.1			4		
X073292	NS0108	88	90	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.8		
X073293	NS0108	90	94	WP	Fresh	Ore	GHD								9.2	0.1	0.1			2.5		
X073299	NS0108	100	104	WP	Fresh	Ore	GHD								8.9	0.1	0.1			4.4		
X073303	NS0108	108	112	WP	Fresh	Ore	GHD								9.1	0.1	0.1			0.7		
X073309	NS0108	120	124	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.8		
X073313	NS0108	128	132	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.8		
X073319	NS0108	140	144	WP	Fresh	Ore	GHD								9.4	0.1	0.1			2.9		
X073323	NS0108	148	152	WP	Fresh	Ore	GHD								9.4	0.1	0.1			1		
X073329	NS0108	160	162	WP	Fresh	Ore	GHD								9.2	0.1	0.1			4.9		
X073333	NS0108	168	172	WP	Fresh	Ore	GHD								9	0.1	0.1			5.2		
X073338	NS0108	178	180	WP	Fresh	Ore	GHD								8.1	0.1	0.1			4.5		
X073339	NS0108	180	184	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.6		
X073343	NS0108	188	192	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.7		
X073350	NS0108	200	202	WP	Fresh	Ore	GHD								9.1	0.1	0.1			4.3		
X073354	NS0108	208	212	WP	Fresh	Ore	GHD								9.1	0.1	0.1			3.9		
X073365	NS0108	230	234	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.8		
X073369	NS0108	238	242	WP	Fresh	Ore	GHD								9.4	0.1	0.1			1		
X073375	NS0108	250	254	WP	Fresh	Waste	GHD								8.4	0.1	0.1			2.3		
X073379	NS0108	258	262	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.1		
X073385	NS0108	270	274	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.7		
X073389	NS0108	278	280	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.7		
X073643	NS0111	48	52	WP	Oxide	Waste	GHD								8.4	0.1	0.1			0.4		
X073649	NS0111	60	62	WP	Oxide	Waste	GHD								8.3	0.1	0.1			0.2		
X073655	NS0111	70	74	WP	Oxide	Waste	GHD								7.8	0.1	0.1	1.8	-1.06	0.9	-0.93	
X073665	NS0111	90	94	WP	Fresh	Ore	GHD								8.4	0.1	0.1			1.6		
X073669	NS0111	98	102	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2.9		
X073669	NS0111	98	102	WP	Fresh	Ore	GHD			0.02					9.1	0.1	0.1			0.6		
X073679	NS0111	118	122	WP	Fresh	Ore	GHD								9	0.1	0.1	-16.1	11.95	1.5	17.57	
X073685	NS0111	130	134	WP	Fresh	Ore	GHD								9.1	0.1	0.1			14.6		
X073695	NS0111	150	154	WP	Fresh	Waste	GHD								8.7	0.1	0.1			6.5		
X073699	NS0111	158	162	WP	Fresh	Ore	GHD								8.8	0.1	0.1			4.8		
X073705	NS0111	168	172	WP	Fresh	Waste	GHD								8.9	0.1	0.1			4.3		
X073711	NS0111	180	184	WP	Fresh	Waste	GHD								8.9	0.1	0.1			0.3		
X073715	NS0111	188	192	WP	Fresh	Waste	GHD								8.4	0.1	0.1	-35.5	80.94	0.4	35.94	
X073721	NS0111	200	204	WP	Fresh	Waste	GHD								8.6	0.1	0.1			2.8		
X073725	NS0111	208	212	WP	Fresh	Waste	GHD								9	0.1	0.1			2.3		
X073731	NS0111	220	224	WP	Fresh	Waste	GHD								9	0.1	0.1			6.7		
X073735	NS0111	228	232	WP	Fresh	Waste	GHD								8.8	0.1	0.1			5.1		
X073739	NS0111	236	240	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.4		
X073741	NS0111	240	244	WP	Fresh	Ore	GHD								9	0.1	0.1	-38.4	35.83	1.1	39.5	
X073745	NS0111	248	252	WP	Fresh	Ore	GHD								9.1	0.1	0.1	-35.7	22.79	1.6	37.34	
X073752	NS0111	260	262	WP	Fresh	Waste	GHD								8.6	0.1	0.1	-25.6	3.6	9.8	35.43	
X073757	NS0111	270	274	WP	Fresh	Waste	GHD								9	0.1	0.1			4.4		
X073761	NS0111	278	282	WP	Fresh	Ore	GHD								9	0.1	0.1			5.5		
X073767	NS0111	290	294	WP	Fresh	Waste	GHD								8.6	0.1	0.1	-41.5	7.51	6.4	47.87	
X073802	NS0112	60	64	WP	Oxide	Waste	GHD								8.1	0.1	0.1			0.4		
X073806	NS0112	68	72	WP	Oxide	Waste	GHD								7.4	0.1	0.1			0.3		
X073812	NS0112	80	84	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1.5		
X073822	NS0112	100	104	WP	Fresh	Ore	GHD								8.3	0.1	0.1			2		
X073826	NS0112	108	112	WP	Fresh	Waste	GHD								9	0.1	0.1			0.7		
X073832	NS0112	120	124	WP	Fresh	Waste	GHD								9.2	0.1	0.1			0.8		
X073836	NS0112	128	132	WP	Fresh	Waste	GHD								8.5	0.1	0.1			0.6		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X073842	NS0112	140	144	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.9		
X073846	NS0112	148	150	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.6		
X073847	NS0112	150	152	WP	Fresh	Ore	GHD								9	0.1	0.1			0.7		
X073852	NS0112	158	162	WP	Fresh	Waste	GHD								9.2	0.1	0.1			0.8		
X073858	NS0112	170	174	WP	Fresh	Waste	GHD								8.6	0.1	0.1			1.9		
X073862	NS0112	178	182	WP	Fresh	Waste	GHD								9.1	0.1	0.1			0.4		
X073868	NS0112	190	194	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.2		
X073872	NS0112	198	202	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.9		
X073878	NS0112	210	214	WP	Fresh	Ore	GHD								8.4	0.1	0.1			0.6		
X073888	NS0112	230	232	WP	Fresh	Waste	GHD								9.1	0.1	0.1			0.3		
X073904	NS0112	260	264	WP	Fresh	Ore	GHD								9.1	0.1	0.1			2.5		
X073908	NS0112	268	272	WP	Fresh	Ore	GHD								9.1	0.1	0.1			3.9		
X073914	NS0112	280	284	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1		
X073918	NS0112	288	292	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.8		
X073922	NS0112	296	298	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.6		
X073964	NS0113	80	84	MP	Fresh	Waste	GHD								7.6	0.1	0.1			5.6		
X073968	NS0113	88	92	MP	Fresh	Waste	GHD								8.1	0.1	0.1			5.6		
X073974	NS0113	100	104	MP	Fresh	Ore	GHD								7.7	0.1	0.1			2.6		
X073978	NS0113	108	112	MP	Fresh	Waste	GHD			0.36					6	0.1	0.1			11		
X073984	NS0113	120	124	MP	Fresh	Ore	GHD								8.4	0.1	0.1			6.1		
X073988	NS0113	128	132	MP	Fresh	Ore	GHD								8.2	0.1	0.1	2.02	0.7	6.6	4.6	5
X073994	NS0113	140	142	MP	Fresh	Waste	GHD			0.15					5.9	0.1	1.8			4.6		
X073998	NS0113	148	152	MP	Fresh	Ore	GHD								8.1	0.1	0.1			5.9		
X074004	NS0113	158	162	MP	Fresh	Waste	GHD			0.16					5.6	0.1	1.2			4.9		
X074010	NS0113	170	174	MP	Fresh	Waste	GHD								8.1	0.1	0.1			7.6		
X074014	NS0113	178	182	MP	Fresh	Waste	GHD								8	0.1	0.1			5		
X074020	NS0113	190	194	MP	Fresh	Ore	GHD								8.5	0.1	0.1			3.9		
X074024	NS0113	198	202	MP	Fresh	Waste	GHD								8.3	0.1	0.1			10.2		
X074034	NS0113	218	222	MP	Fresh	Waste	GHD								7.9	0.1	0.1			9.9		
X074050	NS0113	250	252	WP	Fresh	Waste	GHD								8.1	0.1	0.1			6.7		
X074056	NS0113	260	264	WP	Fresh	Waste	GHD								7.7	0.1	0.1			6.3		
X074061	NS0113	270	282	WP	Fresh	Ore	GHD								8	0.1	0.1			3.4		
X074066	NS0113	280	284	WP	Fresh	Ore	GHD								8.2	0.1	0.1			2.6		
X074070	NS0113	288	292	WP	Fresh	Ore	GHD								8.3	0.1	0.1			1.5		
X074179	NS0115	58	62	WP	Fresh	Waste	GHD								7.4	0.1	0.1			0.2		
X074185	NS0115	70	74	WP	Fresh	Waste	GHD								7.5	0.1	0.1			0.2		
X074193	NS0115	86	90	WP	Fresh	Waste	GHD								7.5	0.1	0.1			52.2		
X074195	NS0115	90	94	WP	Fresh	Waste	GHD								7.9	0.1	0.1			8.9		
X074199	NS0115	98	102	WP	Fresh	Ore	GHD								7.6	0.1	0.1			2.3		
X074205	NS0115	108	112	WP	Fresh	Waste	GHD								7.5	0.1	0.1			4.5		
X074211	NS0115	120	124	WP	Fresh	Ore	GHD								8.1	0.1	0.1			1.3		
X074216	NS0115	130	132	WP	Fresh	Ore	GHD								8.2	0.1	0.1			1.8		
X074221	NS0115	140	144	WP	Fresh	Waste	GHD								7.7	0.1	0.1			1.2		
X074225	NS0115	148	152	WP	Fresh	Ore	GHD								7.7	0.1	0.1			1.1		
X074231	NS0115	160	164	WP	Fresh	Waste	GHD								8	0.1	0.1			1.5		
X074235	NS0115	168	172	WP	Fresh	Waste	GHD								7.6	0.1	0.1			3		
X074241	NS0115	180	182	WP	Fresh	Ore	GHD								8.8	0.1	0.1			3.6		
X074245	NS0115	188	192	WP	Fresh	Waste	GHD								8.4	0.1	0.1			0.7		
X074252	NS0115	200	204	WP	Fresh	Ore	GHD								8.4	0.1	0.1			3.6		
X074257	NS0115	210	214	WP	Fresh	Waste	GHD			0.12					6.4	0.1	0.1			3.7		
X074261	NS0115	218	222	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.8		
X074266	NS0115	228	232	WP	Fresh	Ore	GHD								8.2	0.1	0.1			4.6		
X074272	NS0115	240	244	WP	Fresh	Waste	GHD								8.5	0.1	0.1			1.7		
X074276	NS0115	248	252	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.6		
X074282	NS0115	260	264	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.5		
X074286	NS0115	268	272	WP	Fresh	Waste	GHD								8.6	0.1	0.1			6.1		
X074288	NS0115	272	276	WP	Fresh	Waste	GHD								7.9	0.1	0.1			7		
X074333	NS0116	80	84	MP	Fresh	Waste	GHD								8.2	0.1	0.1			14.9		
X074337	NS0116	88	92	MP	Fresh	Waste	GHD								8.7	0.1	0.1			5.1		
X074343	NS0116	100	104	MP	Fresh	Waste	GHD								8.5	0.1	0.1			6.8		
X074347	NS0116	108	112	MP	Fresh	Waste	GHD			0.55					5	0.1	2			16.8		
X074353	NS0116	118	122	MP	Fresh	Waste	GHD								8.5	0.1	0.1			11.4		
X074359	NS0116	130	132	MP	Fresh	Waste	GHD								8.2	0.1	0.1			13.6		
X074363	NS0116	138	142	MP	Fresh	Waste	GHD								8.4	0.1	0.1			10.8		
X074369	NS0116	150	154	WP	Fresh	Ore	GHD								8.7	0.1	0.1			6.4		
X074373	NS0116	158	162	WP	Fresh	Ore	GHD								8.7	0.1	0.1			4.2		
X074379	NS0116	170	174	WP	Fresh	Ore	GHD								9.1	0.1	0.1			3.1		
X074383	NS0116	178	182	WP	Fresh	Ore	GHD								8.8	0.1	0.1			3.2		
X074389	NS0116	190	192	WP	Fresh	Ore	GHD								9.3	0.1	0.1			3.1		
X074393	NS0116	198	202	WP	Fresh	Waste	GHD								8.5	0.1	0.1			13.9		
X074399	NS0116	210	214	WP	Fresh	Waste	GHD								8.9	0.1	0.1			10.3		
X074405	NS0116	220	224	WP	Fresh	Ore	GHD								8.6	0.1	0.1			7		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X074409	NS0116	228	232	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.5		
X074415	NS0116	240	244	WP	Fresh	Ore	GHD								8.8	0.1	0.1			1.7		
X074419	NS0116	248	252	WP	Fresh	Ore	GHD								7.9	0.1	0.1			4.1		
X074425	NS0116	260	264	MP	Fresh	Ore	GHD								8.4	0.1	0.1			2.2		
X074522	NS0117	170	174	MP	Fresh	Ore	GHD								8.9	0.1	0.1			10.8		
X074526	NS0117	178	182	MP	Fresh	Waste	GHD								9	0.1	0.1			7.2		
X074528	NS0117	182	186	MP	Fresh	Ore	GHD								9.1	0.1	0.1			3.3		
X074528	NS0117	182	186	MP	Fresh	Ore	GHD								8.5	0.1	0.1			3.3		
X074532	NS0117	190	194	MP	Fresh	Ore	GHD								8.8	0.1	0.1			4		
X074536	NS0117	198	202	MP	Fresh	Ore	GHD								8.6	0.1	0.1			6.1		
X074538	NS0117	202	206	MP	Fresh	Ore	GHD								8.6	0.1	0.1			4.3		
X074542	NS0117	210	214	MP	Fresh	Ore	GHD								8.2	0.1	0.1			5.1		
X074546	NS0117	218	222	MP	Fresh	Waste	GHD								7.9	0.1	0.1			7.9		
X074552	NS0117	228	232	MP	Fresh	Waste	GHD								8.3	0.1	0.1			4.4		
X074558	NS0117	240	244	MP	Fresh	Waste	GHD								7.8	0.1	0.1			2.1		
X074562	NS0117	248	252	MP	Fresh	Ore	GHD								8.3	0.1	0.1			3.2		
X074568	NS0117	260	264	MP	Fresh	Ore	GHD								8.4	0.1	0.1			3.5		
X074572	NS0117	268	272	MP	Fresh	Ore	GHD								8.3	0.1	0.1			1.5		
X074574	NS0117	272	276	MP	Fresh	Ore	GHD								8.4	0.1	0.1			3.2		
X074629	NS0118	100	102	WP	Fresh	Waste	GHD								8.3	0.1	0.1			1.3		
X074633	NS0118	108	112	WP	Fresh	Waste	GHD								8	0.1	0.1			7.4		
X074635	NS0118	112	116	WP	Fresh	Ore	GHD								8	0.1	0.1			0.5		
X074639	NS0118	120	124	WP	Fresh	Waste	GHD								7.7	0.1	0.1			1.6		
X074643	NS0118	128	132	WP	Fresh	Waste	GHD								8	0.1	0.1			1.7		
X074649	NS0118	140	144	WP	Fresh	Waste	GHD								6.8	0.1	0.1			14.1		
X074655	NS0118	150	154	WP	Fresh	Waste	GHD								8	0.1	0.1			0.6		
X074806	NS0120	90	94	WP	Fresh	Waste	GHD								9.3	0.1	0.1			5.1		
X074810	NS0120	98	102	WP	Fresh	Waste	GHD								8.5	0.1	0.1			6.9		
X074816	NS0120	110	112	WP	Fresh	Waste	GHD								9.2	0.1	0.1			7.5		
X074822	NS0120	120	124	WP	Fresh	Waste	GHD								8.7	0.1	0.1			7.3		
X074826	NS0120	128	132	WP	Fresh	Waste	GHD								9.3	0.1	0.1			4.8		
X074832	NS0120	140	144	WP	Fresh	Waste	GHD								9.2	0.1	0.1			13.1		
X074836	NS0120	148	152	WP	Fresh	Waste	GHD								9.3	0.1	0.1			7.1		
X074842	NS0120	160	164	WP	Fresh	Waste	GHD								9	0.1	0.1			10		
X074846	NS0120	168	172	WP	Fresh	Waste	GHD								8.6	0.1	0.1			15.7		
X074852	NS0120	178	182	WP	Fresh	Waste	GHD								8.5	0.1	0.1			11.9		
X074858	NS0120	190	194	WP	Fresh	Waste	GHD								8.5	0.1	0.1			13.6		
X074862	NS0120	198	202	WP	Fresh	Waste	GHD								7.4	0.1	0.1			11.5		
X074866	NS0120	206	210	WP	Fresh	Waste	GHD			1					3.2	6.4	12			30.6		
X074869	NS0120	212	214	WP	Fresh	Waste	GHD			0.96					3.6	2.9	9.7			29.4		
X074872	NS0120	218	222	WP	Fresh	Ore	GHD								9	0.1	0.1			3.1		
X074878	NS0120	230	234	WP	Fresh	Ore	GHD								8.9	0.1	0.1			4.1		
X074882	NS0120	238	242	WP	Fresh	Waste	GHD								6.8	0.1	0.1			12.8		
X074888	NS0120	250	254	WP	Fresh	Waste	GHD								8.1	0.1	0.1			9.4		
X074892	NS0120	258	262	WP	Fresh	Waste	GHD								7.4	0.1	0.1			12.6		
X074898	NS0120	270	274	WP	Fresh	Ore	GHD								7.9	0.1	0.1			5.9		
X075077	NS0122	58	62	WP	Oxide	Waste	GHD								9.4	0.1	0.1			5.4		
X075083	NS0122	70	72	WP	Fresh	Waste	GHD								8.8	0.1	0.1			8.1		
X075084	NS0122	72	74	WP	Fresh	Waste	GHD								8.9	0.1	0.1			7.9		
X075087	NS0122	78	82	WP	Fresh	Waste	GHD								9.5	0.1	0.1			5.7		
X075093	NS0122	90	94	WP	Fresh	Ore	GHD								9.5	0.1	0.1			2.1		
X075097	NS0122	98	100	WP	Fresh	Waste	GHD								9.1	0.1	0.1			9.6		
X075098	NS0122	100	102	WP	Fresh	Waste	GHD								8.9	0.1	0.1			4		
X075104	NS0122	110	114	WP	Fresh	Ore	GHD								9.6	0.1	0.1			3.4		
X075108	NS0122	118	120	WP	Fresh	Waste	GHD								9.2	0.1	0.1			13.4		
X075109	NS0122	120	122	WP	Fresh	Waste	GHD								9.4	0.1	0.1			5.7		
X075114	NS0122	130	134	WP	Fresh	Waste	GHD								9.2	0.1	0.1			7.5		
X075118	NS0122	138	142	WP	Fresh	Waste	GHD								9.3	0.1	0.1			9		
X075124	NS0122	150	154	WP	Fresh	Waste	GHD								9.4	0.1	0.1			7.1		
X075128	NS0122	158	162	WP	Fresh	Waste	GHD								9.3	0.1	0.1			4		
X075133	NS0122	168	172	WP	Fresh	Waste	GHD								9.2	0.1	0.1			10.9		
X075139	NS0122	180	184	WP	Fresh	Waste	GHD								9.3	0.1	0.1			9.5		
X075143	NS0122	188	192	WP	Fresh	Waste	GHD								8.3	0.1	0.1			6.7		
X075149	NS0122	200	204	WP	Fresh	Waste	GHD								9.5	0.1	0.1			8.6		
X075154	NS0122	208	212	WP	Fresh	Waste	GHD								9	0.1	0.1			11.5		
X075165	NS0122	230	234	WP	Fresh	Ore	GHD								10	0.1	0.1			4.7		
X075169	NS0122	238	240	WP	Fresh	Ore	GHD								9.4	0.1	0.1			3.6		
X075170	NS0122	240	242	WP	Fresh	Ore	GHD								8.6	0.1	0.1			3.5		
X075175	NS0122	250	254	WP	Fresh	Ore	GHD								9.3	0.1	0.1			4.4		
X075179	NS0122	258	262	WP	Fresh	Waste	GHD								10.1	0.1	0.1			8.5		
X075185	NS0122	270	274	WP	Fresh	Waste	GHD								9	0.1	0.1			6		
X075189	NS0122	278	280	WP	Fresh	Waste	GHD								9.2	0.1	0.1			7.4		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples																					
Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X075359	NS0124	50	52	MP	Oxide	Waste	GHD								8.2	0.1	0.1			0.3		
X075363	NS0124	58	62	MP	Fresh	Waste	GHD								9.1	0.1	0.1			3.1		
X075370	NS0124	72	74	MP	Fresh	Waste	GHD								10.1	0.1	0.1			11.9		
X075373	NS0124	78	82	MP	Fresh	Waste	GHD								9.4	0.1	0.1			8		
X075379	NS0124	90	94	MP	Fresh	Waste	GHD								9	0.1	0.1			11		
X075384	NS0124	100	102	MP	Fresh	Waste	GHD								9.4	0.1	0.1			9.5		
X075385	NS0124	102	106	MP	Fresh	Ore	GHD								10.3	0.1	0.1			3		
X075389	NS0124	110	112	MP	Fresh	Waste	GHD								10.3	0.1	0.1			3.8		
X075393	NS0124	118	122	MP	Fresh	Ore	GHD								10	0.1	0.1	-49.2	20.71	2.5	51.7	23
X075399	NS0124	130	134	MP	Fresh	Waste	GHD			0.42					5.4	0.1	0.8			12.9		
X075405	NS0124	140	144	MP	Fresh	Waste	GHD								8.5	0.1	0.1			7.3		
X075409	NS0124	148	152	MP	Fresh	Waste	GHD								8.4	0.1	0.1			6.2		
X075415	NS0124	160	164	MP	Fresh	Waste	GHD								10.7	0.1	0.1			14.3		
X075417	NS0124	164	168	MP	Fresh	Waste	GHD								8.9	0.1	0.1			2.9		
X075419	NS0124	168	172	MP	Fresh	Waste	GHD								9.4	0.1	0.1			7.3		
X075425	NS0124	180	184	MP	Fresh	Ore	GHD								9.2	0.1	0.1			3.4		
X075435	NS0124	200	204	MP	Fresh	Waste	GHD								8.7	0.1	0.1			5.2		
X075439	NS0124	208	212	MP	Fresh	Waste	GHD								8.3	0.1	0.1			2.6		
X075446	NS0124	222	224	MP	Fresh	Waste	GHD								8.1	0.1	0.1			4.7		
X075449	NS0124	228	232	MP	Fresh	Waste	GHD								8.8	0.1	0.1			6.8		
X075456	NS0124	240	244	WP	Fresh	Waste	GHD								9	0.1	0.1			10.8		
X075461	NS0124	250	252	WP	Fresh	Waste	GHD								9.5	0.1	0.1			1		
X075466	NS0124	260	264	WP	Fresh	Waste	GHD								10.9	0.1	0.1			7.3		
X075470	NS0124	268	272	WP	Fresh	Waste	GHD								10.8	0.1	0.1			6.2		
X075477	NS0124	282	284	WP	Fresh	Waste	GHD								9.4	0.1	0.1			19.3		
X075480	NS0124	288	292	WP	Fresh	Waste	GHD								8.4	0.1	0.1			6.2		
X075484	NS0124	296	298	WP	Fresh	Waste	GHD								8.5	0.1	0.1			5.2		
X075500	NS0125	30	32	WP	Oxide	Waste	GHD								8.6	0.1	0.1	-3.06	2.22	2.5	5.57	
X075505	NS0125	38	42	WP	Fresh	Waste	GHD								7.6	0.1	0.1			1.1		
X075511	NS0125	50	54	WP	Fresh	Ore	GHD								9.8	0.1	0.1			1		
X075515	NS0125	58	62	WP	Fresh	Waste	GHD								8.5	0.1	0.1	-44.5	25.02	1.9	46.35	
X075521	NS0125	70	74	WP	Fresh	Waste	GHD								8.8	0.1	0.1	-44	152.24	0.3	44.29	
X075525	NS0125	78	82	WP	Fresh	Waste	GHD								8.4	0.1	0.1	-50.9	222.61	0.2	51.13	
X075531	NS0125	90	94	WP	Fresh	Waste	GHD								8.7	0.1	0.1			2.6		
X075535	NS0125	98	102	WP	Fresh	Waste	GHD								8.8	0.1	0.1	-39.2	7.45	6.1	45.28	
X075541	NS0125	110	114	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.9		
X075545	NS0125	118	122	WP	Fresh	Ore	GHD								8.7	0.1	0.1			4.7		
X075552	NS0125	130	132	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.7		
X075557	NS0125	140	144	WP	Fresh	Ore	GHD								8.9	0.1	0.1			5.2		
X075561	NS0125	148	152	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.8		
X075567	NS0125	160	164	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.9		
X075571	NS0125	168	172	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1		
X075577	NS0125	180	184	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.8		
X075581	NS0125	188	192	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.7		
X075591	NS0125	208	212	WP	Fresh	Ore	GHD								9	0.1	0.1			3.7		
X075597	NS0125	220	224	WP	Fresh	Ore	GHD								8.7	0.1	0.1			3.4		
X075603	NS0125	230	234	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.5		
X075607	NS0125	238	242	WP	Fresh	Ore	GHD								9	0.1	0.1			0.9		
X075635	NS0126	50	54	WP	Fresh	Waste	GHD								8.2	0.1	0.1			5		
X075639	NS0126	58	60	WP	Fresh	Waste	GHD								8.3	0.1	0.1			2.9		
X075645	NS0126	70	74	WP	Fresh	Waste	GHD								8.4	0.1	0.1			3.9		
X075649	NS0126	78	82	WP	Fresh	Waste	GHD								8.9	0.1	0.1			1.9		
X075655	NS0126	88	92	WP	Fresh	Waste	GHD								8.8	0.1	0.1			1.7		
X075661	NS0126	100	104	WP	Fresh	Waste	GHD								10.6	0.1	0.1			3.6		
X075665	NS0126	108	112	WP	Fresh	Waste	GHD								8.6	0.1	0.1			9		
X075672	NS0126	122	124	WP	Fresh	Waste	GHD								8.6	0.1	0.1			3.4		
X075675	NS0126	128	132	WP	Fresh	Ore	GHD								9.2	0.1	0.1			4.8		
X075681	NS0126	140	144	WP	Fresh	Ore	GHD								10.8	0.1	0.1			1.8		
X075685	NS0126	148	152	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2.3		
X075691	NS0126	160	164	WP	Fresh	Ore	GHD								8.8	0.1	0.1			2.2		
X075695	NS0126	168	172	WP	Fresh	Waste	GHD								7.8	0.1	0.1			13.5		
X075702	NS0126	180	182	WP	Fresh	Ore	GHD								8.5	0.1	0.1	-12.6	7.33	2	14.59	
X075702	NS0126	180	182	WP	Fresh	Ore	GHD								10.6	0.1	0.1			2		
X075703	NS0126	182	184	WP	Fresh	Ore	GHD								8.4	0.1	0.1	-19.2	13.54	1.5	20.73	
X075707	NS0126	190	194	WP	Fresh	Ore	GHD								10.1	0.1	0.1			1.4		
X075708	NS0126	192	194	WP	Fresh	Ore	GHD								8.9	0.1	0.1	-25.4	17.59	1.5	26.93	
X075709	NS0126	194	196	WP	Fresh	Ore	GHD								8.2	0.1	0.1	-28.9	22.95	1.3	30.22	
X075711	NS0126	198	202	WP	Fresh	Ore	GHD								8.4	0.1	0.1			5.4		
X075712	NS0126	200	202	WP	Fresh	Ore	GHD								8.4	0.1	0.1	-5.5	4.39	1.6	7.12	
X075713	NS0126	202	204	WP	Fresh	Ore	GHD								8.1	0.1	0.1	2.2	-0.94	1.1	-1.07	
X075717	NS0126	210	214	WP	Fresh	Ore	GHD								10.1	0.1	0.1			1.5		
X075718	NS0126	212	214	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-27.1	35.03	0.8	27.9	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X075719	NS0126	214	216	WP	Fresh	Ore	GHD								7.9	0.1	0.1	-24.4	18.71	1.4	25.78	
X075721	NS0126	218	222	WP	Fresh	Ore	GHD								10.5	0.1	0.1			2.3		
X075722	NS0126	220	222	WP	Fresh	Ore	GHD								8.3	0.1	0.1	-10.4	6.57	1.9	12.27	
X075725	NS0126	226	228	WP	Fresh	Ore	GHD								8	0.1	0.1	-4.8	3.66	1.8	6.61	
X075727	NS0126	230	234	WP	Fresh	Ore	GHD								8.4	0.1	0.1			2.1		
X075728	NS0126	232	234	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-15.5	6.22	3	18.47	
X075729	NS0126	234	236	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-10	4.17	3.2	13.15	
X075731	NS0126	238	242	WP	Fresh	Ore	GHD								9.1	0.1	0.1			2		
X075732	NS0126	240	242	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.1		
X075733	NS0126	242	244	WP	Fresh	Ore	GHD								9.1	0.1	0.1			4.1		
X075737	NS0126	250	254	WP	Fresh	Ore	GHD								9.3	0.1	0.1			4.8		
X075738	NS0126	252	256	WP	Fresh	Ore	GHD								9	0.1	0.1			2.8		
X075741	NS0126	258	262	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1.7		
X075742	NS0126	260	264	WP	Fresh	Ore	GHD								9.4	0.1	0.1			1.6		
X075747	NS0126	270	274	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.4		
X075748	NS0126	272	276	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.7		
X075753	NS0127	0	2	WP	Oxide	Waste	GHD								6.8	0.1	0.1			0.6		
X075754	NS0127	2	6	WP	Oxide	Waste	GHD								9.2	0.1	0.1			0.5		
X075758	NS0127	10	12	WP	Oxide	Ore	GHD								8.3	0.1	0.1	-5.5	20.95	0.3	5.78	
X075758	NS0127	10	14	WP	Oxide	Ore	GHD								9.2	0.1	0.1			0.2		
X075759	NS0127	12	14	WP	Oxide	Ore	GHD								8.3	0.1	0.1	-5.2	29.3	0.2	5.38	
X075762	NS0127	18	22	WP	Oxide	Ore	GHD								7.9	0.1	0.1	-3.9	19.19	0.2	4.11	
X075764	NS0127	22	26	WP	Oxide	Waste	GHD								9.2	0.1	0.1			0.5		
X075768	NS0127	30	34	WP	Oxide	Waste	GHD								9.3	0.1	0.1			0.3		
X075772	NS0127	38	42	WP	Oxide	Waste	GHD								7.8	0.1	0.1	-11	2.23	8.9	19.94	
X075774	NS0127	42	46	WP	Oxide	Waste	GHD								8	0.1	0.1			0.4		
X075778	NS0127	50	54	WP	Fresh	Ore	GHD								8	0.1	0.1	-20.5	10.84	2.1	22.58	
X075782	NS0127	58	62	WP	Fresh	Ore	GHD								8.4	0.1	0.1	-25.8	14.27	1.9	27.74	
X075788	NS0127	70	72	WP	Fresh	Ore	GHD								8.6	0.1	0.1	-19.4	15.4	1.3	20.75	
X075789	NS0127	72	74	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-9.7	15.4	0.7	10.37	
X075792	NS0127	78	80	WP	Fresh	Ore	GHD								8.8	0.1	0.1	-8	6.12	1.6	9.56	
X075793	NS0127	80	82	WP	Fresh	Ore	GHD								8.7	0.1	0.1	-33.5	4.46	9.7	43.18	
X075798	NS0127	90	92	WP	Fresh	Ore	GHD								7.8	0.1	0.1	-12	2.53	7.8	19.84	
X075799	NS0127	92	94	WP	Fresh	Ore	GHD								8.5	0.1	0.1	-23.4	8.28	3.2	26.62	
X075887	NS0127	266	270	WP	Fresh		GHD								9.9	0.1	0.1			1.2		
X138035	NS0128	80	84	WP	Fresh	Waste	GHD								9.2	0.1	0.1			0.4		
X138039	NS0128	88	92	WP	Fresh	Waste	GHD								9	0.1	0.1			0.3		
X138045	NS0128	100	104	WP	Fresh	Waste	GHD								8.5	0.1	0.1			0.3		
X138049	NS0128	108	112	WP	Fresh	Waste	GHD								9.2	0.1	0.1			0.3		
X138055	NS0128	118	122	WP	Fresh	Waste	GHD								9.1	0.1	0.1			1		
X138061	NS0128	130	134	WP	Fresh	Waste	GHD								9.1	0.1	0.1			0.5		
X138065	NS0128	138	142	WP	Fresh	Waste	GHD								8.9	0.1	0.1			3.2		
X138071	NS0128	150	154	WP	Fresh	Waste	GHD			0.48					5.2	0.1	1.6			14.7		
X138075	NS0128	158	162	WP	Fresh	Waste	GHD								8	0.1	0.1			7		
X138081	NS0128	170	174	WP	Fresh	Waste	GHD								8.7	0.1	0.1			1		
X138085	NS0128	178	182	WP	Fresh	Waste	GHD								8.9	0.1	0.1			1.2		
X138091	NS0128	190	194	WP	Fresh	Waste	GHD								8.2	0.1	0.1			0.3		
X138095	NS0128	198	202	WP	Fresh	Waste	GHD								7.2	0.1	0.1			11.4		
X142517	NS0149	4	6	WP	Oxide		GHD								9.2	0.1	0.1			0.3		
X142518	NS0149	6	8	WP	Oxide		GHD								8.9	0.1	0.1			0.4		
X142535	NS0149	40	44	WP	Oxide	Waste	GHD								7.8	0.1	0.1			0.2		
X142539	NS0149	48	52	WP	Fresh	Waste	GHD								8.3	0.1	0.1			11.9		
X142545	NS0149	60	64	WP	Fresh	Waste	GHD								9.1	0.1	0.1			2.6		
X142549	NS0149	68	72	WP	Fresh	Waste	GHD								8.8	0.1	0.1			4.5		
X142555	NS0149	80	84	WP	Fresh	Ore	GHD								9	0.1	0.1			3.8		
X142565	NS0149	100	104	WP	Fresh	Waste	GHD								8.9	0.1	0.1			3.6		
X142569	NS0149	108	112	WP	Fresh	Waste	GHD								9	0.1	0.1			10.8		
X142575	NS0149	120	124	WP	Fresh	Ore	GHD								9.1	0.1	0.1			3.4		
X142579	NS0149	128	132	WP	Fresh	Ore	GHD								9.2	0.1	0.1			2.3		
X142585	NS0149	140	142	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.3		
X142591	NS0149	150	154	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.6		
X142595	NS0149	158	162	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.8		
X142602	NS0149	170	172	WP	Fresh	Ore	GHD								9.1	0.1	0.1			3.2		
X142607	NS0149	180	184	WP	Fresh	Ore	GHD								9.2	0.1	0.1			1.2		
X142611	NS0149	188	192	WP	Fresh	Ore	GHD								9.2	0.1	0.1			3.1		
X142621	NS0149	208	212	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.4		
X142627	NS0149	220	224	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1.2		
X142630	NS0149	226	228	WP	Fresh		GHD								9.2	0.1	0.1			3.1		
X142631	NS0149	228	232	WP	Fresh	Ore	GHD								9.2	0.1	0.1			2		
X142637	NS0149	240	244	WP	Fresh	Ore	GHD								9.3	0.1	0.1			2.3		
X142640	NS0149	246	248	WP	Fresh	Ore	GHD								9.1	0.1	0.1			1.7		
X142641	NS0149	248	252	WP	Fresh	Ore	GHD								9.1	0.1	0.1			2.1		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X142647	NS0149	260	264	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.9		
X142653	NS0149	270	274	WP	Fresh	Ore	GHD								8.9	0.1	0.1			3.8		
X142657	NS0149	278	280	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.1		
X142658	NS0149	280	282	WP	Fresh	Ore	GHD								9.3	0.1	0.1			1.4		
X072167	NS0151	128	132	WP	Fresh	Ore	GHD								8.1	0.1	0.1			0.7		
X072173	NS0151	140	144	WP	Fresh	Waste	GHD								7.5	0.1	0.1			0.8		
X072175	NS0151	144	148	WP	Fresh	Waste	GHD								8.3	0.1	0.1			7.4		
X072177	NS0151	148	152	WP	Fresh	Ore	GHD								7.2	0.1	0.1			1.5		
X072183	NS0151	160	164	KCF	Fresh	Waste	GHD								7.5	0.1	0.1			11.4		
X072252	NS0152	78	82	MP	Fresh	Waste	GHD			0.55					6	0.1	0.6			16.8		
X072258	NS0152	90	94	MP	Fresh	Waste	GHD								8.3	0.1	0.1			7		
X072263	NS0152	100	104	MP	Fresh	Ore	GHD								9.6	0.1	0.1			9.2		
X072267	NS0152	108	112	MP	Fresh	Ore	GHD								9.4	0.1	0.1			1.7		
X072273	NS0152	120	124	WP	Fresh	Ore	GHD								9.3	0.1	0.1	-57.86	17.36	3.5	61.4	35
X072277	NS0152	128	132	WP	Fresh	Ore	GHD								9.3	0.1	0.1			4		
X072283	NS0152	140	144	WP	Fresh	Ore	GHD								9.1	0.1	0.1			7.7		
X072287	NS0152	148	152	WP	Fresh	Ore	GHD								11.5	0.1	0.1	-74.84	17.4	4.6	79.4	52
X072293	NS0152	160	164	WP	Fresh	Ore	GHD								9.5	0.1	0.1			3.2		
X072297	NS0152	168	172	WP	Fresh	Ore	GHD								9.5	0.1	0.1			3.4		
X072303	NS0152	180	184	WP	Fresh	Ore	GHD								10.1	0.1	0.1			2.4		
X072307	NS0152	188	192	WP	Fresh	Ore	GHD								9.4	0.1	0.1			3.1		
X072313	NS0152	200	204	WP	Fresh	Ore	GHD								10.5	0.1	0.1			2.4		
X072317	NS0152	208	212	WP	Fresh	Ore	GHD								10.2	0.1	0.1			2.4		
X072323	NS0152	220	224	WP	Fresh	Waste	GHD								10	0.1	0.1			4.5		
X072327	NS0152	228	232	WP	Fresh	Waste	GHD								8.9	0.1	0.1			4.1		
X072333	NS0152	240	244	WP	Fresh	Waste	GHD								9.7	0.1	0.1			6.8		
X072335	NS0152	244	248	WP	Fresh	Waste	GHD								11.2	0.1	0.1	-71.04	17.28	4.4	75.4	38
X072337	NS0152	248	252	WP	Fresh	Ore	GHD								10.6	0.1	0.1			3.4		
X072343	NS0152	260	264	WP	Fresh	Ore	GHD								10.5	0.1	0.1			2.8		
X072347	NS0152	268	272	WP	Fresh	Waste	GHD								8.9	0.1	0.1			8.3		
X072353	NS0152	280	282	WP	Fresh	Waste	GHD								8.4	0.1	0.1			19.5		
X072404	NS0153	98	102	WP	Fresh	Waste	GHD								7.5	0.1	0.1	-13.03	4.54	3.7	16.7	1.8
X072410	NS0153	110	114	WP	Fresh	Ore	GHD								7.9	0.1	0.1			1.4		
X072414	NS0153	118	122	WP	Fresh	Waste	GHD								7.8	0.1	0.1			1.9		
X072420	NS0153	130	134	WP	Fresh	Waste	GHD								7.7	0.1	0.1			3.9		
X072424	NS0153	138	142	WP	Fresh	Waste	GHD								7.9	0.1	0.1			2.9		
X072435	NS0153	160	164	WP	Fresh	Ore	GHD								8.6	0.1	0.1			2.4		
X072439	NS0153	168	172	WP	Fresh	Ore	GHD								8.3	0.1	0.1	-24.01	18.23	1.4	25.4	10
X072445	NS0153	180	184	WP	Fresh	Ore	GHD								7.7	0.1	0.1			2.6		
X072449	NS0153	188	192	WP	Fresh	Waste	GHD								7.8	0.1	0.1			3.9		
X072455	NS0153	200	204	WP	Fresh	Waste	GHD			3.4					2	86	99			104.1		
X072465	NS0153	220	224	WP	Fresh	Waste	GHD			0.63					6	0.1	1.9			19.3		
X072469	NS0153	228	232	WP	Fresh	Waste	GHD								7.7	0.1	0.1			1.1		
X072475	NS0153	240	244	WP	Fresh	Ore	GHD								8.3	0.1	0.1			1.6		
X072479	NS0153	248	252	WP	Fresh	Waste	GHD								8.1	0.1	0.1			1.1		
X072493	NS0154	18	22	WP	Oxide	Ore	GHD								9.1	0.1	0.1	-6.95	46.37	0.2	7.1	1.5
X072499	NS0154	30	34	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.4		
X072503	NS0154	38	42	WP	Fresh	Ore	GHD								9.1	0.1	0.1	-64.21	36.84	1.8	66	32
X072509	NS0154	50	54	WP	Fresh	Ore	GHD								9.6	0.1	0.1			2		
X072513	NS0154	58	62	WP	Fresh	Ore	GHD								9.5	0.1	0.1			1.5		
X072519	NS0154	70	74	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.6		
X072523	NS0154	78	82	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.9		
X072527	NS0154	86	90	WP	Fresh	Waste	GHD								7.9	0.1	0.1			6.9		
X072529	NS0154	90	92	WP	Fresh	Ore	GHD								8.4	0.1	0.1			2.2		
X072533	NS0154	98	102	WP	Fresh	Ore	GHD								9.7	0.1	0.1			3.2		
X072539	NS0154	110	114	WP	Fresh	Ore	GHD								8.9	0.1	0.1			13.5		
X072543	NS0154	118	122	WP	Fresh	Waste	GHD								8.2	0.1	0.1			8.9		
X072549	NS0154	130	134	WP	Fresh	Waste	GHD								8.9	0.1	0.1			3.1		
X072555	NS0154	140	144	WP	Fresh	Waste	GHD								8.9	0.1	0.1			8.1		
X072565	NS0154	160	164	WP	Fresh	Waste	GHD								9.1	0.1	0.1			3.2		
X072569	NS0154	168	172	WP	Fresh	Waste	GHD								8.3	0.1	0.1			5.3		
X072570	NS0154	170	174	WP	Fresh	Waste	GHD								9.1	0.1	0.1			2.3		
X072575	NS0154	180	184	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.5		
X072579	NS0154	188	192	WP	Fresh	Ore	GHD								8.9	0.1	0.1			7.1		
X072585	NS0154	200	204	WP	Fresh	Waste	GHD								7.7	0.1	0.1	-14.03	1.91	15.5	29.5	4.5
X072595	NS0154	220	224	MP	Fresh	Waste	GHD								8.5	0.1	0.1			26.8		
X072601	NS0154	230	234	MP	Fresh	Waste	GHD								8.5	0.1	0.1			20.1		
X072605	NS0154	238	242	MP	Fresh	Waste	GHD								8.5	0.1	0.1			7.8		
X072611	NS0154	250	254	MP	Fresh	Waste	GHD								10	0.1	0.1			8.6		
X072615	NS0154	258	262	MP	Fresh	Waste	GHD								9.1	0.1	0.1			6.2		
X072621	NS0154	270	274	MP	Fresh	Waste	GHD								9.7	0.1	0.1			5.7		
X072677	NS0155	100	104	WP	Fresh	Waste	GHD								8.5	0.1	0.1			10.3		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X072681	NS0155	108	112	WP	Fresh	Waste	GHD								6.6	0.1	0.6			22.6		
X072687	NS0155	120	124	WP	Fresh	Waste	GHD								9.3	0.1	0.1			2.6		
X072691	NS0155	128	132	WP	Fresh	Waste	GHD								8.4	0.1	0.1			2.7		
X072697	NS0155	140	144	WP	Fresh	Ore	GHD								9.1	0.1	0.1			3.7		
X072703	NS0155	150	154	WP	Fresh	Ore	GHD								9	0.1	0.1			1.8		
X072707	NS0155	158	162	WP	Fresh	Waste	GHD								9.5	0.1	0.1			5.6		
X072713	NS0155	170	174	WP	Fresh	Ore	GHD								8.9	0.1	0.1			4.2		
X072717	NS0155	178	182	WP	Fresh	Waste	GHD								9.2	0.1	0.1			3.7		
X072723	NS0155	190	194	WP	Fresh	Ore	GHD								9.7	0.1	0.1			2		
X072727	NS0155	198	202	WP	Fresh	Ore	GHD								9.9	0.1	0.1			2		
X072733	NS0155	210	214	WP	Fresh	Ore	GHD								9	0.1	0.1	-44.4	22.17	2.1	46.5	20
X072737	NS0155	218	222	WP	Fresh	Ore	GHD								9.3	0.1	0.1			2.9		
X072743	NS0155	230	234	WP	Fresh	Ore	GHD								9.4	0.1	0.1			3.8		
X072747	NS0155	238	242	WP	Fresh	Ore	GHD								10.5	0.1	0.1			1.7		
X072753	NS0155	250	254	WP	Fresh	Waste	GHD								8.7	0.1	0.1			11.6		
X072757	NS0155	258	262	WP	Fresh	Waste	GHD								8.7	0.1	0.1			11.6		
X072763	NS0155	270	274	WP	Fresh	Ore	GHD								9.9	0.1	0.1			4.6		
X072767	NS0155	278	282	WP	Fresh	Waste	GHD								9	0.1	0.1			2.1		
X072911	NS0157	110	114	WP	Fresh	Waste	GHD								7.8	0.1	0.1			3.4		
X072917	NS0157	122	126	WP	Fresh	Waste	GHD								7.5	0.1	0.1			4.4		
X072919	NS0157	126	130	WP	Fresh	Ore	GHD								7.8	0.1	0.1			1.4		
X072921	NS0157	130	134	WP	Fresh	Ore	GHD								7.2	0.1	0.1			10.7		
X072925	NS0157	138	142	WP	Fresh	Waste	GHD								7.7	0.1	0.1			0.4		
X072931	NS0157	150	152	WP	Fresh	Waste	GHD								7.5	0.1	0.1			1		
X072999	NS0158	38	42	MP	Oxide	Waste	GHD								8.7	0.1	0.1			0.2		
X141506	NS0158	50	54	MP	Oxide	Waste	GHD								8.4	0.1	0.1			0.3		
X141508	NS0158	54	58	MP	Fresh	Ore	GHD								9.5	0.1	0.1			2.8		
X141510	NS0158	58	62	MP	Fresh	Waste	GHD								9.9	0.1	0.1			7.3		
X141514	NS0158	66	70	MP	Fresh	Waste	GHD								8.7	0.1	0.1			25.1		
X141520	NS0158	78	82	MP	Fresh	Ore	GHD								10.9	0.1	0.1			1.7		
X141526	NS0158	90	94	MP	Fresh	Ore	GHD								10.5	0.1	0.1			3.5		
X141531	NS0158	100	102	MP	Fresh	Ore	GHD								10.6	0.1	0.1			1.4		
X141536	NS0158	110	114	MP	Fresh	Ore	GHD								10.2	0.1	0.1			4.2		
X141540	NS0158	118	122	MP	Fresh	Ore	GHD								10.4	0.1	0.1			1.5		
X141546	NS0158	130	134	MP	Fresh	Ore	GHD								10.4	0.1	0.1			1		
X141552	NS0158	140	142	MP	Fresh	Ore	GHD								10.4	0.1	0.1			1.4		
X141557	NS0158	150	154	MP	Fresh	Ore	GHD								10.4	0.1	0.1			0.9		
X141561	NS0158	158	162	MP	Fresh	Ore	GHD								10.5	0.1	0.1			1.1		
X141571	NS0158	178	182	MP	Fresh	Ore	GHD								11	0.1	0.1	-58.05	38.54	1.5	59.6	49
X141575	NS0158	186	190	MP	Fresh	Ore	GHD								8.8	0.1	0.1			2		
X141577	NS0158	190	194	MP	Fresh	Ore	GHD								10.8	0.1	0.1			4.3		
X141581	NS0158	198	202	MP	Fresh	Ore	GHD								9.4	0.1	0.1			3.7		
X141615	NS0159	60	64	WP	Oxide	Waste	GHD								7.2	0.1	0.1			0.2		
X141619	NS0159	68	72	WP	Fresh	Ore	GHD								8	0.1	0.1			0.6		
X141621	NS0159	72	76	WP	Fresh	Ore	GHD								8.1	0.1	0.1			4.4		
X141625	NS0159	80	84	WP	Fresh	Ore	GHD								8.1	0.1	0.1			1.6		
X141631	NS0159	92	96	WP	Fresh	Ore	GHD								8.4	0.1	0.1			3.8		
X141635	NS0159	100	104	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.8		
X141639	NS0159	108	112	WP	Fresh	Ore	GHD								8.8	0.1	0.1			5.4		
X141643	NS0159	116	118	WP	Fresh	Ore	GHD								8.2	0.1	0.1	-26.59	4.24	8.2	34.8	17
X141644	NS0159	118	120	WP	Fresh	Ore	GHD								8.3	0.1	0.1			1.2		
X141645	NS0159	120	124	WP	Fresh	Ore	GHD								8.5	0.1	0.1			2.5		
X141645	NS0159	120	122	WP	Fresh	Ore	GHD								8.9	0.1	0.1			0.9		
X141649	NS0159	128	132	WP	Fresh	Ore	GHD								8.6	0.1	0.1			1.8		
X141655	NS0159	138	142	WP	Fresh	Ore	GHD								7.9	0.1	0.1			0.9		
X141661	NS0159	150	154	WP	Fresh	Ore	GHD								8.4	0.1	0.1			2.7		
X141665	NS0159	158	162	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.8		
X141671	NS0159	170	174	WP	Fresh	Ore	GHD								8.7	0.1	0.1			2.4		
X141681	NS0159	190	194	WP	Fresh	Ore	GHD								8.5	0.1	0.1			1		
X141685	NS0159	198	202	WP	Fresh	Ore	GHD								8.3	0.1	0.1			0.8		
X141691	NS0159	210	212	WP	Fresh	Ore	GHD								8.1	0.1	0.1			0.9		
X141695	NS0159	218	222	WP	Fresh		GHD								8.6	0.1	0.1			0.9		
X141702	NS0159	230	232	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.9		
X141711	NS0159	248	252	WP	Fresh	Ore	GHD								9.5	0.1	0.1			1.6		
X141717	NS0159	260	264	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.3		
X141721	NS0159	268	272	WP	Fresh	Ore	GHD								8.3	0.1	0.1			1		
X141727	NS0159	280	284	WP	Fresh	Ore	GHD								9	0.1	0.1			1		
X141731	NS0159	288	292	WP	Fresh	Ore	GHD								8.9	0.1	0.1			1.6		
X141737	NS0159	300	304	WP	Fresh	Ore	GHD								11	0.1	0.1			0.8		
X141741	NS0159	308	312	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.8		
X141776	NS0160	58	62	WP	Fresh	Waste	GHD								8	0.1	0.1			13.1		
X141782	NS0160	70	74	WP	Fresh	Waste	GHD									0.1	0.1			6.8		

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples																					
Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X141786	NS0160	78	82	WP	Fresh	Waste	GHD								7.7	0.1	0.1			5.7		
X141792	NS0160	90	94	WP	Fresh	Waste	GHD								8.2	0.1	0.1			1.6		
X141796	NS0160	98	102	WP	Fresh	Waste	GHD								8.2	0.1	0.1			9.1		
X141802	NS0160	108	112	WP	Fresh	Waste	GHD								9.1	0.1	0.1			10.9		
X141808	NS0160	120	124	WP	Fresh	Ore	GHD								8.4	0.1	0.1			1.6		
X141812	NS0160	128	132	WP	Fresh	Waste	GHD								8.7	0.1	0.1			13.8		
X141818	NS0160	140	144	WP	Fresh	Waste	GHD								9.4	0.1	0.1			14.3		
X141822	NS0160	148	152	WP	Fresh	Waste	GHD								8.6	0.1	0.1			3.3		
X141828	NS0160	160	164	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.8		
X141832	NS0160	168	172	WP	Fresh	Ore	GHD								8.7	0.1	0.1			4.7		
X141838	NS0160	180	184	WP	Fresh	Waste	GHD								8.5	0.1	0.1			10.4		
X141841	NS0160	186	190	WP	Fresh	Waste	GHD								8.8	0.1	0.1			6		
X141848	NS0160	200	204	WP	Fresh	Ore	GHD								8.7	0.1	0.1			6.8		
X141854	NS0160	210	214	WP	Fresh	Waste	GHD								8.6	0.1	0.1			5.4		
X141858	NS0160	218	222	WP	Fresh	Waste	GHD								8.1	0.1	0.1			3.1		
X141864	NS0160	230	234	WP	Fresh	Waste	GHD								8.4	0.1	0.1			4.4		
X141868	NS0160	238	242	WP	Fresh	Waste	GHD								8.1	0.1	0.1			2.5		
X141874	NS0160	250	254	WP	Fresh	Waste	GHD								8.6	0.1	0.1			3.6		
X141878	NS0160	258	262	WP	Fresh	Waste	GHD								8.6	0.1	0.1			4.4		
X141884	NS0160	270	274	WP	Fresh	Waste	GHD								8.9	0.1	0.1			3.9		
X141888	NS0160	278	282	WP	Fresh	Ore	GHD								8.9	0.1	0.1			2.4		
X141894	NS0160	290	294	WP	Fresh	Waste	GHD								8.8	0.1	0.1			3.5		
X121031	NS0165	60	64	WP	Fresh	Ore	GHD								7.8	0.1	0.1			2.8		
X121035	NS0165	68	72	WP	Fresh	Ore	GHD								8.6	0.1	0.1			0.8		
X121041	NS0165	80	84	WP	Fresh	Ore	GHD								8.5	0.1	0.1			0.7		
X121045	NS0165	88	92	WP	Fresh	Ore	GHD								8.4	0.1	0.1			2.4		
X121052	NS0165	100	104	WP	Fresh	Ore	GHD			0.83					6.4	0.1	0.8			25.4		
X121056	NS0165	108	112	WP	Fresh	Ore	GHD								8.7	0.1	0.1			0.8		
X121061	NS0165	118	122	WP	Fresh	Waste	GHD								8.6	0.1	0.1			0.4		
X121067	NS0165	130	134	WP	Fresh	Ore	GHD								8.1	0.1	0.1			0.4		
X121071	NS0165	138	142	WP	Fresh	Ore	GHD								8.8	0.1	0.1			0.4		
X121077	NS0165	150	154	WP	Fresh	Ore	GHD								9	0.1	0.1			0.4		
X121081	NS0165	158	162	WP	Fresh	Ore	GHD								9.2	0.1	0.1			0.7		
X121087	NS0165	170	174	WP	Fresh	Ore	GHD								8.7	0.1	0.1			1.1		
X121091	NS0165	178	182	WP	Fresh	Waste	GHD								7.5	0.1	0.1			7.9		
X121099	NS0165	194	196	WP	Fresh	Ore	GHD								8.6	0.1	0.1			2.8		
AMD # 0328	NS0572	0	6	KCF	Oxide		Golder	9.1		0.04					8.1	0.5	0.5	-22.8	19.59	1.2	24	
AMD # 0178	NS0572	6	12	KCF	Oxide		Golder	8.8		0.01			0.15		8.2	0.5	0.5	-35.7	117.55	0.3	36	
AMD # 0179	NS0572	12	18	KCF	Fresh		Golder	9.4		0.2					7.9	0.5	0.5	-23.9	4.9	6.1	30	
AMD # 0180	NS0572	18	24	KCF	Fresh		Golder	10		0.15					8	0.5	0.5	-43.4	10.45	4.6	48	
AMD # 0181	NS0572	24	30	KCF	Fresh		Golder	9.9		0.42			0.3		8	0.5	0.5	-52.1	5.05	12.9	65	
AMD # 0182	NS0572	30	36	KCF	Fresh		Golder	9.8		0.51					8.3	0.5	0.5	-81.4	6.21	15.6	97	
AMD # 0183	NS0572	36	42	KCF	Fresh		Golder	9.7		0.58					8	0.5	0.5	-41.2	3.32	17.8	59	
AMD # 0184	NS0572	42	48	KCF	Fresh		Golder	9.9		0.49			0.74		8.1	0.5	0.5	-76	6.06	15	91	
AMD # 0185	NS0572	48	54	KCF	Fresh		Golder	9.8		0.31					8	0.5	0.5	-56.5	6.95	9.5	66	
AMD # 0186	NS0572	54	60	KCF	Fresh		Golder	9.7		0.3					8.1	0.5	0.5	-56.8	7.18	9.2	66	
AMD # 0187	NS0572	60	66	KCF	Fresh		Golder	9.4		0.18					8.5	0.5	0.5	-92.5	17.78	5.5	98	
AMD # 0188	NS0572	66	72	KCF	Fresh		Golder	9.3		0.2					8.3	0.5	0.5	-66.9	11.92	6.1	73	
AMD # 0189	NS0572	72	78	KCF	Fresh		Golder	9.1		0.5					8.1	0.5	0.5	-46.7	4.05	15.3	62	
AMD # 0190	NS0572	78	84	KCF	Fresh		Golder	9		0.4					6.3	0.5	0.5	-11.8	1.96	12.3	24	
AMD # 0191	NS0572	84	90	KCF	Fresh		Golder	8.3		1.61					3.1	23	30	19.3	0.61	49.3	30	
AMD # 0192	NS0572	90	96	KCF	Fresh		Golder	8.6		0.92			0.4		8	0.5	69	-40.8	2.45	28.2	69	
AMD # 0193	NS0572	96	102	KCF	Fresh		Golder	8.9		0.28					7.4	0.5	64	-55.4	7.46	8.6	64	
AMD # 0194	NS0572	102	108	KCF	Fresh		Golder	8.7		0.23					5.2	0.5	13	-6	1.85	7	13	
AMD # 0195	NS0572	108	114	KCF	Fresh		Golder	8.7		0.38			0.05		4.2	2.8	13	-1.4	1.12	11.6	13	
AMD # 0196	NS0572	114	120	KCF	Fresh		Golder	8.3		0.3					4.3	1.3	13	-3.8	1.41	9.2	13	
AMD # 0197	NS0572	120	126	KCF	Fresh		Golder	8.2		0.4					4	3.6	13	-0.8	1.06	12.3	13	
AMD # 0198	NS0572	126	132	KCF	Fresh		Golder	8.2		0.5			0.05		3.9	6.1	13	2.3	0.85	15.3	13	
AMD # 0199	NS0572	132	138	KCF	Fresh		Golder	7.8		1.12					3.5	16	26	8.3	0.76	34.3	26	
AMD # 0200	NS0572	138	144	KCF	Fresh		Golder	8.9		0.42					8.3	0.5	0.5	-0.1	1.01	12.9	13	
AMD # 0201	NS0572	144	150	KCF	Fresh		Golder	8.7		0.66					4.5	0.5	35	-14.8	1.73	20.2	35	
AMD # 0202	NS0572	150	156	KCF	Fresh		Golder	8.8		1.17					7.8	0.5	0.5	-34.2	1.95	35.8	70	
AMD # 0203	NS0572	156	162	KCF	Fresh		Golder	8.8		1.58					7.6	0.5	0.5	-18.6	1.38	48.4	67	
AMD # 0204	NS0572	162	168	KCF	Fresh		Golder	8.6		1.76			0.34		3.7	6.3	56	-2.1	1.04	53.9	56	
AMD # 0205	NS0572	168	174	KCF	Fresh		Golder	8		2.99					2.6	59	23	68.6	0.25	91.6	23	
AMD # 0206	NS0572	174	180	KCF	Fresh		Golder	8.4		3.72					2.9	34	80	33.9	0.7	113.9	80	
AMD # 0207	NS0572	180	186	KCF	Fresh		Golder	8.4		2.44					3.3	16	65	9.7	0.87	74.7	65	
AMD # 0208	NS0572	186	192	KCF	Fresh		Golder	6.7		3.87					2.6	69	29	89.5	0.24	118.5	29	
AMD # 0209	NS0572	192	198	KCF	Fresh		Golder	7.6		1.13					6.4	0.5	0.5	27.5	0.21	34.6	7.1	
AMD # 0210	NS0574	0	6	KCF	Oxide		Golder	9		0.09					8.2	0.5	0.5	-97.2	36.28	2.8	100	
AMD # 0211	NS0574	6	12	KCF	Oxide		Golder	9.1		0.03					8.3	0.5	0.5	-43.1	47.89	0.9	44	
AMD # 0212	NS0574	12	18	KCF	Oxide		Golder	8.4		0.01			0.05		8.2	0.5	0.5	-40.7	133.88	0.3	41	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
AMD # 0213	NS0574	18	24	KCF	Fresh		Golder	8.8		0.04					8.2	0.5	0.5	-34.8	29.39	1.2	36	
AMD # 0214	NS0574	24	30	KCF	Fresh		Golder	8.9		0.13					7.9	0.5	0.5	-54	14.57	4	58	
AMD # 0215	NS0574	30	36	KCF	Fresh		Golder	8.9		0.17					7.4	0.5	0.5	-46.8	9.99	5.2	52	
AMD # 0216	NS0574	36	42	KCF	Fresh		Golder	8.9		0.15					7.5	0.5	0.5	-58.4	13.71	4.6	63	
AMD # 0217	NS0574	42	48	KCF	Fresh		Golder	8.6		0.1			0.05		6.8	0.5	0.5	-15.9	6.2	3.1	19	
AMD # 0218	NS0574	48	54	KCF	Fresh		Golder	8.5		0.19					5.1	0.5	0.5	-13.2	3.27	5.8	19	
AMD # 0219	NS0574	54	60	KCF	Fresh		Golder	8.4		0.68					3.9	5.3	21	-0.2	1.01	20.8	21	
AMD # 0220	NS0574	60	66	KCF	Fresh		Golder	8.4		0.85			0.05		3.3	13	16	10	0.61	26	16	
AMD # 0221	NS0574	66	72	KCF	Fresh		Golder	8.2		1.4					2.8	27	14	28.9	0.33	42.9	14	
AMD # 0222	NS0574	72	78	KCF	Fresh		Golder	8.3		1.6					2.8	28	24	25	0.49	49	24	
AMD # 0223	NS0574	78	84	KCF	Fresh		Golder	8.4		1.88					2.9	30	26	31.6	0.45	57.6	26	
AMD # 0224	NS0574	84	90	KCF	Fresh		Golder	8.7		1.23					3.5	11	33	4.7	0.88	37.7	33	
AMD # 0225	NS0574	90	96	KCF	Fresh		Golder	8.4		1.77			0.05		2.9	29	16	38.2	0.3	54.2	16	
AMD # 0226	NS0574	96	102	KCF	Fresh		Golder	8.8		1.44					7.7	0.5	0.5	-35.9	1.81	44.1	80	
AMD # 0227	NS0574	102	108	KCF	Fresh		Golder	8.7		1.91			0.39		3.9	6.6	60	-1.5	1.03	58.5	60	
AMD # 0228	NS0574	108	114	KCF	Fresh		Golder	8.9		1.39					6.1	0.5	0.5	-19.4	1.46	42.6	62	
AMD # 0229	NS0574	114	120	KCF	Fresh		Golder	8.9		1.07					7.9	0.5	0.5	20.8	0.37	32.8	12	
AMD # 0230	NS0574	120	126	KCF	Fresh		Golder	8.9		1.18					7.6	0.5	0.5	-26.9	1.74	36.1	63	
AMD # 0231	NS0574	126	132	KCF	Fresh		Golder	8.7		2.48					3.2	21	65	11	0.86	76	65	
AMD # 0232	NS0576	0	6	KCF	Oxide		Golder	8.5		0.14					6.5	0.5	0.5	-23.7	6.53	4.3	28	
AMD # 0233	NS0576	6	12	KCF	Oxide		Golder	8.5		0.05					7.3	0.5	0.5	-26.5	18.29	1.5	28	
AMD # 0234	NS0576	12	18	KCF	Fresh		Golder	8.9		0.14					7.7	0.5	0.5	-17.7	5.13	4.3	22	
AMD # 0235	NS0576	18	24	KCF	Fresh		Golder	9		0.24			0.55		8.1	0.5	0.5	-72.7	10.88	7.4	80	
AMD # 0236	NS0576	24	30	KCF	Fresh		Golder	9		0.34					7.7	0.5	0.5	-41.6	4.99	10.4	52	
AMD # 0237	NS0576	30	36	KCF	Fresh		Golder	8.6		0.2					6.7	0.5	0.5	-14.9	3.43	6.1	21	
AMD # 0238	NS0576	36	42	KCF	Fresh		Golder	8.8		0.27					8.1	0.5	0.5	-52.7	7.38	8.3	61	
AMD # 0239	NS0576	42	48	KCF	Fresh		Golder	8.3		0.41					5.7	0.5	0.5	-20.4	2.63	12.6	33	
AMD # 0240	NS0576	48	54	KCF	Fresh		Golder	9		0.04					8.3	0.5	0.5	-54.8	45.71	1.2	56	
AMD # 0241	NS0576	54	60	KCF	Fresh		Golder	9		0.03			0.67		8.1	0.5	0.5	-81.1	89.25	0.9	82	
AMD # 0242	NS0576	60	66	KCF	Fresh		Golder	9.1		0.02					8	0.5	0.5	-95.4	156.73	0.6	96	
AMD # 0243	NS0576	66	72	KCF	Fresh		Golder	9		0.03					7.7	0.5	0.5	-99.1	108.84	0.9	100	
AMD # 0244	NS0576	72	78	KCF	Fresh		Golder	9		0.17					7.6	0.5	0.5	-79.8	16.33	5.2	85	
AMD # 0245	NS0576	78	84	KCF	Fresh		Golder	8.8		1.01					8.2	0.5	0.5	15.9	0.48	30.9	15	
AMD # 0246	NS0576	84	90	KCF	Fresh		Golder	8.7		0.78					3.7	7	23	0.9	0.96	23.9	23	
AMD # 0247	NS0576	90	96	KCF	Fresh		Golder	9		0.62					7.7	0.5	0.5	-58	4.06	19	77	
AMD # 0248	NS0576	96	102	KCF	Fresh		Golder	8.8		1.11					8.1	0.5	0.5	-49	2.44	34	83	
AMD # 0249	NS0576	102	108	KCF	Fresh		Golder	8.6		1.62			0.84		8.5	0.5	0.5	-50.4	2.02	49.6	100	
AMD # 0250	NS0576	108	114	KCF	Fresh		Golder	8.7		1.64					8.9	0.5	0.5	37.2	0.26	50.2	13	
AMD # 0251	NS0576	114	120	KCF	Fresh		Golder	9		0.37					8.2	0.5	0.5	-83.7	8.38	11.3	95	
AMD # 0252	NS0576	120	126	KCF	Fresh		Golder	9		0.59					8.3	0.5	0.5	-68.9	4.81	18.1	87	
AMD # 0253	NS0576	126	132	KCF	Fresh		Golder	8.9		0.83					8.8	0.5	0.5	-64.6	3.54	25.4	90	
AMD # 0254	NS0576	132	138	KCF	Fresh		Golder	8.8		0.89					8.6	0.5	0.5	-58.7	3.16	27.3	86	
AMD # 0255	NS0576	138	144	KCF	Fresh		Golder	9		0.43					8.2	0.5	0.5	-76.8	6.83	13.2	90	
AMD # 0256	NS0576	144	150	KCF	Fresh		Golder	9.1		0.1			0.88		9.1	0.5	0.5	-96.9	32.65	3.1	100	
AMD # 0257	NS0576	150	156	KCF	Fresh		Golder	9.1		0.16					9.1	0.5	0.5	-91.1	19.59	4.9	96	
AMD # 0258	NS0576	156	162	KCF	Fresh		Golder	9.1		0.11					8.2	0.5	0.5	-60.6	19	3.4	64	
AMD # 0259	NS0576	162	168	KCF	Fresh		Golder	9.2		0.07					8.4	0.5	0.5	-41.9	20.52	2.1	44	
AMD # 0260	NS0576	168	174	KCF	Fresh		Golder	9.2		0.31					8.2	0.5	0.5	-54.5	6.74	9.5	64	
AMD # 0261	NS0576	174	180	KCF	Fresh		Golder	9.3		0.25					7.7	0.5	0.5	-35.3	5.62	7.7	43	
AMD # 0262	NS0576	180	186	KCF	Fresh		Golder	9.3		0.3					7.7	0.5	0.5	-36.8	5.01	9.2	46	
AMD # 0263	NS0576	186	192	KCF	Fresh		Golder	9.3		0.18					7.7	0.5	0.5	-38.5	7.98	5.5	44	
AMD # 0264	NS0576	192	198	KCF	Fresh		Golder	9.1		0.4			0.27		8	0.5	0.5	-50.8	5.14	12.3	63	
AMD # 0265	NS0578	0	6	KCF	Oxide		Golder	8.3		0.05					7	0.5	0.5	-13.5	9.8	1.5	15	
AMD # 0266	NS0578	6	12	KCF	Oxide		Golder	7.7		0.04					6.6	0.5	0.5	-9.8	8.98	1.2	11	
AMD # 0267	NS0578	12	18	KCF	Oxide		Golder	7.6		0.04					7.3	0.5	0.5	-5	5.06	1.2	6.2	
AMD # 0268	NS0578	18	24	KCF	Oxide		Golder	7.8		0.03					6.6	0.5	0.5	-4	5.33	0.9	4.9	
AMD # 0269	NS0578	24	30	KCF	Oxide		Golder	7.6		0.02					6.6	0.5	0.5	-5.2	9.47	0.6	5.8	
AMD # 0270	NS0578	30	36	KCF	Oxide		Golder	7.4		0.02					7.2	0.5	0.5	-4.2	7.84	0.6	4.8	
AMD # 0271	NS0578	36	42	KCF	Fresh		Golder	7.6		0.03			0.05		6.4	0.5	0.5	-7.4	9.03	0.9	8.3	
AMD # 0272	NS0578	42	48	KCF	Fresh		Golder	7.9		0.23					5	0.5	0.5	-8	2.13	7	15	
AMD # 0273	NS0578	48	54	KCF	Fresh		Golder	8		0.64					3.6	9.1	18	1.6	0.92	19.6	18	
AMD # 0274	NS0578	54	60	KCF	Fresh		Golder	8		1.44					2.9	28	16	28.1	0.36	44.1	16	
AMD # 0275	NS0578	60	66	KCF	Fresh		Golder	8		1.98					2.8	41	19	41.6	0.31	60.6	19	
AMD # 0276	NS0578	66	72	KCF	Fresh		Golder	7.7		2.19					2.6	45	30	37.1	0.45	67.1	30	
AMD # 0277	NS0578	72	78	KCF	Fresh		Golder	7.7		2.95			0.05		2.4	66	29	61.3	0.32	90.3	29	
AMD # 0278	NS0578	78	84	KCF	Fresh		Golder	7.6		2.66					2.5	58	15	66.5	0.18	81.5	15	
AMD # 0279	NS0578	84	90	KCF	Fresh		Golder	7.4		4.04					2.4	100	25	98.7	0.2	123.7	25	
AMD # 0280	NS0578	90	96	KCF	Fresh		Golder	7.7		2.47					2.6	54	30	45.6	0.4	75.6	30	
AMD # 0281	NS0578	96	102	KCF	Fresh		Golder	7.8		2.68					2.6	53	34	48.1	0.41	82.1	34	
AMD # 0282	NS0578	102	108	KCF	Fresh		Golder	7.7		2.09					2.9	33	23	41	0.36	64	23	
AMD # 0283	NS0578	108	114	KCF	Fresh		Golder	8		1.38					5.2	0.5	0.5	34.9	0.18	42.3	7.4	
AMD # 0284	NS0578	114	120	KCF	Fresh		Golder	7.7		2.31					2.9	32	32	38.7	0.45	70.7	32	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
AMD # 0285	NS0578	120	126	KCF	Fresh		Golder	7.6		2.4			0.05		2.4	41	29	44.5	0.39	73.5	29	
AMD # 0286	NS0578	126	132	KCF	Fresh		Golder	8.5		2.45					7.6	0.5	0.5	65.6	0.13	75	9.4	
AMD # 0287	NS0578	132	138	KCF	Fresh		Golder	7.1		3.17					2.5	68	26	71.1	0.27	97.1	26	
AMD # 0288	NS0578	138	144	KCF	Fresh		Golder	7.4		2.68					3.9	0.5	6.7	75.4	0.08	82.1	6.7	
AMD # 0289	NS0578	144	150	KCF	Fresh		Golder	8		1.15			0.05		7.5	0.5	0.5	24.2	0.31	35.2	11	
AMD # 0290	NS0578	150	156	KCF	Fresh		Golder	8.2		0.34					7.9	0.5	0.5	2.5	0.76	10.4	7.9	
AMD # 0291	NS0578	156	162	KCF	Fresh		Golder	7.2		1.51					6.2	0.5	0.5	38.4	0.17	46.2	7.8	
AMD # 0292	NS0578	162	168	KCF	Fresh		Golder	7.1		1.6					6.1	0.5	0.5	42.2	0.14	49	6.8	
AMD # 0293	NS0578	168	174	WP	Fresh		Golder	7.4		2.16			0.05		4.9	0.5	8.1	58.1	0.12	66.2	8.1	
AMD # 0294	NS0578	174	180	WP	Fresh		Golder	9		0.12					8.8	0.5	0.5	-4.7	2.29	3.7	8.4	
AMD # 0295	NS0578	180	186	WP	Fresh		Golder	9		0.11					8.4	0.5	0.5	-49.6	15.73	3.4	53	
AMD # 0296	NS0578	186	192	WP	Fresh		Golder	9.4		0.08					8.6	0.5	0.5	-3.9	2.57	2.5	6.3	
AMD # 0297	NS0578	192	198	WP	Fresh		Golder	9.7		0.17					8.4	0.5	0.5	-1	1.19	5.2	6.2	
AMD # 0298	NS0580	0	6	KCF	Oxide		Golder	8.6		0.04					8.3	0.5	0.5	-57.8	48.16	1.2	59	
AMD # 0299	NS0580	6	12	KCF	Oxide		Golder	8.5		0.02					7.8	0.5	0.5	-25.4	42.45	0.6	26	
AMD # 0300	NS0580	12	18	KCF	Oxide		Golder	8.4		0.01					7.6	0.5	0.5	-29.7	97.96	0.3	30	
AMD # 0301	NS0580	18	24	KCF	Fresh		Golder	8.8		0.16					8.2	0.5	0.5	-29.1	6.94	4.9	34	
AMD # 0302	NS0580	24	30	KCF	Fresh		Golder	9		0.32					8	0.5	0.5	-56.2	6.73	9.8	66	
AMD # 0303	NS0580	30	36	KCF	Fresh		Golder	9.1		0.34					8.2	0.5	0.5	-34.6	4.32	10.4	45	
AMD # 0304	NS0580	36	42	KCF	Fresh		Golder	9.1		0.27					8.3	0.5	0.5	-77.7	10.4	8.3	86	
AMD # 0305	NS0580	42	48	KCF	Fresh		Golder	9.1		0.48			0.76		8.1	0.5	0.5	-74.3	6.05	14.7	89	
AMD # 0306	NS0580	48	54	KCF	Fresh		Golder	9		0.94					8.4	0.5	0.5	-42.2	2.47	28.8	71	
AMD # 0307	NS0580	54	60	KCF	Fresh		Golder	8.6		0.24					5.7	0.5	0.5	-11.7	2.59	7.4	19	
AMD # 0308	NS0580	60	66	KCF	Fresh		Golder	8		0.8					3.2	13	14	10.5	0.57	24.5	14	
AMD # 0309	NS0580	66	72	KCF	Fresh		Golder	8.3		0.24					4.6	0.5	0.5	-5.7	1.77	7.4	13	
AMD # 0310	NS0580	72	78	KCF	Fresh		Golder	8.4		0.29					4.4	0.5	0.5	-6.1	1.69	8.9	15	
AMD # 0311	NS0580	78	84	KCF	Fresh		Golder	8.6		0.1					6.5	0.5	0.5	-11.9	4.9	3.1	15	
AMD # 0312	NS0580	84	90	KCF	Fresh		Golder	8.6		0.29					4.2	1.8	12	-3.1	1.35	8.9	12	
AMD # 0313	NS0580	90	96	KCF	Fresh		Golder	8.4		0.16					6.3	0.5	0.5	-8.1	2.65	4.9	13	
AMD # 0314	NS0580	96	102	KCF	Fresh		Golder	8.2		0.31			0.05		4.3	1.3	17	-7.5	1.79	9.5	17	
AMD # 0315	NS0580	102	108	KCF	Fresh		Golder	8		0.56					3.8	5.3	16	1.2	0.93	17.2	16	
AMD # 0316	NS0580	108	114	KCF	Fresh		Golder	8.5		0.41					4.1	1.8	16	-3.4	1.27	12.6	16	
AMD # 0317	NS0580	114	120	KCF	Fresh		Golder	8.6		0.37					4.3	1.3	14	-2.7	1.24	11.3	14	
AMD # 0318	NS0580	120	126	KCF	Fresh		Golder	8.4		0.73					3.5	8.8	16	6.4	0.72	22.4	16	
AMD # 0319	NS0580	126	132	KCF	Fresh		Golder	8.3		0.91					3.2	15	18	9.9	0.65	27.9	18	
AMD # 0320	NS0580	132	138	KCF	Fresh		Golder	8.4		0.87					3.3	12	17	9.6	0.64	26.6	17	
AMD # 0321	NS0580	138	144	KCF	Fresh		Golder	8.5		0.89					3.2	12	19	8.3	0.7	27.3	19	
AMD # 0322	NS0580	144	150	KCF	Fresh		Golder	8.2		1.23					2.9	22	16	21.7	0.42	37.7	16	
AMD # 0323	NS0580	150	156	KCF	Fresh		Golder	8		1.67					2.7	33	15	36.1	0.29	51.1	15	
AMD # 0324	NS0580	156	162	KCF	Fresh		Golder	8.3		1.39			0.05		2.9	25	30	12.6	0.7	42.6	30	
AMD # 0325	NS0580	162	168	KCF	Fresh		Golder	8.1		1.88					2.7	38	19	38.6	0.33	57.6	19	
AMD # 0326	NS0580	168	174	KCF	Fresh		Golder	8.6		0.78					3.5	8.1	27	-3.1	1.13	23.9	27	
AMD # 0327	NS0580	174	180	KCF	Fresh		Golder	8.1		2.01					2.9	33	23	38.6	0.37	61.6	23	
X829306	NS0679	84	86	MP	Fresh	Waste	2019NAG			0.3			0.43	1.41	7.5			-13.8	2.5	9.2	23	
X829307	NS0679	86	88	EP	Fresh	Waste	2019NAG			0.19			0.54	2.69	7.8			-18.2	4.12	5.8	24	
X829308	NS0679	88	90	EP	Fresh	Waste	2019NAG			0.69			0.17	0.31	3.7	0.5	5.3	6.1	0.71	21.1	15	
X829309	NS0679	90	92	EP	Fresh	Waste	2019NAG			0.63			0.05	0.2	3.8	0.5	5.8	3.3	0.83	19.3	16	
X829310	NS0679	92	94	EP	Fresh	Waste	2019NAG			2.97			0.05	0.07	2.3	49	71	83.5	0.08	91	7.5	
X829311	NS0679	94	96	EP	Fresh	Waste	2019NAG			0.36			0.34	3.6	7.6			-15	2.36	11	26	
X829312	NS0679	96	98	EP	Fresh	Ore	2019NAG			0.06			0.4	1.89	8.3			-30.2	17.41	1.8	32	
X829458	NS0680	120	122	MP	Fresh	Ore	2019NAG			0.99			0.12	1.27	5.6	0.5	0.5	1.3	0.96	30.3	29	
X829459	NS0680	122	124	MP	Fresh	Ore	2019NAG			0.12			0.69	1.8	8.8			-55.3	16.05	3.7	59	
X829460	NS0680	124	126	MP	Fresh	Ore	2019NAG			0.05			0.62	1.94	8.8			-58.5	39.18	1.5	60	
X829463	NS0680	126	128	MP	Fresh	Ore	2019NAG			0.05			0.76	1.86	8.8			-47.5	32	1.5	49	
X829464	NS0680	128	130	MP	Fresh	Ore	2019NAG			0.08			0.54	1.94	8.7			-44.6	19.18	2.5	47	
X829465	NS0680	130	132	MP	Fresh	Ore	2019NAG			3.75			1.05	1.42	2.4	28	48	58.8	0.49	114.8	56	
X829466	NS0680	132	134	MP	Fresh	Waste	2019NAG			2.81			1.44	1.74	8.2	0.5	0.5	28.1	0.67	86.1	58	
X829467	NS0680	134	136	MP	Fresh	Waste	2019NAG			0.74			0.33	2.35	8.7			-26.3	2.16	22.7	49	
X829468	NS0680	136	138	MP	Fresh	Ore	2019NAG			0.32			0.26	2.3	8.7			-40.2	5.1	9.8	50	
X829995	NS0685	94	96	MP	Fresh	Waste	2019NAG			0.13			0.05	3.14	8.4			-26	7.54	4	30	
X829996	NS0685	96	98	MP	Fresh	Waste	2019NAG			1.03			0.08	2.28	4.7	0.5	8.3	19.5	0.38	31.5	12	
X829997	NS0685	98	100	MP	Fresh	Waste	2019NAG			0.49			0.08	0.53	5.1	0.5	2.5	-1	1.07	15	16	
X829998	NS0685	100	102	MP	Fresh	Waste	2019NAG			0.36			0.15	0.57	7.3			-10	1.9	11	21	
X829999	NS0685	102	104	MP	Fresh	Waste	2019NAG			2.62			0.05	0.52	2.3	39	64	74.4	0.07	80.2	5.8	
X830000	NS0685	104	106	MP	Fresh	Waste	2019NAG			0.52			0.05	0.14	3.5	0.5	8.6	7.7	0.51	15.9	8.2	
X830001	NS0685	106	108	MP	Fresh	Waste	2019NAG			7.59			0.05	0.16	1.9	150	190	231.9	0	232.4	0.5	
X830002	NS0685	108	110	MP	Fresh	Waste	2019NAG			5.5			0.05	0.19	1.9	120	160	167.9	0	168.4	0.5	
X830003	NS0685	110	112	MP	Fresh	Waste	2019NAG			6.76			0.05	0.18	2	120	160	206.5	0	207	0.5	
X830004	NS0685	112	114	MP	Fresh	Waste	2019NAG			8.78			0.05	0.12	1.8	160	210	268.4	0	268.9	0.5	
X830005	NS0685	114	116	MP	Fresh	Waste	2019NAG			2.24			0.05	0.23	2.3	39	62	60	0.13	68.6	8.6	
X830006	NS0685	116	118	MP	Fresh	Waste	2019NAG			0.38			0.05	0.06	3.9	0.5	5.4	1.6	0.86	11.6	10	
X830157	NS0686	150	152	MP	Fresh	Waste	2019NAG			2.58			0.68	1.28	2.6	17	37	42	0.47	79	37	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples																					
Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
X830158	NS0686	152	154	MP	Fresh	Waste	2019NAG			1.04			0.49	0.75	5	0.5	0.5	0.9	0.97	31.9	31	
X830159	NS0686	154	156	MP	Fresh	Waste	2019NAG			1.87			0.53	0.75	2.6	13	32	28.3	0.51	57.3	29	
X830160	NS0686	156	158	MP	Fresh	Waste	2019NAG			1.28			0.71	1.08	5.6			-2.8	1.07	39.2	42	
X830163	NS0686	158	160	MP	Fresh	Waste	2019NAG			1.54			0.75	1.86	6			-6.8	1.14	47.2	54	
X830164	NS0686	160	162	MP	Fresh	Waste	2019NAG			1.63			0.45	0.78	2.9	0.5	23	17.9	0.64	49.9	32	
X830170	NS0686	172	174	MP	Fresh	Waste	2019NAG			0.23			0.08	0.35	6.8			-10	2.41	7	17	
X830171	NS0686	174	176	MP	Fresh	Waste	2019NAG			0.67			0.26	0.5	4.1	0.5	0.5	-1.5	1.07	20.5	22	
X830172	NS0686	176	178	MP	Fresh	Waste	2019NAG			0.54			0.13	0.37	4.3	0.5	1.1	-1.5	1.09	16.5	18	
X830173	NS0686	178	180	MP	Fresh	Waste	2019NAG			0.19			0.1	0.28	6.9			-12.2	3.09	5.8	18	
X830174	NS0686	180	182	MP	Fresh	Waste	2019NAG			0.33			0.32	1.1	7.8			-10.9	2.08	10.1	21	
X830175	NS0686	182	184	MP	Fresh	Waste	2019NAG			0.66			0.28	1.6	6.4			-6.8	1.34	20.2	27	
X830176	NS0686	184	186	MP	Fresh	Waste	2019NAG			0.55			0.38	1.24	6.6			-12.2	1.72	16.8	29	
X830177	NS0686	186	188	MP	Fresh	Waste	2019NAG			0.62			0.09	2.58	6.5			-13	1.69	19	32	
X830178	NS0686	188	190	MP	Fresh	Waste	2019NAG			0.67			0.21	3.31	7			-9.5	1.46	20.5	30	
X830179	NS0686	190	192	MP	Fresh	Waste	2019NAG			1.36			0.32	0.61	3.1	0.5	18	17.7	0.58	41.7	24	
X830180	NS0686	192	194	MP	Fresh	Waste	2019NAG			0.41			0.18	0.44	4.1	0.5	4.1	-1.4	1.11	12.6	14	
X830181	NS0686	194	196	MP	Fresh	Waste	2019NAG			0.48			0.14	3.02	7.4			-17.3	2.18	14.7	32	
X830182	NS0686	196	198	MP	Fresh	Waste	2019NAG			0.63			0.38	1.32	6.5			-9.7	1.5	19.3	29	
X830183	NS0686	198	200	MP	Fresh	Waste	2019NAG			0.52			0.68	1.01	7.9			-17.1	2.07	15.9	33	
X830184	NS0686	200	202	MP	Fresh	Waste	2019NAG			0.55			0.82	1.13	8.6			-26.2	2.55	16.8	43	
X830185	NS0686	202	204	MP	Fresh	Waste	2019NAG			0.3			0.21	0.37	8.3			-16.8	2.83	9.2	26	
X830186	NS0686	204	206	MP	Fresh	Waste	2019NAG			0.31			0.13	0.33	7.2			-7.5	1.79	9.5	17	
X830728	NS0690	210	212	MP	Fresh	Waste	2019NAG			0.56			0.6	1.69	8.4			-25.9	2.51	17.2	43	
X830729	NS0690	212	214	MP	Fresh	Waste	2019NAG			0.79			0.75	1.13	8.7			-28.8	2.19	24.2	53	
X830730	NS0690	214	216	MP	Fresh	Waste	2019NAG			0.94			0.07	0.18	3.1	0.5	17	11.8	0.59	28.8	17	
X830733	NS0690	216	218	MP	Fresh	Waste	2019NAG			0.29			0.05	0.29	4.4	0.5	0.5	-2.1	1.24	8.9	11	
X830734	NS0690	218	220	MP	Fresh	Waste	2019NAG			0.24			0.05	0.71	5.6	0.5	0.5	-1.1	1.14	7.4	8.4	
X830735	NS0690	220	222	MP	Fresh	Waste	2019NAG			0.15			0.05	0.14	6			-6.4	2.39	4.6	11	
X830736	NS0690	222	224	MP	Fresh	Waste	2019NAG			0.12			0.05	0.64	5.5	0.5	0.5	-5.3	2.45	3.7	9	
X831037	NS0693	120	122	WP	Fresh	Waste	2019NAG			1.82			1.02	1.45	3.6	0.5	14	13.7	0.75	55.7	42	
X831038	NS0693	122	124	WP	Fresh	Waste	2019NAG			2.42			0.55	0.95	2.3	32	59	58.1	0.22	74.1	16	
X831039	NS0693	124	126	WP	Fresh	Waste	2019NAG			1.51			0.59	0.91	2.6	15	35	31.2	0.32	46.2	15	
X831040	NS0693	126	128	WP	Fresh	Waste	2019NAG			0.84			0.49	0.82	3.3	1.1	11	6.7	0.74	25.7	19	
X831041	NS0693	128	130	WP	Fresh	Waste	2019NAG			0.7			0.39	0.64	3.1	0.5	13	5.4	0.75	21.4	16	
X831042	NS0693	130	132	WP	Fresh	Waste	2019NAG			0.99			0.47	0.79	3.6	0.5	7.7	5.3	0.82	30.3	25	
X831043	NS0693	132	134	WP	Fresh	Waste	2019NAG			1.36			0.73	0.93	4.8	0.5	3	1.7	0.96	41.7	40	
X831044	NS0693	134	136	WP	Fresh	Waste	2019NAG			0.74			0.39	0.65	3.2	0.5	11	4.7	0.79	22.7	18	
X831045	NS0693	136	138	WP	Fresh	Waste	2019NAG			0.89			0.4	0.66	2.9	7.1	19	13.3	0.51	27.3	14	
X831046	NS0693	138	140	WP	Fresh	Waste	2019NAG			0.57			0.47	0.68	3.2	0.5	9.7	3.5	0.8	17.5	14	
X831047	NS0693	140	142	WP	Fresh	Waste	2019NAG			1.15			0.47	0.72	2.7	11	25	22.2	0.37	35.2	13	
X831048	NS0693	142	144	WP	Fresh	Waste	2019NAG			1.68			0.48	0.69	2.6	18	36	34.5	0.33	51.5	17	
X831049	NS0693	144	146	WP	Fresh	Waste	2019NAG			1.06			0.53	0.77	4.3	0.5	4.2	2.5	0.92	32.5	30	
X831050	NS0693	146	148	WP	Fresh	Waste	2019NAG			0.77			0.41	0.61	3.2	0.5	11	9.6	0.59	23.6	14	
X831051	NS0693	148	150	WP	Fresh	Waste	2019NAG			1.86			2.33	3	5.2	0.5	3.6	27	0.53	57	30	
X831052	NS0693	150	152	WP	Fresh	Waste	2019NAG			1.56			2.33	3.53	6.2			10.8	0.77	47.8	37	
X831053	NS0693	152	154	WP	Fresh	Waste	2019NAG			1.55			0.84	3.09	3	0.5	15	28.5	0.4	47.5	19	
X831054	NS0693	154	156	WP	Fresh	Waste	2019NAG			0.44			0.27	0.59	3.9	0.5	3.1	0.5	0.96	13.5	13	
X831055	NS0693	156	158	WP	Fresh	Waste	2019NAG			0.47			0.07	2.54	7			-10.6	1.74	14.4	25	
X831056	NS0693	158	160	WP	Fresh	Waste	2019NAG			0.49			0.05	2.94	7.1			-9	1.6	15	24	
X831057	NS0693	160	162	WP	Fresh	Waste	2019NAG			0.63			0.38	0.92	3.6	0.5	3.6	0.3	0.98	19.3	19	
X831058	NS0693	162	164	WP	Fresh	Waste	2019NAG			0.58			0.36	2.15	5.8			-9.2	1.52	17.8	27	
X831059	NS0693	164	166	WP	Fresh	Waste	2019NAG			0.47			0.35	1.74	6.8			-11.6	1.81	14.4	26	
X831060	NS0693	166	168	WP	Fresh	Waste	2019NAG			0.46			0.05	3.68	7.1			-12.9	1.92	14.1	27	
X831063	NS0693	168	170	WP	Fresh	Waste	2019NAG			0.44			0.29	0.59	5.8			-3.5	1.26	13.5	17	
X831064	NS0693	170	172	WP	Fresh	Waste	2019NAG			0.32			0.29	3.75	8.7			-26.2	3.67	9.8	36	
X831065	NS0693	172	174	WP	Fresh	Waste	2019NAG			0.51			0.22	2.83	7.5			-14.4	1.92	15.6	30	
X831066	NS0693	174	176	WP	Fresh	Waste	2019NAG			0.49			0.19	0.58	3.6	0.5	6.3	2	0.87	15	13	
X831067	NS0693	176	178	WP	Fresh	Waste	2019NAG			1.77			0.24	0.65	2.7	17	37	35.2	0.35	54.2	19	
X831068	NS0693	178	180	WP	Fresh	Waste	2019NAG			3			0.45	0.94	2.3	31	57	70.9	0.23	91.9	21	
X833076	NS0709	98	100	MP	Fresh	Waste	2019NAG			2.7			0.05	0.11	2.3	39	65	77.6	0.06	82.7	5.1	
X833077	NS0709	100	102	MP	Fresh	Waste	2019NAG			0.83			0.05	0.1	3.2	0.5	14	15.4	0.39	25.4	10	
X833078	NS0709	102	104	MP	Fresh	Waste	2019NAG			1.55			0.05	0.25	2.8	11	28	30.5	0.36	47.5	17	
X833079	NS0709	104	106	MP	Fresh	Waste	2019NAG			0.83			0.05	0.23	3.6	0.5	6.6	8.4	0.67	25.4	17	
X833602	NS0713	144	146	WP	Fresh	Waste	2019NAG			0.96			0.9	1.41	7			-11.6	1.39	29.4	41	
X833603	NS0713	146	148	WP	Fresh	Waste	2019NAG			0.89			0.56	2.34	8.3			-16.7	1.61	27.3	44	
X833604	NS0713	148	150	WP	Fresh	Waste	2019NAG			0.33			0.6	3.24	8.7			-38.9	4.85	10.1	49	
X833605	NS0713	150	152	WP	Fresh	Waste	2019NAG			0.56			0.98	3.12	8.6			-36.9	3.15	17.2	54	
X833606	NS0713	152	154	WP	Fresh	Waste	2019NAG			0.46			0.42	0.8	8.2			-16.9	2.2	14.1	31	
X833607	NS0713	154	156	WP	Fresh	Waste	2019NAG			0.52			0.53	1.58	8.6			-24.1	2.51	15.9	40	
X833608	NS0713	156	158	WP	Fresh	Waste	2019NAG			0.98			0.97	2.32	8.6			-23	1.77	30	53	
X833609	NS0713	158	160	WP	Fresh	Waste	2019NAG															
AMD66a	NSD0031	1	29.7	WP	Oxide		Golder	7	80	0.02		0.01	0.05		5.7	0.5	0.5	-0.5	1.8	0.6	1.1	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples																					
Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
AMD67a	NSD0031	37.48	63.08	WP	Fresh		Golder	8.6	280	0.06		0.01	0.38		8	0.5	0.5	-43.2	24.49	1.8	45	15.9
AMD77a	NSD0031	73.2	80	WP	Fresh		Golder	10	310	0.06		0.01	0.38		8.6	0.5	0.5	-52.2	29.39	1.8	54	
AMD79a	NSD0031	80.4	94.1	WP	Fresh		Golder	9.4	270	0.39		0.01	0.05		4.9	0.5	0.5	-20.1	2.68	11.9	32	
AMD82	NSD0031	99.4	99.6	WP	Fresh		Golder	9.4	470	2.04		0.01	0.05		2.7	7.2	16	28.5	0.54	62.5	34	
AMD83	NSD0031	103.2	103.4	WP	Fresh		Golder	9.5	170	0.01		0.01	0.05		7.9	0.5	0.5	-24.7	81.63	0.3	25	
AMD84	NSD0031	109.7	110	WP	Fresh		Golder	8.7	60	0.01		0.01	0.05		7.8	0.5	0.5	-10.7	35.92	0.3	11	
AMD85	NSD0031	119	119.3	WP	Fresh		Golder	9.9	420	0.37		0.01	0.05		5.9	0.5	0.5	-20.7	2.82	11.3	32	
AMD86	NSD0031	125	125.3	WP	Fresh		Golder	9.5	220	0.05		0.01	0.06		8	0.5	0.5	-27.5	18.94	1.5	29	
AMD87	NSD0031	127.7	128	WP	Fresh		Golder	10	330	0.26		0.01	0.05		5.8	0.5	0.5	-17	3.14	8	25	
AMD88	NSD0031	138.8	139.1	WP	Fresh		Golder	10.2	370	0.02		0.01	0.62		8.9	0.5	0.5	-99.4	163.27	0.6	100	27.5
AMD89	NSD0031	144.8	145.1	WP	Fresh		Golder	9.9	760	0.9		0.01	0.05		6.8	0.5	0.5	-53.4	2.94	27.6	81	
AMD90	NSD0031	152	152.3	WP	Fresh		Golder	10.2	620	0.06		0.01	0.05		8.8	0.5	0.5	-33.2	19.05	1.8	35	
AMD91	NSD0031	156	156.3	WP	Fresh		Golder	9.5	120	0.01		0.01	0.05		6	0.5	0.5	-6.3	21.55	0.3	6.6	
AMD92	NSD0031	162.6	163	WP	Fresh		Golder	10	430	1.15		0.01	0.05		3.3	2.9	6.8	7.2	0.8	35.2	28	
AMD93	NSD0031	171.1	171.4	WP	Fresh		Golder	10.3	400	0.04		0.01	0.51		8.9	0.5	0.5	-51.8	43.27	1.2	53	
AMD94	NSD0031	183.3	183.6	WP	Fresh		Golder	10.1	260	0.04		0.01	0.76		8.9	0.5	0.5	-61.8	51.43	1.2	63	
AMD95	NSD0031	192.5	192.8	WP	Fresh		Golder	10.2	280	0.04		0.01	0.1		8.4	0.5	0.5	-27.8	23.67	1.2	29	
AMD # 0144	NSD0031	197.4	197.7	WP	Fresh		Golder	8.5	200	0.02		0.01	0.5		8.4	0.5	0.5	-42.4	70.2	0.6	43	
AMD96	NSD0031	200	200.4	WP	Fresh		Golder	10.1	530	0.05		0.01	0.05		8.6	0.5	0.5	-82.5	54.86	1.5	84	
AMD97	NSD0031	203	203.4	WP	Fresh		Golder	9.8	250	0.02		0.01	0.48		8.9	0.5	0.5	-53.4	88.16	0.6	54	
AMD98	NSD0031	217	217.3	WP	Fresh		Golder	9.8	290	0.14		0.01	0.6		8.2	0.5	0.5	-53.7	13.53	4.3	58	
AMD99	NSD0031	231.5	231.8	WP	Fresh		Golder	10	340	0.04		0.01	0.14		8.5	0.5	0.5	-36.8	31.02	1.2	38	
AMD100a	NSD0031	234.6	243.3	WP	Fresh		Golder	10.1	450	0.08		0.01	0.24		8.7	0.5	0.5	-39.6	17.14	2.5	42	
AMD102a	NSD0031	259.4	276.6	WP	Fresh		Golder	9.8	250	0.04		0.01	0.81		9	0.5	0.5	-62.8	52.24	1.2	64	
AMD # 0129	NSD0031	280.4	280.7	WP	Fresh		Golder	9.2	330	0.02		0.01	1.23		10	0.5	0.5	-86.4	142.04	0.6	87	
AMD # 0130	NSD0031	289.8	290.1	WP	Fresh		Golder	9.2	190	0.02		0.01	0.44		7.9	0.5	0.5	-46.4	76.73	0.6	47	
AMD # 0131	NSD0031	298	298.3	WP	Fresh		Golder	9.1	210	0.05		0.01	0.52		8.3	0.5	0.5	-56.5	37.88	1.5	58	2.5
AMD # 0132	NSD0031	315.1	315.4	WP	Fresh		Golder	9.4	410	0.1		0.01	0.05		8.4	0.5	0.5	-38.9	13.71	3.1	42	
AMD # 0133	NSD0031	322	322.4	WP	Fresh		Golder	8.9	190	0.02		0.01	0.32		8.4	0.5	0.5	-41.4	68.57	0.6	42	
AMD # 0134	NSD0031	335.4	335.8	WP	Fresh		Golder	8.8	200	0.02		0.01	0.56		8.1	0.5	0.5	-55.4	91.43	0.6	56	
AMD # 0136	NSD0031	348.4	348.8	WP	Fresh		Golder	8.8	130	0.03		0.01	0.39		7.1	0.5	0.5	-40.1	44.63	0.9	41	
AMD # 0135	NSD0031	364	364.3	WP	Fresh		Golder	8.6	100	0.02		0.01	0.14		6.8	0.5	0.5	-22.4	37.55	0.6	23	
AMD # 0137	NSD0031	374.8	375.1	WP	Fresh		Golder	8.7	170	0.01		0.01	0.22		8.7	0.5	0.5	-22.7	75.1	0.3	23	
AMD # 0138	NSD0031	382.9	383.3	WP	Fresh		Golder	8.4	100	0.01		0.01	0.08		7.4	0.5	0.5	-25.7	84.9	0.3	26	
AMD # 0139	NSD0031	392.5	392.8	WP	Fresh		Golder	8.6	120	0.03		0.01	0.15		7.2	0.5	0.5	-26.1	29.39	0.9	27	
AMD # 0140	NSD0031	408.6	408.9	WP	Fresh		Golder	8.5	250	0.01		0.01	0.52		8.8	0.5	0.5	-41.7	137.14	0.3	42	
AMD # 0141	NSD0031	416.9	417.3	WP	Fresh		Golder	7.9	210	0.11		0.01	0.15		7.9	0.5	0.5	-36.6	11.87	3.4	40	
AMD # 0142	NSD0031	422.7	423	WP	Fresh		Golder	8.1	220	0.01		0.01	0.25		8.1	0.5	0.5	-25.7	84.9	0.3	26	
AMD # 0143	NSD0031	437.8	438.1	WP	Fresh		Golder	8.4	190	0.02		0.01	0.3		7.8	0.5	0.5	-27.4	45.71	0.6	28	
AMD # 0145	NSD0031	457.9	458.2	WP	Fresh		Golder	8.9	130	0.03		0.01	0.19		7.8	0.5	0.5	-20.1	22.86	0.9	21	
AMD104a	NSD0032	6.5	30.2	WP	Oxide		Golder	8.2	150	0.01		0.01	0.05		7.4	0.5	0.5	-1.9	7.18	0.3	2.2	
AMD109a	NSD0032	35	68.3	WP	Fresh		Golder	9.4	260	0.04		0.01	0.75		8.6	0.5	0.5	-98.8	81.63	1.2	100	20
AMD113	NSD0032	76.5	76.8	WP	Fresh		Golder	9.7	240	0.05		0.01	0.87		8.8	0.5	0.5	-98.5	65.31	1.5	100	
AMD114	NSD0032	85.4	85.7	WP	Fresh		Golder	9.9	230	0.02		0.01	0.81		8.4	0.5	0.5	-64.4	106.12	0.6	65	
AMD115	NSD0032	95.8	96.2	WP	Fresh		Golder	9.8	260	0.02		0.01	0.72		8.9	0.5	0.5	-63.4	104.49	0.6	64	
AMD116	NSD0032	103.6	103.9	WP	Fresh		Golder	10.1	420	0.05		0.01	0.26		8.7	0.5	0.5	-40.5	27.43	1.5	42	
AMD117	NSD0032	108.8	109.1	WP	Fresh		Golder	10.2	320	0.11		0.01	0.47		8.7	0.5	0.5	-46.6	14.84	3.4	50	
AMD118	NSD0032	112.8	113.2	WP	Fresh		Golder	10.2	460	0.96		0.01	0.05		3	3.9	10	2.4	0.92	29.4	27	
AMD119	NSD0032	117.4	117.7	WP	Fresh		Golder	9.7	260	0.03		0.01	0.95		8.8	0.5	0.5	-80.1	88.16	0.9	81	
AMD120	NSD0032	125.3	125.6	WP	Fresh		Golder	10	620	0.89		0.02	0.17		6	0.5	0.5	-15.7	1.58	27.3	43	
AMD121	NSD0032	126.8	127.2	WP	Fresh		Golder	9.5	160	0.01		0.01	1.17		8.3	0.5	0.5	-73.7	241.63	0.3	74	
AMD122a	NSD0032	136.1	175.8	WP	Fresh		Golder	9.8	240	0.01		0.01	0.29		8.4	0.5	0.5	-42.7	140.41	0.3	43	
AMD127	NSD0032	186.1	186.3	WP	Fresh		Golder	9.7	220	0.01		0.01	0.17		8.5	0.5	0.5	-30.7	101.22	0.3	31	
AMD # 0177	NSD0032	197.4	197.7	WP	Fresh		Golder	9.6	370	0.02		0.01	0.09		8.1	0.5	0.5	-29.4	48.98	0.6	30	
AMD # 0146	NSD0032	200.7	201	WP	Fresh		Golder	9.7	290	0.02		0.01	0.11		8.2	0.5	0.5	-27.4	45.71	0.6	28	
AMD # 0147	NSD0032	214.1	214.5	WP	Fresh		Golder	9.7	320	0.13		0.01	0.11		7.4	0.5	0.5	-20	6.03	4	24	
AMD # 0148	NSD0032	224.2	224.6	WP	Fresh		Golder	9.7	220	0.04		0.01	0.19		8.2	0.5	0.5	-27.8	23.67	1.2	29	
AMD # 0149	NSD0032	245.1	245.4	WP	Fresh		Golder	9.9	340	0.03		0.01	0.05		8.1	0.5	0.5	-15.1	17.41	0.9	16	
AMD # 0150	NSD0032	249.6	250	WP	Fresh		Golder	9.8	320	0.02		0.01	0.05		8.1	0.5	0.5	-32.4	53.88	0.6	33	
AMD # 0151	NSD0032	255.7	256	WP	Fresh		Golder	10.5	790	2.56		0.02	0.05		2.3	31	45	49.4	0.37	78.4	29	
AMD # 0152	NSD0032	259.7	260.1	WP	Fresh		Golder	10	310	0.09		0.01	0.36		8.3	0.5	0.5	-37.2	14.51	2.8	40	
AMD # 0153	NSD0032	268.8	269.2	WP	Fresh		Golder	10	310	0.01		0.01	0.35		8.5	0.5	0.5	-43.7	143.67	0.3	44	
AMD # 0154	NSD0032	273.8	274.1	WP	Fresh		Golder	10.3	900	0.37		0.01	0.06		7.8	0.5	0.5	-62.7	6.53	11.3	74	
AMD # 0155	NSD0032	276.7	277.1	WP	Fresh		Golder	9.7	260	0.01		0.01	0.66		8.3	0.5	0.5	-78.7	257.96	0.3	79	
AMD128	NSD0032	280.4	280.7	WP	Fresh		Golder	9.9	260	0.01		0.01	0.36		8.7	0.5	0.5	-39.7	130.61	0.3	40	
AMD # 0156	NSD0032	283.3	283.6	WP	Fresh		Golder	10.3	890	0.46		0.01	0.24		8.4	0.5	0.5	-40.9	3.9	14.1	55	22.1
AMD # 0157	NSD0032	287.6	287.9	WP	Fresh		Golder	10	330	0.03		0.01	0.3		8.3	0.5	0.5	-44.1	48.98	0.9	45	
AMD # 0158	NSD0032	289.4	289.8	WP	Fresh		Golder	10.3	800	0.49		0.01	0.09		7.8	0.5	0.5	-25	2.67	15	40	
AMD # 0159	NSD0032	294.2	294.6	WP	Fresh		Golder	10	390	0.01		0.01	0.3		8.4	0.5	0.5	-46.7	153.47	0.3	47	
AMD # 0160	NSD0032	311.9	312.3	WP	Fresh		Golder	9.9	430	0.17		0.01	0.78		8.6	0.5	0.5	-94.8	19.21	5.2	100	
AMD # 0161	NSD0032	322.2	322.5	WP	Fresh		Golder	9.8	480	0.28		0.01	0.61		8.4	0.5	0.5	-51.4	7	8.6	60	
AMD # 0162	NSD0032	325.2	325.5	WP	Fresh		Golder	9.5	190	0.01		0.01	0.41		8.3	0.5	0.5	-39.7	130.61	0.3	40	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh		Golder	9.5	700	0.14		0.01	0.05		8.1	0.5	0.5	-115.7	27.99	4.3	120	2.5
AMD # 0164	NSD0032	329.1	329.5	WP	Fresh		Golder	9.6	280	0.01		0.01	0.05		8.1	0.5	0.5	-63.7	208.98	0.3	64	
AMD # 0165	NSD0032	333.4	333.6	WP	Fresh		Golder	10.1	480	0.1		0.01	0.29		8.5	0.5	0.5	-35.9	12.73	3.1	39	
AMD # 0166	NSD0032	338.7	339	WP	Fresh		Golder	9.5	180	0.01		0.01	0.28		8.3	0.5	0.5	-31.7	104.49	0.3	32	
AMD # 0167	NSD0032	343.7	344	WP	Fresh		Golder	8.3	160	0.46		0.01	0.06		6.1	0.5	0.5	3.1	0.78	14.1	11	1.2
AMD # 0168	NSD0032	349.2	349.5	WP	Fresh		Golder	9.9	330	0.01		0.01	0.19		8.2	0.5	0.5	-37.7	124.08	0.3	38	
AMD # 0169	NSD0032	356.5	356.8	WP	Fresh		Golder	9.2	310	0.23		0.01	0.36		8.2	0.5	0.5	-103	15.62	7	110	10
AMD # 0170	NSD0032	367.2	367.6	WP	Fresh		Golder	8.3	190	0.02		0.01	0.29		8.4	0.5	0.5	-73.4	120.82	0.6	74	
AMD # 0171	NSD0032	381.7	382	WP	Fresh		Golder	8.2	190	0.01		0.01	0.15		8.1	0.5	0.5	-30.7	101.22	0.3	31	
AMD # 0172	NSD0032	397.7	398	WP	Fresh		Golder	8.2	200	0.3		0.01	0.12		7.2	0.5	0.5	-64.8	8.05	9.2	74	2.9
AMD # 0173	NSD0032	412.6	413.1	WP	Fresh		Golder	8.2	260	0.47		0.01	0.13		7.2	0.5	0.5	-15.6	2.08	14.4	30	
AMD # 0174	NSD0032	422	422.4	WP	Fresh		Golder	8.2	210	0.03		0.01	0.23		8.2	0.5	0.5	-27.1	30.48	0.9	28	
AMD # 0175	NSD0032	430.8	431.1	WP	Fresh		Golder	8.4	170	0.12		0.01	0.12		7.6	0.5	0.5	-19.3	6.26	3.7	23	
AMD # 0176	NSD0032	449	449.4	WP	Fresh		Golder	7.7	420	1.03		0.01	0.1		7.7	0.5	0.5	-49.5	2.57	31.5	81	
AMD # 039	NSRD0387	184.7	185	WP	Fresh		Golder	10.1	550	0.04		0.01	0.05		8.4	0.5	0.5	-66.8	55.51	1.2	68	
AMD # 040	NSRD0387	196.7	197	WP	Fresh		Golder	10.1	550	0.02		0.01	0.21		8.4	0.5	0.5	-55.4	91.43	0.6	56	
AMD # 041	NSRD0387	201.9	202.2	WP	Fresh		Golder	10	550	0.04		0.01	0.14		8.5	0.5	0.5	-63.8	53.06	1.2	65	
AMD # 042	NSRD0387	204.9	205.2	WP	Fresh		Golder	9.8	630	0.03		0.01	0.05		8.2	0.5	0.5	-64.1	70.75	0.9	65	
AMD # 043	NSRD0387	210.1	210.4	WP	Fresh		Golder	9.8	660	0.09		0.01	0.74		8.6	0.5	0.5	-70.2	26.49	2.8	73	
AMD # 044	NSRD0387	217	217.4	WP	Fresh		Golder	10.1	530	0.16		0.01	0.05		8.2	0.5	0.5	-46.1	10.41	4.9	51	
AMD # 045	NSRD0387	221.9	222.3	WP	Fresh		Golder	9.8	490	0.21		0.01	0.21		8.4	0.5	0.5	-52.6	9.17	6.4	59	
AMD # 046	NSRD0387	226.5	226.9	WP	Fresh		Golder	10.4	410	0.14		0.01	0.05		7.9	0.5	0.5	-65.7	16.33	4.3	70	
AMD # 047	NSRD0387	233.8	234.1	WP	Fresh		Golder	10.2	480	0.06		0.01	0.05		8.1	0.5	0.5	-31.2	17.96	1.8	33	
AMD # 048	NSRD0387	241	241.4	WP	Fresh		Golder	9.7	550	0.03		0.01	0.19		8.6	0.5	0.5	-65.1	71.84	0.9	66	
AMD # 049	NSRD0387	246.7	247	WP	Fresh		Golder	9.9	510	0.16		0.01	0.08		8.3	0.5	0.5	-49.1	11.02	4.9	54	
AMD # 050	NSRD0387	256.4	256.7	WP	Fresh		Golder	9.9	550	0.1		0.01	0.23		8.5	0.5	0.5	-39.9	14.04	3.1	43	
AMD # 051	NSRD0387	259.2	259.6	WP	Fresh		Golder	9.8	550	0.13		0.01	0.05		8.1	0.5	0.5	-18	5.53	4	22	
AMD # 052	NSRD0387	265.8	266.2	WP	Fresh		Golder	9.8	620	0.1		0.01	0.06		8.5	0.5	0.5	-60.9	20.9	3.1	64	
AMD # 053	NSRD0387	279.3	279.6	WP	Fresh		Golder	9.8	580	0.03		0.01	0.17		8.4	0.5	0.5	-55.1	60.95	0.9	56	
AMD # 054	NSRD0387	299.3	299.7	WP	Fresh		Golder	9.6	530	0.15		0.01	0.09		8.3	0.5	0.5	-56.4	13.28	4.6	61	
AMD # 055	NSRD0387	306.9	307.3	WP	Fresh		Golder	9.7	570	0.01		0.01	0.27		8.5	0.5	0.5	-63.7	208.98	0.3	64	
AMD # 056	NSRD0387	311.8	312.2	WP	Fresh		Golder	9.8	590	0.14		0.01	0.05		8.2	0.5	0.5	-45.7	11.66	4.3	50	
AMD # 057	NSRD0387	322.7	323.1	WP	Fresh		Golder	9.8	520	0.05		0.01	0.18		8.2	0.5	0.5	-52.5	35.27	1.5	54	
AMD # 058	NSRD0387	334.2	334.6	WP	Fresh		Golder	10	560	0.06		0.01	0.11		8.4	0.5	0.5	-30.2	17.41	1.8	32	
AMD # 059	NSRD0387	340.2	340.6	WP	Fresh		Golder	9.7	530	0.24		0.01	0.05		8.3	0.5	0.5	-25.7	4.49	7.4	33	
AMD # 060	NSRD0387	349.4	349.7	WP	Fresh		Golder	9.7	530	0.05		0.01	0.12		8.5	0.5	0.5	-31.5	21.55	1.5	33	
AMD # 061	NSRD0387	356.1	356.5	WP	Fresh		Golder	9.8	700	0.39		0.01	0.05		8.5	0.5	0.5	-53.1	5.44	11.9	65	
AMD # 062	NSRD0387	364.4	364.7	WP	Fresh		Golder	8.5	410	0.41		0.01	0.25		8.1	0.5	0.5	-74.4	6.93	12.6	87	
AMD # 063	NSRD0387	373.4	373.8	MP	Fresh		Golder	9.8	680	0.04		0.01	0.5		8.4	0.5	0.5	-72.8	60.41	1.2	74	
AMD # 064	NSRD0387	383.3	383.7	MP	Fresh		Golder	9.5	370	0.33		0.01	0.05		7.2	0.5	0.5	-13.9	2.37	10.1	24	
AMD # 065	NSRD0387	401.5	401.9	MP	Fresh		Golder	8.6	500	0.23		0.01	0.72		8.5	0.5	0.5	-79	12.21	7	86	
AMD_1	NSRD0393	181.1	181.5	WP	Fresh		Golder	10.2	540	0.33		0.01	0.39		8.1	0.5	0.5	-68.9	7.82	10.1	79	
AMD_2	NSRD0393	190.2	190.7	WP	Fresh		Golder	9.7	420	0.73		0.01	0.25		8	0.5	0.5	-50.6	3.27	22.4	73	
AMD_3	NSRD0393	203	203.2	WP	Fresh		Golder	9.6	540	0.11		0.01	0.07		8.3	0.5	0.5	-10.6	4.16	3.4	14	
AMD_4	NSRD0393	205.8	206.1	WP	Fresh		Golder	10.1	730	0.78		0.01	0.24		8.1	0.5	0.5	-50.1	3.1	23.9	74	
AMD_5	NSRD0393	215.7	216.1	WP	Fresh		Golder	10.1	640	0.09		0.01	0.95		8.1	0.5	0.5	-96.2	35.92	2.8	99	
AMD_6	NSRD0393	222.5	222.8	WP	Fresh		Golder	10.3	580	0.36		0.01	0.68		7.7	0.5	0.5	-86	8.8	11	97	
AMD_7	NSRD0393	223.5	223.8	WP	Fresh		Golder	10	640	0.3		0.01	0.98		8.4	0.5	0.5	-100.8	11.97	9.2	110	
AMD_8	NSRD0393	226.7	227.1	WP	Fresh		Golder	10.1	600	0.62		0.01	0.37		7.9	0.5	0.5	-51	3.69	19	70	25
AMD_9	NSRD0393	227.9	228.2	WP	Fresh		Golder	9.4	490	0.14		0.01	0.05		8.2	0.5	0.5	-51.7	13.06	4.3	56	
AMD_10	NSRD0393	229	229.3	WP	Fresh		Golder	9.9	560	0.29		0.01	0.23		8.5	0.5	0.5	-66.1	8.44	8.9	75	
AMD_11	NSRD0393	231.4	231.8	WP	Fresh		Golder	9.9	630	0.34		0.01	0.15		8.4	0.5	0.5	-64.6	7.2	10.4	75	
AMD_12	NSRD0393	233	233.4	WP	Fresh		Golder	9.7	630	0.14		0.01	0.17		8.6	0.5	0.5	-63.7	15.86	4.3	68	
AMD_13	NSRD0393	234.7	234.9	WP	Fresh		Golder	9.9	590	0.14		0.01	0.11		8.5	0.5	0.5	-80.7	19.83	4.3	85	
AMD_14	NSRD0393	236.3	236.7	WP	Fresh		Golder	9.2	530	0.19		0.01	0.05		8	0.5	0.5	-46.2	8.94	5.8	52	
AMD # 015	NSRD0393	238.5	238.8	WP	Fresh		Golder	8.6	100	0.27		0.01	0.05		3.5	2.7	1.5	3.5	0.58	8.3	4.8	
AMD # 016	NSRD0393	246.4	246.8	WP	Fresh		Golder	9.9	600	0.18		0.01	0.82		8.6	0.5	0.5	-94.5	18.14	5.5	100	
AMD # 017	NSRD0393	248.9	249.2	WP	Fresh		Golder	8.3	140	0.91		0.01	0.05		2.8	16	10	19.2	0.31	27.9	8.7	
AMD # 018	NSRD0393	252.1	252.5	WP	Fresh		Golder	9.5	350	0.23		0.01	0.08		8.2	0.5	0.5	-74	11.5	7	81	
AMD # 019	NSRD0393	255	255.4	WP	Fresh		Golder	9	360	2.23		0.01	0.16		2.3	35	26	45.3	0.34	68.3	23	
AMD # 020	NSRD0393	266.5	266.8	WP	Fresh		Golder	9.6	500	0.79		0.01	0.56		7.9	0.5	0.5	-67.8	3.8	24.2	92	
AMD # 021	NSRD0393	270.5	270.8	WP	Fresh		Golder	9.9	470	0.28		0.01	0.58		8.3	0.5	0.5	-78.4	10.15	8.6	87	
AMD # 022	NSRD0393	275.7	276.1	WP	Fresh		Golder	9.1	360	0.51		0.01	0.64		7.6	0.5	0.5	-50.4	4.23	15.6	66	
AMD # 023	NSRD0393	287.6	287.9	MP	Fresh		Golder	8.9	280	0.17		0.01	0.53		7.5	0.5	0.5	-37.8	8.26	5.2	43	
AMD # 024	NSRD0393	292.3	292.6	MP	Fresh		Golder	9.7	660	0.2		0.01	0.1		8.3	0.5	0.5	-79.9	14.04	6.1	86	
AMD # 025	NSRD0393	299.6	300	MP	Fresh		Golder	9.7	680	1.04		0.01	0.05		6.6	0.5	0.5	-57.2	2.79	31.9	89	
AMD # 026	NSRD0393	318.1	318.5	MP	Fresh		Golder	9.9	430	0.31		0.01	0.29		8.1	0.5	0.5	-53.5	6.64	9.5	63	
AMD # 027	NSRD0393	328.8	329.2	MP	Fresh		Golder	8.9	150	0.05		0.01	0.51		7.4	0.5	0.5	-40.5	27.43	1.5	42	
AMD # 028	NSRD0393	341	341.2	MP	Fresh		Golder	9.9	690	0.13		0.01	0.89		8.6	0.5	0.5	-96	25.12	4	100	
AMD # 029	NSRD0393	348.7	349	MP	Fresh		Golder	10	650	0.14		0.01	0.39		8.5	0.5	0.5	-70.7	17.49	4.3	75	
AMD # 030	NSRD0393	359.9	360.3	MP	Fresh		Golder	9.7	450	0.33		0.01	0.17		7.9	0.5	0.5	-25.9	3.56	10.1	36	
AMD # 031	NSRD0393	378.7	379.1	MP	Fresh		Golder	8.6	130	0.24		0.01	0.05		4	1	0.5	0.4	0.94	7.4	6.9	

Appendix A3: ABA and NAG data

Values given as grey are detection limit values

Drill hole samples

Sample ID	HOLE ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
AMD # 032	NSRD0393	391	391.4	MP	Fresh		Golder	8.5	370	0.34		0.01	0.05		8.1	0.5	0.5	-81.6	8.84	10.4	92	
AMD # 033	NSRD0393	395.1	395.5	MP	Fresh		Golder	8.8	180	0.73		0.01	0.12		3	12	7.8	14.6	0.35	22.4	7.8	
AMD # 034	NSRD0393	404.5	404.9	MP	Fresh		Golder	9.6	390	0.23		0.01	0.19		7.9	0.5	0.5	-45	7.38	7	52	
AMD # 035	NSRD0393	410.7	411	MP	Fresh		Golder	8.5	210	0.62		0.01	0.16		3	4.2	1.8	2	0.9	19	17	
AMD # 036	NSRD0393	414.9	415.3	MP	Fresh		Golder	9.6	440	0.19		0.01	0.05		8.3	0.5	0.5	-78.2	14.44	5.8	84	
AMD # 037	NSRD0393	422.7	423	MP	Fresh		Golder	9.4	310	0.15		0.01	0.56		8.7	0.5	0.5	-45.4	10.88	4.6	50	
AMD # 038	NSRD0393	429.4	429.7	MP	Fresh		Golder	9.6	380	0.28		0.01	0.62		8.1	0.5	0.5	-66.4	8.75	8.6	75	

Tailings samples

Sample ID	Type	Description	Source	paste pH	paste EC	TotalS	S-sulfide	S-sulfate	TIC	Total C	NAG pH	NAG4.5	NAG to 7.0	NAPP	NPR	MPA	ANC	ABCC to pH 4.5
				pH units	µS/cm	wt%	wt%	wt%	wt%	wt%	pH units	kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t		kg H_2SO_4/t	kg H_2SO_4/t	kg H_2SO_4/t
(3283 Tails) 1			GHD	9.5		0.17					8.9	<0.1	<0.1	-54.26	11.42	5.21	59.47	42
(3283 Tails) 2			GHD	9.4		0.18					9.4	<0.1	<0.1	-49.57	9.99	5.51	55.08	8.2
(3283 - Year 1-7Tailings)			GHD	8.9		0.12					9.2	<0.1	<0.1	-69.85	20.01	3.68	73.52	19.6
A15951 Bulk Comp	Wet-Fresh	Bulk	Golder	7.3	790	0.01		0.01	0.05		6.2	0.5	0.5	-3.4	12.08	0.3	3.7	
A15967 VARFR01	Wet-Fresh	NON-MAGS	Golder	8.5	560	0.14		0.01	0.49		8.2	0.5	0.5	-85.7	20.99	4.3	90	
A15967 VARFR02	Wet-Fresh	NON-MAGS	Golder	8.3	530	0.14		0.01	0.42		8.1	0.5	0.5	3.3	0.23	4.3	1	
A15967 VARFR03	Wet-Fresh	NON-MAGS	Golder	8.6	260	0.03		0.01	0.38		7.8	0.5	0.5	-39.1	43.54	0.9	40	
A15967 VARFR04	Wet-Fresh	NON-MAGS	Golder	8.4	410	0.09		0.01	0.14		7.9	0.5	0.5	-24.2	9.8	2.8	27	
A15967 VARFR05	Wet-Fresh	NON-MAGS	Golder	8.9	500	0.08		0.01	0.25		8.2	0.5	0.5	-32.6	14.29	2.5	35	
A15967 VARFR06	Wet-Fresh	NON-MAGS	Golder	8.3	560	0.17		0.01	0.23		7.7	0.5	0.5	-28.8	6.53	5.2	34	11.7
A15967 VARFR07	Wet-Fresh	NON-MAGS	Golder	8.9	720	0.12		0.02	0.42		8.3	0.5	0.5	-47.3	13.88	3.7	51	
A15967 VARFR08	Wet-Fresh	NON-MAGS	Golder	8.1	390	0.03		0.01	0.05		7.8	0.5	0.5	-22.1	25.03	0.9	23	
A15967 VARFR09	Wet-Fresh	NON-MAGS	Golder	8.5	300	0.04		0.01	0.13		8	0.5	0.5	-22.8	19.59	1.2	24	
A15967 VARFR10	Wet-Fresh	NON-MAGS	Golder	8.6	250	0.03		0.01	0.19		8	0.5	0.5	-28.1	31.56	0.9	29	4.3
A15967 VAROX 01	Wet-Oxide	NON-MAGS	Golder	7.1	70	0.04		0.01	0.05		5.2	0.5	0.5	0.2	0.82	1.2	7	
A15967 VAROX 02	Wet-Oxide	NON-MAGS	Golder	7.6	60	0.03		0.01	0.05		5.7	0.5	0.5	-0.1	1.09	0.9	1	
A15967 VAROX 03	Wet-Oxide	NON-MAGS	Golder	7	60	0.03		0.01	0.05		5.5	0.5	0.5	-0.1	1.09	0.9	1	
A15967 VAROX 04	Wet-Oxide	NON-MAGS	Golder	8	80	0.03		0.01	0.05		7.9	0.5	0.5	-4.3	5.66	0.9	5.2	
A15967 VAROX 05	Wet-Oxide	NON-MAGS	Golder	8	70	0.02		0.01	0.05		7.7	0.5	0.5	-2.5	5.06	0.6	3.1	
A15967 VAROX 06	Wet-Oxide	NON-MAGS	Golder	7.2	60	0.01		0.01	0.05		6	0.5	0.5	-0.7	3.27	0.3	1	
A15967 VAROX 07	Wet-Oxide	NON-MAGS	Golder	7.6	70	0.01		0.01	0.05		7.6	0.5	0.5	-2.8	10.12	0.3	3.1	
A15967 VAROX 08	Wet-Oxide	NON-MAGS	Golder	7.5	70	0.02		0.01	0.05		5.8	0.5	0.5	-0.5	1.8	0.6	1.1	
A15967 VAROX 09	Wet-Oxide	NON-MAGS	Golder	8.2	220	0.02		0.01	0.05		7.8	0.5	0.5	-24.4	40.82	0.6	25	
A15967 VAROX 10	Wet-Oxide	NON-MAGS	Golder	7.7	50	0.01		0.01	0.05		7.6	0.5	0.5	-1.8	6.86	0.3	2.1	
A16236 Fig 5 (Blend)	Wet-Fresh	PRIMARY AND REGRIND WET LIMS	Golder	9	610	0.1		0.01	0.4		8.5	0.5	0.5	-50.9	17.63	3.1	54	13
Batch Plant Fresh Coarse Cobing Non Mags (A15951)	Dry-Fresh	Stage 2 Process Plant Dry rejects	Golder	9.4	270	0.19		0.01	0.52		7.9	0.5	0.5	-94.2	17.19	5.8	100	31.9
Batch Plant Oxide Coarse Cobing Non Mags (A15951)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.7	170	0.01		0.01	0.05		5.3	0.5	1.1	-2	7.51	0.3	2.3	0.5
VARFR01 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	9.2	310	0.66		0.01	0.56		7.2	0.5	0.5	-29.8	2.47	20.2	50	7
VARFR02 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	8.9	290	0.04		0.01	1.64		7.7	0.5	0.5	-148.8	122.45	1.2	150	
VARFR03 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	8.7	210	0.01		0.01	0.5		8.2	0.5	0.5	-58.7	192.65	0.3	59	
VARFR04 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	9	330	0.07		0.01	0.77		7.9	0.5	0.5	-85.9	41.05	2.1	88	
VARFR05 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	9	280	0.02		0.01	1.07		8.2	0.5	0.5	-94.4	155.1	0.6	95	
VARFR06 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	8.8	300	0.04		0.01	0.98		7.9	0.5	0.5	-98.8	81.63	1.2	100	
VARFR07 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	9.7	300	0.29		0.01	0.4		7.9	0.5	0.5	-82.1	10.25	8.9	91	
VARFR08 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	8.3	210	0.05		0.01	0.34		7.6	0.5	0.5	-86.5	57.47	1.5	88	
VARFR09 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	8.9	220	0.08		0.01	0.49		8	0.5	0.5	-56.6	24.08	2.5	59	8.5
VARFR10 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	8.7	220	0.03		0.01	0.9		8	0.5	0.5	-99.1	108.84	0.9	100	
VAROX01 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7	120	0.01		0.01	0.05		5.8	0.5	0.5	-1.8	6.86	0.3	2.1	
VAROX02 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.5	110	0.01		0.01	0.05		5.3	0.5	0.5	-1.9	7.18	0.3	2.2	
VAROX03 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.3	100	0.01		0.01	0.05		4.8	0.5	0.5	-0.4	2.29	0.3	0.7	0.4
VAROX04 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.4	110	0.01		0.01	0.05		7.8	0.5	0.5	-5.7	19.59	0.3	6	
VAROX05 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.6	80	0.01		0.01	0.05		7.6	0.5	0.5	-3.9	13.71	0.3	4.2	
VAROX06 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	6.4	60	0.01		0.01	0.05		5.1	0.5	0.5	-0.9	3.92	0.3	1.2	
VAROX07 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7	80	0.01		0.01	0.05		7.2	0.5	0.5	-4.6	16	0.3	4.9	
VAROX08 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7	90	0.01		0.01	0.05		5.2	0.5	0.5	-1.2	4.9	0.3	1.5	
VAROX09 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.7	130	0.01		0.01	0.05		7.7	0.5	0.5	-6.7	22.86	0.3	7	0.7
VAROX10 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.3	40	0.01		0.01	0.05		6.5	0.5	0.5	-1.4	5.55	0.3	1.7	

Appendix A4: Deionised water leach

Sample ID	Hole ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	pH	EC	F	NH3 as N	NO3 as N	OH as CaCO3	CO3 as CaCO3	HCO3 as CaCO3	Alkalinity as CaCO3	Acidity as CaCO3	SO4	Cl	Ca	Mg	Na	K	Ag	Al	As	B	Be	Ba	Cd	Cr	Co	Cs	Cu
		From	To					pH units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
E889501	NS0077	0	4	WP	Oxide		GHD	7.4					<1	<1	11	11	3	4	1	6	2	11	<1		0.03	<0.001		<0.001	1.77	0.0001	<0.001	<0.001		<0.001
E889505	NS0077	8	12	WP	Oxide		GHD	7.7					<1	<1	5	5	3	1	1	<1	<1	4	<1		0.03	<0.001		<0.001	0.66	<0.0001	<0.001	<0.001		<0.001
E889511	NS0077	20	24	WP	Oxide		GHD	8					<1	<1	5	5	4	<1	<1	<1	<1	6	<1		0.58	<0.001		<0.001	0.519	<0.0001	0.001	0.001		0.002
E889515	NS0077	28	32	WP	Oxide		GHD	7.9					<1	<1	7	7	3	1	<1	2	<1	9	<1		0.67	<0.001		<0.001	1.09	0.0002	0.001	0.001		0.002
E889591	NS0077	178	182	WP	Fresh		GHD	7.5					<1	<1	15	15	9	124	2	5	15	35	10		0.02	<0.001		<0.001	1.24	0.0002	<0.001	0.001		<0.001
E889643	NS0078	0	4	WP	Oxide		GHD	7.8					<1	<1	6	6	3	3	1	3	<1	9	<1		0.01	<0.001		<0.001	1.24	<0.0001	<0.001	<0.001		<0.001
E889648	NS0078	8	12	WP	Oxide		GHD	7.7					<1	<1	6	6	4	2	7	2	<1	11	<1		2.89	<0.001		<0.001	1.52	0.0001	0.012	<0.001		<0.001
E889653	NS0078	18	24	WP	Oxide		GHD	8					<1	<1	8	8	3	1	2	3	<1	16	<1		1.1	<0.001		<0.001	1.9	0.0002	0.01	<0.001		0.002
E889657	NS0078	26	32	WP	Oxide		GHD	8.1					<1	<1	10	10	6	1	1	2	<1	16	<1		1	<0.001		<0.001	1.53	<0.0001	0.011	<0.001		0.002
E889683	NS0078	78	80	WP	Fresh		GHD	8.3					<1	<1	12	12	2	<1	<1	3	1	15	<1		0.44	<0.001		<0.001	1.25	<0.0001	0.002	<0.001		<0.001
E889781	NS0078	274	278	WP	Fresh		GHD	8.2					<1	<1	24	24	3	54	1	1	2	36	2		1.14	0.005		<0.001	0.626	<0.0001	0.017	0.002		0.004
E889833	NS0079	94	98	WP	Fresh		GHD	7.7					<1	<1	33	33	6	32	3	5	5	22	<1		<0.01	<0.001		<0.001	1.37	0.0002	<0.001	<0.001		0.002
X068378	NS0083	158	162	MP	Fresh		GHD	8.8					<1	<1	40	40	<1	56	2	6	1	44	2		0.47	<0.001		<0.001	1.72	<0.0001	0.008	<0.001		0.002
X068517	NS0084	140	144	WP	Fresh		GHD	7.6					<1	<1	31	31	<1	16	2	4	3	19	<1		0.32	<0.001		<0.001	1.54	0.0002	0.001	<0.001		0.002
X068527	NS0084	158	162	WP	Fresh		GHD	6.8					<1	<1	3	3	3	62	1	5	10	14	<1		0.03	<0.001		<0.001	1.49	0.0002	<0.001	0.008		0.002
X068544	NS0084	190	194	WP	Fresh		GHD	8.7					<1	2	30	33	<1	5	1	4	2	13	<1		0.54	0.001		<0.001	1.06	<0.0001	0.002	<0.001		0.002
X068586	NS0084	270	274	WP	Fresh		GHD	8.8					<1	2	37	39	<1	15	<1	3	2	25	<1		0.16	0.002		<0.001	0.937	0.0002	<0.001	<0.001		0.002
X068592	NS0085	0	2	WP	Oxide		GHD	8.2					<1	<1	4	4	4	1	<1	2	<1	8	<1		2.65	<0.001		<0.001	0.926	0.0001	0.005	<0.001		0.002
X068597	NS0085	10	2	WP	Oxide		GHD	7.6					<1	<1	3	3	3	<1	<1	<1	<1	4	<1		2.42	<0.001		<0.001	0.22	<0.0001	0.012	<0.001		0.002
X068601	NS0085	18	22	WP	Oxide		GHD	7.8					<1	<1	4	4	3	1	1	1	<1	10	<1		0.79	<0.001		<0.001	0.67	<0.0001	0.003	<0.001		0.013
X068607	NS0085	30	34	WP	Oxide		GHD	7.6					<1	<1	7	7	2	1	2	1	<1	10	<1		0.55	<0.001		<0.001	0.732	<0.0001	0.001	<0.001		0.002
X068621	NS0085	58	62	WP	Fresh		GHD	8.6					<1	<1	29	29	<1	8	<1	7	3	12	<1		0.15	0.002		<0.001	1.48	0.0001	<0.001	<0.001		0.002
X068638	NS0085	90	94	WP	Fresh		GHD	8.8					<1	<1	29	29	<1	<1	1	6	2	10	<1		0.03	<0.001		<0.001	1.39	<0.0001	<0.001	<0.001		<0.001
X068699	NS0085	208	212	WP	Fresh		GHD	8.3					<1	<1	36	36	<1	3	2	4	4	13	<1		0.02	<0.001		<0.001	1.12	<0.0001	<0.001	<0.001		0.001
X068741	NS0086	8	12	WP	Oxide		GHD	7.4					<1	<1	4	4	8	<1	2	2	<1	9	<1		<0.01	<0.001		<0.001	1.34	0.0002	<0.001	<0.001		<0.001
X068751	NS0086	28	32	WP	Oxide		GHD	6.8					<1	<1	6	6	10	2	1	2	<1	13	<1		0.78	<0.001		<0.001	0.519	<0.0001	0.005	<0.001		0.002
X068884	NS0087	8	12	WP	Oxide		GHD	7.6					<1	<1	5	5	4	1	<1	1	<1	7	<1		1.73	<0.001		<0.001	0.853	<0.0001	0.009	<0.001		0.003
X068923	NS0087	84	88	WP	Fresh		GHD	7.4					<1	<1	7	7	4	<1	<1	2	<1	11	<1		0.98	<0.001		<0.001	1.56	0.0001	0.003	0.001		0.003
X068925	NS0087	88	92	WP	Fresh		GHD	9.2					<1	8	28	36	<1	7	<1	4	1	18	<1		0.26	<0.001		<0.001	1.1	<0.0001	0.002	<0.001		0.002
X070079	NS0087	380	384	WP	Fresh		GHD	8.7					<1	<1	34	34	<1	1	<1	6	3	13	<1		0.04	<0.001		<0.001	1.66	<0.0001	<0.001	<0.001		<0.001
X070089	NS0088	0	2	WP	Oxide		GHD	7.7					<1	<1	9	9	3	3	<1	4	1	8	<1		0.05	<0.001		<0.001	1.13	0.0002	<0.001	<0.001		<0.001
X070093	NS0088	8	12	WP	Oxide		GHD	7.8					<1	<1	3	3	4	<1	<1	1	<1	7	<1		0.95	<0.001		<0.001	0.84	<0.0001	0.004	<0.001		<0.001
X070145	NS0088	108	112	WP	Fresh		GHD	7.3					<1	<1	44	44	4	3	<1	8	6	8	<1		<0.01	<0.001		<0.001	1.43	0.0002	<0.001	<0.001		0.002
X070167	NS0088	150	154	WP	Fresh		GHD	7.3					<1	<1	28	28	6	10	<1	6	4	4	<1		<0.01	<0.001		<0.001	0.821	0.0001	<0.001	<0.001		0.002
X070233	NS0088	280	284	WP	Fresh		GHD	7.5					<1	<1	38	38	2	4	<1	8	5	8	<1		<0.01	<0.001		<0.001	1.23	0.0002	<0.001	<0.001		0.002
X070267	NS0088	346	350	WP	Fresh		GHD	7.1					<1	<1	37	37	2	6	<1	7	4	12	<1		<0.01	<0.001		<0.001	1.38	0.0002	<0.001	<0.001		0.002
X070269	NS0089	0	4	WP	Oxide		GHD	7					<1	<1	4	4	<1	3	2	2	<1	9	<1		2.02	<0.001		<0.001	1.09	<0.0001	0.014	<0.001		0.004
X070299	NS0089	60	64	WP	Oxide		GHD	7.1					<1	<1	4	4	2	<1	<1	1	<1	6	<1		0.9	<0.001		<0.001	0.818	<0.0001	0.005	<0.001		0.002
X070313	NS0089	88	92	WP	Fresh		GHD	7.7					<1	<1	24	24	3	15	1	6	4	10	<1		0.03	<0.001		<0.001	1.43	0.0001	<0.001	<0.001		0.002
X070333	NS0089	128	132	WP	Fresh		GHD	7.6					<1	<1	26	26	3	22	1	8	7	8	<1		0.04	<0.001		<0.001	1.62	0.0002	<0.001	<0.001		0.001
X070359	NS0089	178	180	WP	Fresh		GHD	7.6					<1	<1	24	24	3	16	1	6	5	5	<1		<0.01	<0.001		<0.001	0.673	0.0001	<0.001	<0.001		0.001
X070375	NS0089	210	214	WP	Fresh		GHD	7.4					<1	<1	39	39	3	1	<1	8	5	9	<1		<0.01	<0.001		<0.001	1.48	0.0002	<0.001	<0.001		0.001
X070405	NS0089	268	272	WP	Fresh		GHD	7.5					<1	<1	34	34	6	4	2	7	5	10	<1		0.02	<0.001		<0.001	1.55	0.0002	<0.001	<0.001		0.002
X070451	NS0089	360	364	WP	Fresh		GHD	8					<1	<1	64	64	<1	4	<1	10	9	7	<1		<0.01	<0.001		<0.001	0.937	0.0003	<0.001	<0.001		0.003
X070473	NS0090	0	4	WP	Oxide		GHD	7.1					<1	<1	3	3	3	2	2	3	<1	8	<1		0.2	<0.001		<0.001	1.3	<0.0001	<0.001	<0.001		<0.001
X070477	NS0090	8	12	WP	Oxide		GHD	7.6					<1	<1	3	3	4	1	1	1	<1	6	<1		1.81	<0.001		<0.001	0.683	<0.0001	0.008	<0.001		0.003
X070483	NS0090	20	24	WP	Oxide		GHD	7					<1	<1	2	2	3	2	4	<1	<1	5	<1		0.81	<0.001		<0.001	0.086	<0.0001	0.004	<0.001		0.002
X070569	NS0090	190	194	WP	Fresh		GHD	7.5					<1	<1	22	22	<1	4	2	4	3	7	<1		0.31	<0.001		<0.001	1.01	0.0002	0.001	<0.001		0.002
X070609	NS0090	268	272	WP	Fresh		GHD	8.2					<1	<1	29	29	<1	10	3	6	4	8	<1		0.07	0.002		<0.001	0.733	0.0001	<0.001	<0.001		0.003
X070779	NS0092	40	44	WP	Fresh		GHD	8.4					<1	<1	48	48	2	4	<1	6	2	16	<1		0.15	<0.001		<0.001	0.607	0.0001	<0.001	<0.001		0.002
X070783	NS0092	48	52	WP	Fresh		GHD	8.8					<1	<1	39	39	<1	<1	<1	6	2	15	<1		0.17	<0.001		<0.001	0.836	0.0003	0.002	<0.001		0.002
X070839	NS0092	158	162	WP	Fresh		GHD	9.1					<1	3	33	35	<1	<1	<1	6	2	12	<1		0.03	0.002		<0.001	1.07	<0.0001	<0.001	<0.001		<0.001
X071013	NS0093	216	220	WP	Fresh		GHD	8.1					<1	<1	48	48	2	2	2	7	4	14	<1		0.02	<0.001		<0.001	1.38	0.0001	<0.001	<0.001		<0.001
X071061	NS0094	28	32	WP	Oxide		GHD	7.8					<1	<1	5	5	6	<5	<1	2	<1	11	<1		0.96	<0.001		<0.001	1.34	0.0001	0.002	0.001		0.003
X071127	NS0094	160	164	WP	Fresh		GHD	9.2					<1	2	30	32	<1	4	2	5	2	13	<1		0.28	0.007		<0.001	0.827	<0.0001	<0.001	0.001		0.002
X071205	NS0095	30	34	WP	Oxide		GHD	7.9					<1	<1	4	4	2	1	2	2	<1	9	<1		0.83	0.002		<0.001	0.962	0.0001	0.003	0.002		0.002
X071209	NS0095	38	42	WP	Oxide		GHD	8.1					<1	<1	4	4	2	4	1	2	<1	7	<1		1.18	0.002		<0.001	0.708	<0.0001	0.006	0.002		0.004
X071328	NS0096	20	24	WP	Oxide		GHD	7.9					<1	<1	4	4	6	<1	4	2	<1	12	<1		0.95	<0.001		<0.001	1.02	0.0001	0.002	<0.001		0.002
X071353	NS0096	70	74	WP	Fresh		GHD	9.2					<1	4	31	35	<1	1	1	5	2	17	<1		0.09	0.002		<0.001	1.49	0.0001	<0.001	<0.001		<0.001
X071379	NS0096	120	124	WP	Fresh		GHD	9.2					<1	<1	27	27	<1	16	<1	4	3	16	<1		0.29	0.004		<0.001	0.685	<0.0001	<0.001	<0.001		0.002
X071435	NS0096	230	234	WP	Fresh		GHD	8.7					<1	<1	23	23	<1	31	2	3	2	26	<1		0.47	0.002		<0.001	1.19	0.0001	0.003	<0.001		<0.001
X071476	NS0097	28	32	WP	Oxide		GHD	7.6					<1	<1	4	4	3	3	4	3	1	12	<1		1.71	0.001		<0.001	0.921	0.0001	0.008	0.003		0.004
X071482	NS0097	40	44	WP	Fresh		GHD	7					<1	<1	<1	<1	3	192	2	12	32	12	<1		0.03	<0.001		<0.001	0.82	0.0003	<0.001	0.084		<0.001
X071606	NS0098	0	4	WP	Oxide		GHD	7.5					<1	<1	4	4	5	1	2	2	<1	6	<1		5.98	<0.001		<0.001	0.678	<0.0001	0.016	<0.001		0.003
X071616	NS0098	20	24	WP	Oxide		GHD	7.4					<1	<1	3	3	5	<1	2	2	<1	8	<1		0.48	<0.001		<0.001	0.556	<0.0001	0.003	<0.001		<0.001
X071634	NS0098	56	58	WP	Fresh		GHD	7.5					<1	<1	11	11	3	39	1	7	7	14	<1		0.02	<0.001		<0.001	1.76	0.0002	<0.001	<0.001		<0.001
X071635	NS0098	58	62	WP	Fresh		GHD	7.3					<1	<1	14	14	2	18	1	5	4	8	<1		0.04	0.001		<0.001	0.98	0.0002	<0.001	<0.001		<0.001
X071697	NS0098	180	184	WP	Fresh		GHD	8.1					<1	<1	30	30	3	7	2	6	4	12	<1		0.04	<0.001		<0.001	1.08	0.0002	<0.001	<0.001		<0.001
X071933	NS0100	78	82	WP	Fresh		GHD	8.4					<1	<1	35	35	<1	2	<1	5	1	26	<1		1.59	0.002		<0.001	2.58	0.0002	0.015	<0.001		0.003
X073003	NS0106	2	4	WP	Oxide		GHD	8					<1	<1	8	8	3	1	2	<1	11	<1		9.07	<0.001		<0.001	0.89	<0.0001	0.022	<0.001		0.004
X073006	NS0106	8	12	WP	Oxide		GHD	7.9					<1	<1	4	4	3	<1	<1	1	<1	6	<1		1.78	0.001		<0.001	0.803	0.0001	0.004	<0.001		0.005
X073012	NS0106	20	24	WP	Oxide		GHD	5.6					<1	<1	6	6	3	1	<1	1	<1	11	<1		0.73	<0.001		<0.001	1.08	<0.0001	0.001	0.002		0.001
X073016	NS0106	28	32	WP	Oxide		GHD	7.5					<1	<1	5	5	<1	1	<1	2	<1	8	<1		0.78	0.001		<0.001	1.14	0.0001	0.003	0.002		0.005
X073027	NS0106	48	52	WP	Fresh		GHD	8.8					<1	<1	28	28	<1	2	2	5	2	10	<1		0.46	0.004		<0.001	0.885	0.0001	0.002	0.001		0.004
X073049	NS0106	92	96	WP	Fresh		GHD	7.7					<1	<1	24	24	3	24	<1	6	3	21	<1		0.16	<0.001		<0.001	1.7	<0.0001	<0.001	<0.001		<0.001
X073089	NS0106	170	172	WP	Fresh		GHD	9					<1	2	24	26	<1	3	<1	6	3	9	<1		0.03	0.003		<0.001	1.15	<0.0001	<0.001	<0.001		0.002
X073206	NS0107	120	124	KCC	Fresh		GHD	6.5					<1	<1	2	2	8	291	<1	6	55	7	<1		0.02	<0.001		<0.001	0.994	0.0018	<0.001	0.042		<0.001

Appendix A4: Deionised water leach

Sample ID	Hole ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	pH	EC	F	NH3 as N	NO3 as N	OH as CaCO3	CO3 as CaCO3	HCO3 as CaCO3	Alkalinity as CaCO3	Acidity as CaCO3	SO4	Cl	Ca	Mg	Na	K	Ag	Al	As	B	Be	Ba	Cd	Cr	Co	Cs	Cu
		From	To					pH units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
X073210	NS0107	128	132	KCC	Fresh		GHD	6.4					<1	<1	2	2	17	154	<1	5	26	8	<1		<0.01	<0.001		<0.001	1.26	0.0012	<0.001	0.191		<0.001
X073216	NS0107	140	142	KCC	Fresh		GHD	7.3					<1	<1	16	16	2	76	1	24	8	6	<1		<0.01	<0.001		<0.001	1.01	0.0001	<0.001	0.003		0.001
X073220	NS0107	148	152	KCC	Fresh		GHD	6.3					<1	<1	<1	<1	55	105	<1	10	17	11	<1		0.01	<0.001		<0.001	1.8	0.0024	<0.001	0.287		0.014
X073226	NS0107	160	164	KCC	Fresh		GHD	7.1					<1	<1	2	2	7	83	<1	5	14	7	<1		<0.01	<0.001		<0.001	1.28	0.0019	<0.001	0.246		0.002
X073231	NS0107	170	174	KCC	Fresh		GHD	7.5					<1	<1	16	16	2	75	2	21	8	7	<1		<0.01	<0.001		<0.001	1.06	0.0001	<0.001	0.002		0.001
X073338	NS0108	178	180	WP	Fresh		GHD	7.7					<1	<1	24	24	3	24	3	6	6	9	<1		0.03	0.001		<0.001	1.14	0.0002	<0.001	<0.001		0.002
X073994	NS0113	140	142	MP	Fresh		GHD	7.8					<1	<1	11	11	3	45	2	4	6	20	2		0.02	<0.001		<0.001	1.17	0.0001	<0.001	<0.001		<0.001
X074004	NS0113	158	162	MP	Fresh		GHD	7.6					<1	<1	12	12	3	27	1	4	7	9	<1		<0.01	<0.001		<0.001	0.993	0.0001	<0.001	<0.001		<0.001
X074024	NS0113	198	202	MP	Fresh		GHD	8					<1	<1	32	32	2	16	2	7	6	10	<1		0.02	<0.001		<0.001	0.834	<0.0001	<0.001	<0.001		0.001
X074347	NS0116	108	112	MP	Fresh		GHD	7.6					<1	<1	20	20	3	26	2	4	2	18	1		0.15	<0.001		<0.001	0.895	<0.0001	0.002	<0.001		<0.001
X074359	NS0116	130	132	MP	Fresh		GHD	8					<1	<1	30	30	2	22	2	6	2	21	1		0.2	<0.001		<0.001	0.959	0.0002	0.002	<0.001		0.002
X074532	NS0117	190	194	MP	Fresh		GHD	9.1					<1	<1	36	37	<1	31	3	7	3	21	1		0.09	<0.001		<0.001	0.821	<0.0001	<0.001	<0.001		<0.001
X074649	NS0118	140	144	WP	Fresh		GHD	7.4					<1	<1	28	28	2	20	2	5	8	7	<1		<0.01	<0.001		<0.001	1.02	0.0001	<0.001	0.003		<0.001
X074866	NS0120	206	210	WP	Fresh		GHD	8.2					<1	<1	20	20	2	16	4	5	2	16	<1		0.11	<0.001		<0.001	0.894	<0.0001	0.002	<0.001		<0.001
X075399	NS0124	130	134	MP	Fresh		GHD	9.6					<1	22	23	44	<1	41	1	3	1	38	2		2.71	0.005		<0.001	1.34	0.0001	0.051	0.002		0.007
X138071	NS0128	150	154	WP	Fresh		GHD	7.6					<1	<1	16	16	8	25	2	5	7	8	<1		0.01	<0.001		<0.001	1.22	0.0002	<0.001	<0.001		0.001
X072252	NS0152	78	82	MP	Fresh		GHD	8.3					<1	<1	29	29	<1	30	1	13	5	8	<1		0.01	<0.001		<0.001	1.14	0.0001	<0.001	<0.001		<0.001
X072273	NS0152	120	124	WP	Fresh		GHD	9.4					<1	13	27	41	<1	8	<1	5	2	21	<1		0.12	0.001		<0.001	1.14	<0.0001	<0.001	<0.001		<0.001
X072335	NS0152	244	248	WP	Fresh		GHD	9.4					<1	14	28	42	<1	19	<1	6	1	28	<1		0.33	0.003		<0.001	1.45	<0.0001	0.002	<0.001		0.002
X072404	NS0153	98	102	WP	Fresh		GHD	8.2					<1	<1	14	14	2	3	3	4	2	11	<1		0.5	<0.001		<0.001	1.52	0.0001	0.008	<0.001		0.002
X072439	NS0153	168	172	WP	Fresh		GHD	8.4					<1	<1	34	34	<1	2	1	7	3	10	<1		0.02	<0.001		<0.001	1.27	<0.0001	<0.001	<0.001		<0.001
X072455	NS0153	200	204	WP	Fresh		GHD	5					<1	<1	<1	<1	34	197	<1	6	32	11	1		0.47	<0.001		0.003	1.24	0.0055	0.007	0.182		0.079
X072465	NS0153	220	224	WP	Fresh		GHD	6.8					<1	<1	24	24	3	12	1	6	5	8	2		0.01	<0.001		<0.001	1.23	0.0002	<0.001	0.002		<0.001
X072493	NS0154	18	22	WP	Oxide		GHD	7.4					<1	<1	5	5	5	<1	<1	2	<1	9	<1		0.6	<0.001		<0.001	0.937	<0.0001	0.001	0.001		<0.001
X072499	NS0154	30	34	WP	Fresh		GHD	8.6					<1	<1	30	30	<1	1	<1	4	2	15	<1		0.35	<0.001		<0.001	1.44	0.0001	<0.001	<0.001		<0.001
X072503	NS0154	38	42	WP	Fresh		GHD	9					<1	3	34	37	<1	2	1	5	2	16	1		0.12	0.002		<0.001	0.958	<0.0001	<0.001	<0.001		<0.001
X072585	NS0154	200	204	WP	Fresh		GHD	9.3					<1	10	34	43	<1	6	2	3	1	25	<1		0.68	<0.001		<0.001	1.44	<0.0001	0.012	<0.001		0.001
X072677	NS0155	100	104	WP	Fresh		GHD	9.8					<1	17	31	48	<1	8	1	3	<1	25	<1		0.48	0.001		<0.001	1.08	<0.0001	0.005	<0.001		<0.001
X072681	NS0155	108	112	WP	Fresh		GHD	9.1					<1	4	33	37	<1	12	2	4	2	21	<1		0.08	<0.001		<0.001	1.31	<0.0001	<0.001	<0.001		0.001
X072921	NS0157	130	134	WP	Fresh		GHD	8					<1	<1	21	21	2	5	1	4	2	9	<1		0.13	<0.001		<0.001	0.728	<0.0001	<0.001	<0.001		<0.001
X141514	NS0158	66	70	MP	Fresh		GHD	8.5					<1	<1	36	36	<1	6	2	7	3	15	<1		0.05	<0.001		<0.001	1.34	<0.0001	<0.001	<0.001		<0.001
X141536	NS0158	110	114	MP	Fresh		GHD	8.6					<1	2	28	29	<1	3	1	8	3	6	<1		0.17	<0.001		<0.001	0.902	<0.0001	<0.001	<0.001		<0.001
X141571	NS0158	178	182	MP	Fresh		GHD	7.8					<1	<1	30	30	3	4	<1	7	3	6	<1		0.27	0.002		<0.001	1.56	0.0003	<0.001	<0.001		0.001
X141776	NS0160	58	62	WP	Fresh		GHD	8.6					<1	<1	38	38	<1	6	<1	4	2	21	<1		0.84	<0.001		<0.001	1.19	<0.0001	0.016	<0.001		0.001
X121052	NS0165	100	104	WP	Fresh		GHD	7.7					<1	<1	26	26	2	7	1	6	3	5	<1		0.04	<0.001		<0.001	0.387	<0.0001	<0.001	<0.001		0.001
AMD66a	NSD0031	1	29.7	WP	Oxide		Golder	6.8	1	0.09	0.01	0.11				2		1	0.6	0.2	0.2	1.2	<0.1	<0.0001	0.007	<0.001	<0.02		0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD67a	NSD0031	37.48	63.08	WP	Fresh		Golder	8.6	9	0.21	0.06	0.11				45		0.7	1	2	2.1	13.7	2.4	<0.0001	0.079	<0.001	0.04		0.48	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD77a	NSD0031	73.24	80	WP	Fresh		Golder	9.7	9	<0.05	0.13	<0.05				65		1.1	<0.5	2.2	0.9	12.9	1.2	<0.0001	0.19	<0.001	0.02		0.011	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD79a	NSD0031	80.38	94.1	WP	Fresh		Golder	8.7	5.8	<0.05	0.04	0.08				29		2	<0.5	<0.1	0.4	10.9	0.8	<0.0001	0.64	<0.001	0.04		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD83	NSD0031	103.17	103.43	WP	Fresh		Golder	7.7	4.5	<0.05	0.02	<0.05				24		0.2	<0.5	0.6	1.7	5.1	0.5	<0.0001	0.006	<0.001	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD85	NSD0031	119	119.33	WP	Fresh		Golder	9.6	8.4	0.1	0.11	0.07				39		2.3	1	<0.1	0.2	16.3	0.7	<0.0001	1.5	0.007	0.06		0.061	<0.0001	0.004	<0.005	0.0002	<0.0001
AMD87	NSD0031	127.7	128	WP	Fresh		Golder	9.7	5.8	0.11	0.08	0.08				28		0.8	0.7	<0.1	0.3	10.9	0.5	<0.0001	2.5	0.009	0.06		0.034	<0.0001	0.003	<0.005	<0.0001	0.0001
AMD89	NSD0031	144.77	145.06	WP	Fresh		Golder	9.3	8.9	<0.05	0.04	0.12				34		8.4	<0.5	0.1	0.6	18.7	0.8	<0.0001	0.4	0.003	0.02		0.015	<0.0001	<0.001	<0.005	0.0001	0.0006
AMD91	NSD0031	156	156.34	WP	Fresh		Golder	7.7	1.1	<0.05	<0.01	<0.05				6		<0.1	<0.5	1.1	0.3	0.9	<0.1	<0.0001	0.012	<0.001	<0.02		0.016	<0.0001	<0.001	<0.005	<0.0001	0.0001
AMD93	NSD0031	171.06	171.42	WP	Fresh		Golder	9.7	8.2	<0.05	0.02	<0.05				37		2.8	<0.5	3.5	1.6	10.9	0.5	<0.0001	0.068	0.002	<0.02		0.012	<0.0001	<0.001	<0.005	<0.0001	0.0002
AMD95	NSD0031	192.53	192.82	WP	Fresh		Golder	9.6	5.1	<0.05	0.02	0.08				26		0.2	<0.5	1.6	1	7.7	0.4	<0.0001	0.2	0.001	<0.02		0.006	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD97	NSD0031	203	203.36	WP	Fresh		Golder	9.5	5.7	<0.05	0.01	<0.05				29		0.3	<0.5	3.8	1.6	4.7	0.2	<0.0001	0.077	<0.001	<0.02		0.008	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD99	NSD0031	231.48	231.82	WP	Fresh		Golder	9.6	5.6	<0.05	0.03	<0.05				29		0.2	<0.5	1.4	1.1	9.1	0.4	<0.0001	0.16	<0.001	<0.02		0.005	<0.0001	<0.001	<0.005	<0.0001	0.0003
AMD102a	NSD0031	259.38	276.55	WP	Fresh		Golder	9.6	6.7	<0.05	0.01	<0.05				34		0.2	<0.5	<0.1	<0.1	5.7	0.2	<0.0001	0.17	<0.001	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0129	NSD0031	280.4	280.7	WP	Fresh		Golder	9.6	6.7	<0.05	<0.01	<0.05				35		<0.1	<0.5	7.1	2.1	3.7	0.2	<0.0001	0.13	<0.001	<0.02		0.005	<0.0001	<0.001	<0.005	<0.0001	0.0004
AMD # 0131	NSD0031	297.96	298.26	WP	Fresh		Golder	9.1	4.5	0.06	0.02	<0.05				24		0.3	<0.5	0.2	0.5	10	0.4	<0.0001	0.58	0.002	0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0133	NSD0031	321.98	322.38	WP	Fresh		Golder	8.6	5	<0.05	<0.01	<0.05				28		0.1	<0.5	3.9	2.5	2.7	0.2	<0.0001	0.13	<0.001	<0.02		0.005	<0.0001	<0.001	<0.005	<0.0001	0.0003
AMD # 0135	NSD0031	363.98	364.29	WP	Fresh		Golder	7.7	3.9	<0.05	<0.01	<0.05				22		0.2	<0.5	3.1	2.7	0.4	0.3	<0.0001	<0.005	<0.001	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0137	NSD0031	374.83	375.12	WP	Fresh		Golder	7.9	4.4	<0.05	0.01	0.05				23		0.1	<0.5	5	2	0.3	0.3	<0.0001	0.012	<0.001	<0.02		0.028	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0139	NSD0031	392.48	392.79	WP	Fresh		Golder	8	4.5	<0.05	0.01	<0.05				25		0.3	<0.5	3.4	3.3	0.3	0.6	<0.0001	0.033	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0141	NSD0031	416.93	417.25	WP	Fresh		Golder	7.7	8.5	<0.05	<0.01	<0.05				44		0.6	<0.5	10.6	4.5	0.2	0.1	<0.0001	<0.005	<0.001	<0.02		0.005	<0.0001	<0.001	<0.005	<0.0001	0.0003
AMD # 0143	NSD0031	437.77	438.09	WP	Fresh		Golder	7.9	9	<0.05	0.01	<0.05				48		0.1	<0.5	11.1	4.5	0.2	0.6	<0.0001	<0.005	<0.001	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0145	NSD0031	457.91	458.2	WP	Fresh		Golder	8.1	5	<0.05	<0.01	<0.05				27		0.5	<0.5	5.2	2.9	0.5	0.3	<0.0001	0.085	<0.001	<0.02		0.002	<0.0001	<0.001	<0.005	<0.0001	0.0002
AMD104a	NSD0032	6.47	30.16	WP	Oxide		Golder	7.2	2.8	0.15	0.03	0.15				5		1.3	4	5.9	1.9	5.1	0.3	<0.0001	0.13	<0.001	<0.02		0.007	<0.0001	<0.001	<0.005	0.0001	0.0004
AMD109a	NSD0032	35	68.32	WP	Fresh		Golder	9.3	8.7	<0.05	0.09	0.05				44		0.8	<0.5	3.7	1.3	12.6	2.2	<0.0001	0.048	<0.001	<0.02		0.042	<0.0001	<0.001	<0.005	0.0003	<0.0001
AMD113	NSD0032	76.52	76.84	WP	Fresh		Golder	9.6	8.2	<0.05	0.05	<0.05				42		0.3	<0.5	6.4	2.1	7.3	0.4	<0.0001	0.17	<0.001	<0.02		0.011	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD115	NSD0032	95.75	96.18	WP	Fresh		Golder	9.6	7.8	<0.05	0.03	<0.05				40		0.5	<0.5	6	2	7.5	0.4	<0.0001	0.14	<0.001	<0.02		0.02	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD118	NSD0032	112.8	113.15	WP	Fresh		Golder	9.5	4.3	<0.05	0.04	0.1				20		1.4	<0.5	<0.1	0.2	9.5	0.3	<0.0001	2.2	0.003	<0.02		<0.002	<0.0001	0.003	<0.005	0.0001	<0.0001
AMD119	NSD0032	117.35	117.71	WP	Fresh		Golder	9.5	7.2	<0.05	0.02	<0.05				37		0.3	<0.5	5.5	1.7	7.2	0.3	<0.0001	0.13	<0.001	<0.02		0.006	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD121	NSD0032	126.79	127.15	WP	Fresh		Golder	9.5	6.5	<0.05	<0.01	<0.05				34		0.2	<0.5	7.7	1.9	2.8	0.1	<0.0001	0.022	<0.001	<0.02		0.016	<0.0001	<0.001	<0.005	<0.0001	0.0006
AMD127	NSD0032	186.12	186.32	WP	Fresh		Golder	9.2	5.1	<0.05	0.01	<0.05				27		0.1	<0.5	2.8	1.6	6.1	0.2	<0.0001	0.067	<0.001	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0146	NSD0032	200.68	200.98	WP	Fresh		Golder	8.8	6.8	<0.05	0.02	<0.05				37		0.2	<0.5	2.4	2.3	9.7	0.4	<0.0001	0.041	<0.001	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	0.0002
AMD # 0148	NSD0032	224.19	224.56	WP	Fresh		Golder	9.2	6	<0.05	0.02	<0.05				32		0.4	<0.5	3.1	1.9	6.6	0.3	<0.0001	0.12	<0.001	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	0.0004
AMD # 0150	NSD0032	249.64	249.99	WP	Fresh		Golder	9.4	6.1	<0.05	0.02	<0.05				31		0.3	<0.5	1.1	1.2	11.3	0.4	<0.0001	0.25	<0.001	<0.02		0.053	<0.0001	<0.001	<0.005	<0.0001	0.0002
AMD # 0151	NSD0032	255.68	256.03	WP	Fresh		Golder	10	12.1	0.12	0.17	0.09				41		10	1	0.1	1	25.6	0.7	<0.0001	2.7	0.018	0.05		0.075	<0.0001	0.007	<0.005	0.0007	0.0003
AMD # 0154	NSD0032	273.79	274.07	WP	Fresh		Golder	9.4	8.1	0.11	0.06	<0.05				38		1.4	1	0.5	0.7	18.2	0.6	<0.0001	1.5	0.003	0.02		0.28	<0.0001	0.005	<0.005	0.0002	0.0004
AMD # 0156	NSD0032	283.31	283.61	WP	Fresh		Golder	9.8	9.9	<0.05	0.05	<0.05				44		1.3	1.8	1.8	1.8	24.3	0.4	<0.0001	0.34	0.002	<0.02		0.004	<0.0001	<0.001	<0.005	0.0001	0.0005
AMD # 0158	NSD0032	289.44	289.8	WP	Fresh		Golder	9.8	10.3	<0.05	0.07	0.05				45		1.9	1.3	0.7	0.7	19.9	0.4	<0.0001	0.42	0.003	<0.02		0.003	<0.0001	<0.001	<0.005	0.0001	<0.0001
AMD # 0160	NSD0032	311.87	312.26	WP	Fresh		Golder	9.5	8.9	<0.05	<0.01	<0.05				39		1	3	5.3	2	9.7	0.2	<0.0001	0.24	0.001	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh		Golder	9.1	9.4	<0.05	0.03	<0.05				49		0.7	<0.5	0.3	1.3	19.1	0.4	<0.0001	0.25	<0.001	<0.02		0.004	<0.0001	<0.001	<0.005	0.0001	0.0039
AMD # 0164	NSD0032	329.11	329.52	WP	Fresh		Golder	7.9	4.9	<0.05	0.01	<0.05				27		0.1	<0.5	0.7	1.1	9.6	0.3	<0.0001	0.017	<0.001	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 0167	NSD0032	343.73	344.04	WP	Fresh		Golder	7.6	5	<0.05	0.03	0.06				21		3.4	1.5	3.3	2.6	2.5	0.4	<0.0001	0.01	<0.001	<0.02		0.006	<0.0001	<0.001	<0.005	<0.0001	0.0004

Appendix A4: Deionised water leach

Sample ID	Hole ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	pH	EC	F	NH3 as N	NO3 as N	OH as CaCO3	CO3 as CaCO3	HCO3 as CaCO3	Alkalinity as CaCO3	Acidity as CaCO3	SO4	Cl	Ca	Mg	Na	K	Ag	Al	As	B	Be	Ba	Cd	Cr	Co	Cs	Cu
		From	To					pH units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
AMD # 0168	NSD00032	349.2	349.53	WP	Fresh		Golder	9.2	6.6	<0.05	0.02	<0.05				34		0.2	<0.5	2.9	1.5	10	0.3	<0.0001	0.068	<0.001	<0.02		0.005	<0.0001	<0.001	<0.005	<0.0001	0.0004
AMD # 0169	NSD00032	356.45	356.8	WP	Fresh		Golder	8.4	7.8	<0.05	0.01	<0.05				42		1.4	<0.5	5.9	3.2	6.3	0.3	<0.0001	0.21	<0.001	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	0.0003
AMD # 0174	NSD00032	421.98	422.39	WP	Fresh		Golder	8	11	<0.05	0.01	<0.05				57		2	<0.5	13.1	6.1	0.3	0.3	<0.0001	<0.005	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	0.0002
AMD # 0176	NSD00032	449.04	449.4	WP	Fresh		Golder	7.6	10.7	<0.05	0.01	<0.05				50		6.1	<0.5	9.6	7.5	0.2	0.6	<0.0001	<0.005	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	0.0003
AMD # 039	NSDR0387	184.65	184.96	WP	Fresh		Golder	10.3	14.2	<0.05	0.36	0.1				61		0.4	<0.5	0.2	0.3	22.7	1.3	<0.0001	0.38	0.002	0.03		0.004	<0.0001	0.004	<0.005	<0.0001	<0.0001
AMD # 041	NSDR0387	201.93	202.24	WP	Fresh		Golder	10.2	12.4	<0.05	0.2	<0.05				55		0.4	<0.5	0.9	0.6	19.2	1.1	<0.0001	0.18	<0.001	0.03		<0.002	<0.0001	0.002	<0.005	<0.0001	<0.0001
AMD # 043	NSDR0387	210.08	210.43	WP	Fresh		Golder	10.1	12.7	<0.05	0.18	<0.05				59		0.4	<0.5	3.4	1	16.9	1.1	<0.0001	0.086	<0.001	0.03		<0.002	<0.0001	0.002	<0.005	<0.0001	<0.0001
AMD # 045	NSDR0387	221.94	222.3	WP	Fresh		Golder	10	10	<0.05	0.13	0.06				43		1.6	<0.5	1.4	0.6	14.6	0.9	<0.0001	0.13	<0.001	0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 047	NSDR0387	233.78	234.13	WP	Fresh		Golder	10.4	12.5	<0.05	0.44	0.06				48		1.3	<0.5	<0.1	<0.1	18.9	0.9	<0.0001	0.55	0.005	0.04		0.004	<0.0001	0.002	<0.005	<0.0001	<0.0001
AMD # 049	NSDR0387	246.67	247	WP	Fresh		Golder	10.2	13.4	<0.05	0.36	0.09				58		1	<0.5	0.3	0.3	21.7	1.3	<0.0001	0.17	0.001	0.08		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 051	NSDR0387	259.19	259.56	WP	Fresh		Golder	10.1	12.1	<0.05	0.27	0.1				52		2.6	<0.5	<0.1	0.2	20	1.2	<0.0001	0.22	0.001	0.07		<0.002	<0.0001	0.001	<0.005	<0.0001	0.0017
AMD # 053	NSDR0387	279.3	279.62	WP	Fresh		Golder	10.1	12.3	<0.05	0.26	0.05				55		0.5	<0.5	1.4	0.5	21.3	1.5	<0.0001	0.13	<0.001	0.04		<0.002	<0.0001	0.002	<0.005	<0.0001	0.0002
AMD # 055	NSDR0387	306.92	307.32	WP	Fresh		Golder	10	12.9	<0.05	0.18	<0.05				60		0.2	<0.5	1.5	0.7	20.8	1.3	<0.0001	0.095	<0.001	0.07		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 057	NSDR0387	322.68	323.07	WP	Fresh		Golder	9.9	10.8	<0.05	0.2	0.07				49		0.6	<0.5	0.5	0.5	16.8	1.2	<0.0001	0.12	<0.001	0.05		<0.002	<0.0001	0.002	<0.005	<0.0001	0.0018
AMD # 059	NSDR0387	340.23	340.57	WP	Fresh		Golder	10.2	12.9	<0.05	0.42	0.05				54		3.3	<0.5	1	0.3	20.6	1.4	<0.0001	0.18	<0.001	0.07		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 061	NSDR0387	356.08	356.46	WP	Fresh		Golder	10.1	17	<0.05	0.5	0.11				69		6.7	<0.5	0.4	0.5	29.7	2	<0.0001	0.29	0.002	0.07		<0.002	<0.0001	0.001	<0.005	<0.0001	<0.0001
AMD # 063	NSDR0387	373.42	373.83	MP	Fresh		Golder	10.1	12.8	<0.05	0.21	<0.05				59		0.4	<0.5	2.4	1.2	17	1.2	<0.0001	0.12	<0.001	<0.02		0.005	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 065	NSDR0387	401.48	401.85	MP	Fresh		Golder	9.3	10.8	<0.05	0.04	<0.05				56		1.4	<0.5	5.1	2.1	12.9	1.2	<0.0001	0.38	<0.001	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD_1	NSDR0393	181.1	181.45	WP	Fresh		Golder	10.1	10.1	<0.05	0.13	<0.05				43		1.1	<0.5	2.1	0.3	14.8	0.9	<0.0001	0.7	0.002	<0.02		0.004	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD_3	NSDR0393	202.96	203.23	WP	Fresh		Golder	9.6	8.2	<0.05	0.08	0.06				39		1.1	<0.5	1.4	0.7	14	1	<0.0001	0.22	<0.001	<0.02		<0.002	<0.0001	0.002	<0.005	<0.0001	<0.0001
AMD_6	NSDR0393	222.46	222.75	WP	Fresh		Golder	10.2	15	<0.05	0.3	0.06				66		1.8	<0.5	2.2	0.3	27.1	1.7	<0.0001	0.73	0.002	<0.02		0.007	<0.0001	0.001	<0.005	<0.0001	<0.0001
AMD_7	NSDR0393	223.45	223.78	WP	Fresh		Golder	10.1	12.5	<0.05	0.17	<0.05				57		1.1	<0.5	1.9	0.4	19.7	1.2	<0.0001	0.65	0.001	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD_8	NSDR0393	226.74	227.08	WP	Fresh		Golder	10	12	<0.05	0.19	0.05				53		2.4	<0.5	1.3	0.2	21.6	1.5	<0.0001	1.1	0.002	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD_11	NSDR0393	231.44	231.8	WP	Fresh		Golder	10.1	14.2	<0.05	0.28	0.06				63		2.2	<0.5	1.1	0.3	27	1.8	<0.0001	0.8	<0.001	<0.02		0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD_13	NSDR0393	234.67	234.94	WP	Fresh		Golder	9.9	10	<0.05	0.09	<0.05				47		0.7	<0.5	1.6	0.5	15.5	1	<0.0001	0.35	<0.001	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 015	NSDR0393	238.46	238.82	WP	Fresh		Golder	7.9	1.6	<0.05	0.12	<0.05				6		1.7	<0.5	0.4	0.6	1	1.3	<0.0001	0.62	<0.001	<0.02		<0.002	<0.0001	0.001	<0.005	<0.0001	<0.0001
AMD # 017	NSDR0393	248.88	249.17	WP	Fresh		Golder	7.7	3.7	<0.05	0.1	<0.05				10		6.3	<0.5	1.8	1.5	1.3	0.9	<0.0001	0.28	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	0.0008
AMD # 019	NSDR0393	255.02	255.37	WP	Fresh		Golder	9.2	8.5	<0.05	0.06	<0.05				26		13.5	<0.5	4.7	1.1	9.6	1.3	<0.0001	0.16	<0.001	<0.02		0.011	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 021	NSDR0393	270.45	270.8	WP	Fresh		Golder	9.9	11.4	<0.05	0.16	<0.05				53		2.4	<0.5	3.5	0.6	18.4	1.5	<0.0001	0.75	<0.001	<0.02		0.009	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 023	NSDR0393	287.6	287.92	MP	Fresh		Golder	9.4	7.8	<0.05	0.14	<0.05				40		1.2	<0.5	5.4	1.2	7.4	2.1	<0.0001	0.65	0.002	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 025	NSDR0393	299.6	299.97	MP	Fresh		Golder	10	15.3	<0.05	0.25	0.07				64		6.9	<0.5	0.2	0.4	29.7	2	<0.0001	0.56	<0.001	<0.02		0.006	<0.0001	0.002	<0.005	<0.0001	<0.0001
AMD # 027	NSDR0393	328.83	329.19	MP	Fresh		Golder	9.5	4.4	<0.05	0.04	<0.05				22		0.3	<0.5	5.5	0.4	1.9	0.4	<0.0001	0.035	<0.001	<0.02		0.003	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 029	NSDR0393	348.67	349	MP	Fresh		Golder	10.1	12.6	<0.05	0.18	<0.05				57		1.1	<0.5	1.7	0.3	20.9	1.3	<0.0001	0.62	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 031	NSDR0393	378.65	379.06	MP	Fresh		Golder	7.9	2.7	<0.05	0.06	<0.05				10		2.8	<0.5	1.2	1.4	0.3	2.4	<0.0001	0.61	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 033	NSDR0393	395.11	395.52	MP	Fresh		Golder	8.3	4.3	<0.05	0.14	0.07				14		5.6	<0.5	1.9	1.3	0.5	4.6	<0.0001	0.46	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 035	NSDR0393	410.72	411	MP	Fresh		Golder	8.2	5.9	<0.05	0.06	<0.05				23		7.5	<0.5	4.4	2.7	0.3	1.6	<0.0001	0.38	<0.001	<0.02		<0.002	<0.0001	<0.001	<0.005	<0.0001	<0.0001
AMD # 037	NSDR0393	422.71	423.02	MP	Fresh		Golder	9.5	9.3	<0.05	0.08	<0.05				46		1.4	<0.5	4.1	0.8	12.6	1.3	<0.0001	0.71	<0.001	<0.02		0.005	<0.0001	<0.001	<0.005	<0.0001	<0.0001

Tailings samples

Sample ID	Type	Description	Source	pH	EC	F	NH3 as N	NO3 as N	OH as CaCO3	CO3 as CaCO3	HCO3 as CaCO3	Alkalinity as CaCO3	Acidity as CaCO3	SO4	Cl	Ca	Mg	Na	K	Ag	Al	As	B	Be	Ba	Cd	Cr	Co	Cs	Cu
				pH units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
(3283 Tails) 1			GHD						<1	29	23	52	<1	4	<1	3	<1	24	1		0.29	0.002		<0.001	0.233	<0.0001	<0.001	<0.001		<0.001
(3283 - Year 1-7Tailings)			GHD						<1	15	30	46	<1	5	1	6	3	13	<1		0.03	0.012		<0.001	0.227	<0.0001	<0.001	<0.001		<0.001
(3283 Tails) 2			GHD						<1	30	22	53	<1	4	<1	4	<1	25	2		0.31	0.005		<0.001	0.309	<0.0001	<0.001	<0.001		<0.001
A15967 VARFR06	Wet-Fresh	NON-MAGS	Golder	8	18.6	<0.1	0.02	1.8				45		24.1	1.9	13.6	6.4	10	2.7	<0.005	0.012	0.001	0.03		0.048	<0.002	<0.001	<0.005	0.0002	0.08
A15967 VARFR10	Wet-Fresh	NON-MAGS	Golder	8.2	8.3	<0.1	0.01	<0.2				35		6.2	1.4	5.9	4.5	3.1	0.6	<0.005	0.029	<0.001	0.03		0.014	<0.002	<0.001	<0.005	<0.0001	<0.002
A16236 Fig 5 (Blend)	Wet-Fresh	PRIMARY AND REGRIND WET LIMS	Golder	7.8	24	-	-	3				35		1.7	1	7	4.1	11.1	2.5	<0.005	0.056	<0.001	0.59		0.011	<0.002	0.01	<0.005	<0.0001	<0.002
Batch Plant Fresh Coarse Cobing Non Mags (A1	Dry-Fresh	Stage 2 Process Plant Dry rejects	Golder	7.6	5.5	0.4	0.06	2.3				25		8.6	2.3	7.1	1	1.5	0.5	<0.005	0.58	<0.001	0.04		0.025	<0.002	0.002	<0.005	<0.0001	<0.002
Batch Plant Oxide Coarse Cobing Non Mags (A1	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7	2.1	0.2	0.04	<0.2				10		3.4	3.4	0.8	0.5	2.4	<0.1	<0.005	0.018	<0.001	0.03		0.013	<0.002	<0.001	<0.005	<0.0001	<0.002
VARFR01 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	9.3	12	<0.1	0.23	<0.2				50		14.4	<0.5	3.2	0.7	21.7	3.3	<0.005	0.85	0.001	0.05		0.008	<0.002	0.005	<0.005	0.0002	<0.002
VARFR09 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	8	7.8	<0.1	0.02	<0.2				50		2.1	<0.5	4.3	2.9	8.6	0.7	<0.005	0.071	<0.001	0.04		0.013	<0.002	<0.001	<0.005	<0.0001	<0.002
VAROX03 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	7.5	3.4	0.3	0.06	<0.2				25		1.8	1.3	1.8	1.8	3.5	0.6	<0.005	0.52	<0.001	0.04		0.019	<0.002	0.001	<0.005	0.0003	0.002
VAROX09 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	9.7	12.9	0.2	0.05	<0.2				65		7.5	<0.5	4.4	2	21	2.1	<0.005	0.16	0.002	0.05		0.008	<0.002	<0.001	<0.005	0.0001	<0.002

Appendix A4: Deionised water leach

Sample ID	Hole ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Fe	Hg	Li	Mn	Mo	Ni	P	Pb	Rb	S	Sb	Se	Si	Sr	Th	U	V	Zn
		From	To					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
E889501	NS0077	0	4	WP	Oxide		GHD	<0.05	<0.0001		0.009		0.001		<0.001				<0.01					<0.01	0.388
E889505	NS0077	8	12	WP	Oxide		GHD	<0.05	<0.0001		0.003		<0.001		<0.001				<0.01					<0.01	0.166
E889511	NS0077	20	24	WP	Oxide		GHD	4.11	<0.0001		0.368		0.003		<0.001				<0.01					<0.01	0.158
E889515	NS0077	28	32	WP	Oxide		GHD	4.83	<0.0001		0.576		0.005		<0.001				<0.01					<0.01	0.326
E889591	NS0077	178	182	WP	Fresh		GHD	<0.05	<0.0001		1.5		0.009		<0.001				<0.01					<0.01	0.517
E889643	NS0078	0	4	WP	Oxide		GHD	<0.05	<0.0001		0.006		<0.001		<0.001				<0.01					<0.01	0.231
E889648	NS0078	8	12	WP	Oxide		GHD	9.62	<0.0001		0.008		0.004		<0.001				<0.01					<0.01	0.522
E889653	NS0078	18	24	WP	Oxide		GHD	6.78	<0.0001		0.013		0.006		<0.001				<0.01					<0.01	0.618
E889657	NS0078	26	32	WP	Oxide		GHD	5.69	<0.0001		0.009		0.007		<0.001				<0.01					<0.01	0.452
E889683	NS0078	78	80	WP	Fresh		GHD	6.94	<0.0001		0.099		0.004		<0.001				<0.01					<0.01	0.281
E889781	NS0078	274	278	WP	Fresh		GHD	11	0.0001		0.163		0.01		0.002				<0.01					<0.01	0.242
E889833	NS0079	94	98	WP	Fresh		GHD	<0.05	<0.0001		0.025		0.001		<0.001				<0.01					<0.01	0.375
X068378	NS0083	158	162	MP	Fresh		GHD	1.88	<0.0001		0.028		0.004		<0.001				<0.01					<0.01	0.341
X068517	NS0084	140	144	WP	Fresh		GHD	3.16	<0.0001		0.196		0.006		<0.001				<0.01					<0.01	0.238
X068527	NS0084	158	162	WP	Fresh		GHD	0.07	<0.0001		0.787		0.018		<0.001				<0.01					<0.01	0.369
X068544	NS0084	190	194	WP	Fresh		GHD	4.64	<0.0001		0.173		0.004		<0.001				<0.01					<0.01	0.141
X068586	NS0084	270	274	WP	Fresh		GHD	0.35	<0.0001		0.008		<0.001		<0.001				<0.01					<0.01	0.116
X068592	NS0085	0	2	WP	Oxide		GHD	2.86	<0.0001		0.035		0.003		<0.001				<0.01					<0.01	0.263
X068597	NS0085	10	2	WP	Oxide		GHD	18.7	<0.0001		0.042		0.003		<0.001				<0.01					<0.01	0.168
X068601	NS0085	18	22	WP	Oxide		GHD	4.8	<0.0001		0.171		0.002		<0.001				<0.01					<0.01	0.244
X068607	NS0085	30	34	WP	Oxide		GHD	3.18	<0.0001		0.323		0.003		<0.001				<0.01					<0.01	0.224
X068621	NS0085	58	62	WP	Fresh		GHD	0.44	<0.0001		0.022		0.002		<0.001				<0.01					<0.01	0.245
X068638	NS0085	90	94	WP	Fresh		GHD	<0.05	<0.0001		0.005		0.001		<0.001				<0.01					<0.01	0.267
X068699	NS0085	208	212	WP	Fresh		GHD	0.1	<0.0001		0.008		<0.001		<0.001				<0.01					<0.01	0.209
X068741	NS0086	8	12	WP	Oxide		GHD	<0.05	<0.0001		0.004		0.001		<0.001				<0.01					<0.01	0.312
X068751	NS0086	28	32	WP	Oxide		GHD	3.93	<0.0001		0.006		0.004		<0.001				<0.01					<0.01	0.279
X068884	NS0087	8	12	WP	Oxide		GHD	11.2	<0.0001		0.018		0.003		0.001				<0.01					<0.01	0.327
X068923	NS0087	84	88	WP	Fresh		GHD	6.44	<0.0001		0.111		0.007		<0.001				<0.01					<0.01	0.425
X068925	NS0087	88	92	WP	Fresh		GHD	2.1	<0.0001		0.031		0.002		<0.001				<0.01					<0.01	0.148
X070079	NS0087	380	384	WP	Fresh		GHD	<0.05	<0.0001		0.004		<0.001		<0.001				<0.01					<0.01	0.341
X070089	NS0088	0	2	WP	Oxide		GHD	<0.05	<0.0001		0.029		0.001		<0.001				<0.01					<0.01	0.228
X070093	NS0088	8	12	WP	Oxide		GHD	13.3	<0.0001		0.021		0.003		<0.001				<0.01					<0.01	0.269
X070145	NS0088	108	112	WP	Fresh		GHD	<0.05	<0.0001		0.112		0.001		<0.001				<0.01					<0.01	0.388
X070167	NS0088	150	154	WP	Fresh		GHD	<0.05	<0.0001		0.077		<0.001		<0.001				<0.01					<0.01	0.249
X070233	NS0088	280	284	WP	Fresh		GHD	<0.05	<0.0001		0.021		<0.001		<0.001				<0.01					<0.01	0.275
X070267	NS0088	346	350	WP	Fresh		GHD	<0.05	<0.0001		0.028		0.002		<0.001				<0.01					<0.01	0.35
X070269	NS0089	0	4	WP	Oxide		GHD	4.45	<0.0001		0.013		0.004		0.001				<0.01					<0.01	0.334
X070299	NS0089	60	64	WP	Oxide		GHD	4.91	<0.0001		0.186		0.014		<0.001				<0.01					<0.01	0.219
X070313	NS0089	88	92	WP	Fresh		GHD	0.07	<0.0001		0.015		0.001		<0.001				<0.01					<0.01	0.254
X070333	NS0089	128	132	WP	Fresh		GHD	0.33	<0.0001		0.039		0.002		<0.001				<0.01					<0.01	0.35
X070359	NS0089	178	180	WP	Fresh		GHD	<0.05	<0.0001		0.058		<0.001		<0.001				<0.01					<0.01	0.176
X070375	NS0089	210	214	WP	Fresh		GHD	<0.05	<0.0001		0.048		0.001		<0.001				<0.01					<0.01	0.351
X070405	NS0089	268	272	WP	Fresh		GHD	0.09	<0.0001		0.047		0.002		<0.001				<0.01					<0.01	0.366
X070451	NS0089	360	364	WP	Fresh		GHD	<0.05	<0.0001		0.05		0.001		<0.001				<0.01					<0.01	0.296
X070473	NS0090	0	4	WP	Oxide		GHD	0.28	<0.0001		0.003		0.001		<0.001				<0.01					<0.01	0.268
X070477	NS0090	8	12	WP	Oxide		GHD	6.56	<0.0001		0.01		0.004		<0.001				<0.01					<0.01	0.304
X070483	NS0090	20	24	WP	Oxide		GHD	8.16	<0.0001		0.072		0.003		<0.001				<0.01					<0.01	0.116
X070569	NS0090	190	194	WP	Fresh		GHD	2.75	<0.0001		0.109		0.003		<0.001				<0.01					<0.01	0.191
X070609	NS0090	268	272	WP	Fresh		GHD	1.73	<0.0001		0.082		0.001		<0.001				<0.01					<0.01	0.193
X070779	NS0092	40	44	WP	Fresh		GHD	1.35	<0.0001		0.062		0.001		<0.001				<0.01					<0.01	0.129
X070783	NS0092	48	52	WP	Fresh		GHD	1.68	<0.0001		0.046		0.002		<0.001				<0.01					<0.01	0.125
X070839	NS0092	158	162	WP	Fresh		GHD	<0.05	<0.0001		0.005		<0.001		<0.001				<0.01					<0.01	0.164
X071013	NS0093	216	220	WP	Fresh		GHD	<0.05	<0.0001		0.011		0.001		<0.001				<0.01					<0.01	0.312
X071061	NS0094	28	32	WP	Oxide		GHD	5.56	<0.0001		0.402		0.006		<0.001				<0.01					<0.01	0.349
X071127	NS0094	160	164	WP	Fresh		GHD	3.38	<0.0001		0.321		0.002		<0.001				<0.01					<0.01	0.151
X071205	NS0095	30	34	WP	Oxide		GHD	9.61	<0.0001		1.09		0.006		<0.001				<0.01					<0.01	0.286
X071209	NS0095	38	42	WP	Oxide		GHD	17.1	<0.0001		1.23		0.01		<0.001				<0.01					<0.01	0.247
X071328	NS0096	20	24	WP	Oxide		GHD	5.03	<0.0001		0.742		0.003		<0.001				<0.01					<0.01	0.281
X071353	NS0096	70	74	WP	Fresh		GHD	0.38	<0.0001		0.02		0.001		<0.001				<0.01					<0.01	0.252
X071379	NS0096	120	124	WP	Fresh		GHD	2.23	<0.0001		0.088		0.002		<0.001				<0.01					<0.01	0.093
X071435	NS0096	230	234	WP	Fresh		GHD	2.34	<0.0001		0.056		0.003		<0.001				<0.01					<0.01	0.218
X071476	NS0097	28	32	WP	Oxide		GHD	16.4	<0.0001		1.41		0.028		<0.001				<0.01					<0.01	0.277
X071482	NS0097	40	44	WP	Fresh		GHD	0.41	<0.0001		8.77		0.168		<0.001				0.01					<0.01	0.53
X071606	NS0098	0	4	WP	Oxide		GHD	8.34	<0.0001		0.011		0.005		0.001				<0.01					<0.01	0.265
X071616	NS0098	20	24	WP	Oxide		GHD	5.12	<0.0001		0.01		0.001		<0.001				<0.01					<0.01	0.163
X071634	NS0098	56	58	WP	Fresh		GHD	<0.05	<0.0001		0.613		0.004		<0.001				<0.01					<0.01	0.47
X071635	NS0098	58	62	WP	Fresh		GHD	0.19	<0.0001		0.391		0.002		<0.001				<0.01					<0.01	0.203
X071697	NS0098	180	184	WP	Fresh		GHD	0.06	<0.0001		0.015		0.001		<0.001				<0.01					<0.01	0.18
X071933	NS0100	78	82	WP	Fresh		GHD	9.68	<0.0001		0.128		0.011		<0.001				<0.01					<0.01	0.548
X073003	NS0106	2	4	WP	Oxide		GHD	6.53	<0.0001		0.019		0.006		0.002				<0.01					<0.01	0.482
X073006	NS0106	8	12	WP	Oxide		GHD	6.12	<0.0001		0.328		0.003		0.004				<0.01					<0.01	0.302
X073012	NS0106	20	24	WP	Oxide		GHD	5.1	<0.0001		0.603		0.005		<0.001				<0.01					<0.01	0.356
X073016	NS0106	28	32	WP	Oxide		GHD	6.08	<0.0001		0.609		0.006		<0.001				<0.01					<0.01	0.337
X073027	NS0106	48	52	WP	Fresh		GHD	3.67	<0.0001		0.315		0.003		<0.001				<0.01					<0.01	0.172
X073049	NS0106	92	96	WP	Fresh		GHD	0.7	<0.0001		0.028		0.002		<0.001				<0.01					<0.01	0.27
X073089	NS0106	170	172	WP	Fresh		GHD	0.08	<0.0001		0.009		0.001		<0.001				<0.01					<0.01	0.198
X073206	NS0107	120	124	KCC	Fresh		GHD	0.72	<0.0001		17.1		0.345		<0.001				<0.01					<0.01	0.514

Appendix A4: Deionised water leach

Sample ID	Hole ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Fe	Hg	Li	Mn	Mo	Ni	P	Pb	Rb	S	Sb	Se	Si	Sr	Th	U	V	Zn
		From	To					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
X073210	NS0107	128	132	KCC	Fresh		GHD	5.85	<0.0001		8.67		0.651		<0.001				<0.01					<0.01	1.13
X073216	NS0107	140	142	KCC	Fresh		GHD	<0.05	<0.0001		0.196		0.008		<0.001				<0.01					<0.01	0.243
X073220	NS0107	148	152	KCC	Fresh		GHD	0.89	<0.0001		2.65		0.738		<0.001				<0.01					<0.01	1.4
X073226	NS0107	160	164	KCC	Fresh		GHD	0.47	<0.0001		5.75		0.576		<0.001				<0.01					<0.01	0.804
X073231	NS0107	170	174	KCC	Fresh		GHD	<0.05	<0.0001		0.108		0.006		<0.001				<0.01					<0.01	0.231
X073338	NS0108	178	180	WP	Fresh		GHD	0.18	<0.0001		0.051		0.003		<0.001				<0.01					<0.01	0.291
X073994	NS0113	140	142	MP	Fresh		GHD	<0.05	<0.0001		0.023		0.001		<0.001				<0.01					<0.01	0.198
X074004	NS0113	158	162	MP	Fresh		GHD	<0.05	<0.0001		0.112		0.003		<0.001				<0.01					<0.01	0.191
X074024	NS0113	198	202	MP	Fresh		GHD	<0.05	<0.0001		0.03		<0.001		<0.001				<0.01					<0.01	0.173
X074347	NS0116	108	112	MP	Fresh		GHD	0.7	<0.0001		0.013		0.001		<0.001				<0.01					<0.01	0.156
X074359	NS0116	130	132	MP	Fresh		GHD	0.62	<0.0001		0.006		0.001		<0.001				<0.01					<0.01	0.135
X074532	NS0117	190	194	MP	Fresh		GHD	<0.05	<0.0001		0.004		<0.001		<0.001				<0.01					<0.01	0.1
X074649	NS0118	140	144	WP	Fresh		GHD	<0.05	<0.0001		0.624		0.008		<0.001				<0.01					<0.01	0.235
X074866	NS0120	206	210	WP	Fresh		GHD	0.46	<0.0001		0.016		0.001		<0.001				<0.01					<0.01	0.101
X075399	NS0124	130	134	MP	Fresh		GHD	12.6	<0.0001		0.048		0.018		0.002				<0.01					0.01	0.267
X138071	NS0128	150	154	WP	Fresh		GHD	<0.05	<0.0001		0.06		0.001		<0.001				<0.01					<0.01	0.246
X072252	NS0152	78	82	MP	Fresh		GHD	<0.05	<0.0001		0.009		<0.001		<0.001				<0.01					<0.01	0.181
X072273	NS0152	120	124	WP	Fresh		GHD	0.62	<0.0001		0.013		<0.001		<0.001				<0.01					<0.01	0.174
X072335	NS0152	244	248	WP	Fresh		GHD	2.56	<0.0001		0.04		0.003		<0.001				<0.01					<0.01	0.232
X072404	NS0153	98	102	WP	Fresh		GHD	6.33	<0.0001		0.125		0.003		<0.001				<0.01					<0.01	0.364
X072439	NS0153	168	172	WP	Fresh		GHD	<0.05	<0.0001		0.016		<0.001		<0.001				<0.01					<0.01	0.147
X072455	NS0153	200	204	WP	Fresh		GHD	11.5	<0.0001		11.3		2.78		<0.001				<0.01					<0.01	2.24
X072465	NS0153	220	224	WP	Fresh		GHD	0.09	<0.0001		0.254		0.028		<0.001				<0.01					<0.01	0.281
X072493	NS0154	18	22	WP	Oxide		GHD	4.3	<0.0001		0.524		0.003		<0.001				<0.01					<0.01	0.24
X072499	NS0154	30	34	WP	Fresh		GHD	3.6	<0.0001		0.235		0.003		<0.001				<0.01					<0.01	0.26
X072503	NS0154	38	42	WP	Fresh		GHD	0.67	<0.0001		0.032		0.003		<0.001				<0.01					<0.01	0.148
X072585	NS0154	200	204	WP	Fresh		GHD	6.99	0.0002		0.074		0.003		<0.001				<0.01					<0.01	0.26
X072677	NS0155	100	104	WP	Fresh		GHD	1.67	<0.0001		0.016		0.002		<0.001				<0.01					<0.01	0.147
X072681	NS0155	108	112	WP	Fresh		GHD	1.47	<0.0001		0.02		0.001		<0.001				<0.01					<0.01	0.204
X072921	NS0157	130	134	WP	Fresh		GHD	0.16	<0.0001		0.016		<0.001		<0.001				<0.01					<0.01	0.127
X141514	NS0158	66	70	MP	Fresh		GHD	<0.05	<0.0001		0.006		<0.001		<0.001				<0.01					<0.01	0.128
X141536	NS0158	110	114	MP	Fresh		GHD	<0.05	<0.0001		0.003		<0.001		<0.001				<0.01					<0.01	0.116
X141571	NS0158	178	182	MP	Fresh		GHD	<0.05	<0.0001		0.006		0.002		<0.001				<0.01					<0.01	0.173
X141776	NS0160	58	62	WP	Fresh		GHD	4.66	<0.0001		0.053		0.007		<0.001				<0.01					<0.01	0.2
X121052	NS0165	100	104	WP	Fresh		GHD	0.21	<0.0001		0.006		<0.001		<0.001				<0.01					<0.01	0.052
AMD66a	NSD0031	1	29.7	WP	Oxide		Golder	<0.005	<0.0001	<0.005	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0002	0.4	<0.0001	<0.001	5.4	0.003	<0.0001	<0.0001	<0.005	<0.005
AMD67a	NSD0031	37.48	63.08	WP	Fresh		Golder	0.89	<0.0001	<0.005	0.03	<0.02	<0.01	<0.1	<0.0001	0.0061	0.4	<0.0001	<0.001	6.2	0.013	<0.0001	<0.0001	<0.005	0.019
AMD77a	NSD0031	73.24	80	WP	Fresh		Golder	0.061	<0.0001	<0.005	0.002	<0.02	<0.01	<0.1	<0.0001	0.0069	1.3	0.0001	<0.001	3.7	0.003	<0.0001	<0.0001	<0.005	<0.005
AMD79a	NSD0031	80.38	94.1	WP	Fresh		Golder	0.78	<0.0001	<0.005	0.012	<0.02	<0.01	<0.1	<0.0001	0.0042	2.1	0.0003	<0.001	2.3	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD83	NSD0031	103.17	103.43	WP	Fresh		Golder	0.082	<0.0001	0.006	0.032	<0.02	<0.01	<0.1	<0.0001	0.0029	0.1	<0.0001	<0.001	1.7	0.002	<0.0001	<0.0001	<0.005	<0.005
AMD85	NSD0031	119	119.33	WP	Fresh		Golder	1.4	<0.0001	<0.005	0.01	<0.02	<0.01	<0.1	<0.0001	0.0029	2.6	0.0007	<0.001	4.1	<0.002	<0.0001	<0.0001	<0.005	0.01
AMD87	NSD0031	127.7	128	WP	Fresh		Golder	1.3	<0.0001	<0.005	0.004	<0.02	<0.01	<0.1	<0.0001	0.0017	1.5	0.0005	<0.001	4.8	<0.002	<0.0001	<0.0001	0.008	0.015
AMD89	NSD0031	144.77	145.06	WP	Fresh		Golder	1.1	0.0001	0.059	0.021	<0.02	<0.01	<0.1	0.0002	0.0033	8.1	0.0005	0.001	3.3	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD91	NSD0031	156	156.34	WP	Fresh		Golder	0.15	<0.0001	<0.005	0.004	<0.02	<0.01	<0.1	<0.0001	0.0003	0.1	<0.0001	<0.001	5.3	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD93	NSD0031	171.06	171.42	WP	Fresh		Golder	0.021	<0.0001	0.03	0.002	<0.02	<0.01	<0.1	<0.0001	0.0019	1.7	0.0001	<0.001	3.6	0.004	<0.0001	<0.0001	<0.005	<0.005
AMD95	NSD0031	192.53	192.82	WP	Fresh		Golder	0.23	<0.0001	0.016	0.005	<0.02	<0.01	<0.1	<0.0001	0.0015	0.3	0.0002	<0.001	4.3	0.003	<0.0001	<0.0001	<0.005	<0.005
AMD97	NSD0031	203	203.36	WP	Fresh		Golder	0.031	<0.0001	0.009	0.003	<0.02	<0.01	<0.1	<0.0001	0.001	0.4	0.0001	<0.001	2.8	0.004	<0.0001	<0.0001	<0.005	<0.005
AMD99	NSD0031	231.48	231.82	WP	Fresh		Golder	0.14	<0.0001	0.02	0.005	<0.02	<0.01	<0.1	<0.0001	0.0015	0.2	0.0002	<0.001	3.2	0.003	<0.0001	<0.0001	<0.005	<0.005
AMD102a	NSD0031	259.38	276.55	WP	Fresh		Golder	1.1	<0.0001	<0.005	0.02	<0.02	<0.01	<0.1	<0.0001	0.0011	0.5	0.0002	<0.001	9.8	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD # 0129	NSD0031	280.4	280.7	WP	Fresh		Golder	0.022	<0.0001	0.012	0.001	<0.02	<0.01	<0.1	<0.0001	0.0009	0.2	0.0002	<0.001	3	0.005	<0.0001	<0.0001	<0.005	<0.005
AMD # 0131	NSD0031	297.96	298.26	WP	Fresh		Golder	0.2	<0.0001	0.017	0.005	<0.02	<0.01	<0.1	<0.0001	0.0017	0.6	0.0006	<0.001	2.3	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD # 0133	NSD0031	321.98	322.38	WP	Fresh		Golder	0.007	<0.0001	0.007	0.025	<0.02	<0.01	<0.1	<0.0001	0.0011	0.2	0.0002	<0.001	1.2	0.007	<0.0001	<0.0001	<0.005	<0.005
AMD # 0135	NSD0031	363.98	364.29	WP	Fresh		Golder	0.008	<0.0001	<0.005	0.45	<0.02	<0.01	<0.1	<0.0001	0.0011	<0.1	0.0002	<0.001	1.2	0.009	<0.0001	<0.0001	<0.005	<0.005
AMD # 0137	NSD0031	374.83	375.12	WP	Fresh		Golder	0.048	<0.0001	<0.005	0.12	<0.02	<0.01	<0.1	<0.0001	0.0011	<0.1	0.0005	<0.001	1.9	0.014	<0.0001	<0.0001	<0.005	<0.005
AMD # 0139	NSD0031	392.48	392.79	WP	Fresh		Golder	0.012	<0.0001	0.006	0.099	<0.02	<0.01	<0.1	<0.0001	0.0005	0.2	0.0002	<0.001	1.1	0.01	<0.0001	<0.0001	<0.005	<0.005
AMD # 0141	NSD0031	416.93	417.25	WP	Fresh		Golder	0.013	<0.0001	0.008	0.33	<0.02	<0.01	<0.1	<0.0001	0.0005	0.3	<0.0001	<0.001	0.8	0.023	<0.0001	<0.0001	<0.005	<0.005
AMD # 0143	NSD0031	437.77	438.09	WP	Fresh		Golder	0.008	<0.0001	<0.005	0.21	<0.02	<0.01	<0.1	<0.0001	0.0006	<0.1	0.0001	<0.001	0.8	0.02	<0.0001	<0.0001	<0.005	<0.005
AMD # 0145	NSD0031	457.91	458.2	WP	Fresh		Golder	0.008	<0.0001	<0.005	0.065	<0.02	<0.01	<0.1	<0.0001	0.0012	0.2	0.0002	<0.001	1	0.011	<0.0001	<0.0001	<0.005	<0.005
AMD104a	NSD0032	6.47	30.16	WP	Oxide		Golder	0.01	<0.0001	0.012	0.002	<0.02	<0.01	<0.1	<0.0001	0.0005	0.2	<0.0001	<0.001	2.9	0.007	<0.0001	<0.0001	<0.005	<0.005
AMD109a	NSD0032	35	68.32	WP	Fresh		Golder	0.064	<0.0001	<0.005	0.009	<0.02	<0.01	<0.1	<0.0001	0.012	0.6	0.0001	<0.001	3.4	0.02	<0.0001	<0.0001	<0.005	<0.005
AMD113	NSD0032	76.52	76.84	WP	Fresh		Golder	0.019	<0.0001	0.008	0.005	<0.02	<0.01	<0.1	<0.0001	0.0032	0.3	0.0002	<0.001	3.3	0.01	<0.0001	<0.0001	<0.005	<0.005
AMD115	NSD0032	95.75	96.18	WP	Fresh		Golder	0.017	<0.0001	0.011	0.005	<0.02	<0.01	<0.1	<0.0001	0.0024	0.3	0.0002	<0.001	3.1	0.012	<0.0001	<0.0001	<0.005	<0.005
AMD118	NSD0032	112.8	113.15	WP	Fresh		Golder	0.88	<0.0001	0.006	0.003	<0.02	<0.01	<0.1	<0.0001	0.0018	7.2	0.0022	<0.001	4.6	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD119	NSD0032	117.35	117.71	WP	Fresh		Golder	0.061	<0.0001	0.013	0.005	<0.02	<0.01	<0.1	<0.0001	0.0017	0.6	0.0002	<0.001	2.4	0.013	<0.0001	<0.0001	<0.005	<0.005
AMD121	NSD0032	126.79	127.15	WP	Fresh		Golder	0.005	0.0002	0.007	0.007	<0.02	<0.01	<0.1	<0.0001	0.0009	0.2	0.0001	<0.001	2.7	0.013	<0.0001	<0.0001	<0.005	<0.005
AMD127	NSD0032	186.12	186.32	WP	Fresh		Golder	0.022	<0.0001	0.011	0.004	<0.02	<0.01	<0.1	<0.0001	0.0014	0.1	0.0004	<0.001	2.2	0.005	<0.0001	<0.0001	<0.005	<0.005
AMD # 0146	NSD0032	200.68	200.98	WP	Fresh		Golder	0.022	<0.0001	0.017	0.014	<0.02	<0.01	<0.1	<0.0001	0.0026	0.2	0.0004	<0.001	1.4	0.008	<0.0001	<0.0001	<0.005	0.029
AMD # 0148	NSD0032	224.19	224.56	WP	Fresh		Golder	0.017	<0.0001	0.01	0.007	<0.02	<0.01	<0.1	<0.0001	0.0021	0.5	0.0005	<0.001	1.9	0.008	<0.0001	<0.0001	<0.005	<0.005
AMD # 0150	NSD0032	249.64	249.99	WP	Fresh		Golder	0.41	<0.0001	0.01	0.019	<0.02	<0.01	<0.1	<0.0001	0.0019	0.9	0.0013	<0.001	2.8	0.004	<0.0001	<0.0001	<0.005	0.009
AMD # 0151	NSD0032	255.68	256.03	WP	Fresh		Golder	5.4	0.0001	0.012	0.025	<0.02	<0.01	<0.1	0.0012	0.0052	34	0.0077	0.001	14	<0.002	<0.0001	<0.0001	0.006	0.019
AMD # 0154	NSD0032	273.79	274.07	WP	Fresh		Golder	3.2	<0.0001	0.007	0.021	<0.02	<0.01	<0.1	0.0008	0.0024	3.9	0.0036	<0.001	4.7	0.003	<0.0001	<0.0001	<0.005	0.018
AMD # 0156	NSD0032	283.31	283.61	WP	Fresh		Golder	0.077	<0.0001	0.036	0.002	<0.02	<0.01	<0.1	<0.0001	0.0022	6.5	0.0021	<0.001	4.3	0.007	<0.0001	<0.0001	<0.005	0.023
AMD # 0158	NSD0032	289.44	289.8	WP	Fresh		Golder	0.048	0.0002	0.025	0.002	<0.02	<0.01	<0.1	<0.0001	0.0027	6.4	0.0033	<0.001	4.1	0.004	<0.0001	<0.0001	<0.005	0.011
AMD # 0160	NSD0032	311.87	312.26	WP	Fresh		Golder	0.022	<0.0001	0.012	0.002	<0.02	<0.01	<0.1	<0.0001	0.0014	3.5	0.0019	<0.001	2.5	0.01	<0.0001	<0.0001	<0.005	<0.005
AMD # 0163	NSD0032	326.3	326.7	WP	Fresh		Golder	0.28	0.0001	0.025	0.007	<0.02	<0.01	<0.1	<0.0001	0.0031	1.5	0.0021	<0.001	1.2	0.003	<0.0001	<0.0001	<0.005	0.014
AMD # 0164	NSD0032	329.11	329.52	WP	Fresh		Golder	0.27	<0.0001	0.009	0.016	<0.02	<0.01	<0.1	<0.0001	0.002	0.1	0.0011	<0.001	1.5	0.005	<0.0001	<0.0001	<0.005	<0.005
AMD # 0167	NSD0032	343.73	344.04	WP	Fresh		Golder	<0.005	<0.0001	0.005	0.063	<0.02	<0.01	<0.1	<0.0001	0.0023	1.6	0.0012	<0.001	1.3	0.018	<0.0001	<0.0001	<0.005	0.008

Appendix A4: Deionised water leach

Sample ID	Hole ID	Sample Interval		Lithology	Weathering	Waste/Ore	Source	Fe	Hg	Li	Mn	Mo	Ni	P	Pb	Rb	S	Sb	Se	Si	Sr	Th	U	V	Zn
		From	To					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
AMD # 0168	NSD0032	349.2	349.53	WP	Fresh		Golder	0.03	<0.0001	0.012	0.004	<0.02	<0.01	<0.1	<0.0001	0.0016	0.2	0.0015	<0.001	1.8	0.01	<0.0001	<0.0001	<0.005	<0.005
AMD # 0169	NSD0032	356.45	356.8	WP	Fresh		Golder	0.005	<0.0001	0.006	0.009	<0.02	<0.01	<0.1	<0.0001	0.0016	1.4	0.003	<0.001	0.8	0.017	<0.0001	<0.0001	<0.005	<0.005
AMD # 0174	NSD0032	421.98	422.39	WP	Fresh		Golder	<0.005	<0.0001	0.006	0.078	<0.02	<0.01	<0.1	<0.0001	0.001	0.7	0.0002	<0.001	0.6	0.018	<0.0001	<0.0001	<0.005	<0.005
AMD # 0176	NSD0032	449.04	449.4	WP	Fresh		Golder	<0.005	<0.0001	0.005	0.4	<0.02	0.01	<0.1	<0.0001	0.0007	2.4	<0.0001	<0.001	0.6	0.029	<0.0001	<0.0001	<0.005	<0.005
AMD # 039	NSDR0387	184.65	184.96	WP	Fresh		Golder	0.88	<0.0001	0.11	0.025	<0.02	<0.01	<0.1	<0.0001	0.0066	0.3	<0.0001	<0.001	8.7	<0.002	<0.0001	<0.0001	<0.005	0.012
AMD # 041	NSDR0387	201.93	202.24	WP	Fresh		Golder	0.44	<0.0001	0.072	0.007	<0.02	<0.01	<0.1	<0.0001	0.0058	0.3	0.0001	<0.001	5.5	0.003	<0.0001	<0.0001	<0.005	0.017
AMD # 043	NSDR0387	210.08	210.43	WP	Fresh		Golder	0.031	<0.0001	0.078	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0058	0.4	<0.0001	<0.001	4.8	0.007	<0.0001	<0.0001	<0.005	<0.005
AMD # 045	NSDR0387	221.94	222.3	WP	Fresh		Golder	0.42	<0.0001	0.068	0.007	<0.02	<0.01	<0.1	<0.0001	0.0047	1.1	0.0002	<0.001	5.1	0.003	<0.0001	<0.0001	<0.005	<0.005
AMD # 047	NSDR0387	233.78	234.13	WP	Fresh		Golder	1.2	<0.0001	0.069	0.006	<0.02	<0.01	<0.1	<0.0001	0.0047	0.7	0.0004	<0.001	11	<0.002	<0.0001	<0.0001	<0.005	0.018
AMD # 049	NSDR0387	246.67	247	WP	Fresh		Golder	0.9	<0.0001	0.073	0.012	<0.02	<0.01	<0.1	<0.0001	0.0061	0.7	0.0001	<0.001	7.3	<0.002	<0.0001	<0.0001	<0.005	0.024
AMD # 051	NSDR0387	259.19	259.56	WP	Fresh		Golder	1.7	<0.0001	0.08	0.026	<0.02	<0.01	<0.1	0.0002	0.0064	1.3	0.0003	<0.001	7.3	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD # 053	NSDR0387	279.3	279.62	WP	Fresh		Golder	0.55	<0.0001	0.071	0.008	<0.02	<0.01	<0.1	<0.0001	0.0064	0.3	0.0001	<0.001	5	0.003	<0.0001	<0.0001	<0.005	<0.005
AMD # 055	NSDR0387	306.92	307.32	WP	Fresh		Golder	0.27	<0.0001	0.059	0.004	<0.02	<0.01	<0.1	<0.0001	0.006	<0.1	<0.0001	<0.001	4.7	0.003	<0.0001	<0.0001	<0.005	<0.005
AMD # 057	NSDR0387	322.68	323.07	WP	Fresh		Golder	0.75	<0.0001	0.062	0.014	<0.02	<0.01	<0.1	0.0003	0.006	0.4	<0.0001	<0.001	4.5	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD # 059	NSDR0387	340.23	340.57	WP	Fresh		Golder	0.45	<0.0001	0.077	0.004	<0.02	<0.01	<0.1	<0.0001	0.0064	1.9	0.0001	<0.001	6.3	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD # 061	NSDR0387	356.08	356.46	WP	Fresh		Golder	1	<0.0001	0.1	0.008	<0.02	<0.01	<0.1	<0.0001	0.0089	4.4	0.0003	<0.001	6.8	<0.002	<0.0001	<0.0001	<0.005	<0.005
AMD # 063	NSDR0387	373.42	373.83	MP	Fresh		Golder	0.043	<0.0001	0.084	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0056	0.5	0.0001	<0.001	6.7	0.01	<0.0001	<0.0001	<0.005	<0.005
AMD # 065	NSDR0387	401.48	401.85	MP	Fresh		Golder	<0.005	<0.0001	0.024	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0056	1.2	<0.0001	<0.001	1.1	0.011	<0.0001	<0.0001	<0.005	0.016
AMD_1	NSDR0393	181.1	181.45	WP	Fresh		Golder	0.26	<0.0001	0.026	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0037	0.8	0.0003	<0.001	5.5	0.012	<0.0001	<0.0001	<0.005	0.014
AMD_3	NSDR0393	202.96	203.23	WP	Fresh		Golder	0.15	<0.0001	0.04	0.002	<0.02	<0.01	<0.1	<0.0001	0.004	0.5	0.0001	<0.001	2.3	0.004	<0.0001	<0.0001	<0.005	<0.005
AMD_6	NSDR0393	222.46	222.75	WP	Fresh		Golder	0.21	<0.0001	0.054	0.001	<0.02	<0.01	<0.1	<0.0001	0.0063	1	0.0007	<0.001	6.3	0.023	<0.0001	<0.0001	0.005	<0.005
AMD_7	NSDR0393	223.45	223.78	WP	Fresh		Golder	0.082	<0.0001	0.044	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0054	0.8	0.0005	<0.001	4.5	0.018	<0.0001	<0.0001	<0.005	<0.005
AMD_8	NSDR0393	226.74	227.08	WP	Fresh		Golder	0.35	<0.0001	0.034	0.003	<0.02	<0.01	<0.1	<0.0001	0.0061	2.1	0.0007	<0.001	4.6	0.013	<0.0001	<0.0001	<0.005	<0.005
AMD_11	NSDR0393	231.44	231.8	WP	Fresh		Golder	0.41	<0.0001	0.059	0.006	<0.02	<0.01	<0.1	<0.0001	0.0066	1.1	0.0004	<0.001	4.6	0.011	<0.0001	<0.0001	<0.005	<0.005
AMD_13	NSDR0393	234.67	234.94	WP	Fresh		Golder	0.26	0.0002	0.07	0.003	<0.02	<0.01	<0.1	<0.0001	0.0043	0.5	0.0001	<0.001	3.4	0.01	<0.0001	<0.0001	<0.005	<0.005
AMD # 015	NSDR0393	238.46	238.82	WP	Fresh		Golder	0.14	<0.0001	<0.005	<0.001	<0.02	<0.01	<0.1	<0.0001	0.004	0.8	0.0003	<0.001	1.8	0.006	<0.0001	<0.0001	<0.005	0.007
AMD # 017	NSDR0393	248.88	249.17	WP	Fresh		Golder	0.019	<0.0001	<0.005	0.003	<0.02	<0.01	<0.1	<0.0001	0.0044	3.3	0.0003	<0.001	1.4	0.006	<0.0001	<0.0001	<0.005	<0.005
AMD # 019	NSDR0393	255.02	255.37	WP	Fresh		Golder	<0.005	<0.0001	<0.005	0.003	<0.02	<0.01	<0.1	<0.0001	0.0048	7.3	0.0002	<0.001	1.2	0.025	<0.0001	<0.0001	<0.005	<0.005
AMD # 021	NSDR0393	270.45	270.8	WP	Fresh		Golder	0.027	<0.0001	0.021	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0056	1.8	<0.0001	<0.001	3.4	0.022	<0.0001	<0.0001	<0.005	<0.005
AMD # 023	NSDR0393	287.6	287.92	MP	Fresh		Golder	0.005	<0.0001	<0.005	<0.001	<0.02	<0.01	<0.1	0.0001	0.0075	0.8	<0.0001	<0.001	2.3	0.029	<0.0001	<0.0001	<0.005	<0.005
AMD # 025	NSDR0393	299.6	299.97	MP	Fresh		Golder	1.5	<0.0001	0.12	0.027	<0.02	<0.01	<0.1	<0.0001	0.0078	4.1	0.0003	<0.001	4.9	0.004	<0.0001	<0.0001	<0.005	<0.005
AMD # 027	NSDR0393	328.83	329.19	MP	Fresh		Golder	0.026	<0.0001	0.009	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0014	0.3	<0.0001	<0.001	4.5	0.029	<0.0001	<0.0001	<0.005	0.028
AMD # 029	NSDR0393	348.67	349	MP	Fresh		Golder	0.12	<0.0001	0.11	<0.001	<0.02	<0.01	<0.1	<0.0001	0.005	0.9	<0.0001	<0.001	4.5	0.01	<0.0001	<0.0001	<0.005	0.009
AMD # 031	NSDR0393	378.65	379.06	MP	Fresh		Golder	0.045	<0.0001	<0.005	0.001	<0.02	<0.01	<0.1	<0.0001	0.0046	1	0.0005	<0.001	1.8	0.004	<0.0001	<0.0001	<0.005	<0.005
AMD # 033	NSDR0393	395.11	395.52	MP	Fresh		Golder	0.043	<0.0001	<0.005	0.003	<0.02	<0.01	<0.1	<0.0001	0.012	2.2	0.0086	<0.001	2.8	0.005	<0.0001	<0.0001	<0.005	<0.005
AMD # 035	NSDR0393	410.72	411	MP	Fresh		Golder	0.005	<0.0001	<0.005	0.009	<0.02	<0.01	<0.1	<0.0001	0.0038	3.6	0.0013	<0.001	1.4	0.011	<0.0001	<0.0001	<0.005	<0.005
AMD # 037	NSDR0393	422.71	423.02	MP	Fresh		Golder	0.009	<0.0001	<0.005	<0.001	<0.02	<0.01	<0.1	<0.0001	0.0054	1.1	<0.0001	<0.001	2.2	0.016	<0.0001	<0.0001	<0.005	0.018

Tailings samples

Sample ID	Type	Description	Source	Fe	Hg	Li	Mn	Mo	Ni	P	Pb	Rb	S	Sb	Se	Si	Sr	Th	U	V	Zn
				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
(3283 Tails) 1			GHD	0.46	<0.0001		0.011		<0.001		<0.001				<0.01					<0.01	0.019
(3283 - Year 1-7Tailings)			GHD	0.1	<0.0001		0.004		<0.001		<0.001				<0.01					<0.01	0.012
(3283 Tails) 2			GHD	0.56	<0.0001		0.013		0.005		0.001				<0.01					<0.01	0.031
A15967 VARFR06	Wet-Fresh	NON-MAGS	Golder	0.11	<0.0001	<0.005	0.025	0.002	0.019	<0.1	<0.0001	0.013		<0.0001	<0.001	3.3	0.052	<0.0001	<0.0001	<0.005	0.005
A15967 VARFR10	Wet-Fresh	NON-MAGS	Golder	0.014	<0.0001	<0.005	0.019	0.005	<0.001	<0.1	<0.0001	0.0025		0.0004	<0.001	1.6	0.019	<0.0001	<0.0001	<0.005	<0.005
A16236 Fig 5 (Blend)	Wet-Fresh	PRIMARY AND REGRIND WET LIMS	Golder	0.015	0.0025	0.008	0.027	0.007	<0.001	0.2	<0.0001	0.0097		0.002	<0.001	3.1	0.013	<0.0001	<0.0001	<0.005	0.23
Batch Plant Fresh Coarse Cobing Non Mags (A1	Dry-Fresh	Stage 2 Process Plant Dry rejects	Golder	0.29	<0.0001	<0.005	0.002	<0.001	<0.001	<0.1	<0.0001	0.0011		<0.0001	<0.001	7.9	0.042	<0.0001	<0.0001	<0.005	<0.005
Batch Plant Oxide Coarse Cobing Non Mags (A1	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	0.062	<0.0001	<0.005	0.004	<0.001	<0.001	<0.1	<0.0001	0.0004		<0.0001	<0.001	7	0.005	<0.0001	<0.0001	<0.005	<0.005
VARFR01 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	1.4	<0.0001	<0.005	0.015	0.001	0.001	<0.1	<0.0001	0.013		0.0001	<0.001	4.8	0.011	<0.0001	<0.0001	<0.005	0.015
VARFR09 Dry LIMs Non Mags (A16166)	Dry-Fresh	Stage 2 Process Plant Dry Rejects	Golder	0.032	0.0002	<0.005	0.004	0.001	<0.001	<0.1	<0.0001	0.0037		0.0004	<0.001	2	0.012	<0.0001	<0.0001	<0.005	<0.005
VAROX03 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	2.5	<0.0001	<0.005	0.35	<0.001	0.002	<0.1	<0.0001	0.0058		<0.0001	<0.001	13	0.014	<0.0001	<0.0001	<0.005	<0.005
VAROX09 Dry MIMS Non Mags (A16166)	Dry-Oxide	Stage 1 Process Plant Dry Rejects	Golder	0.039	0.0001	0.013	0.003	0.001	<0.001	<0.1	<0.0001	0.009		0.004	<0.001	3.9	0.012	<0.0001	<0.0001	<0.005	<0.005

Appendix A5: Kinetic (column) tests

					Analyte:	pH Value	EC @ 25°C	OH as CaCO3	CO3 as CaCO3	HCO3 as CaCO3	Alkalinity as CaCO3	Acidity as CaCO3	SO4	Cl	Ca	Mg	Na	K	Al	As	Be	Ba
Sample ID	Kinetic Leach	Sample date	Sample weight (kg)	Volume leachate collected (L)	Units:	pH Unit	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
					LOR:	0.01	1	1	1	1	1	1	1	1	1	1	1	1	0.01	0.001	0.001	0.001
Col 1 - Chert	Leach 1	05/12/2012	2	0.43		8.64	2160	0.5	16	98	114	0.5	877	24	2	0.5	488	38		0.004	0.0005	0.045
Col 1 (Footwall)	Leach 5	2/01/2013	2	0.51		8.77	465	0.5	21	142	162	3	69	5	0.5	0.5	98	8	0.49	0.009	0.0005	0.08
Col 1 (Footwall)	Leach 10	7/02/2013	2	0.43		9.46	421	0.5	85	120	205	0.5	23	2	0.5	0.5	92	7	0.65	0.014	0.0005	0.122
Col 1 (Footwall)	Leach 14	07/03/2013	2	0.47		9.02	354	0.5	34	148	182	2	14	0.5	0.5	0.5	84	9	0.48	0.01	0.0005	0.082
Col 1 (Footwall)	Leach 18	04/04/2013	2	0.47		9.26	313	0.5	41	112	153	0.5	12	0.5	0.5	0.5	67	8	0.55	0.007	0.0005	0.086
Col 1 (Footwall)	Leach 22	02/05/2013	2	0.43		8.14	109	0.5	0.5	57	57	2	5	0.5	0.5	0.5	24	2	0.08	0.002	0.0005	0.04
Col 1 (Footwall)	Leach 27	06/06/2013	2	0.46		9	284	0.5	31	116	146	0.5	7	0.5	0.5	0.5	66	6	0.32	0.004	0.0005	0.108
Col 1 (Footwall)	Leach 31	04/07/2013	2	0.43		8.71	204	0.5	13	95	108	2	4	0.5	0.5	0.5	48	6	0.39	0.003	0.0005	0.091
Col 1 (Footwall)	Leach 36	06/08/2013	2	0.45		8.56	238	0.5	8	99	108	0.5	6	0.5	2	0.5	55	6	0.27	0.003	0.106	0.0005
Col 1 (Footwall)	Leach 44	01/10/2013	2	0.45		7.74	213	0.5	0.5	32	32	2	5	0.5	2	1	37	4	0.07	0.0005	0.0005	0.142
Col 1 (Footwall)	Leach 49	04/11/2013	2	0.40		8.08	307	0.5	0.5	53	53	2	12	0.5	2	1	55	7	0.15	0.002	0.0005	0.142
Col 1 (Footwall)	Leach 53	03/12/2013	2	0.40		8.04	277	0.5	0.5	65	65	12	15	0.5	3	2	51	7	0.09	0.001	0.0005	0.162
Col 2 - Shale	Leach 1	05/12/2012	2	0.52		7.11	929	0.5	0.5	3	3	3	461	14	42	92	19	6		0.0005	0.0005	0.04
Col 2 (Hanging Wall)	Leach 5	2/01/2013	2	0.50		7.52	391	0.5	0.5	31	31	3	190	2	17	33	5	4	0.005	0.0005	0.0005	0.092
Col 2 (Hanging Wall)	Leach 10	7/02/2013	2	0.52		7.5	404	0.5	0.5	36	36	2	195	0.5	18	36	3	2	0.005	0.0005	0.0005	0.101
Col 2 (Hanging Wall)	Leach 14	07/03/2013	2	0.50		7.51	311	0.5	0.5	27	27	2	127	0.5	14	32	2	2	0.005	0.0005	0.0005	0.086
Col 2 (Hanging Wall)	Leach 18	04/04/2013	2	0.50		7.68	335	0.5	0.5	30	30	3	136	1	11	32	2	2	0.02	0.0005	0.0005	0.102
Col 2 (Hanging Wall)	Leach 22	02/05/2013	2	0.51		7.42	217	0.5	0.5	5	5	2	84	0.5	6	21	0.5	0.5	0.005	0.0005	0.0005	0.058
Col 2 (Hanging Wall)	Leach 27	06/06/2013	2	0.51		7.55	253	0.5	0.5	32	32	2	97	1	7	28	1	0.5	0.01	0.0005	0.0005	0.09
Col 2 (Hanging Wall)	Leach 31	04/07/2013	2	0.49		7.72	220	0.5	0.5	35	35	5	72	2	6	23	1	0.5	0.02	0.0005	0.0005	0.094
Col 2 (Hanging Wall)	Leach 36	06/08/2013	2	0.53		7.77	263	0.5	0.5	40	40	3	107	2	6	28	1	0.5	0.01	0.0005	0.075	0.0005
Col 2 (Hanging Wall)	Leach 44	01/10/2013	2	0.48		7.9	323	0.5	0.5	65	65	2	110	2	6	32	1	1	0.02	0.0005	0.0005	0.106
Col 2 (Hanging Wall)	Leach 49	04/11/2013	2	0.47		7.96	377	0.5	0.5	45	45	2	160	1	7	42	1	2	0.03	0.0005	0.0005	0.084
Col 2 (Hanging Wall)	Leach 53	03/12/2013	2	0.46		7.83	348	0.5	0.5	49	49	12	159	2	7	44	1	2	0.005	0.0005	0.0005	0.092
Col 3 - Cherty BIF	Leach 1	05/12/2012	2	0.44		7.74	1820	0.5	0.5	71	71	5	1020	49	133	182	44	29		0.0005	0.0005	0.076
Col 3 (BIF_North/South)	Leach 5	2/01/2013	2	0.55		8.26	184	0.5	0.5	79	79	2	27	0.5	11	16	0.5	2	0.005	0.0005	0.0005	0.199
Col 3 (BIF_North/South)	Leach 10	7/02/2013	2	0.45		8.19	284	0.5	0.5	106	106	2	46	2	11	30	1	2	0.02	0.0005	0.0005	0.141
Col 3 (BIF_North/South)	Leach 14	07/03/2013	2	0.45		8.23	258	0.5	0.5	98	98	2	37	2	9	26	1	1	0.01	0.0005	0.0005	0.142
Col 3 (BIF_North/South)	Leach 18	04/04/2013	2	0.45		8.29	268	0.5	0.5	99	99	2	40	2	9	27	1	1	0.02	0.0005	0.0005	0.161
Col 3 (BIF_Nonht/South)	Leach 22	02/05/2013	2	0.45		7.95	138	0.5	0.5	50	50	2	22	1	4	14	0.5	0.5	0.005	0.0005	0.0005	0.096
Col 3 (BIF_North/South)	Leach 27	06/06/2013	2	0.46		8.22	226	0.5	0.5	96	96	2	27	1	8	26	0.5	0.5	0.02	0.0005	0.0005	0.148
Col 3 (BIF_North/South)	Leach 31	04/07/2013	2	0.45		8.22	154	0.5	0.5	70	70	2	17	2	6	17	0.5	0.5	0.01	0.0005	0.0005	0.103
Col 3 (BIF_North/South)	Leach 36	06/08/2013	2	0.47		8.1	147	0.5	0.5	64	64	3	21	0.5	5	16	0.5	0.5	0.02	0.0005	0.103	0.0005
Col 3 (BIF_North/South)	Leach 44	01/10/2013	2	0.45		7.99	149	0.5	0.5	54	54	1	25	1	4	14	0.5	0.5	0.01	0.0005	0.0005	0.124
Col 3 (BIF_North/South)	Leach 49	04/11/2013	2	0.44		8.27	219	0.5	0.5	68	68	2	53	2	7	24	0.5	0.5	0.02	0.0005	0.0005	0.128
Col 3 (BIF_North/South)	Leach 53	03/12/2013	2	0.43		8.14	268	0.5	0.5	80	80	0.5	61	2	8	30	0.5	0.5	0.005	0.0005	0.0005	0.148
Col 4 - Mineralised shale	Leach 1	05/12/2012	2	0.44		3.66	6460	0.5	0.5	0.5	0.5	540	22800	30	113	1100	22	2		0.002	0.076	0.044
Col 4 (Hanging Wall)	Leach 5	2/01/2013	2	0.50		3.07	1320	0.5	0.5	0.5	0.5	196	672	4	17	90	2	0.5	6.52	0.0005	0.038	0.059
Col 4 (Hanging Wall)	Leach 10	7/02/2013	2	0.50		2.63	3580	0.5	0.5	0.5	0.5	1350	2740	2	32	223	1	0.5	96.4	0.01	0.073	0.057
Col 4 (Hanging Wall)	Leach 14	07/03/2013	2	0.50		2.47	3830	0.5	0.5	0.5	0.5	2130	2180	0.5	20	140	0.5	0.5	111	0.013	0.03	0.039
Col 4 (Hanging Wall)	Leach 18	04/04/2013	2	0.50		2.47	4620	0.5	0.5	0.5	0	2780	3100	0.5	18	131	1	0.5	157	0.014	0.023	0.045
Col 4 (Hanging Wall)	Leach 22	02/05/2013	2	0.48		2.61	3600	0.5	0.5	0.5	0	2350	2670	0.5	13	95	0.5	0.5	128	0.007	0.012	0.026
Col 4 (Hanging Wall)	Leach 27	06/06/2013	2	0.49		2.41	4190	0.5	0.5	0.5	0	3030	2940	0.5	15	102	0.5	0.5	141	0.017	0.011	0.025
Col 4 (Hanging Wall)	Leach 31	04/07/2013	2	0.48		2.55	3140	0.5	0.5	0.5	0	1960	1770	0.5	8	58	1	0.5	91.7	0.01	0.005	0.027
Col 4 (Hanging Wall)	Leach 36	06/08/2013	2	0.51		2.39	4380	0.5	0.5	0.5	0	3080	2960	0.5	12	82	0.5	0.5	160	0.016	0.026	0.006
Col 4 (Hanging Wall)	Leach 44	01/10/2013	2	0.50		2.28	6410	0.5	0.5	0.5	0		4750	0.5	17	159	0.5	0.5	288	0.018	0.012	0.034
Col 4 (Hanging Wall)	Leach 49	04/11/2013	2	0.44		2.24	6360	0.5	0.5	0.5	0	5900	5620	0.5	16	163	0.5	0.5	302	0.024	0.01	0.032
Col 4 (Hanging Wall)	Leach 53	03/12/2013	2	0.44		2.26	6950	0.5	0.5	0.5	0	6750	7080	0.5	20	236	0.5	0.5	375	0.023	0.012	0.035
Col 5 - Mineralised shale/Tailings blend	Leach 1	17/01/2013	2	0.56		7.72	3060	0.5	0.5	40	40	5	1750	85	131	266	302	23	0.005	0.002	0.0005	0.072
Col 5 (PAF/Tailings)	Leach 5	14/02/2013	2	0.43		7.55	702	0.5	0.5	32	32	3	287	5	12	21	97	12	0.01	0.002	0.0005	0.073
Col 5 (PAF/Tailings)	Leach 10	21/03/2013	2	0.38		7.55	438	0.5	0.5	28	28	3	183	2	11	12	48	9	0.02	0.001	0.0005	0.107
Col 5 (PAF/Tailings)	Leach 14	18/04/2013	2	0.41		7.67	617	0.5	0.5	30	30	5	259	1	18	19	64	12	0.06	0.0005	0.0005	0.092
Col 5 (PAF/Tailings)	Leach 18	16/05/2013	2	0.40		7.86	948	0.5	0.5	46	46	3	441	2	41	41	97	19	0.005	0.0005	0.0005	0.025
Col 5 (PAF/Tailings)	Leach 22	13/06/2013	2	0.43		7.66	324	0.5	0.5	29	29	1	131	0.5	14	10	29	7	0.1	0.0005	0.0005	0.103
Col 5 (PAF/Tailings)	Leach 26	11/07/2013	2	0.40		7.59	249	0.5	0.5	23	23	10	90	0.5	15	9	19	5	0.1	0.002	0.0005	0.102
Col 5 (PAF/Tailings)	Leach 30	06/08/2013	2	0.41		7.67	386	0.5	0.5	25	25	3	137	34	27	16	38	6	0.08	0.002	0.082	0.0005
Col 5 (PAF/Tailings)	Leach 34	03/09/2013	2	0.42		7.47	371	0.5	0.5	39	39	5	123	0.5	23	17	21	7	0.07	0.003	0.0005	0.112
Col 5 (PAF/Tailings)	Leach 38	01/10/2013	2	0.41		7.52	355	0.5	0.5	31	31	2	120	0.5	19	15	19	5	0.05	0.0005	0.0005	0.104
Col 5 (PAF/Tailings)	Leach 43	04/11/2013	2	0.35		7.64	331	0.5	0.5	25	25	10	138	0.5	20	17	16	5	0.06	0.0005	0.0005	0.086
Col 5 (PAF/Tailings)	Leach 47	03/12/2013	2	0.35		7.18	325	0.5	0.5	14	14	0.5	166	0.5	17	20	14	5	0.02	0.0005	0.0005	0.069
Col 5 (PAF/Tailings)	Leach 52	07/01/2014	2	0.40		7.21	240	0.5	0.5	12	12	5	104	0.5	12	14	10	4	0.06	0.001	0.0005	0.066
Col 6 - Tailings	Leach 1	17/01/2013	2	0.48		9.94	1160	0.5	339	193	532	0.5	71	29	0.5	0.5	268	16	0.18	0.036	0.0005	0.174
Col 6 (Tailings)	Leach 5	14/02/2013	2	0.35		9.79	920	0.5	255	150	406	0.5	78	3	0.5	0.5	209	15	0.22	0.023	0.0005	0.159
Col 6 (Tailings)	Leach 10	21/03/2013	2	0.32		9.79	471	0.5	112	67	179	0.5	13	0.5	0.5	0.5	106	11	0.24	0.01	0.0005	0.073
Col 6 (Tailings)	Leach 14	18/04/2013	2	0.35		9.66	324	0.5	84	76	161	0.5	6	0.5	0.5	0.5	65	6	0.19	0.007	0.0005	0.159
Col 6 (Tailings)	Leach 18	16/05/2013	2	0.41		9.37	487	0.5	106	158	265	0.5	8	0.5	1	2	114	12	0.06	0.003	0.0005	0.169
Col 6 (Tailings)	Leach 22	13/06/2013	2	0.35		9.4	293	0.5	58	97	155	0.5	4	0.5	0.5	0.5	62	7	0.12	0.003	0.0005	0.146
Col 6 (Tailings)	Leach 26	11/07/2013	2	0.38		9.44	220	0.5	41	74	115	0.5	4	0.5	0.5	0.5	52	7	0.13	0.002	0.0005	0.129
Col 6 (Tailings)	Leach 30	06/08/2013	2	0.35		9.33	246	0.5	38	94	132	0.5	5	2	0.5	1	60	7	0.11	0.002	0.128	0.0005
Col 6 (Tailings)	Leach 34	03/09/2013	2	0.35		9.1	281	0.5	31	163	194	0.5	6	0.5	0.5	0.5	65	10	0.1	0.004	0.0005	0.145
Col 6 (Tailings)	Leach 38	01/10/2013	2	0.35		8.4	202	0.5	4	102	106	0.5	6	0.5	0.5	1	44	6	0.11	0.002	0.0005	0.129
Col 6 (Tailings)	Leach 43	04/11/2013	2	0.30		8.59	192	0.5	9	92	101	0.5	8	0.5	0.5	0.5	43	6	0.14	0.002	0.0005	0.128
Col 6 (Tailings)	Leach 47	03/12/2013	2	0.30		7.9	90	0.5	0.5	44	44	0.5	3	0.5	0.5	0.5	20	3	0.02	0.0005	0.0005	0.114
Col 6 (Tailings)	Leach 52	07/01/2014	2	0.35		7.84	77	0.5	0.5	45	45	2	3	0.5	0.5	0.5	14	3	0.03	0.001	0.0005	0.102

Appendix A5: Kinetic (column) tests

					Analyte:	pH Value	EC @ 25°C	OH as CaCO3	CO3 as CaCO3	HCO3 as CaCO3	Alkalinity as CaCO3	Acidity as CaCO3	SO4	Cl	Ca	Mg	Na	K	Al	As	Be	Ba
					Units:	pH Unit	µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Sample ID	Kinetic Leach	Sample date	Sample weight (kg)	Volume leachate collected (L)	LOR:	0.01	1	1	1	1	1	1	1	1	1	1	1	1	0.01	0.001	0.001	0.001
Col 7 - Cherty BIF	Leach 1	05/12/2012	2	0.52		8.35	2080	0.5	3	103	106	0.5	863	56	5	15	452	33		0.003	0.0005	0.05
Col 7 (North/South)	Leach 5	2/01/2013	2	0.50		8.25	226	0.5	0.5	91	91	2	33	1	0.5	0.5	50	4	0.14	0.003	0.0005	0.095
Col 7 (North/South)	Leach 10	7/02/2013	2	0.50		8.07	201	0.5	0.5	84	84	2	24	0.5	0.5	3	38	4	0.14	0.002	0.0005	0.101
Col 7 (North/South)	Leach 14	07/03/2013	2	0.50		7.99	133	0.5	0.5	69	69	10	12	0.5	0.5	3	26	3	0.08	0.001	0.0005	0.088
Col 7 (North/South)	Leach 18	04/04/2013	2	0.50		8.04	163	0.5	0.5	66	66	6	18	0.5	2	4	26	4	0.19	0.0005	0.0005	0.123
Col 7 (North/South)	Leach 22	02/05/2013	2	0.49		7.64	68	0.5	0.5	30	30	2	8	0.5	0.5	2	11	1	0.04	0.0005	0.0005	0.074
Col 7 (North/South)	Leach 27	06/06/2013	2	0.50		7.4	125	0.5	0.5	46	46	5	17	0.5	2	5	17	2	0.1	0.0005	0.0005	0.088
Col 7 (North/South)	Leach 31	04/07/2013	2	0.50		8.06	116	0.5	0.5	52	52	5	7	0.5	2	6	16	2	0.07	0.0005	0.0005	0.107
Col 7 (North/South)	Leach 36	06/08/2013	2	0.49		7.95	131	0.5	0.5	55	55	3	11	0.5	2	8	14	2	0.15	0.0005	0.087	0.0005
Col 7 (North/South)	Leach 44	01/10/2013	2	0.49		7.72	153	0.5	0.5	40	40	12	28	0.5	3	9	14	2	0.1	0.0005	0.0005	0.12
Col 7 (North/South)	Leach 49	04/11/2013	2	0.43		8.01	174	0.5	0.5	55	55	5	31	0.5	3	10	17	3	0.11	0.0005	0.0005	0.116
Col 7 (North/South)	Leach 53	03/12/2013	2	0.43		7.73	189	0.5	0.5	63	63	12	26	0.5	3	12	16	2	0.05	0.0005	0.0005	0.128

Appendix A5: Kinetic (column) tests

					Analyte:	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Fe	Hg	Se
Sample ID	Kinetic Leach	Sample date	Sample weight (kg)	Volume leachate collected (L)	Units:	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
					LOR:	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.005	0.05	0.0001	
Col 1 - Chert	Leach 1	05/12/2012	2	0.43		0.00005	0.0005	0.001	0.015	0.0005	0.002	0.001	0.005	0.007		0.00005	
Col 1 (Footwall)	Leach 5	2/01/2013	2	0.51		0.00005	0.001	0.0005	0.004	0.0005	0.004	0.0005	0.02	0.01	0.17	0.00005	0.0042
Col 1 (Footwall)	Leach 10	7/02/2013	2	0.43		0.00005	0.003	0.0005	0.005	0.0005	0.004	0.001	0.02	0.065	0.53	0.00005	0.0022
Col 1 (Footwall)	Leach 14	07/03/2013	2	0.47		0.00005	0.002	0.0005	0.003	0.0005	0.004	0.0005	0.02	0.037	0.29	0.00005	0.001
Col 1 (Footwall)	Leach 18	04/04/2013	2	0.47		0.00005	0.001	0.0005	0.003	0.0005	0.003	0.0005	0.01	0.02	0.26	0.00005	0.0006
Col 1 (Footwall)	Leach 22	02/05/2013	2	0.43		0.00005	0.0005	0.0005	0.002	0.0005	0.002	0.0005	0.005	0.01	0.14	0.00005	0.0002
Col 1 (Footwall)	Leach 27	06/06/2013	2	0.46		0.00005	0.001	0.0005	0.001	0.0005	0.004	0.0005	0.005	0.016	0.37	0.00005	0.0004
Col 1 (Footwall)	Leach 31	04/07/2013	2	0.43		0.00005	0.003	0.0005	0.002	0.0005	0.008	0.001	0.005	0.023	0.78	0.00005	0.0002
Col 1 (Footwall)	Leach 36	06/08/2013	2	0.45		0.00005	0.0005	0.002	0.001	0.005	0.0005	0.0005	0.005	0.014	0.42	0.00005	0.0001
Col 1 (Footwall)	Leach 44	01/10/2013	2	0.45		0.00005	0.0005	0.0005	0.0005	0.0005	0.004	0.0005	0.005	0.023	0.18	0.00005	0.0001
Col 1 (Footwall)	Leach 49	04/11/2013	2	0.40		0.00005	0.0005	0.0005	0.001	0.0005	0.004	0.0005	0.005	0.02	0.17	0.00005	0.0003
Col 1 (Footwall)	Leach 53	03/12/2013	2	0.40		0.00005	0.0005	0.0005	0.002	0.003	0.005	0.0005	0.005	0.021	0.23	0.00005	0.0004
Col 2 - Shale	Leach 1	05/12/2012	2	0.52		0.00005	0.0005	0.002	0.001	0.0005	0.722	0.007	0.005	0.009		0.00005	
Col 2 (Hanging Wall)	Leach 5	2/01/2013	2	0.50		0.00005	0.0005	0.0005	0.0005	0.0005	0.375	0.002	0.005	0.031	0.025	0.00005	0.0008
Col 2 (Hanging Wall)	Leach 10	7/02/2013	2	0.52		0.00005	0.0005	0.0005	0.0005	0.0005	0.556	0.002	0.005	0.063	0.025	0.00005	0.0007
Col 2 (Hanging Wall)	Leach 14	07/03/2013	2	0.50		0.00005	0.0005	0.0005	0.0005	0.0005	0.429	0.0005	0.005	0.047	0.025	0.00005	0.0004
Col 2 (Hanging Wall)	Leach 18	04/04/2013	2	0.50		0.00005	0.0005	0.0005	0.0005	0.0005	0.346	0.0005	0.005	0.049	0.025	0.00005	0.0004
Col 2 (Hanging Wall)	Leach 22	02/05/2013	2	0.51		0.00005	0.0005	0.0005	0.0005	0.0005	0.187	0.0005	0.005	0.05	0.025	0.00005	0.0002
Col 2 (Hanging Wall)	Leach 27	06/06/2013	2	0.51		0.00005	0.0005	0.0005	0.0005	0.0005	0.23	0.0005	0.005	0.044	0.025	0.00005	0.0003
Col 2 (Hanging Wall)	Leach 31	04/07/2013	2	0.49		0.00005	0.0005	0.0005	0.0005	0.0005	0.164	0.0005	0.005	0.035	0.025	0.00005	0.0002
Col 2 (Hanging Wall)	Leach 36	06/08/2013	2	0.53		0.00005	0.0005	0.0005	0.0005	0.138	0.0005	0.0005	0.005	0.032	0.025	0.00005	0.0003
Col 2 (Hanging Wall)	Leach 44	01/10/2013	2	0.48		0.00005	0.0005	0.0005	0.0005	0.0005	0.11	0.001	0.005	0.023	0.025	0.00005	0.0003
Col 2 (Hanging Wall)	Leach 49	04/11/2013	2	0.47		0.00005	0.0005	0.0005	0.0005	0.0005	0.095	0.0005	0.005	0.026	0.025	0.00005	0.0004
Col 2 (Hanging Wall)	Leach 53	03/12/2013	2	0.46		0.00005	0.0005	0.0005	0.0005	0.0005	0.072	0.0005	0.005	0.022	0.025	0.00005	0.0004
Col 3 - Cherty BIF	Leach 1	05/12/2012	2	0.44		0.00005	0.0005	0.0005	0.004	0.0005	0.148	0.003	0.005	0.028		0.00005	
Col 3 (BIF_North/South)	Leach 5	2/01/2013	2	0.55		0.00005	0.0005	0.0005	0.0005	0.0005	0.016	0.0005	0.005	0.008	0.025	0.00005	0.0004
Col 3 (BIF_North/South)	Leach 10	7/02/2013	2	0.45		0.00005	0.0005	0.0005	0.0005	0.0005	0.032	0.002	0.005	0.018	0.05	0.00005	0.0015
Col 3 (BIF_North/South)	Leach 14	07/03/2013	2	0.45		0.00005	0.0005	0.0005	0.0005	0.0005	0.015	0.0005	0.005	0.012	0.025	0.00005	0.0009
Col 3 (BIF_North/South)	Leach 18	04/04/2013	2	0.45		0.00005	0.0005	0.0005	0.0005	0.0005	0.015	0.0005	0.005	0.012	0.025	0.00005	0.0008
Col 3 (BIF_Nonht/South)	Leach 22	02/05/2013	2	0.45		0.00005	0.0005	0.0005	0.0005	0.0005	0.007	0.0005	0.005	0.011	0.025	0.00005	0.0005
Col 3 (BIF_North/South)	Leach 27	06/06/2013	2	0.46		0.00005	0.0005	0.0005	0.0005	0.0005	0.022	0.0005	0.005	0.015	0.025	0.00005	0.0005
Col 3 (BIF_North/South)	Leach 31	04/07/2013	2	0.45		0.00005	0.0005	0.0005	0.0005	0.0005	0.01	0.0005	0.005	0.01	0.025	0.00005	0.0002
Col 3 (BIF_North/South)	Leach 36	06/08/2013	2	0.47		0.00005	0.0005	0.0005	0.0005	0.01	0.0005	0.0005	0.005	0.01	0.025	0.00005	0.0003
Col 3 (BIF_North/South)	Leach 44	01/10/2013	2	0.45		0.00005	0.0005	0.0005	0.0005	0.0005	0.006	0.0005	0.005	0.015	0.025	0.00005	0.0002
Col 3 (BIF_North/South)	Leach 49	04/11/2013	2	0.44		0.00005	0.0005	0.0005	0.0005	0.0005	0.009	0.0005	0.005	0.015	0.025	0.00005	0.0005
Col 3 (BIF_North/South)	Leach 53	03/12/2013	2	0.43		0.00005	0.0005	0.0005	0.0005	0.0005	0.008	0.0005	0.005	0.012	0.025	0.00005	0.0006
Col 4 - Mineralised shale	Leach 1	05/12/2012	2	0.44		0.114	0.037	5.09	0.132	0.0005		67.9	0.005	7.44		0.00005	
Col 4 (Hanging Wall)	Leach 5	2/01/2013	2	0.50		0.0172	0.021	0.515	0.121	0.0005	41.6	5.41	0.005	1.13	40.8	0.00005	0.0036
Col 4 (Hanging Wall)	Leach 10	7/02/2013	2	0.50		0.0425	0.377	2.11	0.671	0.0005	102	14.1	0.005	8.3	335	0.00005	0.0001
Col 4 (Hanging Wall)	Leach 14	07/03/2013	2	0.50		0.0221	0.794	2.12	0.671	0.0005	48.8	10.8	0.03	5.48	501	0.00005	0.01
Col 4 (Hanging Wall)	Leach 18	04/04/2013	2	0.50		0.0184	1.4	2.49	0.802	0.0005	38.8	13.6	0.05	4.9	726	0.00005	0.0093
Col 4 (Hanging Wall)	Leach 22	02/05/2013	2	0.48		0.0124	1.41	2.05	0.666	0.001	26.1	10.7	0.04	3.45	610	0.00005	0.0086
Col 4 (Hanging Wall)	Leach 27	06/06/2013	2	0.49		0.01	2.24	2.48	0.738	0.002	21.7	12.5	0.05	3.04	814	0.00005	0.0092
Col 4 (Hanging Wall)	Leach 31	04/07/2013	2	0.48		0.005	1.41	1.5	0.469	0.0005	13.1	8.7	0.02	1.76	610	0.00005	0.013
Col 4 (Hanging Wall)	Leach 36	06/08/2013	2	0.51		0.0049	1.83	2.15	0.619	15.2	12.5	0.0005	0.05	1.83	916	0.00005	
Col 4 (Hanging Wall)	Leach 44	01/10/2013	2	0.50		0.0066	4.34	3.03	0.831	0.0005	20	20.7	0.08	3.06	1450	0.00005	0.0001
Col 4 (Hanging Wall)	Leach 49	04/11/2013	2	0.44		0.0049	5.27	3.28	1.04	0.002	16	20.1	0.08	2.72	1320	0.00005	0.0118
Col 4 (Hanging Wall)	Leach 53	03/12/2013	2	0.44		0.0062	6.4	3.78	1.24	0.086	16.4	23.9	0.09	3.46	1330	0.00005	0.0133
Col 5 - Mineralised shale/Tailings blend	Leach 1	17/01/2013	2	0.56		0.00005	0.0005	0.004	0.005	0.0005	8.15	0.015	0.005	0.007	0.025	0.00005	0.033
Col 5 (PAF/Tailings)	Leach 5	14/02/2013	2	0.43		0.00005	0.001	0.0005	0.003	0.0005	0.034	0.0005	0.005	0.017	0.025	0.00005	0.0045
Col 5 (PAF/Tailings)	Leach 10	21/03/2013	2	0.38		0.00005	0.0005	0.0005	0.001	0.0005	0.024	0.0005	0.005	0.017	0.025	0.00005	0.0025
Col 5 (PAF/Tailings)	Leach 14	18/04/2013	2	0.41		0.00005	0.001	0.0005	0.001	0.0005	0.073	0.0005	0.005	0.029	0.06	0.00005	0.0026
Col 5 (PAF/Tailings)	Leach 18	16/05/2013	2	0.40		0.00005	0.0005	0.0005	0.001	0.0005	0.51	0.0005	0.005	0.029	0.025	0.00005	0.0033
Col 5 (PAF/Tailings)	Leach 22	13/06/2013	2	0.43		0.00005	0.002	0.0005	0.002	0.0005	0.056	0.001	0.005	0.053	0.2	0.00005	0.001
Col 5 (PAF/Tailings)	Leach 26	11/07/2013	2	0.40		0.00005	0.001	0.0005	0.002	0.0005	0.081	0.002	0.005	0.055	0.1	0.00005	0.0007
Col 5 (PAF/Tailings)	Leach 30	06/08/2013	2	0.41		0.00005	0.0005	0.0005	0.001	0.19	0.0005	0.0005	0.005	0.064	0.08	0.00005	0.001
Col 5 (PAF/Tailings)	Leach 34	03/09/2013	2	0.42		0.00005	0.0005	0.0005	0.0005	0.0005	0.159	0.0005	0.005	0.051	0.06	0.00005	0.0012
Col 5 (PAF/Tailings)	Leach 38	01/10/2013	2	0.41		0.00005	0.0005	0.0005	0.0005	0.0005	0.132	0.001	0.005	0.035	0.05	0.00005	0.0013
Col 5 (PAF/Tailings)	Leach 43	04/11/2013	2	0.35		0.00005	0.0005	0.0005	0.0005	0.0005	0.101	0.0005	0.005	0.043	0.05	0.00005	0.0012
Col 5 (PAF/Tailings)	Leach 47	03/12/2013	2	0.35		0.00005	0.0005	0.0005	0.0005	0.0005	0.074	0.0005	0.005	0.041	0.025	0.00005	0.0015
Col 5 (PAF/Tailings)	Leach 52	07/01/2014	2	0.40		0.00005	0.001	0.0005	0.002	0.0005	0.093	0.001	0.005	0.036	0.08	0.00005	0.0011
Col 6 - Tailings	Leach 1	17/01/2013	2	0.48		0.00005	0.003	0.001	0.008	0.0005	0.113	0.002	0.005	0.012	2.03	0.0008	0.013
Col 6 (Tailings)	Leach 5	14/02/2013	2	0.35		0.00005	0.002	0.0005	0.004	0.0005	0.012	0.0005	0.005	0.036	0.17	0.00005	0.0045
Col 6 (Tailings)	Leach 10	21/03/2013	2	0.32		0.0002	0.001	0.0005	0.006	0.002	0.006	0.0005	0.005	0.096	0.08	0.00005	0.0014
Col 6 (Tailings)	Leach 14	18/04/2013	2	0.35		0.00005	0.0005	0.0005	0.002	0.0005	0.008	0.0005	0.005	0.021	0.13	0.00005	0.0007
Col 6 (Tailings)	Leach 18	16/05/2013	2	0.41		0.00005	0.0005	0.0005	0.001	0.0005	0.007	0.0005	0.005	0.006	0.025	0.00005	0.0006
Col 6 (Tailings)	Leach 22	13/06/2013	2	0.35		0.00005	0.001	0.0005	0.002	0.0005	0.012	0.0005	0.005	0.012	0.18	0.00005	0.0004
Col 6 (Tailings)	Leach 26	11/07/2013	2	0.38		0.00005	0.0005	0.0005	0.002	0.0005	0.012	0.0005	0.005	0.02	0.16	0.00005	0.0003
Col 6 (Tailings)	Leach 30	06/08/2013	2	0.35		0.00005	0.0005	0.0005	0.002	0.01	0.0005	0.0005	0.005	0.007	0.12	0.00005	0.0003
Col 6 (Tailings)	Leach 34	03/09/2013	2	0.35		0.00005	0.0005	0.0005	0.002	0.0005	0.005	0.0005	0.005	0.008	0.06	0.00005	0.0004
Col 6 (Tailings)	Leach 38	01/10/2013	2	0.35		0.00005	0.0005	0.0005	0.0005	0.0005	0.008	0.0005	0.005	0.01	0.08	0.00005	0.0003
Col 6 (Tailings)	Leach 43	04/11/2013	2	0.30		0.00005	0.0005	0.0005	0.002	0.0005	0.011	0.0005	0.005	0.017	0.12	0.00005	0.0003
Col 6 (Tailings)	Leach 47	03/12/2013	2	0.30		0.00005	0.0005	0.001	0.003	0.0005	0.018	0.0005	0.005	0.019	0.15	0.00005	0.0001
Col 6 (Tailings)	Leach 52	07/01/2014	2	0.35		0.00005	0.0005	0.0005	0.002	0.0005	0.009	0.0005	0.005	0.02	0.12	0.00005	0.0001

Appendix A5: Kinetic (column) tests

					Analyte:	Cd	Cr	Co	Cu	Pb	Mn	Ni	V	Zn	Fe	Hg	Se
Sample ID	Kinetic Leach	Sample date	Sample weight (kg)	Volume leachate collected (L)	Units:	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
					LOR:	0.0001	0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.005	0.05	0.0001	
Col 7 - Cherty BIF	Leach 1	05/12/2012	2	0.52		0.0001	0.0005	0.003	0.007	0.0005	0.24	0.033	0.005	0.009		0.00005	
Col 7 (North/South)	Leach 5	2/01/2013	2	0.50		0.00005	0.0005	0.0005	0.001	0.0005	0.015	0.002	0.005	0.012	0.025	0.00005	0.0038
Col 7 (North/South)	Leach 10	7/02/2013	2	0.50		0.00005	0.0005	0.0005	0.002	0.0005	0.006	0.0005	0.005	0.012	0.3	0.00005	0.0017
Col 7 (North/South)	Leach 14	07/03/2013	2	0.50		0.00005	0.0005	0.0005	0.001	0.0005	0.006	0.0005	0.005	0.012	0.1	0.00005	0.0008
Col 7 (North/South)	Leach 18	04/04/2013	2	0.50		0.00005	0.001	0.002	0.002	0.0005	0.033	0.01	0.005	0.016	0.52	0.00005	0.0007
Col 7 (North/South)	Leach 22	02/05/2013	2	0.49		0.00005	0.0005	0.0005	0.001	0.0005	0.004	0.0005	0.005	0.039	0.025	0.00005	0.0003
Col 7 (North/South)	Leach 27	06/06/2013	2	0.50		0.00005	0.0005	0.0005	0.0005	0.0005	0.014	0.003	0.005	0.014	0.22	0.00005	0.0005
Col 7 (North/South)	Leach 31	04/07/2013	2	0.50		0.00005	0.0005	0.0005	0.0005	0.0005	0.008	0.0005	0.005	0.01	0.14	0.00005	0.0003
Col 7 (North/South)	Leach 36	06/08/2013	2	0.49		0.00005	0.0005	0.0005	0.0005	0.012	0.0005	0.0005	0.005	0.014	0.6	0.00005	0.0004
Col 7 (North/South)	Leach 44	01/10/2013	2	0.49		0.00005	0.0005	0.0005	0.0005	0.0005	0.007	0.0005	0.005	0.017	0.36	0.00005	0.0006
Col 7 (North/South)	Leach 49	04/11/2013	2	0.43		0.00005	0.0005	0.0005	0.0005	0.0005	0.013	0.004	0.005	0.017	0.2	0.00005	0.0008
Col 7 (North/South)	Leach 53	03/12/2013	2	0.43		0.00005	0.0005	0.0005	0.0005	0.0005	0.012	0.002	0.005	0.015	0.08	0.00005	0.0007

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Report Title: North Star Magnetite Project Subsurface Materials Characterisation

Date Issued: 15 December 2020

Name/Title	Company
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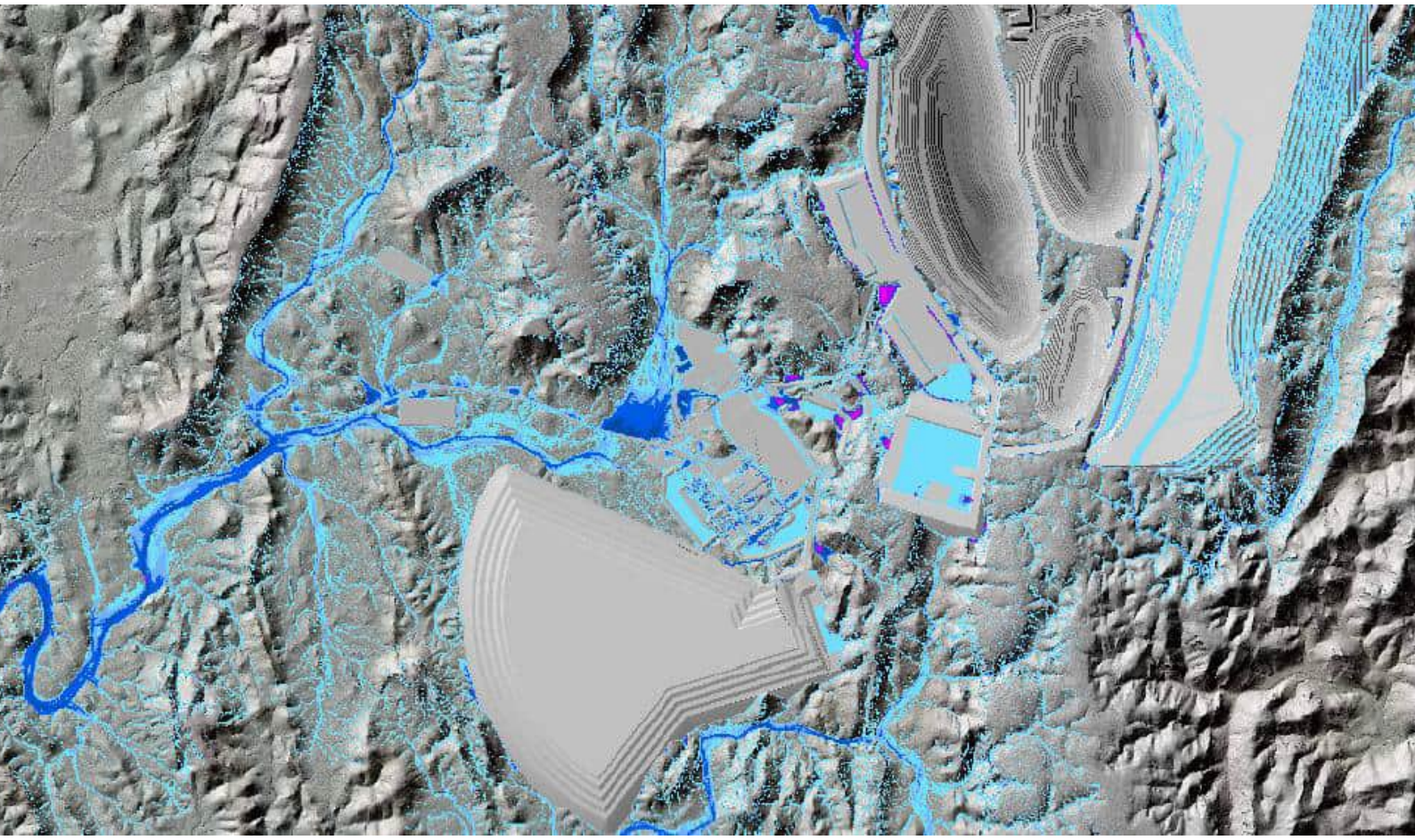
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Appendix 5: BG&E: WRD Hydraulic Modelling

North Star *Mine Site*—

Waterways Investigation



FOR / Water Engineering Services

CLIENT / Fortescue Metals Group

DOCUMENT NO / P18150-REP-W-002 REV / 0 DATE / 22/02/19

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Sections of this report that are not relevant to the Waste Rock Dump assessment have been redacted.
Data presented in this report should not be used for other areas of the mine, due to changes in mine layouts.

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Document *Control*

Revision	Date	Description	Prepared	Reviewed	Approved
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1 INTRODUCTION

1.1 General

BG&E Pty Limited (BG&E) has been engaged by Fortescue Metals Group Ltd (FMG) to carry out a flood investigation and impact assessment for the future Stage 2 works associated with the North Star Mine Site. The site is located approximately 110 km south of Port Hedland in Western Australia as shown in Figure 1-1.

1.2 Scope

The following scope of works was undertaken for this investigation:

- Reviewed available data and delineated major catchments within the mine site.
- Developed 2-dimensional (2D) TUFLOW hydrodynamic models for each catchment utilising the direct rainfall approach.
- Estimated design flows within each catchment using various regional methods and rainfall-runoff modelling to validate the results from the TUFLOW models.
- Carried out baseline hydraulic modelling to estimate present day flood behaviour (levels, depths, velocities etc) within each catchment.
- Updated the hydraulic models to incorporate earthworks associated with the Stage 2 works and identified potential impacts to existing flood behaviour.
- Carried out a detailed assessment for the waste rock dump (WRD) across an extended range of durations to identify potential retention capacity and downstream impacts.

RORB rainfall-runoff models and TUFLOW hydraulic models have been issued to FMG for internal use. A more detailed description of the methodology used to validate the TUFLOW models can be found in Section 2 of this report.

1.3 Data

The following data was utilised for this investigation:

- 2018, 2014 and 2011 LiDAR data provided by FMG on 7 and 13 September 2018 as 1 metre grid resolution digital elevation models (DEM)
- Shuttle Radar Topography Mission (SRTM) elevation model
- Aerial image provided on 26 September 2018 and Bing Aerial Mapping (via plugin for QGIS)
- Shapefiles provided by FMG on 17 December 2018 proposed Stage 2 infrastructure
- 3D design files provided by FMG on 17 December 2018 for the proposed Stage 2 infrastructure in DXF and 12da formats
- 3D design files provided by FMG on 28 December 2018 for the WRD earthworks in DXF and 12da formats.

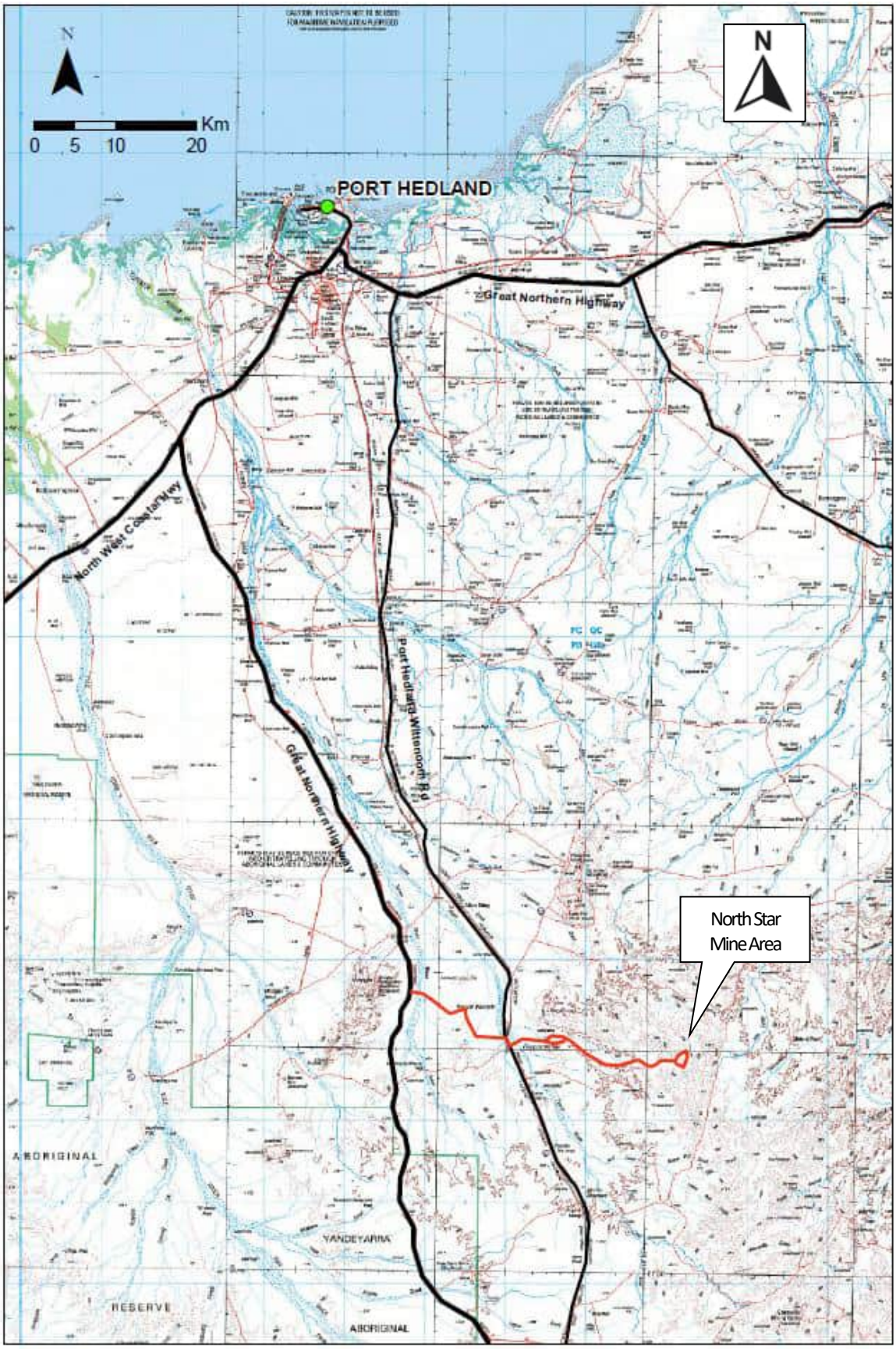


Figure 1-1: Locality Plan

1.3.1 LiDAR Review

A review was carried out of the three LiDAR datasets provided by FMG which have different extents as shown in Figure A2. 2018 DEM elevations are typically 200 mm to 400 mm higher than the 2011 DEM. 2014 DEM elevations were typically between the two. Following consultation with FMG it was agreed the 2018 DEM would take precedence, followed by the 2014 DEM and the 2011 DEM. Metadata for each dataset states the vertical accuracy is +/- 0.10 m at a 68% confidence level (1 sigma).

Several small areas were not covered by LiDAR survey, and were supplemented using SRTM data with smoothing to transition between the two datasets. These areas are at the edges of the catchments and do not impact the results within the area of interest.

1.4 Software

The following specialist software was used for this project:

RORB v6.41

RORB is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce the hydrograph.

ArcGIS v10.5

ArcGIS is a geographic information system (GIS) for working with maps and geographic information. The ArcRORB tool was used to develop the RORB model geometry file.

TUFLOW v2018-03-AB

TUFLOW is a powerful computational engine that provides one-dimensional (1D) and two-dimensional (2D) solutions of the free-surface flow equations to simulate flood and tidal wave propagation. TUFLOW is ideally suited to modelling flooding of rivers and creeks with complex flow patterns and overland flows.

QGIS v2.18.26

QGIS an open-source cross-platform desktop GIS application that supports viewing, editing, and analysis of geospatial data. QGIS was used for pre- and post-processing of TUFLOW model data.

TUFLOW QGIS Plugin v2018-10-AD (QGIS 2.x)

The ARR2016 to TUFLOW utility was used to setup TUFLOW models that use ARR 2016 input parameters and BOM 2016 rainfall by automating the collection and processing of the data.

1.5 Terminology

Annual Exceedance Probability (AEP) terminology has been adopted for consistency with the recommended probability terminology in the 2016 edition of Australian Rainfall and Runoff (ARR 2016). AEP is the probability or likelihood of an event occurring or being exceeded within any given year.

The use of Average Recurrence Interval (ARI) is no longer recommended by ARR2016. Table 1-1 shows the relationship between AEP and ARI.

Table 1-1: Probability Terminology

Annual Exceedance Probability (AEP)	10%	5%	2%	1%	1 in 500	1 in 2000
Average Recurrence Interval (ARI)	9.49 yr	20 yr	50 yr	100 yr	500 yr	2000 yr

Event frequency terminology has been adopted for consistency with Book 1 Chapter 2 of ARR 2016, as shown in Table 1-2.

Table 1-2: Frequency Terminology

Frequency Descriptor	AEP Range
Rare	10% to 1%
Very Rare	>1% to 1 in 2000
Extreme	>1 in 2000 to PMP

The AEP of the Probable Maximum Precipitation (PMP) event is estimated as 1 in 10,000,000 based on the mine site catchment area in accordance with ARR 2016 Figure 8.3.2.

2 METHODOLOGY

It was initially envisaged that 2D modelling with a direct rainfall approach would be used to establish design flows within each catchment. Preliminary results showed that flows generated by 2D modelling were notably less than the regional flood frequency methods therefore an alternative approach was adopted to validate the results.

The following methodology was developed for each catchment in close consultation with the FMG's representative Dr David Westwater (Principal Surface Water Engineer). The methodology is based on guidance contained within ARR 2016 for the development of hydrological routing models using ARR 2016 data. Weekly progress meetings were carried out between BG&E and FMG to discuss results and methodology.

- The Monte Carlo event method was applied in RORB to estimate peak flows for events up to and including 1 in 2000 AEP at 3 reporting locations. The ensemble event method was used for the PMP event.
- The critical duration storm for each AEP was selected based on the RORB results.
- A single temporal pattern was selected from the 1% AEP critical duration event and simulated in TUFLOW for an extended period to fill artificial depressions in the model topography (sink-filling). The resulting water surface was used as an initial water level input for the 2D model.
- For each AEP, 10 rainfall temporal patterns from the critical duration were simulated using the TUFLOW 2D model with a direct rainfall approach.
- A design temporal pattern was selected which produced peak flows in TUFLOW closest to (but not less than) those obtained using RORB (Monte Carlo approach). In each catchment flows were compared at 3 reporting locations which had varying catchment areas and geometry.
- Peak flows from TUFLOW and RORB up to and including 1% AEP were compared with the Regional Flood Frequency Procedure (RFFP) described in *Design flood estimation in Western Australia* (Flavell, D. 2012) and the Regional Flood Frequency Estimation (RFFE) method developed as part of ARR 2016. The regional methods generally resulted in higher flow estimates (refer Section 3.7).

2.1 Scenarios

The following scenarios were considered as part of this investigation:

Baseline – The baseline scenario reflects the condition of the site when the 2018 LiDAR was captured. This includes the Stage 1 infrastructure however does not include culverts due to lack of data (refer Sections 3 and 4).

Developed – The developed scenario involved updating the baseline model to include proposed infrastructure associated with the 2 year mine plan (Stage 2). Mitigation works and culverts were not included in this scenario (refer Section 5).

Waste Rock Dump Assessment – A detailed assessment was carried out for the Waste Rock Dump across an extended range of durations to identify retention capacity and downstream impacts (refer Section 6).

2.2 Climate Change

The mine site has a 50 year design life. The ARR 2016 Data Hub recommends a 10% and 16% increase in rainfall intensities to 2070 based on the RCP 4.5 and RCP 8.5 Global Climate Models. Climate change scenarios were not explicitly modelled, however a suitable range of flood events was assessed to understand the sensitivity to increasing rainfall intensities associated with climate change.

3 HYDROLOGY

3.1 Catchment Description

The mine area is located on the divide between the Turner River catchment (to the west) and the De Grey River catchment (to the east) as shown in Figure A1. Local hydrology for the mine site was described in the *Public Environmental Review - North Star Magnetite Project* (FMG, 2013):

"The local topography of the proposed mine area consists of a series of plateaus, hills, ridges and valleys ranging from approximately 220 m AHD to 420 m AHD. As a result, numerous ephemeral drainages are found across the site.

- *Lost Boys Creek to the north of the proposed mine pit, within the area required for the TSF, which ultimately flows into the Turner River via Chinnamon Creek*
- *An unnamed creek which roughly parallels the mine access road and flows into the Turner River just south of Pincunah Waterhole.*
- *Several small drainages on the eastern edge of the mine area flow into Six Mile Creek which ultimately flows into East Strelley River."*

Local catchment sizes vary between 1 km^2 and 35 km^2 as shown in Table 3-1. Catchment ID's are shown in Figure A3. Minor catchments 7, 8, and 9 are on the outskirts of the mine site and do not contain any infrastructure and were not modelled. Catchment 5 relates to the waste rock dump.

Table 3-1: Catchment Characteristics

ID	Area (km^2)	Mainstream Length (km)	Equal Area Slope (m/km)	Centroid Latitude (°S)	Centroid Longitude (°E)	Outlet Latitude (°S)	Outlet Longitude (°E)
1	16.4	8.2	7.1	21.291	119.017	21.297	119.017
2	1.0	1.9	42.7	21.298	119.069	21.298	119.076
3	3.2	3.1	33.2	21.290	119.076	21.288	119.085
4	3.4	4.4	15.2	21.278	119.071	21.283	119.089
5	8.9	5.9	16.6	21.249	119.072	21.244	119.091
6	34.7	6.6	17.8	21.216	119.034	21.187	119.008
10	21.3	12.2	6.5	21.259	119.029	21.270	118.983
11	16.6	7.9	9.4	21.248	118.999	21.263	118.977

3.2 Historical Data

FMG advised that no private rainfall or stream gauging data was available for the site. The nearest public gauging station is located 20 km west of the mine site at Pincunah (#709010). The gauge is situated on the Turner River with a catchment area of 885 km^2 and records dating back to 1989. While several of the mine site catchments are situated within the Pincunah catchment, they are considerably smaller therefore gauge

data has not been directly used for this study. Data from this gauge was however used in the development of the RFFE and RFFP methods.

3.3 Regional Flood Frequency Estimation (RFFE)

As part of the 2016 revision to ARR, an additional 30 years of stream gauge information was used to provide a revised flood estimation methodology across Australia, including Western Australia. The RFFE method provides an online tool whereby peak flows are estimated based on catchment location and area. For this site the RFFE method uses data from 7 catchments with areas ranging from 41 km^2 to 885 km^2 (Pincunah). Except for Pincunah, the gauges are located more than 150 km from the mine site.

3.4 Regional Flood Frequency Procedure (RFFP)

The RFFP2000 method was developed by David Flavell and published in the technical paper *Design flood estimation in Western Australia* (Flavell, D. 2012). The method is based on data from 15 gauging stations in the Pilbara region with areas ranging from 52 km^2 to 7,900 km^2. Catchment areas in the mine site are smaller than each of the catchments used to develop the RFFP.

3.5 Rainfall-runoff Modelling (RORB)

A RORB rainfall-runoff model was developed for each catchment. The number of sub-areas ranged from 12 to 25 and each model contained three reporting nodes to observe variation in peak flows and critical durations throughout the catchment. A minimum of 5 sub-areas was included upstream of the first reporting node.

A value of 0.8 was adopted for the exponent m. The empirical coefficient K_c was estimated using the procedure outlined in *Estimation of RORB K_c Parameter for Ungauged Catchments in the Pilbara Region of Western Australia* (Pearcey et al, 2014). The procedure uses data from 19 catchments within the Pilbara region with areas ranging from 41 to 7,200 km^2.

$$K_c = D_{av} * C$$

Where:

- D_{av} is the average flow distance in the channel network from the centroid of each sub-area to the catchment outlet and is calculated and reported in RORB.
- C is the mean coefficient 0.59 as derived in Pearcey et al. (2014).

Table 3-2: RORB model parameters

Catchment ID	1	2	3	4	5	6	10	11
Area (km^2)	16.4	1.0	3.2	3.4	8.9	34.7	21.3	16.6
D_{av} (km)	4.76	0.96	1.47	2.61	3.18	6.81	7.59	3.99
K_c	2.81	0.57	0.87	1.54	1.88	4.02	4.48	2.35

3.5.1 Burst Rainfall

Burst rainfall depths were obtained from the Bureau of Meteorology (BoM) Design Rainfall Data System (2016) which can be accessed via http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016. Growth factors obtained from *Growth curves and temporal patterns of short duration design storms for extreme events* (Jordan et al, 2005) were used to develop depths for very rare events with durations of 6 hours or less which was not included in the BoM data. A growth factor of 2.0 (based on 1% AEP rainfall depths) was used to estimate 1 in 10,000 AEP rainfall depths required for the Monte Carlo event method. Rainfall depths for the PMP event were obtained using the Generalised Short-Duration Method (GSDM) described in *The Estimation of Probable Maximum Precipitation in Australia: Generalised Short-Duration Method* (BoM, 2003a) which is valid for catchments up to 1,000 km^2 and storm durations 6 hours or less. The Generalised Tropical Storm Method (GTSMR) described in *Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method* (BoM, 2003b) was used to obtain rainfall depths for PMP durations 12 hours and greater. Rainfall depths for Catchment 1 are attached in Appendix D (values for other catchments vary slightly).

For rare and very rare events, burst temporal patterns were obtained from the ARR 2016 Data Hub. The Rangelands West region applied to all catchments and point temporal patterns were extracted from the intermediate (used for 10% and 5% AEP) and rare (used for 1% AEP and above) bins which is the default procedure in RORB. For the PMP event, ensemble patterns were obtained from Jordan et al. (2005) for durations up to and including 6 hours and GTSMR for durations greater than 6 hours.

3.5.2 Pre-burst Rainfall

Median pre-burst rainfall depths were obtained from the ARR 2016 Data Hub for each catchment which provides values up to and including the 1% AEP event. For the 1% AEP event, pre-burst rainfall can be greater than 25% of the burst rainfall which is significant, therefore pre-burst rainfall has been included in the assessment. For very rare events the default approach in RORB was used whereby the pre-burst depth was calculated using the same burst depth ratio as the 1% AEP event.

For rare and very rare events the default approach in RORB was used which adopts temporal patterns for long durations from *Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method* (BoM, 2006) Coastal Zone and short durations from Jordan et al (2005). The 1 hour and 3 hour patterns were used for the 1.5 and 4.5 hour patterns respectively which are not included in the default RORB patterns.

Pre-burst rainfall was not applied for the PMP event given zero initial loss has been used (refer Section 3.5.3).

3.5.3 Losses

Storm loss values were obtained from the ARR 2016 Data Hub for each catchment. Regional losses are based on data from 38 catchments across Australia. Pilbara losses appear to be based on the Harding River catchment. For rare and very rare events, an initial loss of 59 mm and continuing loss of 8.2 mm/hr was applied uniformly to all catchments. Loss values provided by the Data Hub apply to complete storms which include pre-burst rainfall.

With regards to losses from the Data Hub, ARR 2016 Book 5 Chapter 3 Section 3.5.2.3 states:

"The median loss values in the Pilbara are some of the highest in Australia. There was only 1 catchment from the Pilbara included in the Hill et al. (2014a) study but information is also available from Pearcey et al. (2014) which documents the calibration of RORB models to 19 catchments in the Pilbara region. Although the events in Pearcey et al. (2014) were selected on the basis of streamflow rather than rainfall (and hence potentially biased towards wet antecedent conditions), they support high values of loss.

For the Pilbara, Flavell and Belstead (1986) recommended IL values of approximately 40 to 50 mm and a CL of 5 mm/h. It should be noted that the loss values were derived from reconciling rainfall based estimates with flood frequency analysis and thus the IL reflects a burst initial loss and a higher initial loss would be expected if complete storms are adopted so the range of IL reported by Flavell and Belstead (1986) should be considered a lower limit of expected ILs values."

For the PMP event, zero initial loss was adopted in accordance with ARR 2016 Book 8 Chapter 4.3.2.3, which recommends no initial loss should be deducted for the remainder of WA outside the forested south-west region. A continuing loss value of 2 mm/hr was adopted in accordance with ARR 2016 Book 8 Chapter 4.3.4.3 which states it is unlikely continuing loss would be higher than 3 mm/hr for the same region.

3.5.4 Areal Reduction Factors

Areal reduction factors (ARFs) were applied in accordance with the parameters obtained from the ARR 2016 Data Hub for each catchment. This is the default option in RORB. ARFs vary for each catchment, event, and duration.

3.5.5 Spatial Distribution

For all events, rainfall was evenly distributed over the catchment. The GSDM guideline recommends a spatial distribution be applied to the mean PMP rainfall depth using a series of ellipses. This was not considered necessary given:

- The catchments are relatively small and only fall within 1, 2, or 3 ellipses depending on size. The rainfall variance across the catchment would be minor.
- The investigation is focused on the entire catchment rather than a specific location where it may be necessary to distribute the most intense rainfall upstream to create higher flows or volumes.
- For each catchment the spatial distribution would need to be calculated for each event and duration.
- There were issues with the spatial distribution dialogue in RORB v6.41. Subarea labels used in the dialogue box did not match the labels used in the output files. The software has since been updated to fix this issue.

3.5.6 Monte Carlo Event Approach

RORB simulations were carried out for events up to and including 1 in 2000 AEP using a Monte Carlo event approach, to identify the critical duration during each event, and the range of uncertainty in peak flow estimates. The Monte Carlo approach derives a probability-neutral best estimate for design flows by repeating simulations many thousands of times to adequately sample the joint probability nature of selected inputs (in this case initial loss and temporal patterns).

Simulations were carried out for durations ranging from 1 hour to 12 hours. The number of time increments modelled was 999 and the number of rainfall divisions and samples per division was 100. Within each AEP division, the number of runs which generate a flow above each threshold is calculated as a proportion of the total number of runs within that division. This probability is then multiplied by the probability of that AEP division, and those numbers summed for all bins to calculate the likelihood that a certain flow threshold will be exceeded. If this calculation is completed for multiple flow thresholds, a complete flood frequency curve can be established.

3.5.7 Ensemble Event Approach

The Monte Carlo approach samples across a range of event magnitudes to establish a flood frequency curve. To derive a peak flow estimate for the PMP event using Monte Carlo analysis, rainfall inputs for events greater than the PMP would be required which are not available. The ensemble event approach in RORB was used

to obtain peak flow estimates for the PMP event. The ensemble approach simulates 10 temporal patterns for each duration. Out of the 10 ensemble patterns the pattern that gave the highest peak was selected for the PMF . Simulations were carried out for durations ranging from 1 hour to 6 hours.

3.6 Design Flow Estimates

1% AEP design flow estimates for each catchment obtained using RFFE, RFFP, and RORB are shown in Table 3-3. Results for all events are attached in Appendix B. Based on peak flow criteria, critical storm durations within each catchment are 6 hours or less and the critical duration may vary in the upstream parts of the catchment.

Table 3-3: 1% AEP Design Flow Estimates (m^3/s) and Critical Durations at Outlet

Catchment ID	Area (km^2)	RFFE Peak Flow (m^3/s)	RFFP Peak Flow (m^3/s)	RORB MCA Peak Flow (m^3/s)	RORB Critical Duration
1	16.4	291	255	167	6 hour
2	1.0	60	55	19	1 hour
3	3.2	113	135	49	2 hour
4	3.4	116	97	43	6 hour
5	8.9	201	227	104	6 hour
6	34.7	442	475	285	6 hour
10	21.3	337	313	167	6 hour
11	16.6	298	293	176	6 hour

3.7 Adopted Design Flows

Design flows produced from the RORB rainfall-runoff models are lower than the regional flood frequency methods, however are considered the most robust estimates for the following reasons:

- The RFFE and RFFP methods rely upon the availability of recorded flood data and only provide flow estimates for events up to and including 1% AEP. The period of record for the gauge data used to develop these methods in the Pilbara is less than 35 years. For the RFFE method the 5% and 95% confidence limits are approximately 15% and 500% of the expected peak flow.
- RFFE and RFFP estimates are only applicable to the range of catchment characteristics used in development of the model. Both methods were derived from gauged data for catchments significantly larger than those being assessed in this study.
- Rainfall based applications are applicable over a wider range of AEPs than techniques based directly on the analysis of flow. Rainfall characteristics vary across space in a more predictable and generally more uniform fashion than floods. This characteristic, along with the greater length and density of rainfall gauging, allows the derivation of probabilistic estimates of rainfalls that are much rarer and more easily transposed than flood characteristics.

- The Monte Carlo event approach provides a rigorous means of deriving expected probability estimates that are probability neutral by repeating simulations many thousands of times to adequately sample the joint probability nature of selected inputs.
- A key advantage of rainfall-based approaches is that they provide the means to derive flood hydrographs which provide flood peak, volume, and critical duration while the regional methods only provide flood peak.
- The primary RORB model parameters K_c and m are based on the results of 19 calibrated RORB models across the Pilbara.
- RORB results matched well with those obtained using the TUFLOW direct rainfall approach (Section 4).
- The Monte Carlo event approach using RORB has been adopted for similar mining developments by FMG (Chichester and Eliwana).

3.8 Sensitivity Testing

Several simulations were carried out to test the sensitivity of adopted model parameters under the baseline scenario:

- Sensitivity to burst temporal patterns was carried out by using the Jordan et al. (2005) temporal patterns for Rare and Very Rare events in lieu of the ARR 2016 Rare bin patterns which is the default procedure in RORB. For the Jordan et al. (2005) patterns, 1% AEP flows for Catchment 5 were 4% lower and the 1 in 2000 AEP flows were 17% lower. The ARR 2016 Rare patterns were adopted acknowledging the results may be conservative for very rare events.
- Towards the end of this investigation the 2016 IFDs published by BoM were updated to include rainfall depths for very rare events with durations up to and including 6 hours. Rainfall depth differences between the Jordan et al. (2005) growth factor approach and the new IFDs was less than 2% and no change to the inputs was considered necessary.
- The 1987 edition of Australian Rainfall and Runoff (ARR 1987) recommend regional loss values for the Pilbara. Initial loss values vary between 22 mm and 52 mm depending on AEP with a continuing loss of 8 mm/hr. It should be noted that the initial loss values are intended for use with burst rainfall whereas the adopted ARR 2016 loss values (59 mm initial loss and 8.2 mm/hr continuing loss) are intended for use with complete storms i.e including pre-burst rainfall. For the mine site, pre-burst rainfall can be significant. For example, for Catchment 6 the 1% AEP critical duration is 6 hours which includes 42 mm of pre-burst rainfall. The storm initial loss if 59 mm therefore the burst initial loss would be 17 mm which is comparable to the value of 22 mm recommended by ARR 1987.

4 HYDRAULIC MODELLING

4.1 Model Development

A total of eight TUFLOW 2D hydraulic models were developed for the individual mine site catchments incorporating the direct rainfall approach. Simulations were carried out using the TUFLOW HPC Solver with GPU hardware acceleration. Model stability was verified using the traditional TUFLOW Classic CPU Solver.

4.1.1 Topography

2018, 2014, and 2011 1 m grid resolution LiDAR data provided by FMG was used to develop the terrain surface. In some areas SRTM data was used to gap fill outside the LiDAR extents (Figure A2) and the transition between LiDAR and SRTM was treated with a smoothing algorithm. A 5 m fixed grid resolution was selected to achieve practical simulation times. A global Manning's 'n' roughness parameter of 0.055 was adopted based on similar studies carried out by FMG.

4.1.2 Rainfall

Rainfall excess is applied directly to the model domain using the direct rainfall approach. Rainfall inputs were obtained using the TUFLOW extension in QGIS and manually verified. Rainfall inputs are consistent with those adopted for the RORB models (Section 3.5) with the following exceptions:

- Pre-burst rainfall was not included in the TUFLOW models for rare and very rare events. Instead, the storm initial loss (59 mm) was reduced to a burst initial loss for each event and duration by subtracting the pre-burst rainfall.
- For rare and very rare events burst initial loss was interpolated between 1% AEP values obtained from the ARR 2016 Data Hub and the adopted PMP value of 0 mm using Equation 8.4.1 in ARR 2016 Book 8 Chapter 4 Section 4.3.2.2.
- ARFs have been applied to the rainfall depths in the TUFLOW rainfall file. Separate rainfall files were developed for each catchment, event, and duration. Rainfall depths in the TUFLOW rainfall files are less than those used in RORB given the RORB rainfall depths do not include ARFs which are applied separately.

Burst initial and continuing losses were applied as rainfall losses via the TUFLOW materials definition file. The exception was the waste rock dump which incorporated a burst initial loss of 0 mm and continuing loss of 18.8 mm/hr. Two Infiltration tests were carried out by Landloch on behalf of FMG (Appendix E) from which a storm initial loss of 17.9 mm and continuing loss of 18.8 mm/hr was estimated. For this area it was assumed that the pre-burst rainfall is equal to the storm initial loss (17.9 mm) and thus a burst initial loss of 0 mm was used. This was considered suitable given pre-burst depths are generally around this value, there was uncertainty in the initial loss value based on testing, and the majority of losses will occur due to continuing loss.

4.1.3 Downstream Boundaries

Water Level vs Flow (HQ) downstream boundaries were located such that boundary does not influence results in the area of interest for the upstream catchment.

4.1.4 Structures

There was no data available to confirm that culverts are present within the existing Stage 1 project area. Consequently culverts were not included in the model given adequate data was not available. Ponding is

evident upstream of the road embankment which may not reflect actual conditions if/where culverts are present.

4.2 Scenarios

The baseline scenario reflects the condition of the site when the 2018 LiDAR was captured. This includes the Stage 1 infrastructure however does not include existing culverts due to lack of confirmed data. Table 4-1 and Figure A3 summarises the events simulated for each catchment. A reduced number of events was modelled for Catchment 11 given there is limited new infrastructure proposed during the Stage 2 development. TUFLOW model scenarios and file naming conventions are listed in Appendix C for each scenario including several sensitivity tests (refer Section 4.4).

Table 4-1: Baseline TUFLOW Scenarios

Catchments	Events
1, 2, 3, 4, 5, 6, 10	10%, 5%, 1%, 1 in 500, 1 in 2000 AEP and PMP
11	10%, 5%, 1% AEP

For each AEP, 10 rainfall temporal patterns from the critical duration identified using RORB, were simulated using the TUFLOW model. A design temporal pattern was selected which produced peak flows in TUFLOW closest to (but not less than) those obtained using RORB at the three reporting locations which had varying catchment areas. An example of this process is shown in Table 4-2 for the 1% AEP event in Catchment 6 which had a critical duration of 6 hours. Design flows obtained from RORB using the Monte Carlo approach for PO49, PO55, and PO27 were 285, 124, and 128 m^3/s respectively. Based on this, temporal pattern 10 was selected as the design temporal pattern. Peak flows from the selected temporal pattern were generally in the middle of the ensemble group for all catchments. The range of flows in Table 4-2 provides an indication as to how sensitive peak flows are to adopted temporal patterns.

4.3 Results

1% AEP peak flows obtained from TUFLOW for each catchment at the outlet are summarised in Table 4-3, along with adopted temporal patterns. Results for other events and reporting locations are included in Appendix B. The relationship between catchment area and 1% AEP peak flow for each method is shown in Figure 4-1. Smaller catchments exhibit larger differences in peak flow between the TUFLOW/RORB results and the regional flood frequency methods.

1% AEP baseline flood depth mapping across the mine site is shown in Figure A4.

Table 4-2: Catchment 6 1% AEP Temporal Pattern Selection

TUFLOW Temp. Pattern	TUFLOW Peak Flow (m^3/s)	TUFLOW Temp. Pattern	TUFLOW Peak Flow (m^3/s)	TUFLOW Temp. Pattern	TUFLOW Peak Flow (m^3/s)
PO49 RORB peak flow 285		PO55 RORB peak flow 124		PO27 RORB peak flow 128	
6	210	6	80	4	83
2	226	4	82	6	86
4	234	9	98	9	112
8	249	8	104	8	119
9	255	**10**	**124**	**10**	**158**
10	**299**	2	128	2	159
1	391	1	154	1	160
3	421	3	171	3	187
7	454	5	193	5	196
5	494	7	207	7	244

Table 4-3: TUFLOW 1% AEP Results Comparison

Catchment ID	Area (km^2)	RFFE Peak Flow (m^3/s)	RFFP Peak Flow (m^3/s)	RORB Peak Flow (m^3/s)	RORB Critical Duration	TUFLOW Peak Flow (m^3/s)	TUFLOW Selected Duration	TUFLOW Temp. Pattern
1	16.4	291	255	167	6 hour	181	6 hour	10
2	1.0	60	55	19	1 hour	25	1 hour	5
3	3.2	113	135	49	2 hour	58	2 hour	5
4	3.4	116	97	43	6 hour	46	2 hour	1
5	8.9	201	227	104	6 hour	133	6 hour	10
6	34.7	442	475	285	6 hour	299	6 hour	10
10	21.3	337	313	167	6 hour	240	6 hour	1
11	16.6	298	293	176	6 hour	204	6 hour	10

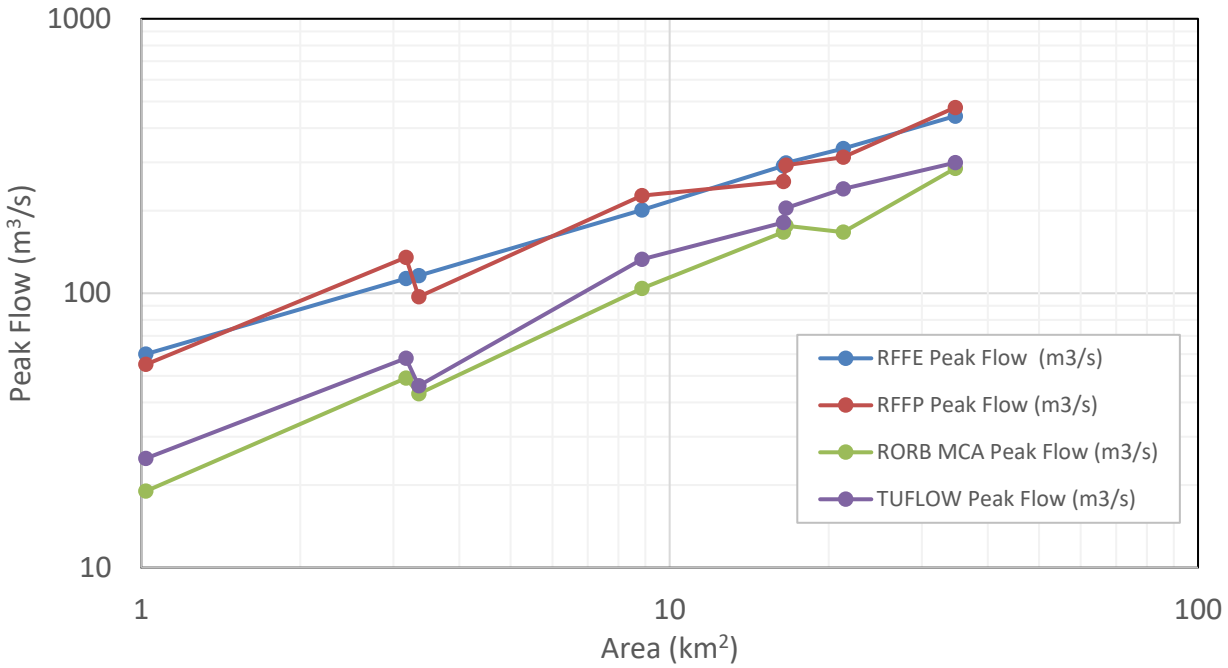


Figure 4-1: 1% AEP Peak Flow Versus Area Comparison

4.4 Sensitivity Testing

Several simulations were carried out to test the sensitivity of adopted model parameters under the baseline scenario:

- Various model cell sizes were tested for Catchment 11. For a 1% AEP 2 hour duration event, the peak flow at the catchment outlet was 70% and 15% lower for the 20 m and 10 m cell sizes when compared to the peak flow obtained from the adopted 5 m cell size. Using a 2 m cell size resulted in a peak flow within 3% of the adopted 5 m cell size which was considered suitable.
- Losses were applied to the model domain as infiltration via the TUFLOW soils file. Differences in peak flows at the catchment outlet were negligible when compared to the adopted rainfall loss method
- An assessment was carried out to determine storm durations resulting in peak runoff volumes for Catchment 6. The assessment was based on median values for the 1% and 5% AEP events using the ensemble approach. The assessment showed that runoff volumes from the critical duration were typically within 20% of the peak runoff volume across all durations. Alternative durations and temporal patterns may result in higher flow depths in locations where the primary flooding mechanism is a function of storage volume.
- A proportional loss of 49% was applied to the 1% AEP rainfall for Catchment 6 as per Flavell, D. (2012). This resulted in lower flows compared to the adopted initial loss/continuing loss method
- Increasing Manning's 'n' roughness parameter to 0.06 (from adopted 0.055) had negligible impact to peak flows. A value of 0.055 was adopted based on similar studies by FMG.
- Pre-wetting the model domain to fill artificial depression storages in the topography resulted in a notable increase in 10% and 5% AEP flows, but minor impact to 1% AEP flows. This method was adopted.

5 IMPACT ASSESSMENT

A flood impact assessment was carried out to identify potential impacts to existing flood behaviour as a result of the earthworks associated with the Stage 2 development.

5.1 Scenarios

The **developed** scenario involved updating several **baseline** scenario TUFLOW models to include proposed earthworks associated with the Stage 2 development. Earthworks designs in 12D format were provided by FMG and are listed in Table 5-1 in order of layer priority in the TUFLOW models. No allowance was made in this scenario for future culverts or mitigation works.

Rainfall over the coarse rejects area was excluded from the model given the course rejects area will be designed to retain runoff. Rainfall was also excluded above the proposed pits which align with model boundaries. Results within the pit areas are not representative and should not be used to inform flood management decisions.

Table 5-1: Stage 2 12D Design Information Summary

Design file	Description	Catchments Impacted
REDACTED		
NS St2 Mine Infra WRD only 20181207.12da (Rev 1)	Waste rock dump earthworks *Note: For the impact assessment the WRD design was incorporated directly from the 12da file. Perimeter bunds along the benches were not continuous allowing water to shed from the benches. This was amended in the detailed WRD assessment (Section 6).*	5
REDACTED		
REDACTED		

Developed scenario modelling was carried out for Catchments 1, 5, 6, and 10 for the 1%, 1 in 500, 1 in 2000 AEP and PMP events. Flood mapping for the developed scenario 1% AEP event is presented in Figures A7 to A10. Areas where the proposed earthworks impact existing flood behaviour are highlighted on the figures. 1% AEP flood level difference mapping is presented in Figures A11 to A14.

Where necessary, options to mitigate these impacts will be identified as part of a future study.

6 WASTE ROCK DUMP ASSESSMENT

A detailed assessment was carried out for the Waste Rock Dump (WRD) across an extended range of durations to identify retention capacity and downstream impacts. The assessment was based on the **developed** scenario for Catchment 5 with several modifications:

- Breaklines were incorporated into the TUFLOW model to ensure bund crest levels were represented. Perimeter bunds located on each bench were manually extended in the TUFLOW model to retain runoff on the bench. An additional design file was provided by FMG for an outlet ramp to transition flow from the dump to the natural surface (tin reduce z wst 001 s02 rev02 201812 outlet C 03 VULCAN IB WST 001 S02.12da)
- Losses for the WRD footprint were applied as infiltration to the model domain via the TUFLOW soils file given the dump is designed to retain and infiltrate runoff and has a higher continuing loss of 18.8 mm/h. Outside the WRD footprint ARR 2016 losses were applied to rainfall via the TUFLOW materials file (Section 4.1.2)
- The Manning's 'n' roughness value of 0.055 was maintained for the WRD
- The INTERPOLATE ZUVH ALL command was used in TUFLOW to prevent high flood depths being reported on steep terrain (batter slopes etc.)
- Modelling was carried out for the 10%, 1%, 1 in 500 AEP and PMP events for the storm durations listed in Table 6-1
- An ensemble of ten temporal patterns was simulated for each duration. Temporal pattern selection did not have a significant influence on flood levels within the benches given the rainfall volume of each temporal pattern is the same
- Modelling was carried out using the existing 5 m grid resolution given 170 simulations were required.

Table 6-1: WRD Modelled Storm Durations

10% AEP	1% AEP	1 in 500 AEP	PMP
6, 24, 72 hours	6, 24, 72 hours	6, 9, 12, 24, 48, 72 hours	1, 12, 24, 48, 72 hours

Based on the scenarios modelled, the benches are shown to retain runoff for events up to the PMP 72 hour storm. Peak flows within the catchment were compared at 3 different locations (refer Figure 8) and summarised in Table 6-2.

Table 6-2: Peak Flows at Reporting Locations (m^3/s)

Event	PO3		PO4		PO1 (outlet)	
	Baseline	Developed	Baseline	Developed	Baseline	Developed
10% AEP	18	1	10	8	43	25
1% AEP	60	2	32	26	133	77
1 in 500 AEP	78	2	42	39	195	117
PMP	700	25	397	356	1490	915

Peak flows at PO1 (the catchment outlet) for the critical duration storm reduced by 38-42% for each event compared to the baseline scenario. A comparison of flow volumes was carried out at PO1 (the catchment outlet) for the 10% and 1% AEP events (Figure 6-1). For both events a 35% reduction in runoff volume occurred. This is expected given the benches and area trapped behind the WRD which retain runoff are approximately 35% of the catchment area. The top of the WRD also attenuates some runoff and has a higher continuing loss value applied to from this area.

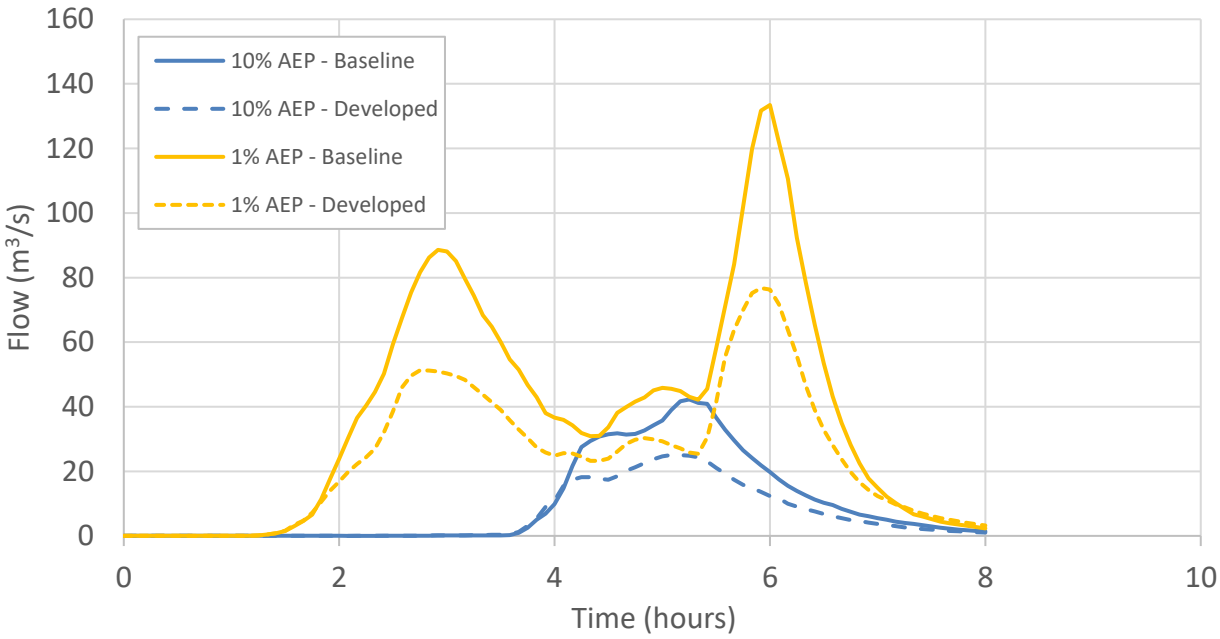


Figure 6-2: Peak Flow and Volume Comparison at Catchment 5 Outlet

A refined model was developed using a 2 m grid resolution to assess the sensitivity to flood levels in the benches due to grid size using several storm durations for the PMP event. The reduced cell resolution resulted in a reduction in water level in the benches of 100-200 mm, however overtopping still occurred in only the PMP 72 hour event.

7 CONCLUSION

Key findings from the waterways investigation are as follows:

- Design flows produced from the RORB rainfall-runoff models using Monte Carlo and ensemble event approaches are considered the most robust estimates. RORB flows are lower than those predicted using the regional flood frequency methods which are based on data from significantly larger catchments.
- 1% AEP critical storm durations for each catchment outlet are generally 6 hours except for Catchments 2 and 3 which resulted in 1 hour and 2 hour critical durations respectively. Critical duration may vary in the upstream parts of the catchment and other AEP events.
- TUFLOW models were used to simulate 10 rainfall temporal patterns from the critical duration for each AEP identified using RORB. Design temporal patterns were selected which produced peak flows in TUFLOW closest to (but not less than) those obtained using RORB at the three reporting locations which had varying catchment areas.
- Peak flows estimated using TUFLOW from the selected temporal patterns were generally around the median of the ensemble group for all catchments.
- Smaller catchments exhibit larger differences in peak flows when comparing the results from TUFLOW and RORB against the regional flood frequency methods which report higher flows
- The TUFLOW models for Catchments 1, 5, and 10 were updated to incorporate earthworks associated with the Stage 2 development. This scenario identified locations where mitigation measures will need to be investigated further to manage adverse impacts to existing flood behaviour and protect mine site infrastructure.
- A detailed assessment of the WRD demonstrated that the benches are shown to retain runoff for events up to the PMP 72 hour storm. Peak flows at the catchment outlet for the critical duration storm reduced by 38-42% for each event compared to the baseline scenario. Runoff volumes reduced by 35% for the 10% and 1% AEP events.

7.1 Limitations

The findings of this study are subject to the following limitations:

- The accuracy of modelled flood levels is directly related to the accuracy of the survey data. In this case LiDAR data was used to develop the hydraulic models. LiDAR data typically has a vertical accuracy of approximately +/- 0.15m however in places this accuracy can vary to several hundred millimetres.
- RORB and TUFLOW models have incorporated ARFs based on the total catchment size. For smaller catchments (or catchment part upstream) rainfall depths may need to increase to ensure flows are not underestimated given a smaller ARF would apply.
- Peak flows generated by TUFLOW have been validated against RORB results at the three reporting locations within each catchment. For areas outside of these locations (especially minor catchments) caution should be used when reviewing the results from TUFLOW.
- Rainfall was also excluded from the proposed pits which align with model boundaries. Results within the pit areas are not representative and should not be used.

8 REFERENCES

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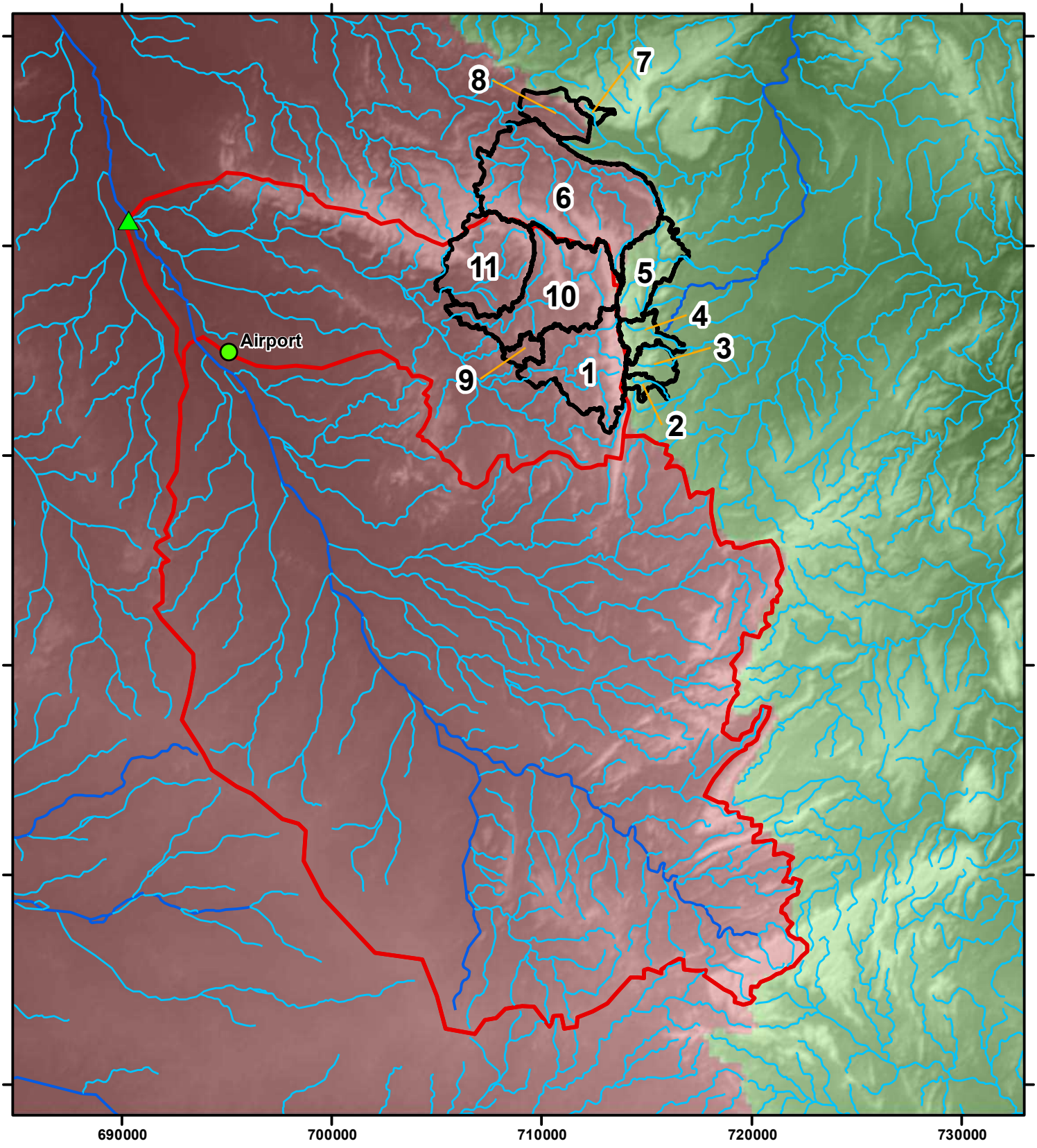
9 GLOSSARY

1D	one-dimensional
2D	two-dimensional
AEP	Annual Exceedance Probability
ARF	Aerial Reduction Factor
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
GIS	Geographic Information System
GSAM	Generalised Southeast Australia Method
GSDM	Generalised Short-Duration Method
GTSMR	Generalised Tropical Storm Method
IFD	Intensity Frequency Duration
PMP	Probable Maximum Precipitation
PMPF	Probable Maximum Precipitation Flood
PMF	Probable Maximum Flood
RFFE	Regional Flood Frequency Estimation
RFFP	Regional Flood Frequency Procedure
SRTM	Shuttle Radar Topography Mission
WRD	Waste Rock Dump

APPENDIX A

Figures

North Star Mine Site – Waterways Investigation - Figure A1 – General Overview of Project Area



Legend

Stream Gauge

709010 - Pincunah

Drainage

River

Watercourse

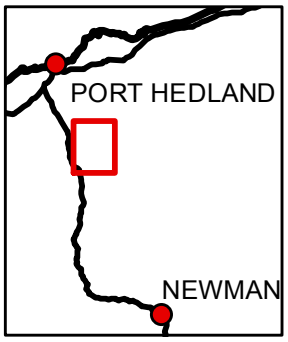
Catchments

Modelled Catchments

Airport Catchments

Turner River Catchment

De Grey River Basin



ACKNOWLEDGEMENT

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APPROVED BS	DATUM GDA 1994 MGA Zone 50

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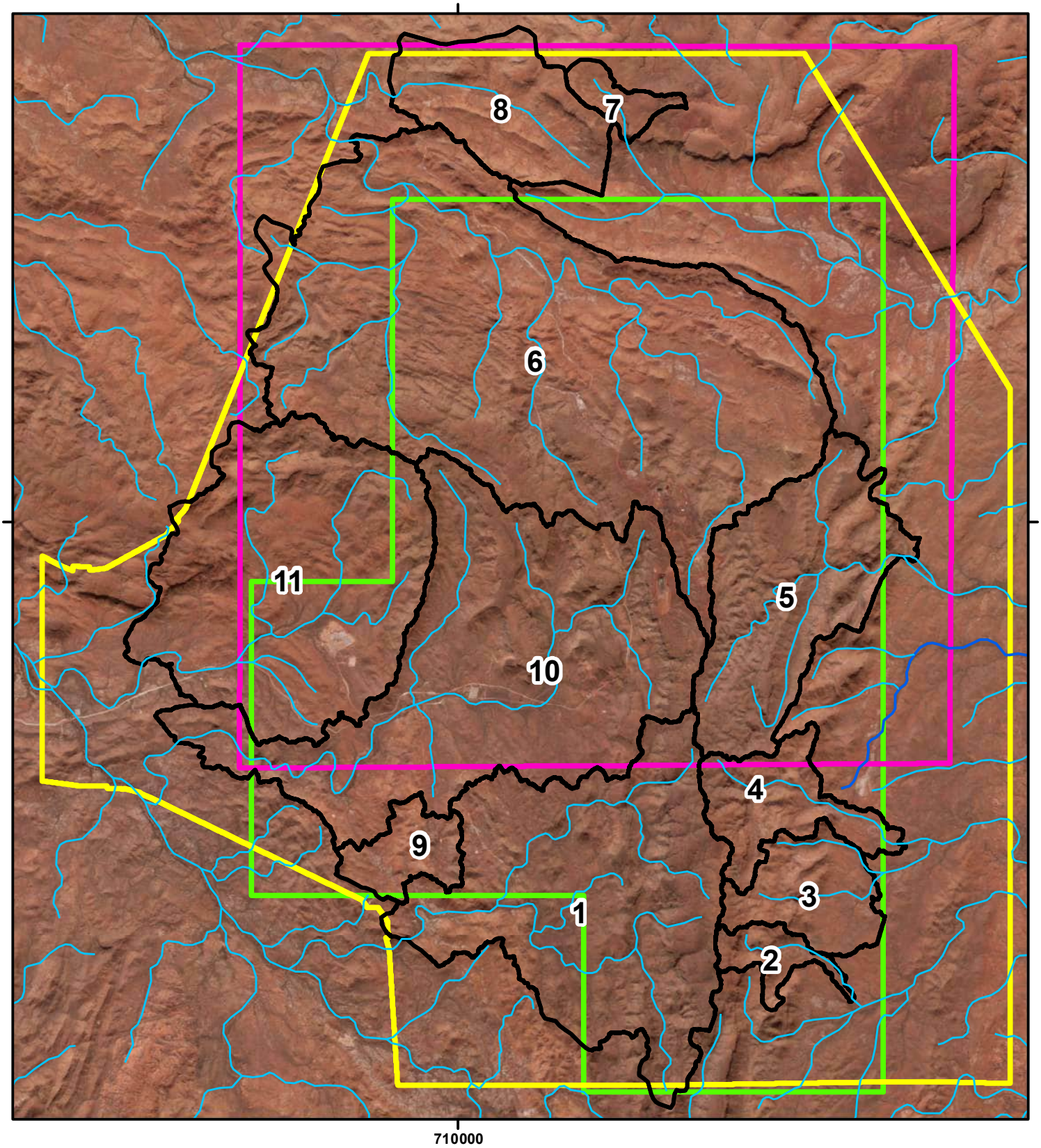
N

0 1 2 4 6 8 10 Km

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P:\P18150 NORTH STAR FLOOD STUDY UPDATE\100 DRAWINGS\102 Civil & Water\GIS\Maps\Report Maps\Figure A1 – General Overview of Project Area.mxd

North Star Mine Site – Waterways Investigation - Figure A2 - Available Lidar Extents



Legend

LiDAR Extents

- 2011 Extents
- 2014 Extents
- 2018 Extents

Catchments

- Modelled Catchments

Drainage

- River
- Watercourse

ACKNOWLEDGEMENT

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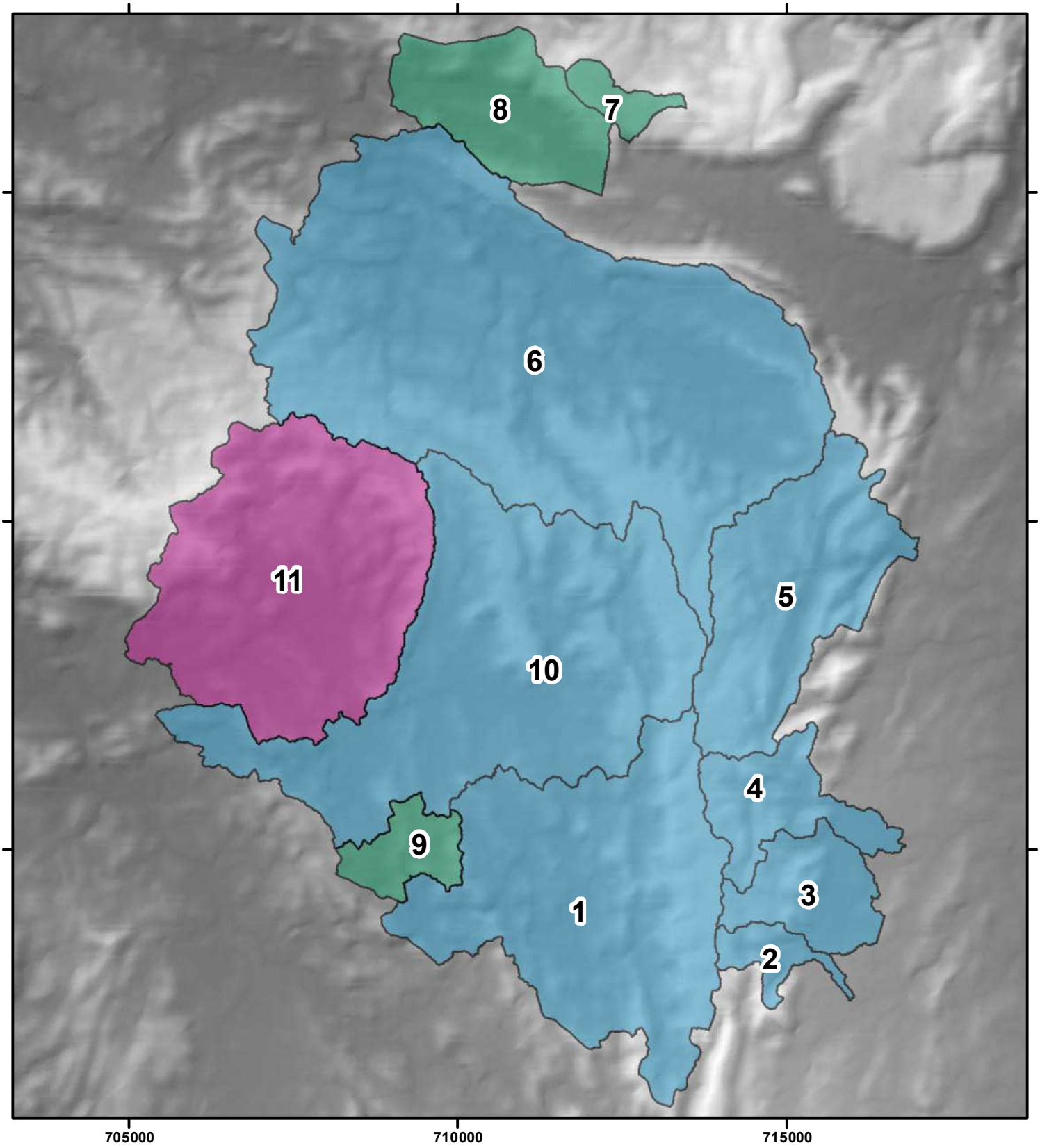
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0 0.5 1 2 3 Km

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North Star Mine Site – Waterways Investigation - Figure A3 - Modelled Catchments - FMG North Star Area



Legend

Drainage

- River
- Watercourse

Catchments

- All Runs including PMP
- Up to 1% AEP
- Not Modelled

ACKNOWLEDGEMENT

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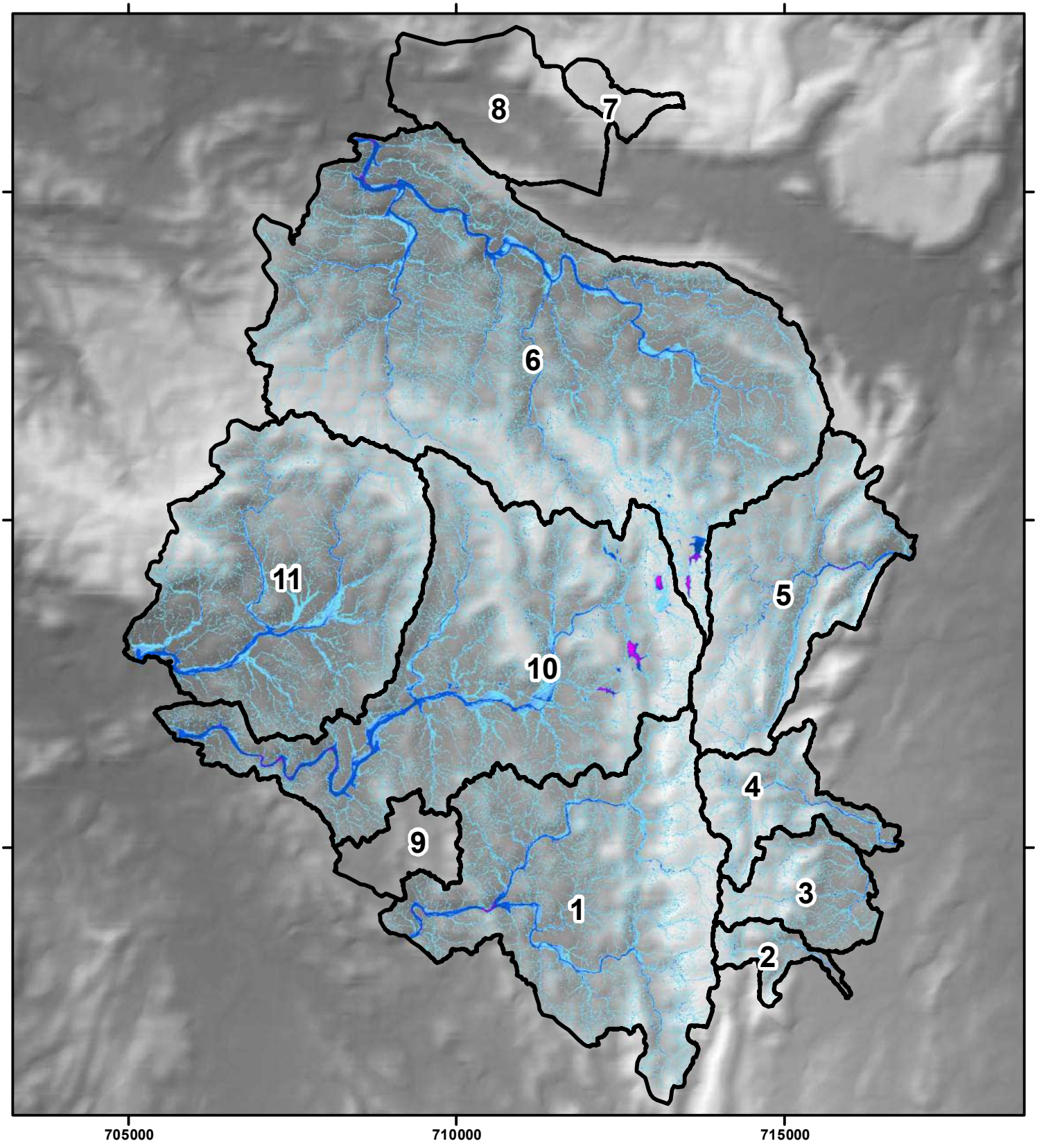
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North Star Mine Site – Waterways Investigation - Figure A4 - Maximum Flood Extents and Depths – Baseline 1% AEP



Baseline 1% AEP
Maximum Depth (mAHD)

0 - 0.1	0.5 - 1.0	2.0 - 3.0
0.1 - 0.5	1.0 - 2.0	3.0 - 5.0
		>5.0

ACKNOWLEDGEMENT

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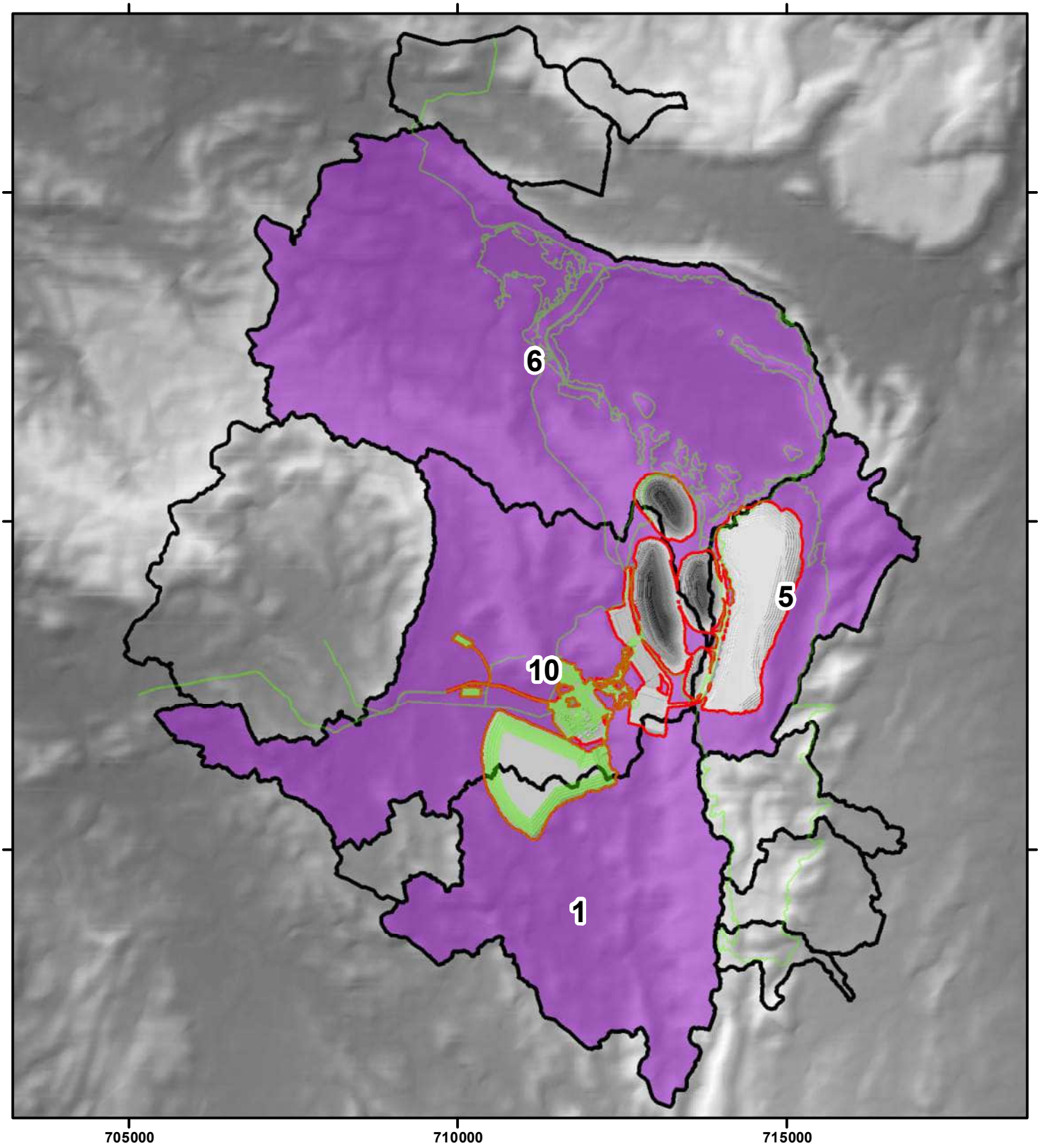
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0 0.5 1 2 3 Km

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North Star Mine Site – Waterways Investigation - Figure A5 - Developed Scenario Catchments



Legend

Catchments

- Modelled Catchments
- Not Modelled

Infrastructure

- Modelled Infrastructure Footprint
- Overall Infrastructure Footprint

ACKNOWLEDGEMENT

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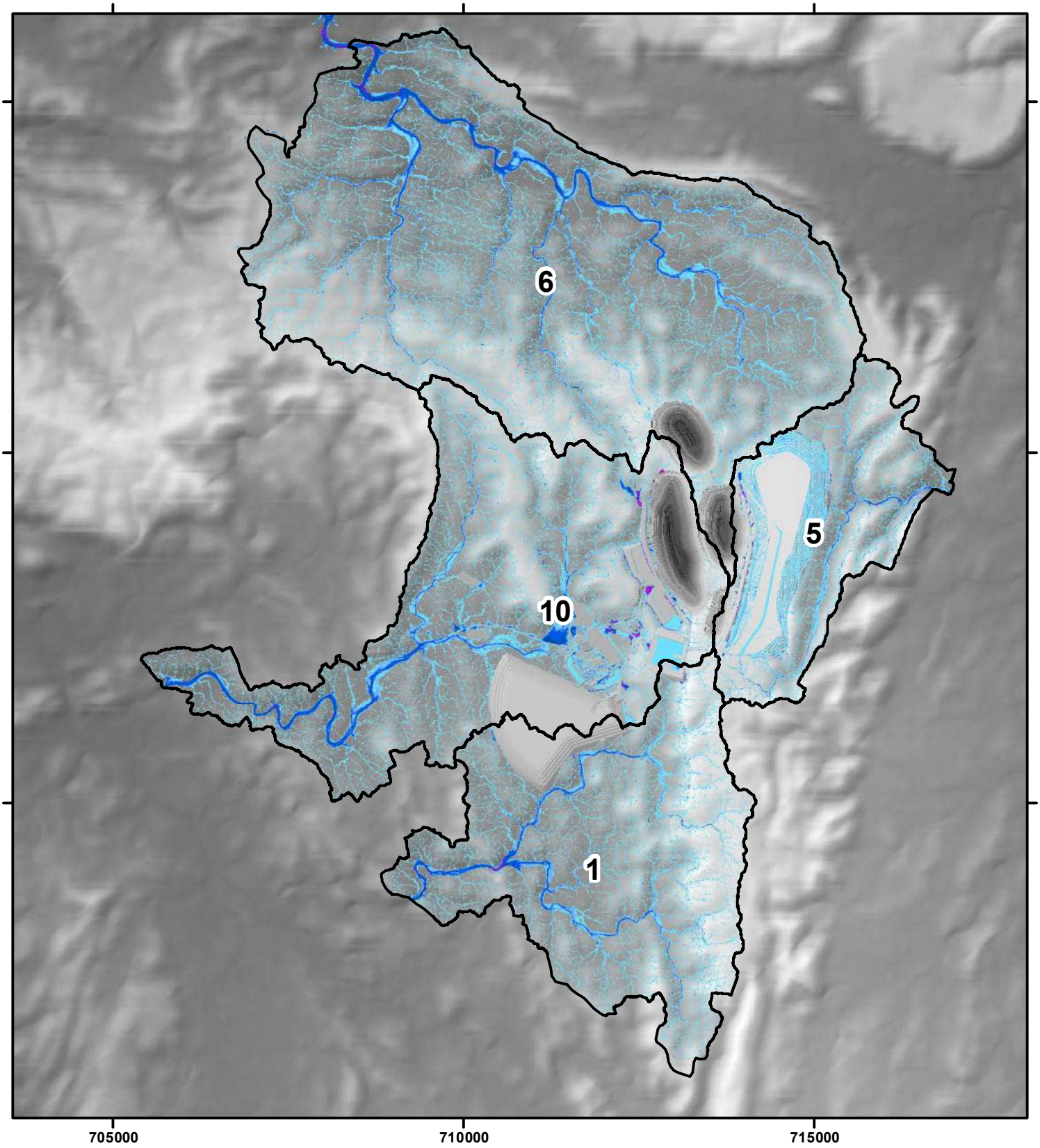
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0 0.5 1 2 3 Km

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North Star Mine Site – Waterways Investigation - Figure A6 - Maximum Flood Extents and Depths – Developed Scenario 1% AEP



Option 1% AEP
Maximum Depth (mAHD)

0 - 0.1	0.5 - 1.0	2.0 - 3.0
0.1 - 0.5	1.0 - 2.0	3.0 - 5.0
		>5.0

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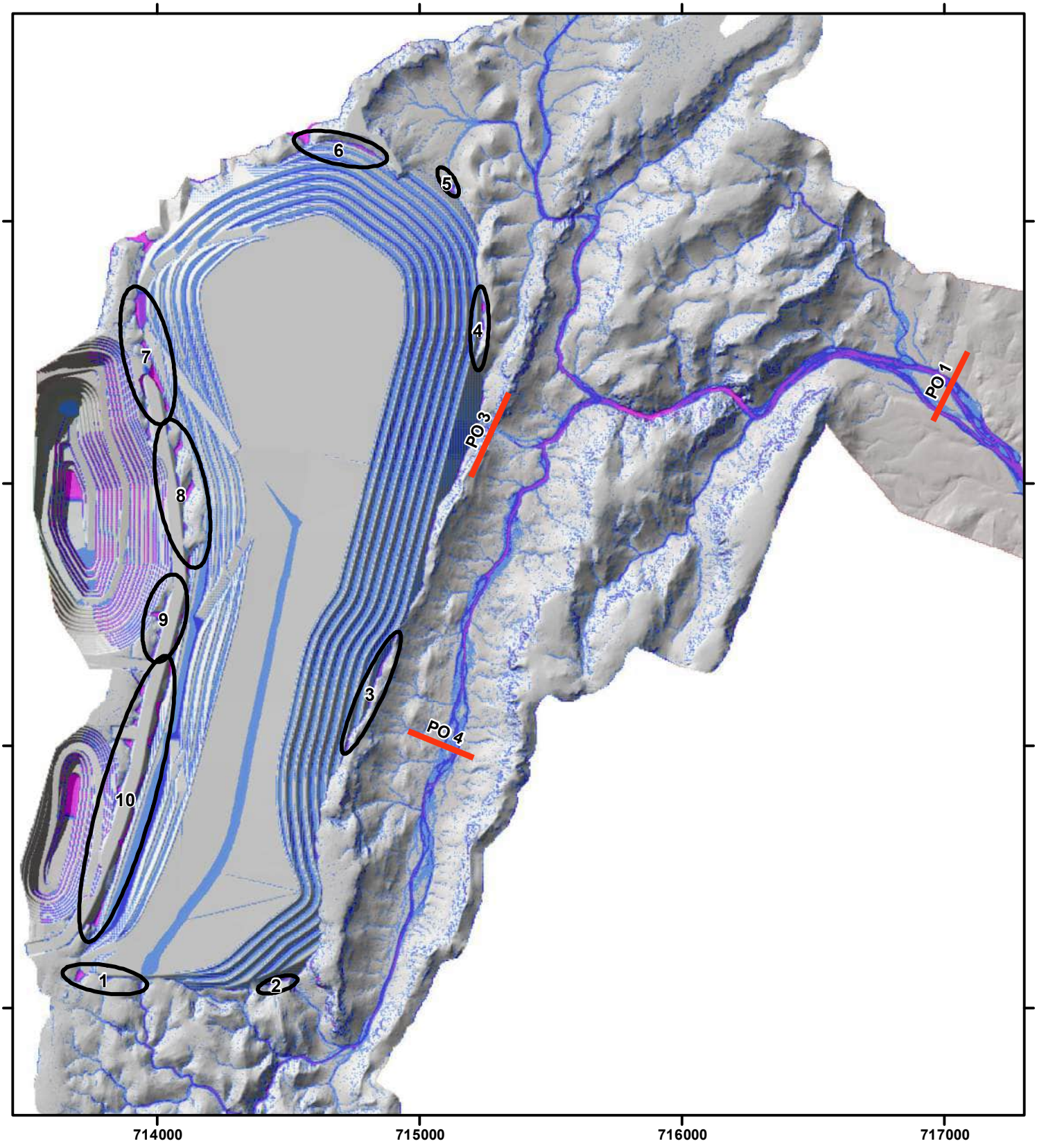
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0 0.5 1 2 3 Km

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North Star Mine Site – Waterways Investigation - Figure A8 – Flood Impact Locations – Catchment 5 – 1% AEP



Legend

Potential Impact Location Maximum Depth (mAHD)

0 - 0.1	1.0 - 2.0
0.1 - 0.5	2.0 - 20.0
0.5 - 1.0	

Reported flow locations

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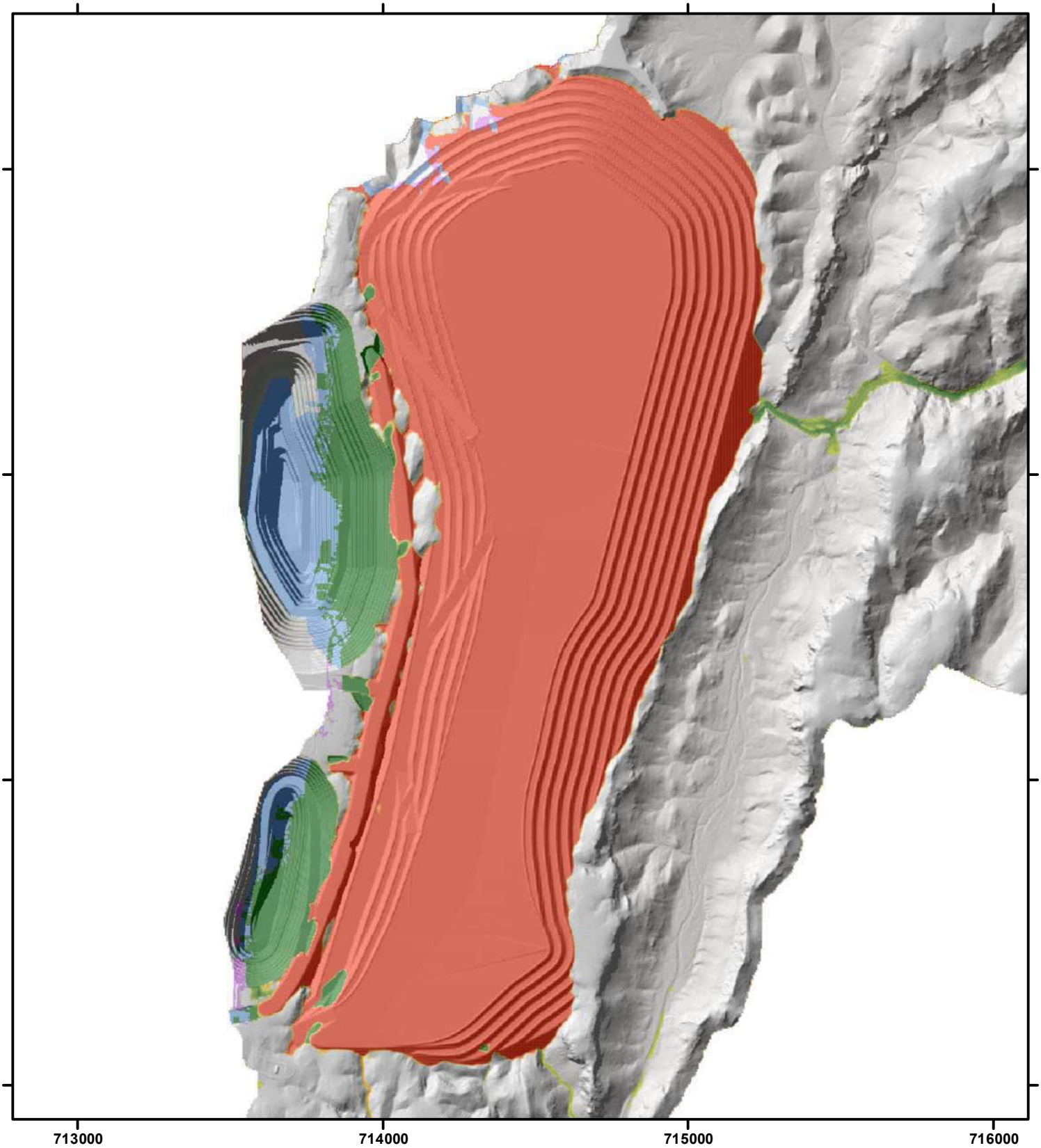
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0 0.1 0.2 0.4 0.6 0.8 Km

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North Star Mine Site – Waterways Investigation - Figure A12 – Flood Level Difference – Catchment 5 – 1% AEP



Legend - WL Difference (m)

- < -1.0 - WL decreased on Option 1
- -1.0 - -0.75 - WL decreased on Option 1
- -0.75 - -0.5 - WL decreased on Option 1
- -0.5 - -0.25 - WL decreased on Option 1
- -0.25 - -0.1 - WL decreased on Option 1
- -0.1 - 0.1 - negligible difference (+/-10cm)
- 0.1 - 0.25 - WL increased on Option 1
- 0.25 - 0.5 - WL increased on Option 1
- 0.5 - 0.75 - WL increased on Option 1
- 0.75 - 1.0 - WL increased on Option 1
- >1.0 - WL increased on Option 1
- Was wet, now dry
- Was dry, now wet (or wasn't modelled in baseline)

ACKNOWLEDGEMENT

FMG

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0 0.1 0.2 0.4 0.6 0.8 Km

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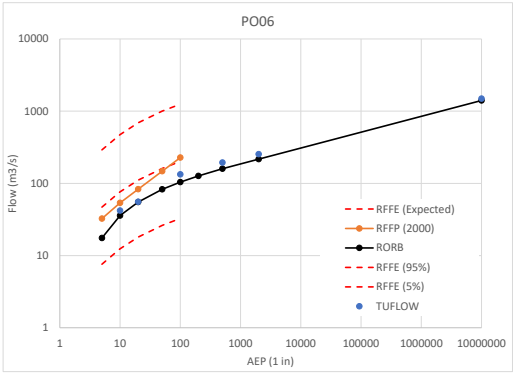
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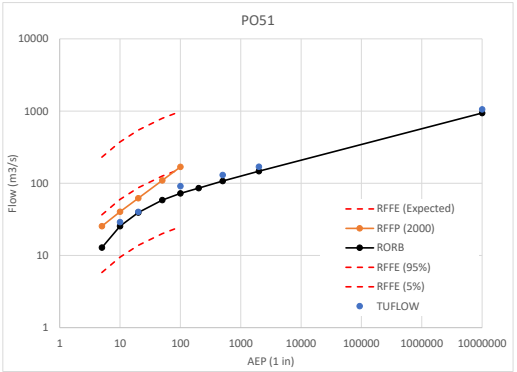
APPENDIX B

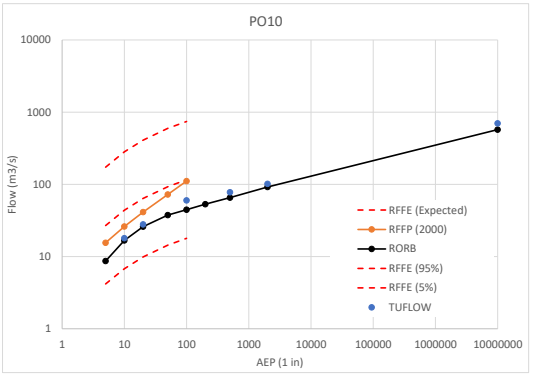
Peak Flow Estimates

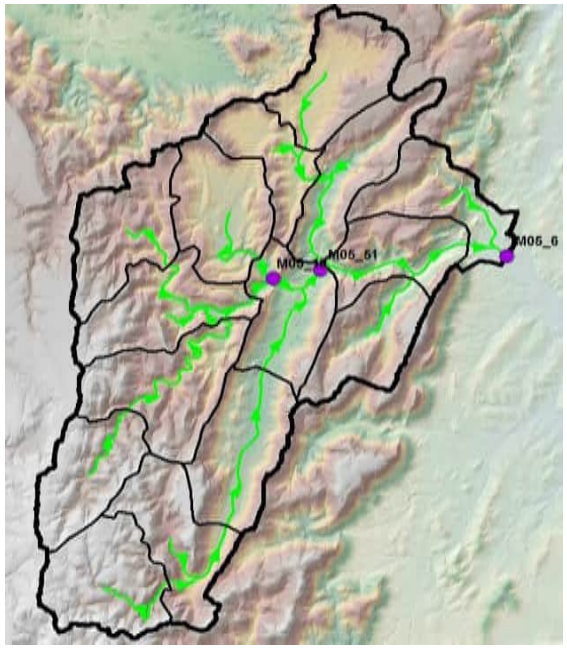
CATCHMENT 5

AEP (1 in)	AEP (%)	RFFE Expected Peak Flow (m3/s)			RFFE Lower (5%) Peak Flow (m3/s)			RFFE Upper (5%) Peak Flow (m3/s)			RFFP (2000) Peak Flow (m3/s)			RORB Peak Flow (m3/s)			RORB Critical Duration			TUFLOW Duration	Temp. Pattern	TUFLOW Peak Flow (m3/s)		
		PO06	PO51	PO10	PO06	PO51	PO10	PO06	PO51	PO10	PO06	PO51	PO10	PO06	PO51	PO10	PO06	PO51	PO10			PO06	PO51	PO10
5	20%	47	37	27	8	6	4	291	230	173	32	25	16	18	13	9	6 hr	6 hr	6 hr					
10	10%	76	60	44	12	9	7	474	374	282	54	40	26	36	25	17	6 hr	6 hr	6 hr	6 hr	8	42	29	18
20	5%	111	87	64	18	14	10	690	545	410	83	62	41	55	39	26	6 hr	6 hr	6 hr	6 hr	7	56	40	28
50	2%	161	126	93	26	20	14	1000	792	596	147	109	73	83	59	38	6 hr	6 hr	6 hr					
100	1%	201	157	116	33	25	18	1250	988	743	227	168	111	104	72	45	6 hr	6 hr	6 hr	6 hr	10	133	91	60
200	0.5%													127	85	53	6 hr	6 hr	2 hr					
500	0.2%													159	107	65	6 hr	6 hr	2 hr	6 hr	1	195	130	78
2000	0.05%													217	147	92	6 hr	6 hr	1 hr	6 hr	1	254	169	102
10000000	0.00001%													1405	939	573	1 hr	1 hr	1 hr	1 hr	3	1489	1056	700









APPENDIX C

TUFLOW Model Scenarios

No	TCF file name	Comment	Issued to FMG?
Baseline – Catchment 1			
1	M01_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: CLASSIC VS HPC	No
2	M01_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_03	Extended model run to generate IWL grid for baseline runs	No
3	M01_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_02	Baseline model Runs	Yes
Baseline – Catchment 2			
4	M02_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: CLASSIC VS HPC	No
5	M02_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_03	Extended model run to generate IWL grid for baseline runs	No
6	M02_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_02	Baseline model Runs	Yes
Baseline – Catchment 3			
7	M03_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: CLASSIC VS HPC	No
8	M03_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_03	Extended model run to generate IWL grid for baseline runs	No
9	M03_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_04	Baseline model Runs	Yes
Baseline – Catchment 4			
10	M04_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: CLASSIC VS HPC	No
11	M04_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_03	Extended model run to generate IWL grid for baseline runs	No
12	M04_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_04	SENSITIVITY: Prewetting and wet/dry depth changed to test Mass Balance	No
13	M04_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_05	SENSITIVITY: +20% downstream boundary slope change	No
14	M04_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_06	SENSITIVITY: -20% downstream boundary slope change	No
15	M01_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_02	Baseline model Runs	Yes
Baseline – Catchment 5			
16	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: model run to test resolution (20m, 10m, 5m, 2m)/also run in CLASSIC VS HPC	No
17	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_04	Extended model run to generate IWL grid for baseline runs	No
18	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_06	Baseline model Runs	Yes
Pilot Study/Baseline – Catchment 6			
20	M06_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: model run to test resolution (20m, 10m, 5m, 2m)/also run in CLASSIC VS HPC	No
21	M06_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_03	SENSITIVITY: Applied proportional loss to rainfall (as per Flavell 2006)	No
22	M06_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_04	SENSITIVITY: Manning's n changed from 0.06 to 0.055	No
23	M06_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_05	SENSITIVITY: Pre-wetting test run	No
24	M06_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_06	SENSITIVITY: Pre-wetting test run + Manning's n set to 0.055	No
25	M06_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_08	Extended model run to generate IWL grid for baseline runs	No
26	M06_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_09	Baseline model Runs	Yes
Baseline – Catchment 10			
27	M10_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: model run to test resolution (20m, 10m, 5m, 2m)/also run in CLASSIC VS HPC	No
28	M10_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_03	Extended model run to generate IWL grid for baseline runs	No
29	M10_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_04	Baseline model Runs	Yes
Pilot Study/Baseline – Catchment 11			
30	M11_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_01	SENSITIVITY: model run to test resolution (20m, 10m, 5m, 2m)/also run in CLASSIC VS HPC	No
31	M11_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_04	SENSITIVITY: no loss in material file applied, losses applied to rainfall file	No
32	M11_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_05	SENSITIVITY: IL/CL applied through TSOILF file in TUFLOW	No
33	M11_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_06	SENSITIVITY: Applied proportional loss to rainfall (as per Flavell 2006)	No
34	M11_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_08	Extended model run to generate IWL grid for baseline runs	No
35	M11_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_09	Baseline model Runs	Yes

No	TCF file name	Comment	Issued to FMG?
Developed Case Scenario - Option 1			
36	M01_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_04	Model 1 - Option 1	Yes
37	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_07	Model 5 - Option 1	Yes
38	M10_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_05	Model 10 - Option 1	Yes
Developed Case Scenario - Option 1 - Waste Rock Dump Refined option run			
39	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_08	WRD extended model run to generate Initial Water Level	No
40	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_09	SENSITIVITY: output file type option 1	No
41	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_10	SENSITIVITY: output file type option 2	No
42	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_11	SENSITIVITY: output file type option 3	No
43	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_12	Design run, as per received WRD 12DA files with no amendments (water leaks through the sides of each bund)	No
44	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_13	Amended WRD design in TUFLOW model to have closed cells for each WRD bench, extended model run to generate IWL	No
45	M05_~s1~_~s2~_~s3~_~e1~_~e2~_~e3~_14	Design run as above with IWL	Yes

APPENDIX D

Catchment 1 IFD Data

Catchment 1 Rainfall Intensity Frequency Duration (IFD) Data

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IFD Design Rainfall Depth (mm)
Issued: 7-Nov-18
Location
Requested Latitude -21.291 Longitude 119.044
Nearest gri Latitude 21.2875(S) Longitude 119.0375(E)

		Annual Exceedance Probability (AEP)												
Duration	Duration in	63.20%	50%#	20%*	10%	5%	2%	1%	0.50%	0.20%	0.10%	0.05%	0.01%	PMP
1 hour	60	28.4	32.9	47.3	57.3	67.3	80.8	91.7	105	123	138	156	183	450
1.5 hour	90	32.1	37.3	54	65.7	77.3	93.3	106	121	142	160	180	212	570
2 hour	120	34.8	40.6	59.2	72.3	85.5	104	119	136	159	180	202	238	670
3 hour	180	38.8	45.5	67.6	83.3	99.3	122	140	160	188	211	238	280	810
4.5 hour	270	43.2	51.2	77.5	96.7	116	144	167	190	224	252	284	334	970
6 hour	360	46.8	55.7	85.8	108	131	164	190	217	255	287	323	380	1080
9 hour	540	52.4	63	99.1	126	155	196	229	261	307	346	389	458	
12 hour	720	56.8	68.7	110	141	175	222	259	295	347	391	440	518	1170
18 hour	1080	63.7	77.7	126	164	204	260	304	347	407	459	517	608	
24 hour	1440	69	84.4	138	180	225	286	334	382	455	514	577	668	1220
30 hour	1800	73.3	89.8	147	192	240	304	355	406	479	537	597	710	
36 hour	2160	76.8	94.2	155	201	251	317	369	421	493	552	610	738	1500
48 hour	2880	82.4	101	165	214	266	333	386	437	509	567	624	772	1760
72 hour	4320	89.9	110	178	228	281	346	397	449	521	577	635	794	2210
96 hour	5760	94.8	116	185	235	287	350	399	454	525	581	641	798	2480
120 hour	7200	98.3	120	190	240	290	352	399	458	530	585	646	798	2600
144 hour	8640	101	123	194	244	294	355	400	463	535	591	653	800	
168 hour	10080	103	126	198	248	297	359	405	469	541	598	660	810	

Values estimated using Jordan et al. (2005) growth factors
Values estimated using growth factor of 2.0 based 0.01% values for longer duration events from BoM
Values estimated using Generalised Short Duration Method (GSDM)
Values estimated using Generalised Tropical Storm Method (GTSMR)

Note: Values for other catchments vary slightly

APPENDIX E

WRD Infiltration Test Results

Brett Stinton

From: Evan Howard <howarde@landloch.com.au>
Sent: Friday, 7 December 2018 8:39 AM
To: David Westwater; Justin Dixon
Subject: RE: Ironbridge Testing

Hi Dave,

For the data below, the steady rate is the final figures in the table: 24.7mm/hr and 12.9mm/hr. For modelling I suggest running them both or averaging the two.

The value is calculated from data collected from application of simulated rain. Rainfall is applied as a steady and known rate and runoff is measured at regular intervals. Infiltration is the difference between steady rain and the measured runoff. The steady rainfall rate is that value listed at time=0 minutes (101.81mm/hr for Plot 2 and 110.61mm/hr for Plot 3). These rainfall rates are calibrated against physical measures of rain from rain gauges positioned at the edges of the test plots (average of 4 measures).

Regards
Evan

From: David Westwater <dwestwater@fmgl.com.au>
Sent: Friday, December 7, 2018 7:08 AM
To: Justin Dixon <jdixon@fmgl.com.au>; Evan Howard <howarde@landloch.com.au>
Subject: RE: Ironbridge Testing

Hi Evan

This is really useful data.

Can you please provide the steady infiltration rate, and advise how you calculated that?

Thanks

Dave

Dr David Westwater
Principal Surface Water Engineer | Long Term Planning
Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace East Perth WA 6004
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Twitter: @FortescueNews I **www.fmgl.com.au**

From: Justin Dixon
Sent: Thursday, 6 December 2018 4:10 PM
To: David Westwater
Subject: FW: Ironbridge Testing

From: Evan Howard <howarde@landloch.com.au>
Sent: Thursday, 6 December 2018 4:09 PM
To: Justin Dixon <jdixon@fmgl.com.au>
Subject: RE: Ironbridge Testing

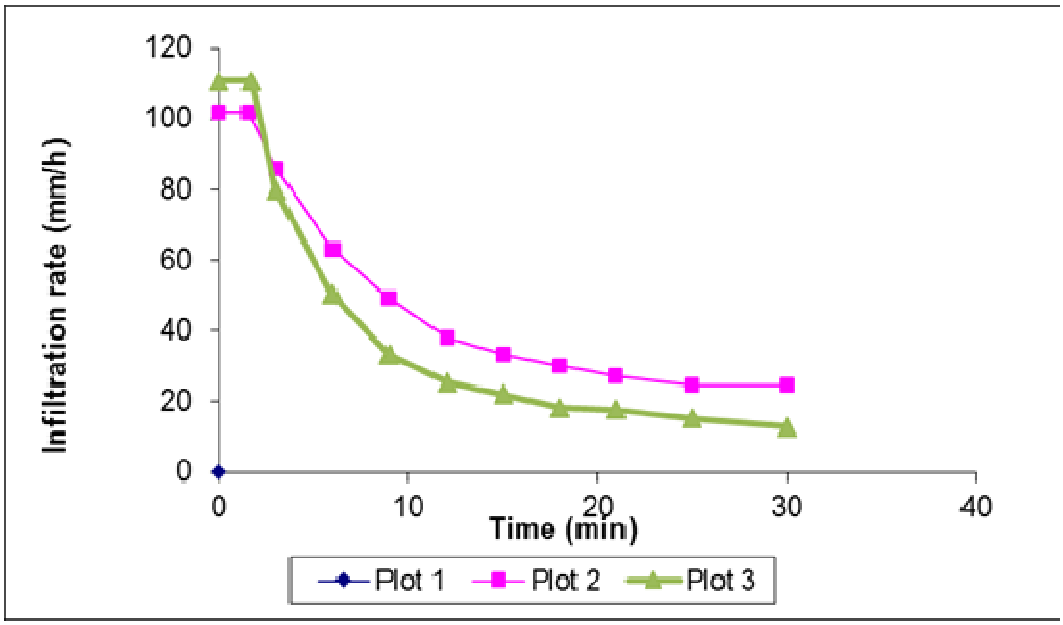
To generate the hydraulic conductivity we first get a steady state infiltration. I could supply those. Here is the data for the oxides. We did duplicate plots known as Plot 2 and 3 in the data I gave below (that's just the way our standard lab templates describe them).

Plot 2

Time from start (min)	Runoff rate (mm/h)	Infiltrn rate (mm/h)
0	0	101.81
1.5	0.0	101.8
3.0	16.0	85.9
6.0	38.6	63.2
9.0	52.5	49.3
12.0	63.6	38.2
15.0	68.4	33.4
18.0	71.6	30.3
21.0	74.6	27.2
25.0	77.0	24.8
30.0	77.1	24.7

Plot 3

Time from start (min)	Runoff rate (mm/h)	Infiltrn rate (mm/h)
0	0	110.61
1.67	0.0	110.6
3.0	30.7	79.9
6.0	60.2	50.4
9.0	77.2	33.4
12.0	85.2	25.4
15.0	88.5	22.1
18.0	92.3	18.3
21.0	92.9	17.7
25.0	95.5	15.1
30.0	97.7	12.9



From: Justin Dixon <jdixon@fmgl.com.au>
Sent: Thursday, December 6, 2018 3:46 PM
To: Evan Howard <howarde@landloch.com.au>
Subject: Ironbridge Testing

Hi Evan,

Do you recall if an infiltration test was completed for the IB Oxides?

There is a result for the coarse rejects results, but only an effective hydraulic conductivity for the oxides.

Regards,

Justin Dixon
Long Term Planning / Principal Geotechnical Engineer

Fortescue Metals Group Ltd
Level 2, 87 Adelaide Terrace East Perth WA 6004

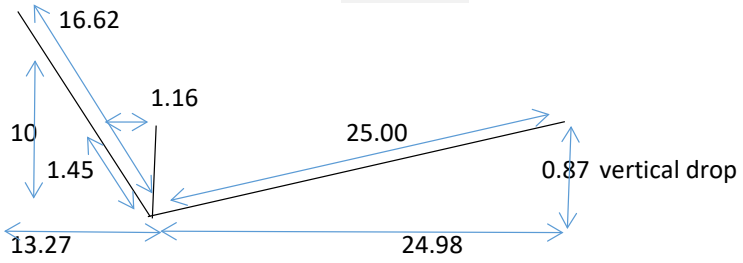
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Appendix 6: FMG: Berm Capacity Calculations

Project: North Star WD
Title: Berm option 0, 25m berm width, 2 degree back-slope

Inputs

permeability (saturated)	5.00E-06	m/s	18.0	mm/hr	lower limit rate		
permeability (saturated)	7.00E-06	m/s	25.2	mm/hr	upper limit rate		
continuing loss rate (slope)			18.8	mm/hr			
berm length	25	m					
berm back slope angle	2	degree	0.034907	radians			
vertical drop from horizontal	0.87	m					
berm horizontal footprint	24.98	m					
distance to batter	1.16	m					
Slope configuration:	Slope				n/a		
lift height	10	m			0	m	
batter slope angle	37	degree	0.645772	radians	2	degree	0.034907
horizontal distance	13.27	m			0.00	m	
batter slope length	16.62	m			0.00	m	
batter slope to vertical drop	1.45	m					



Available Storage

Storage volume available to top edge of berm			11	m3 per metre length
Maximum effective loss length (storage berm and batter under water)			21	m
Total length (berm and batter face)			42	m
			52%	storage infiltration
Additional crest bund storage				
Crest bund height	1.5	m		
Crest bund freeboard	0.5	m		
Crest bund footprint	5	m		
Additional storage			42	m3 per metre length
Maximum available storage including bund storage			54	m3 per metre length
Horizontal footprint	38	m		

	PMP	1230	1:2000	508	1:100	289	
Rainfall without infiltration compensation							mm
Rainfall reporting to landform (upper-lower)	998	994	233	230	40	40	mm
Rainfall runoff reporting to storage	38	38	9	9	2	1.5	
	m3 per metre length						

Assessment comments

Storage depth against bund (upper-lower limits)				Result
PMP	1.27	1.26	m	*Contained below freeboard*
1:2000	0.00	0.00	m	*Contained on berm*
1:100	0.00	0.00	m	*Contained on berm*

Probable Maximum Rainfall treatment

Excess = Rainfall rate - (%storage slope * permeability loss) - (%contributing slope * continuing loss rate)

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**175.69**	58.56	49.02	147.05	47.78	143.34
6	**158.09**	52.70	43.01	129.04	43.01	129.04
9	**134.54**	44.85	35.16	105.49	35.16	105.49
12	**292.27**	97.42	87.74	263.22	87.74	263.22
15	**219.03**	73.01	63.33	189.98	63.33	189.98
18	**84.81**	28.27	18.59	55.76	18.59	55.76
21	**104.64**	34.88	25.20	75.60	25.20	75.60
24	**60.93**	20.31	10.63	31.88	10.63	31.88
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**1230.00**		Lower limit	**998.02**	Upper limit	**994.31**

2000 year Rainfall treatment

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**72.60**	24.20	14.66	43.97	13.42	40.26
6	**65.33**	21.78	12.09	36.28	12.09	36.28
9	**55.60**	18.53	0.00	0.00	0.00	0.00
12	**120.78**	40.26	30.58	91.73	30.58	91.73
15	**90.52**	30.17	20.49	61.47	20.49	61.47
18	**35.05**	11.68	0.00	0.00	0.00	0.00
21	**43.24**	14.41	0.00	0.00	0.00	0.00
24	**25.18**	8.39	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**508.30**		Lower limit	**233.45**	Upper limit	**229.74**

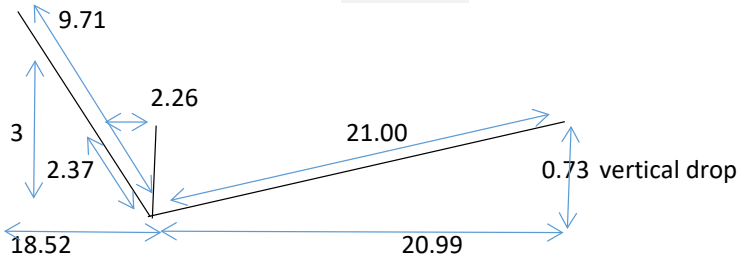
100 year Rainfall treatment

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**41.31**	13.77	0.00	0.00	0.00	0.00
6	**37.17**	12.39	0.00	0.00	0.00	0.00
9	**31.63**	10.54	0.00	0.00	0.00	0.00
12	**68.72**	22.91	13.22	39.67	13.22	39.67
15	**51.50**	17.17	0.00	0.00	0.00	0.00
18	**19.94**	6.65	0.00	0.00	0.00	0.00
21	**24.60**	8.20	0.00	0.00	0.00	0.00
24	**14.33**	4.78	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**289.20**		Lower limit	**39.67**	Upper limit	**39.67**

Project: North Star WD
Title: Berm option 1, 21m berm width, 2 degree back-slope

Inputs

permeability (saturated)	5.00E-06	m/s	18.0	mm/hr	lower limit rate		
permeability (saturated)	7.00E-06	m/s	25.2	mm/hr	upper limit rate		
continuing loss rate (slope)			18.8	mm/hr			
berm length	21	m					
berm back slope angle	2	degree	0.034907	radians			
vertical drop from horizontal	0.73	m					
berm horizontal footprint	20.99	m					
distance to batter	2.26	m					
Slope configuration:	buttress				top slope		
lift height	3	m			7	m	
batter slope angle	18	degree	0.314159	radians	37	degree	0.645772
horizontal distance	9.23	m			9.29	m	
batter slope length	9.71	m			11.63	m	
batter slope to vertical drop	2.37	m					



batter **<--dimensions-->** **berm**

Available Storage

Storage volume available to top edge of berm				9	m3 per metre length
Maximum effective loss length (storage berm and batter under water)				18	m
Total length (berm and batter face)				42	m
				43%	storage infiltration
Additional crest bund storage					
Crest bund height	1.5	m	Crest bund footprint	5	m
Crest bund freeboard	0.5	m			
			Additional storage	36	m3 per metre length
			Maximum available storage including bund storage	45	m3 per metre length
Horizontal footprint	40	m			

	PMP	1230	1:2000	508	1:100	289	
Rainfall without infiltration compensation							mm
Rainfall reporting to landform (upper-lower)	1035	1032	252	249	44	44	mm
Rainfall runoff reporting to storage	41	41	10	10	2	1.7	
	m3 per metre length						

Assessment comments

Storage depth against bund (upper-lower limits)				***Result***
PMP	1.77	1.77	m	***Contained in freeboard***
1:2000	0.08	0.07	m	***Contained below freeboard***
1:100	0.00	0.00	m	***Contained on berm***

Probable Maximum Rainfall treatment

Excess = Rainfall rate - (%storage slope * permeability loss) - (%contributing slope * continuing loss rate)

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**175.69**	58.56	50.53	151.58	49.48	148.45
6	**158.09**	52.70	44.54	133.63	44.54	133.63
9	**134.54**	44.85	36.70	110.09	36.70	110.09
12	**292.27**	97.42	89.27	267.81	89.27	267.81
15	**219.03**	73.01	64.86	194.58	64.86	194.58
18	**84.81**	28.27	20.12	60.36	20.12	60.36
21	**104.64**	34.88	26.73	80.19	26.73	80.19
24	**60.93**	20.31	12.16	36.47	12.16	36.47
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**1230.00**		Lower limit	**1034.70**	Upper limit	**1031.58**

2000 year Rainfall treatment

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**72.60**	24.20	16.16	48.49	15.12	45.37
6	**65.33**	21.78	13.62	40.87	13.62	40.87
9	**55.60**	18.53	0.00	0.00	0.00	0.00
12	**120.78**	40.26	32.11	96.33	32.11	96.33
15	**90.52**	30.17	22.02	66.06	22.02	66.06
18	**35.05**	11.68	0.00	0.00	0.00	0.00
21	**43.24**	14.41	0.00	0.00	0.00	0.00
24	**25.18**	8.39	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**508.30**		Lower limit	**251.75**	Upper limit	**248.63**

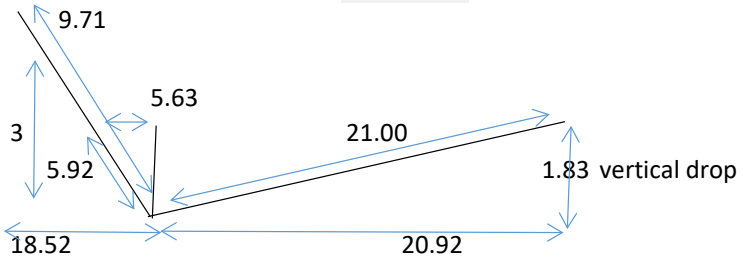
100 year Rainfall treatment

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**41.31**	13.77	0.00	0.00	0.00	0.00
6	**37.17**	12.39	0.00	0.00	0.00	0.00
9	**31.63**	10.54	0.00	0.00	0.00	0.00
12	**68.72**	22.91	14.75	44.26	14.75	44.26
15	**51.50**	17.17	0.00	0.00	0.00	0.00
18	**19.94**	6.65	0.00	0.00	0.00	0.00
21	**24.60**	8.20	0.00	0.00	0.00	0.00
24	**14.33**	4.78	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**289.20**		Lower limit	**44.26**	Upper limit	**44.26**

Project: North Star WD
Title: Berm option 2, 21m berm width, 5 degree back-slope

Inputs

permeability (saturated)	5.00E-06	m/s	18.0	mm/hr	lower limit rate		
permeability (saturated)	7.00E-06	m/s	25.2	mm/hr	upper limit rate		
continuing loss rate (slope)			18.8	mm/hr			
berm length	21	m					
berm back slope angle	5	degree	0.087266	radians			
vertical drop from horizontal	1.83	m					
berm horizontal footprint	20.92	m					
distance to batter	5.63	m					
Slope configuration:	buttress				top slope		
lift height	3	m			7	m	
batter slope angle	18	degree	0.314159	radians	37	degree	0.645772
horizontal distance	9.23	m			9.29	m	
batter slope length	9.71	m			11.63	m	
batter slope to vertical drop	5.92	m					



Available Storage

Storage volume available to top edge of berm			24	m3 per metre length
Maximum effective loss length (storage berm and batter under water)			22	m
Total length (berm and batter face)			42	m
			52%	storage infiltration
Additional crest bund storage				
Crest bund height	1.5	m		
Crest bund freeboard	0.5	m		
Crest bund footprint	5	m		
Additional storage			43	m3 per metre length
Maximum available storage including bund storage			67	m3 per metre length
Horizontal footprint	39	m		

	PMP	1230	1:2000	508	1:100	289	
Rainfall without infiltration compensation							mm
Rainfall reporting to landform (upper-lower)	998	994	233	230	40	40	mm
Rainfall runoff reporting to storage	39	39	9	9	2	1.6	
	m3 per metre length						

Assessment comments

Storage depth against bund (upper-lower limits)				Result
PMP	0.70	0.69	m	*Contained below freeboard*
1:2000	0.00	0.00	m	*Contained on berm*
1:100	0.00	0.00	m	*Contained on berm*

Probable Maximum Rainfall treatment

Excess = Rainfall rate - (%storage slope * permeability loss) - (%contributing slope * continuing loss rate)

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**175.69**	58.56	49.00	147.00	47.76	143.29
6	**158.09**	52.70	43.00	128.99	43.00	128.99
9	**134.54**	44.85	35.15	105.45	35.15	105.45
12	**292.27**	97.42	87.72	263.17	87.72	263.17
15	**219.03**	73.01	63.31	189.94	63.31	189.94
18	**84.81**	28.27	18.57	55.71	18.57	55.71
21	**104.64**	34.88	25.18	75.55	25.18	75.55
24	**60.93**	20.31	10.61	31.83	10.61	31.83
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**1230.00**		Lower limit	**997.64**	Upper limit	**993.92**

2000 year Rainfall treatment

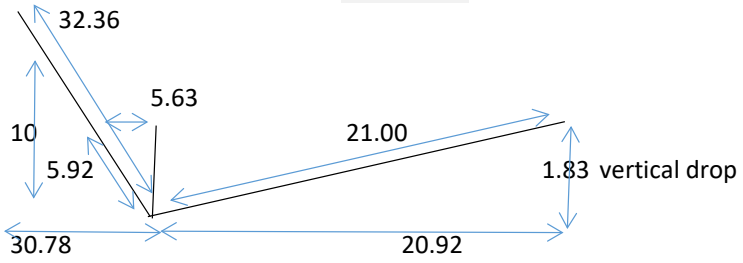
24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**72.60**	24.20	14.64	43.92	13.40	40.20
6	**65.33**	21.78	12.08	36.23	12.08	36.23
9	**55.60**	18.53	0.00	0.00	0.00	0.00
12	**120.78**	40.26	30.56	91.68	30.56	91.68
15	**90.52**	30.17	20.47	61.42	20.47	61.42
18	**35.05**	11.68	0.00	0.00	0.00	0.00
21	**43.24**	14.41	0.00	0.00	0.00	0.00
24	**25.18**	8.39	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**508.30**		Lower limit	**233.25**	Upper limit	**229.54**

100 year Rainfall treatment

24 hour event			**Lower limit**		**Upper limit**	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**41.31**	13.77	0.00	0.00	0.00	0.00
6	**37.17**	12.39	0.00	0.00	0.00	0.00
9	**31.63**	10.54	0.00	0.00	0.00	0.00
12	**68.72**	22.91	13.21	39.62	13.21	39.62
15	**51.50**	17.17	0.00	0.00	0.00	0.00
18	**19.94**	6.65	0.00	0.00	0.00	0.00
21	**24.60**	8.20	0.00	0.00	0.00	0.00
24	**14.33**	4.78	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**289.20**		Lower limit	**39.62**	Upper limit	**39.62**

Inputs

permeability (saturated)	5.00E-06	m/s	18.0	mm/hr	lower limit rate	
permeability (saturated)	7.00E-06	m/s	25.2	mm/hr	upper limit rate	
continuing loss rate (slope)			18.8	mm/hr		
berm length	21	m				
berm back slope angle	5	degree	0.087266	radians		
vertical drop from horizontal	1.83	m				
berm horizontal footprint	20.92	m				
distance to batter	5.63	m				
Slope configuration:	linear				n/a	
lift height	10	m			0	m
batter slope angle	18	degree	0.314159	radians	37 degree	0.645772
horizontal distance	30.78	m			0.00	m
batter slope length	32.36	m			0.00	m
batter slope to vertical drop	5.92	m				



Available Storage

Storage volume available to top edge of berm			24	m3 per metre length
Maximum effective loss length (storage berm and batter under water)			22	m
Total length (berm and batter face)			53	m
			41%	storage infiltration
Additional crest bund storage				
Crest bund height	1.5	m	Crest bund footprint	5 m
Crest bund freeboard	0.5	m		
		Additional storage	43	m3 per metre length
		Maximum available storage including bund storage	67	m3 per metre length
Horizontal footprint	52	m		

	PMP	1230	1:2000	508	1:100	289	
Rainfall without infiltration compensation							mm
Rainfall reporting to landform (upper-lower)	1046	1043	257	254	46	46	mm
Rainfall runoff reporting to storage	54	54	13	13	2	2.4	
	m3 per metre length						

Assessment comments

Storage depth against bund (upper-lower limits)				Result
PMP	1.38	1.37	m	*Contained below freeboard*
1:2000	0.00	0.00	m	*Contained on berm*
1:100	0.00	0.00	m	*Contained on berm*

Probable Maximum Rainfall treatment

Excess = Rainfall rate - (%storage slope * permeability loss) - (%contributing slope * continuing loss rate)

24 hour event			Lower limit		Upper limit	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**175.69**	58.56	50.98	152.93	49.99	149.98
6	**158.09**	52.70	45.00	135.00	45.00	135.00
9	**134.54**	44.85	37.15	111.46	37.15	111.46
12	**292.27**	97.42	89.73	269.18	89.73	269.18
15	**219.03**	73.01	65.32	195.95	65.32	195.95
18	**84.81**	28.27	20.57	61.72	20.57	61.72
21	**104.64**	34.88	27.19	81.56	27.19	81.56
24	**60.93**	20.31	12.61	37.84	12.61	37.84
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**1230.00**		Lower limit	**1045.63**	Upper limit	**1042.68**

2000 year Rainfall treatment

24 hour event			Lower limit		Upper limit	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**72.60**	24.20	16.61	49.84	15.63	46.90
6	**65.33**	21.78	14.08	42.24	14.08	42.24
9	**55.60**	18.53	0.00	0.00	0.00	0.00
12	**120.78**	40.26	32.56	97.69	32.56	97.69
15	**90.52**	30.17	22.48	67.43	22.48	67.43
18	**35.05**	11.68	0.00	0.00	0.00	0.00
21	**43.24**	14.41	0.00	0.00	0.00	0.00
24	**25.18**	8.39	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**508.30**		Lower limit	**257.21**	Upper limit	**254.26**

100 year Rainfall treatment

24 hour event			Lower limit		Upper limit	
Time	Volume	Rate	Excess rainfall	Ponding	Excess rainfall	Ponding
hrs	mm	mm/hr	mm/hr	mm cumulative	mm/hr	mm cumulative
0	**0.00**					
3	**41.31**	13.77	0.00	0.00	0.00	0.00
6	**37.17**	12.39	0.00	0.00	0.00	0.00
9	**31.63**	10.54	0.00	0.00	0.00	0.00
12	**68.72**	22.91	15.21	45.63	15.21	45.63
15	**51.50**	17.17	0.00	0.00	0.00	0.00
18	**19.94**	6.65	0.00	0.00	0.00	0.00
21	**24.60**	8.20	0.00	0.00	0.00	0.00
24	**14.33**	4.78	0.00	0.00	0.00	0.00
27	**0.00**	0.00	0.00	0.00	0.00	0.00
Total	**289.20**		Lower limit	**45.63**	Upper limit	**45.63**

Appendix 7: Hydrobiology: Site 12 Pool Water Quality Monitoring & Hydrological Regime

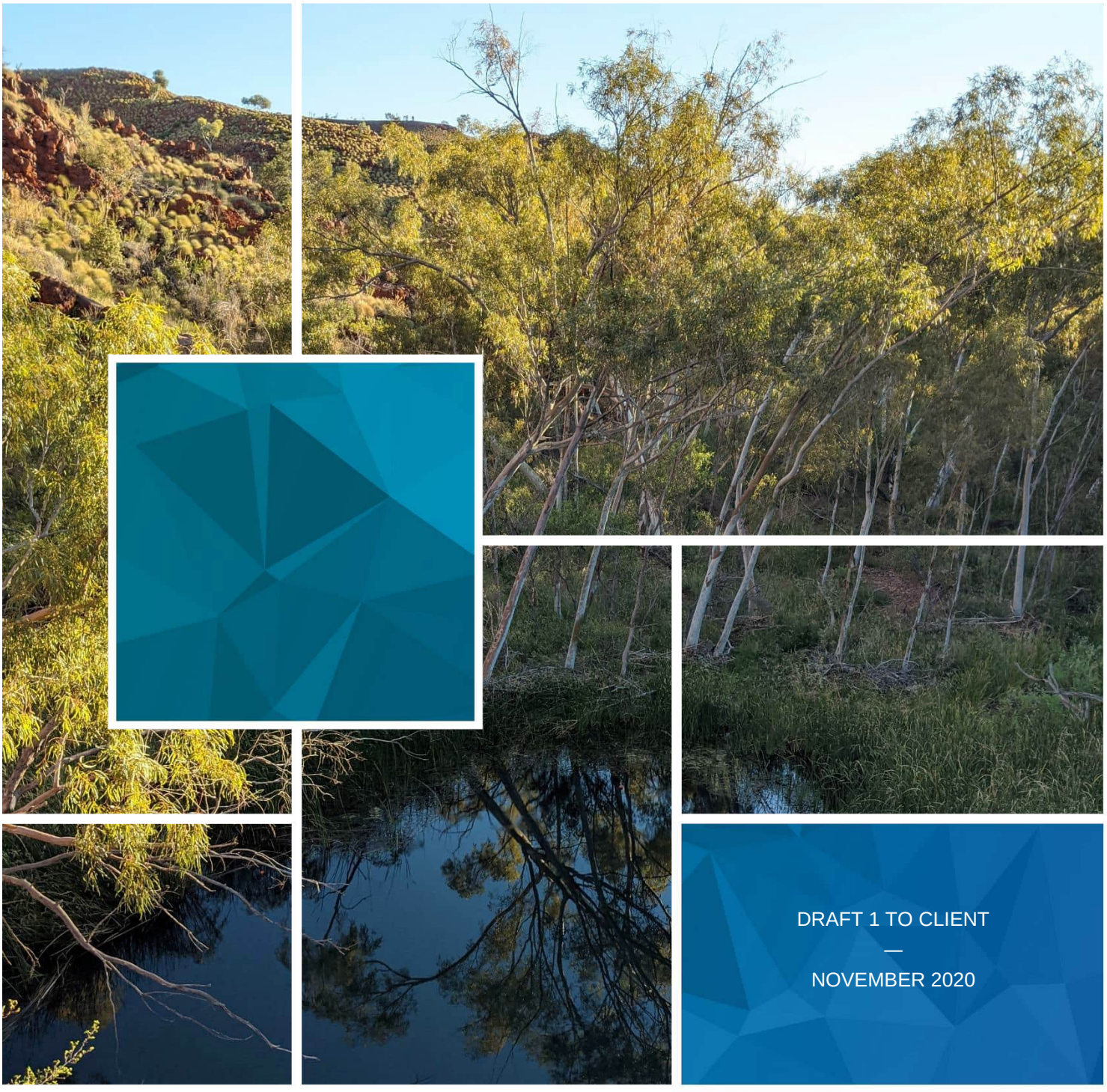
Hydrobiology

IRON BRIDGE: SURFACE WATER MONITORING AND AQUATIC ECOLOGY SURVEY BASELINE REPORT

LATE WET 2019/2020

BRISBANE | PERTH | SINGAPORE | PAPUA NEW GUINEA

FMG IRON BRIDGE (AUST) PTY LTD



DRAFT 1 TO CLIENT

—

NOVEMBER 2020

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GLOSSARY OF ACRONYMS

Acronym	Definition
ANZG	Australian and New Zealand Guidelines for fresh and marine water quality
BRUV	Baited remote underwater video- a sampling method for fish
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DSIAR	Diatom Species Index for Australian Rivers
EC	Electrical Conductivity
EPT	Ephemeroptera, Plecoptera, Tricoptera
FMGIB	FMG Iron Bridge (Aust) Pty Ltd
N	Nitrogen
NTU	Nephelometric Turbidity Units
P	Phosphorous
QA/QC	Quality Assurance/Quality Control
SO4	Sulphate
SPC	Specific Conductivity (conductivity normalized to 25°C)
TDS	Total Dissolved Solids
TIC	Total Inorganic Carbon
TOC	Total Organic Carbon
TSS	Total Suspended Solids

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1. INTRODUCTION

This report presents the findings of a baseline aquatic ecology survey of surface water pools at the Iron Bridge – North Star project in the 2019/2020 late wet season.

1.1 BACKGROUND

Hydrobiology WA Pty Ltd (Hydrobiology) conducted an aquatic ecology survey of North Star surface water pools to support the baseline development and approvals of the North Star Magnetite Project (the Project) in the Pilbara region of Western Australia (Figure 1) on behalf of FMG Iron Bridge (Aust) Pty Ltd (FMGIB). The managing entity for the Project is IB Operations Pty Ltd (Iron Bridge), a joint venture company between FMGIB and Formosa Steel IB Pty Ltd.

1.2 OBJECTIVES

The objectives of the aquatic ecology survey are the following:

- Establish baseline aquatic ecology conditions at five surface water pools, which will support future assessments of impact potentially resulting from the Project;
- Implement the North Star Surface Water Management Plan (FMG, 2020).
- Inform the Site 12 Pool Water Quality and Hydrological Regime Investigation (Hydrobiology, 2020) and provide technical input to the Site 12 Pool Water Quality and Quantity Management Plan (FMG, 2020).

2. METHODOLOGY

2.1 SITE LOCATIONS

The Project is located 145 km by road south of Port Hedland in the Pilbara region and incorporates the North Star Magnetite ore bodies. The aquatic ecology survey was conducted at five surface water pools located at Iron Bridge within the across a divide between the Turner and Strelley/Shaw River catchments (Figure 1), and is situated within the Chichester IBRA bioregion and the Grassland climate class. Hydrological data was additionally collected from surface water creeks at Iron Bridge.

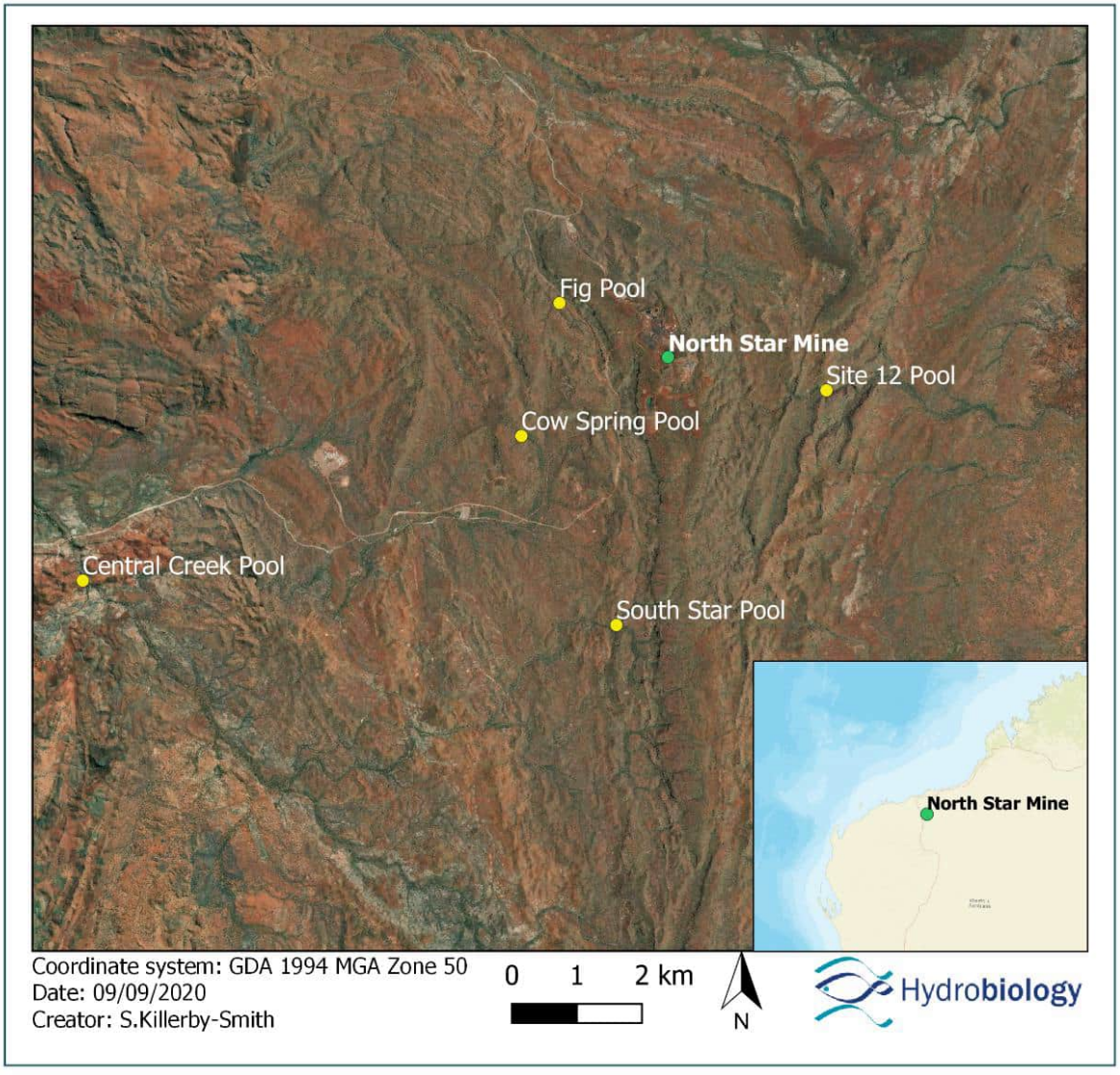


Figure 1 Locations of surface water pools surveyed at Iron Bridge

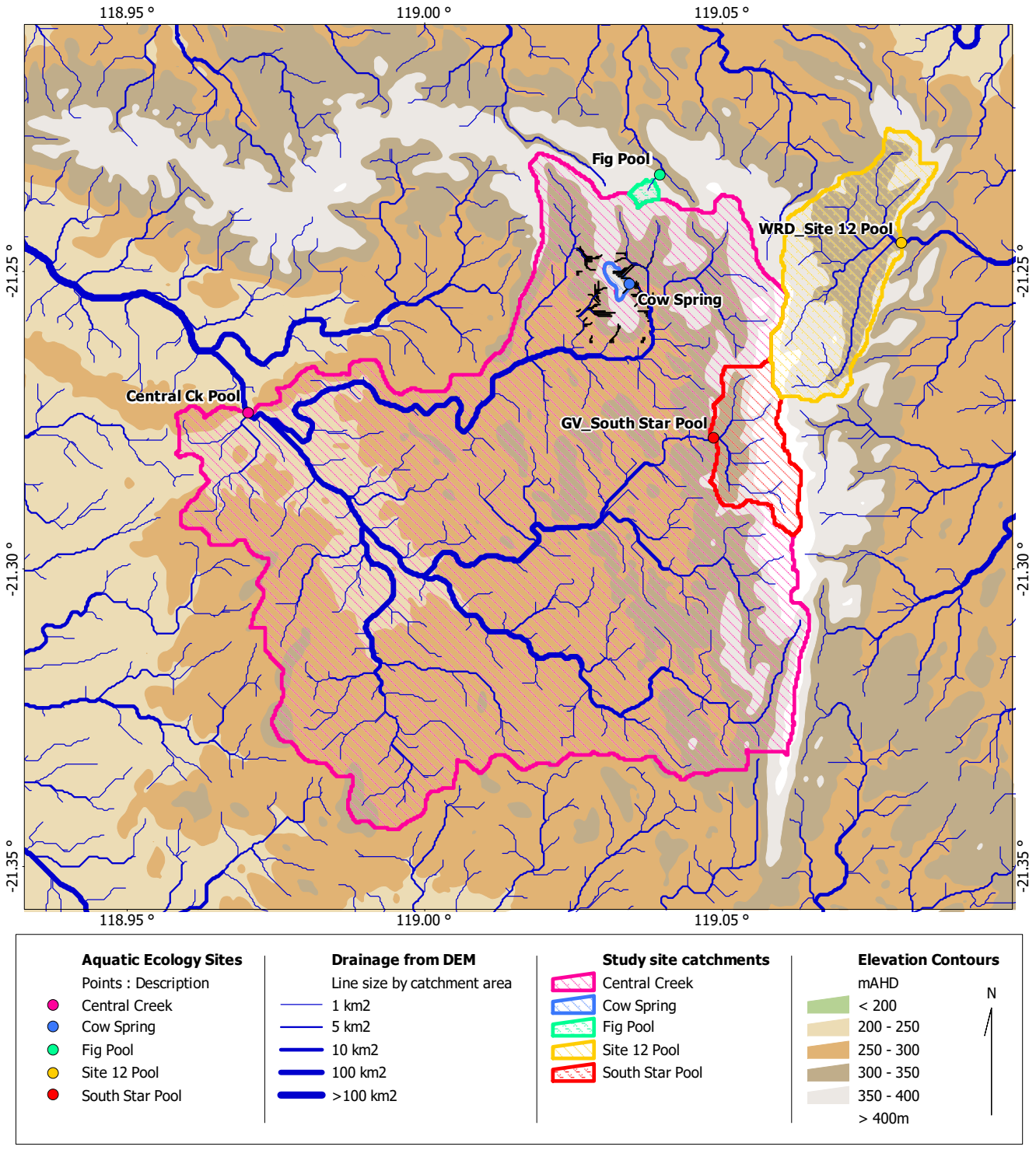


Figure 2 Study site catchments and drainage lines

Study site catchment areas and coordinates are provided in Table 1.

Table 1 Study site location details

Site Name	Catchment area (km^2)	Northing (MGAz50; GDA94)	Easting (MGAz50; GDA94)
Fig Pool	0.16	711668	7650632
South Star Pool	3.3	712558	7645667
Site 12 Pool	7.6	716248	7649263
Cow Spring	0.15	711103	7648587
Central Creek Pool	85.1	704385	7646299

2.2 MONITORING TIMING

The late wet season baseline aquatic ecology survey was conducted between May and June 2020. Collecting baseline data during this period captures conditions when the aquatic food web is established, and early life stages of some aquatic organisms are present which enables effective characterisation of the ecosystem health. The timing of baseline data collection aims to align with the water quality sampling periods for the assessment period, being the wet and drying season.

The late wet season baseline conditions are expected to show greater species diversity and abundance, relative to dry season conditions when stressors (such as high temperature and salinity) are typically greater and result in declining ecosystem health. Capturing the seasonal variability is expected to allow for a more accurate assessment of baseline conditions and variability which will inform surface water management.

2.3 WATER QUALITY AND HYDROLOGICAL MONITORING

2.3.1 IN-SITU SAMPLING

Water level, temperature and conductivity loggers were installed in each pool to continuously monitor the effects of rainfall, the rate of drying, and evapo-concentration effects. Insitu Aquatroll CTD data loggers were installed in Site 12 Pool, Fig Pool and South Star Pool from December 2019 and currently remain in situ. Further Insitu Aquatroll CTD data loggers were installed in Cow Spring Pool and Central Creek Pool in May 2020 and currently remain in situ. Data from loggers at Site 12 Pool, Fig Pool and South Star Pool was collected for the period December 2019 to May 2020 and is presented in this report.

In addition to the permanently deployed loggers, a calibrated YSI DSS Pro water quality sonde was used to collect in situ measurements from all sites where sufficient water was present during field surveys in December 2019 and May to June 2020. Measurements were collected following the 'Field sampling guidelines: A guideline for field sampling for surface water quality monitoring programs' procedure for physical parameter sampling (Department of Water, 2009 pg. 13). In-situ measurements were collected before all other activities to ensure that no disturbance to water quality was caused by sampler activity. The following field parameters were collected; temperature (°C), pH, oxidation reduction potential (mV), specific conductivity (µs/cm), salinity (ppt) and turbidity (NTU). This data was collated with in-situ field readings from other surveys and is present in Appendix A.

2.3.2 SURFACE WATER QUALITY

Water samples were collected following the 'Field sampling guidelines: A guideline for field sampling for surface water quality monitoring programs' (Department of Water, 2009) procedure for direct sampling. Water samples were collected by submerging the sample containers in the water at the waters' edge with the sampler on the bank to minimise disturbance. Powder-free nitrile gloves and laboratory prepared bottles were used in order to avoid potential sources of contamination. Unpreserved sample containers were rinsed three times with sample water before retaining a representative sample and preserved bottles were filled from a pre-rinsed syringe. Samples for dissolved metals analysis were syringe filtered within 1 minute of collection through 0.45 µm membrane filters using 50 mL polyethylene disposable syringes.

Upon collection, samples were immediately placed on ice in a dedicated esky and then transferred to a fridge at the earliest convenience. For delivery to ALS Australia, samples were packed in clean coolers with ice bricks. All bottles and filtering equipment were prepared by NATA-accredited ALS, Perth. Samples were sent to a NATA accredited laboratory for analysis for parameters which allowed for a broad characterisation of the examined environments. The parameters are identified in Appendix A.

Water quality samples were also delivered to the Stable Isotope Laboratory, West Australian Biogeochemistry Centre, University of Western Australia for isotope analysis. Samples were analysed for δ^2H and $\delta^{18}O$, using an Isotopic Liquid Water and Continuous Water Vapour Analyser Picarro 2130i and followed the procedure of Skrzypek and Ford (2014).

2.3.3 SEDIMENT QUALITY

Sediment samples were collected following the 'Handbook for Sediment Quality Assessment' procedures for collection of surface sediment (Simpson *et al.*, 2005). Surface sediment was collected from the top 5 cm of sediment and homogenised in a bowl before transferring to sterile jars. Powder-free nitrile gloves and laboratory prepared jars were used in order to avoid potential sources of contamination. Samples were stored on ice in a dedicated esky and transferred to a fridge at the earliest convenience. For delivery to ALS Australia, samples were packed in clean coolers with ice bricks. Samples were sent to a NATA accredited laboratory for analysis for parameters including total metals, major ions, total organic carbon, total nitrogen and total phosphorous. The specific parameters are identified in Appendix B.

2.4 AQUATIC ECOLOGY MONITORING

2.4.1 MONITORING PARAMETERS

Aquatic ecology monitoring parameters were selected following the ANZG process (ANZG, 2019) for selecting relevant ecological indicators of water quality through establishing environmental value and identifying conceptual impact mechanisms. These indicators are diatom communities, macrophyte communities, macroinvertebrate communities and fish communities. The selection of these four communities provides multiple lines of evidence and spans multiple trophic levels and phyla which is recommended by ANZG (2019) in order to capture the variable impact of ecosystems stressors and detect, for example, impacts of bioaccumulation and biomagnification. Algae (diatoms), macroinvertebrates, fish and macrophytes typically underpin the food web in pools, providing habitat and/or food sources for a diversity of native species including terrestrial or semi-aquatic organisms that may utilise the pool such as reptiles (e.g. Pilbara olive python), avian fauna and amphibians (Halse et al. 2001).

2.4.2 FISH AND DECAPOD CRUSTACEANS

2.4.2.1 SAMPLING

Fish and decapod communities were sampled to collect data on higher order organisms with relatively long-life spans, which is useful for assessing bioaccumulation and biomagnification effects, interannual survivability and reproduction. Evidence of reproduction was sought (i.e. presence of juveniles) to detect sub-lethal effects impacting reproduction or vulnerable size classes.

Fish and decapod crustaceans were sampled using fyke nets and traps. Two trap types, box traps and bait traps, were used to collect a more representative sample of size classes present at a site (Osawa et al. 2015). Fyke nets were 4 m long, 1 m diameter, 4 m wings, with a 4 mm mesh size and 150 cm diameter entry hole. Bait traps were 40 cm long, 25 cm wide and 25 cm high, with a 5 mm mesh size and 30 mm diameter entry holes. Box traps were 60 cm long, 45 cm wide and 20 cm high, with a 10 mm mesh size. Traps were baited with a 50/50 ratio of cat food biscuits and whiting based burley. At each pool, one fyke net, two bait traps, and two box traps were set for overnight an average of 17 hours (maximum 19 hours). Traps were set along the length of the pools, predominantly in bank habitats with high structural complexity (e.g. macrophytes, woody debris, root masses) where abundance was likely to be highest.

Following capture, individuals were counted, measured and released near the point of collection. Size was described using standard length and total length, and was measured to the nearest 1.0 mm. Thirty individuals of each species at each pool were randomly selected to form a subsample that was measured, the remaining individuals were allocated to one of four size classes based on visual size estimation. This method was used to reduce the stress and handling of the community whilst still gathering size class data.

Hydrobiology also utilised a presence / absence approach to determine whether species are present using baited underwater video traps (BRUVs). Baited underwater GoPro 5 cameras were deployed in suitable habitat at each site and video recorded for 10 minutes at each site.

2.4.2.2 ANALYSIS

Catch per unit effort (CPUE) was used as a measure of abundance and was defined as the species total catch divided by the soak time in hours. Juvenile presence was defined by the presence of size classes that are smaller than the size at sexual maturity described in relevant literature (based on wild populations).

2.4.3 MACROINVERTEBRATES

2.4.3.1 SAMPLING

Macroinvertebrates are a commonly used bioindicator for assessing a variety of environmental issues. ANZG (2019) recommends macroinvertebrate monitoring to assess changes in biodiversity and/or changes in ecosystem processes of waterbodies due to contaminant inputs. The taxonomic groups sensitive or tolerant to declines in water quality are well known and the presence and abundance of these taxa are used to score the water condition of surface water pools.

Macroinvertebrate sampling followed the procedures of 'Western Australia AUSRIVAS sampling and processing manual' (van Looij, 2009). Samples were collected using a 250 µm mesh pond net, 35 cm by 25 cm opening, a 30 cm depth (tail) and a 1.5 m handle. The net was rinsed and checked for holes between each site. Two samples were collected from each pool. Due to the small size of the pool, two replicates from the same habitat (i.e. macrophyte, pool) was not possible for all pools without risking resweeping the extent of the previous sweep. Therefore, samples were obtained from different habitats for most pools. Sites were sampled by sweeping the net starting at the downstream end of the 10 m sampling area and moving upstream while collecting the sample, aiming to sample all the different sub-components of the habitat and at different depths. The contents of the net were then rinsed into labelled sterile containers

using 70% ethanol for preservation. Samples were transported to Stream Macroinvertebrate Identification for identification and enumeration.

Specimens in each sample were laboratory picked following the AusRivAS methods. Samples were identified to family level, where possible. A 10% error margin is allowed for the identifications and enumerations of macroinvertebrates (as required for AusRivAS macroinvertebrate identification accreditation). Any taxa that could not be identified (usually due to their immature stage or deterioration/damage) were recorded at a higher taxonomic level (i.e. Order). Taxa were recorded as present if the head was present in the sample (provided it appeared to be alive at the time of collection). This is common with Ephemeroptera, Zygoptera and Oligochaeta, which are often damaged at the time of collection and only part of the specimen is retained in the sample. Empty (dead) Gastropoda shells are not recorded as being present. Specimens were preserved in a solution of 70% methylated spirits, 5% Glycerol and 25% water and retained for QA/QC purposes.

2.4.3.2 ANALYSIS

Several indices were derived from the macroinvertebrate data and are described below as per Negus *et al.* (2013) and (Chessman, 2003).

SIGNAL 2 Index - The SIGNAL index (Stream Invertebrate Grade Number - Average Level) was developed for the bioassessment of water quality in rivers in Australia. It is calculated by grading each macroinvertebrate family based upon the level of its sensitivity to various pollutants. The grades applied range from 1 (tolerant) to 10 (sensitive) (Chessman, 2003) and a weight is applied to each taxa depending on its abundance. The SIGNAL score for a sample is calculated by averaging the weighted sensitivity grades of the macroinvertebrate families collected. The version applied here is SIGNAL version 2.iv, SIGNAL 2 Scores suit both family and order-class-phylum identification (Chessman, 2003).

EPT taxa richness - the number of aquatic macroinvertebrate families collected from three orders of aquatic insects: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). Macroinvertebrates belonging to these three orders are considered sensitive to changes in their environment and therefore EPT is often used to assess condition. Sensitivity would generally be indicated by a decrease in EPT in the presence of changed environmental conditions; however, increases can occur depending on the nature of the impacts that are present.

Taxa richness - the number of aquatic macroinvertebrate taxa collected in a sample. This index is used as a common measure in many monitoring programs. Use of taxa richness is based on the premise that with changes in the condition of a site the taxa richness will increase or decrease from the baseline condition. Increases or decreases will depend on the nature of the threats that are influencing the ecosystem.

2.4.4 DIATOMS

2.4.4.1 SAMPLING

Diatoms (single-celled algae with siliceous cell walls) are effective indicators for ecological change in freshwater systems (Gale, 2015). Diatoms are an important component of the riverine algae community and are commonly used for assessing water quality based on the tolerance of species present to pollution (Oeding and Taffs, 2017). Artificial substrates called periphytometers were used to collect living diatoms over a specified period of time. Two periphytometers each containing 10 microscope slides were deployed at each of the five pools. The substrates were left immersed for an average of four weeks (May – June 2020) to enable diatom communities to establish, reflecting the ambient water quality. On retrieval, the 10 slides from each artificial substrate were scraped into a small, labelled sample container and preserved with 70% ethanol. They were then submitted to the laboratory for taxonomic identification to species level and enumeration. Dr John Tibby of the University of Adelaide was engaged as the sub-consultant for the taxonomic identification and enumeration.

2.4.4.2 ANALYSIS

The most widely used biotic indices in Australia, DSIAR score (Diatom Species Index for Australian Rivers score), was derived to quantify diatom ecology at the pools. The DSIAR score estimates water quality by the relative abundance of diatom species sensitive to water quality stressors, where a higher DSIAR score represents higher water quality (Chessman *et al.*, 2007). Total count per sample for each species is also presented.

2.4.5 MACROPHYTES

Macrophytes (aquatic plants) are sensitive indicators of ecosystem health and can be used to assess when physico-chemical thresholds are reached (e.g. turbidity blocking photosynthesis of submerged macrophytes or impacts of sedimentation) (Barko *et al.*, 1982) and the abundance and spatial distribution of heavy metals in aquatic environments (Cardwell *et al.*, 2002). They play a fundamental role in aquatic systems by, for example, reducing erosion of stream banks, increasing dissolved oxygen levels, providing a food source and mediating food web dynamics by providing habitat structural complexity (Warfe and Barmuta, 2006).

Macrophyte sampling followed the AusRivAS guidance (van Looij, 2009). Macrophyte surface area coverage of emergent, submerged and floating macrophytes was visually estimated across the pool habitat and defined as isolated, scattered, in beds or choking the stream as per the 'Field Sampling and Habitat Assessment Sheet 2006 v.14'. Macrophytes included those which were out of the water but in the active channel. Specimens were photographed and samples collected and preserved in 70% ethanol for subsequent confirmation of taxonomic identification (macrophyte guide here) and retained. Macrophytes were identified to the species level.

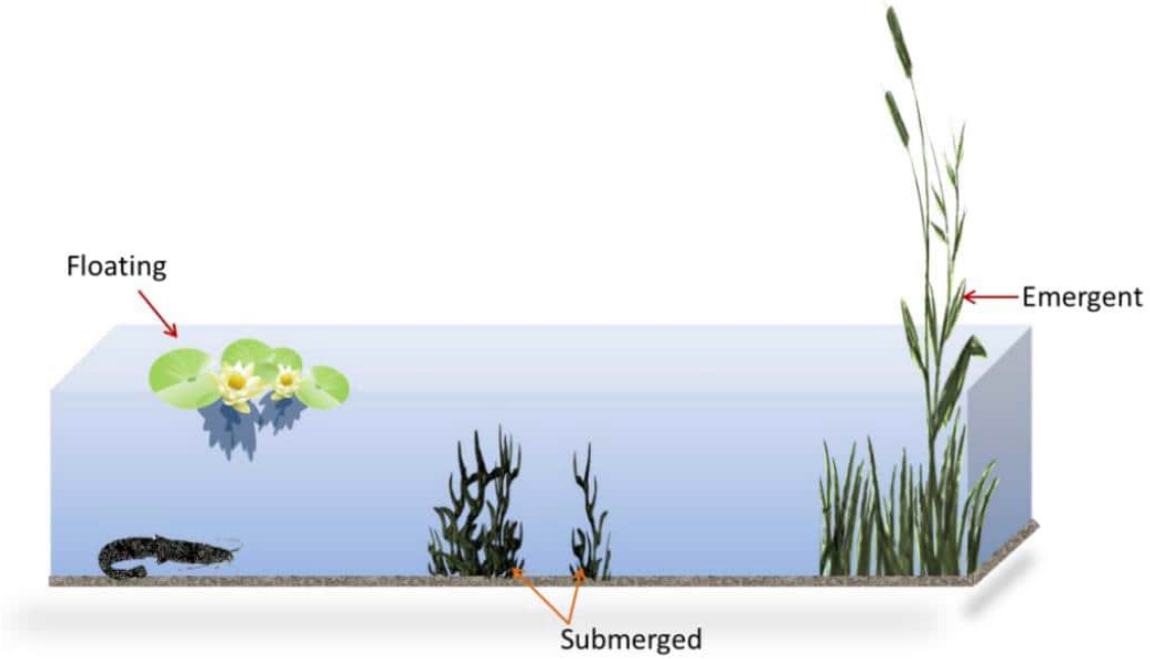


Figure 3 Schematic of floating, submerged and emergent macrophytes (DES, 2018).

3. RESULTS

This section presents the findings of the 2019/2020 aquatic ecology survey. The results are presented as distinct chapters for each site to reflect that the surface water pools should not be directly assessed relative to other pools but rather to the temporal patterns of the pool. For example, each pool has a different hydrology, size and habitats, and the methods used are not spatially uniform (i.e. macroinvertebrate sampling of different habitat types between pools).

3.1 SITE 12 POOL

Site 12 Pool is part of a series of shallow pools that lie to the east of the Project on a small tributary to the upper Six Mile Creek. It is connected to both surface water and groundwater sources over the hydrologic cycle, typically sustained by groundwater sources though has been known to dry out following small wet seasons. During the late wet season sampling it was a fresh-brackish, predominantly bedrock habitat that supported fish, macroinvertebrates, algal communities, macrophytes and riparian vegetation (Plate 1).



Plate 1 Late wet season June 2020 (above) and late dry season December 2019 (below).

3.1.1 WATER QUALITY AND HYDROLOGY

Water quality sampling included physico-chemical parameters, metals analysis and major ions to characterise the surface water system. Stable isotope analysis at Site 12 Pool was also conducted to inform the connectivity of surface water and groundwater. A logger recorded conductivity, temperature and water level on a 6 hourly basis at Site 12 Pool between December 2019 and May 2020.

Site 12 Pool is a shallow bedrock supported natural habitat with a 7.6 km^2 catchment area (Figure 6) with typically low rainfall and infrequent high rainfall events largely driven by storm and cyclonic activity. The water quality experiences high seasonal variability due to the climatic conditions of the region, with the greatest variability recorded following rainfall events (Figure 8).

The water quality was predominantly clear (mean turbidity = 2.5 NTU), slightly alkaline (mean pH = 8.5) and a magnesium-bicarbonate (Ca/Mg-HCO_3) dominated water type with low sulphates (SO_4) (Figure 7). However, it is expected that during surface water flow events the turbidity temporarily increases. Similarly, during rainfall events, the typically slightly brackish pool (1,100-1,300 µS/cm) would become temporality extremely fresh (<100 µS/cm).

Figure 8 displays a high-resolution water level, salinity (conductivity) and temperature logger record from Site 12 Pool for the wet season of 2019/20. The rapid change in conductivity after rainfall events is evident with one minor inflow at the start of the wet season that partially flushed and filled the pool as well as four major inflows that displayed flooding peaks and complete pool flushing. This preliminary baseline data indicates that the pool is largely sustained by groundwater and is periodically flushed with fresh surface water flows after rainfall events. The ratio of Site 12 Pool volume against inflow volume is presented in *Site 12 Pool Water Quantity Assessment and Management* (FMG, 2020) It takes approximately 2 – 3 weeks for the groundwater to displace the surface water flows once a flushing event has occurred.

Site 12 Pool is a larger habitat area relative to other North Star pools, comprising a series of isolated pools spanning approximately a 650 m reach and 1266 m^2, and likely has greater downstream connectivity relative to other pools in the North Star area. Most pools are shallow, with the deepest being approximately 2.5 m. The total volume of the pools is estimated to be 2,532 m^3 based on an average depth of 2 m. This is a small volume relative to the inflow volume; for example, the 1EY post development estimated inflow is substantially higher (54,198 m^3) (FMG, 2020). Recorded water levels were a maximum of ~0.6 m above the pool overflow levels during high-flow events, which typically lasted less than 24 hours before flows receded. The rapid falling stage after large flow events indicates there is little retention capacity in the system beyond the pool spill point.

Although the pool is typically sustained by groundwater throughout the dry season, it has been recorded as completely dry in recent years (2015 and 2016 dry seasons) following low rainfall wet seasons (BOM 2020). The most recent observations noted it did not completely dry out in 2019/2020 (Plate 2). The pool naturally drying out or experiencing substantially lower water levels would be expected to impact significantly on the ecological health of Site 12 Pool due to evapo-concentration increasing environmental stressors (e.g. salinity) and lower water levels reducing available habitat.

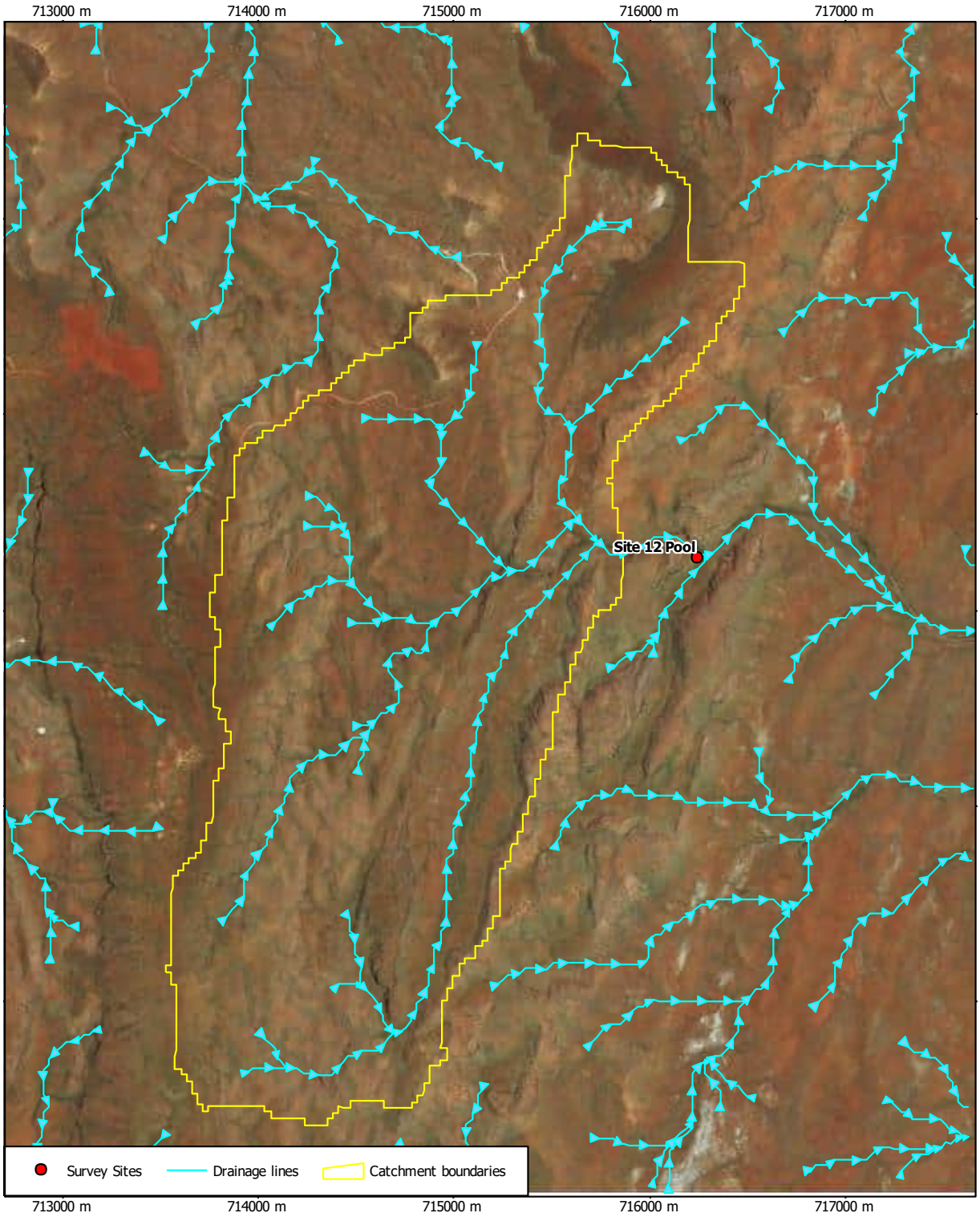


Figure 6 Site 12 Pool catchment area

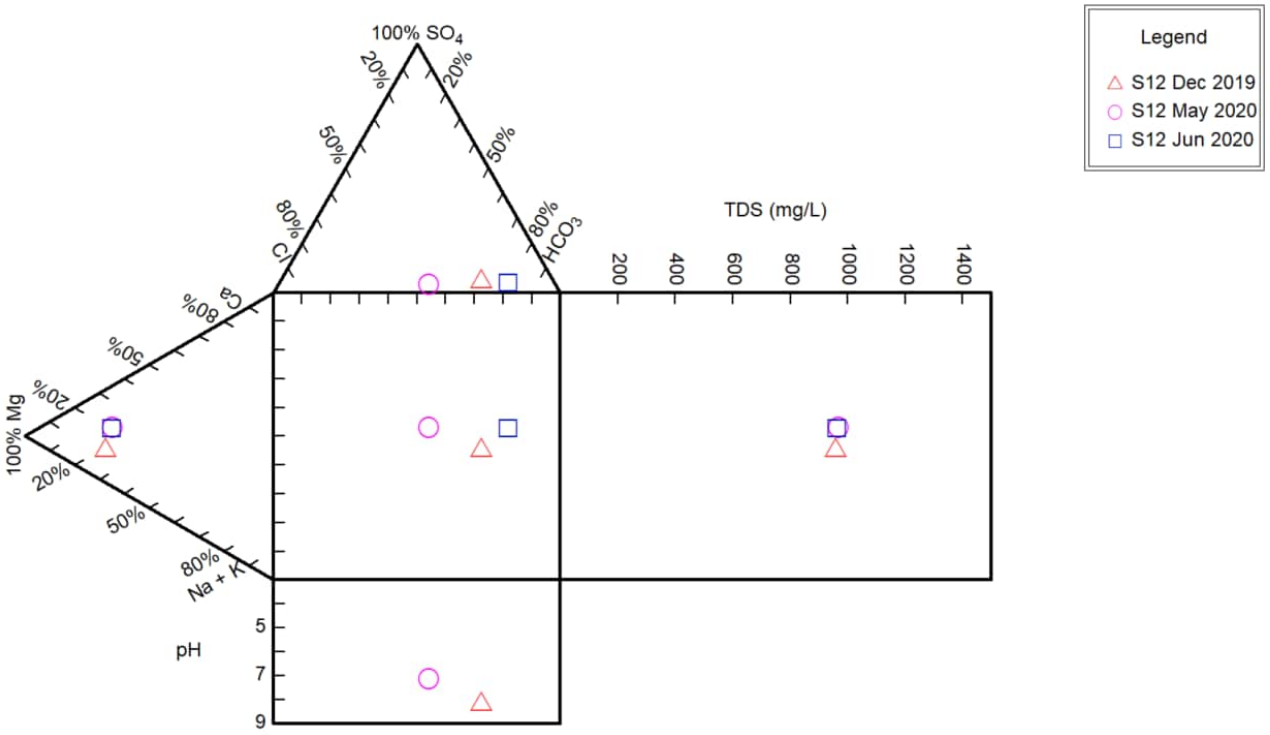


Figure 7 Durov diagram illustrates Site 12 Pool is a magnesium-bicarbonate (Ca/Mg-HCO_3) dominated water type. It is fresh-brackish, alkaline (481 mg/kg $CaCO_3$) with low sodium, chloride and sulphate (SO_4).

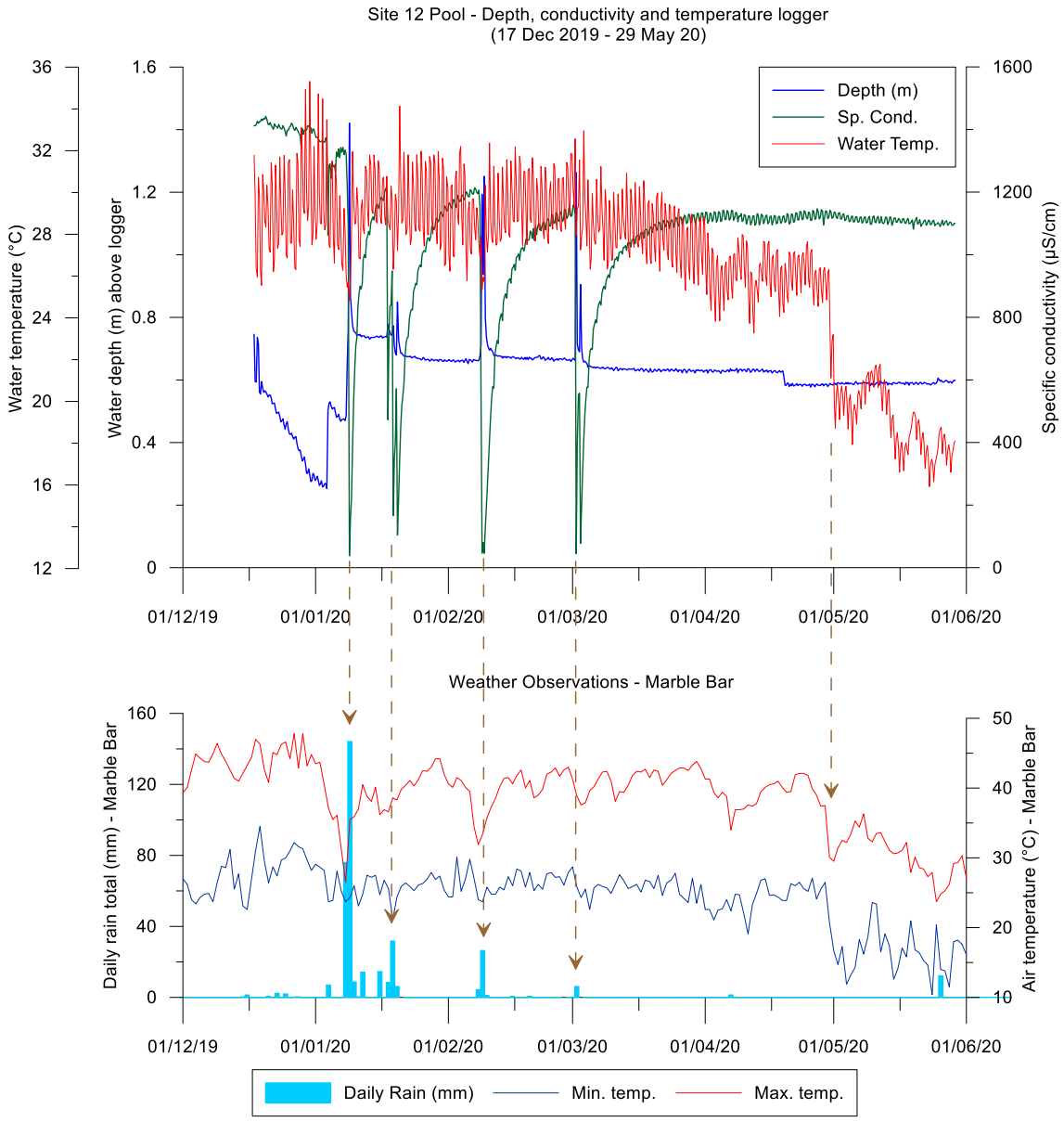


Figure 8 Depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below).

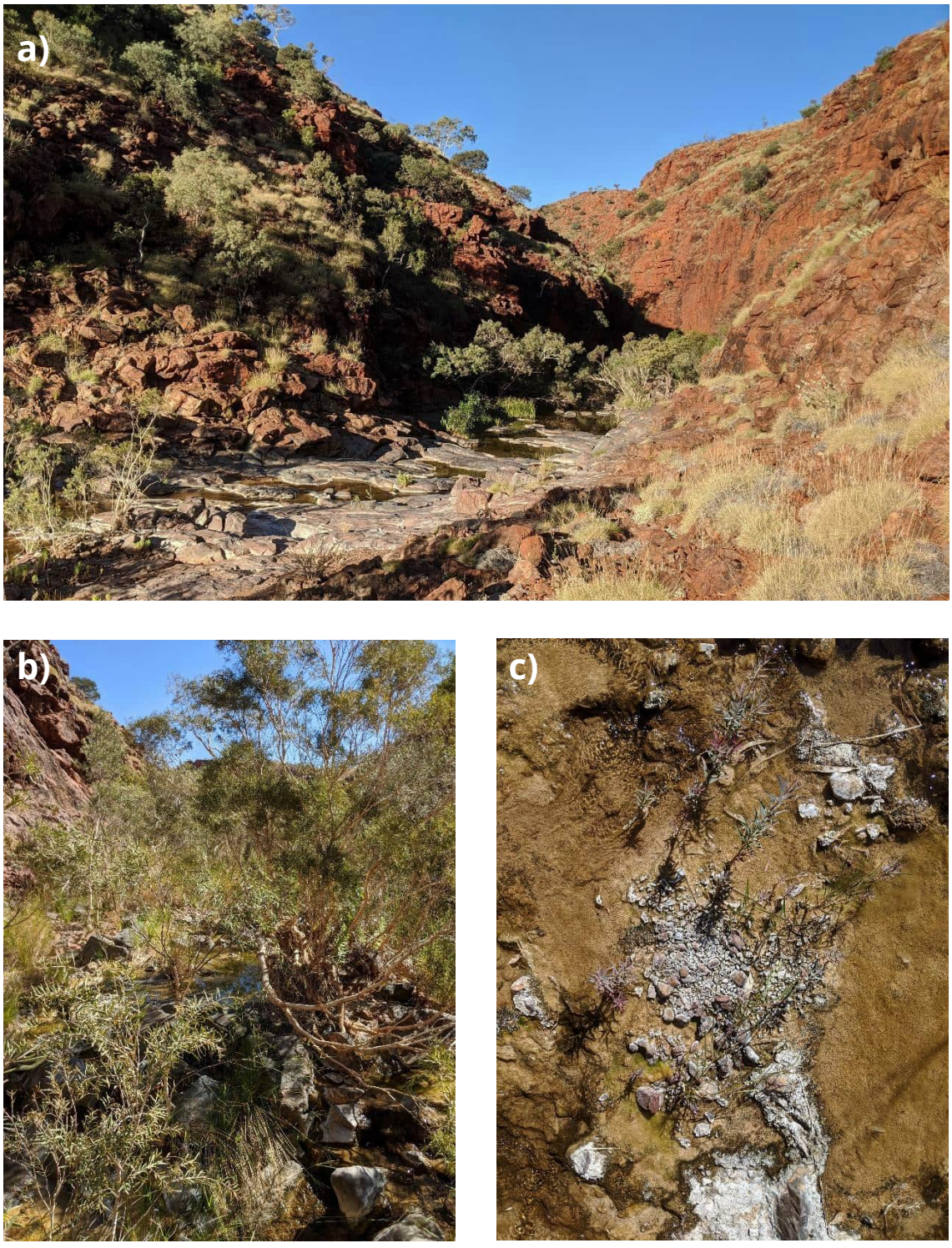


Plate 2 Site 12 Pool hydrological characteristics including; a) high flows over a steeper gradient of bedrock habitat b) confined creek line supporting riparian vegetation and c) sustained groundwater flow

3.1.2 SEDIMENT QUALITY

Table 2 provides the surface sediment quality at Site 12 Pool during the late wet season (sample collection 29th May 2020). Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs.

Chromium concentration (384 mg/kg) and nickel concentration (179 mg/kg) exceeded the DGV and the GV-high. Chromium and nickel both naturally occur at high concentrations across the Project area and were similarly above DGVs at most other surveyed surface water pools in the Project area.

Table 2 Sediment quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	Concentration
Total Soluble Salts	mg/kg	5	**408**
Moisture Content (Dried @ 105-110°C)	%	1.0	**28.6**
Total Alkalinity as CaCO3	mg/kg	1	**71**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**67**
Carbonate Alkalinity as CaCO3	mg/kg	1	**4**
Acidity	mg/kg	1	**4**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**20**
Chloride (by Discrete Analyser)	mg/kg	10	**30**
Calcium	mg/kg	10	**50**
Magnesium	mg/kg	10	**60**
Sodium	mg/kg	10	**40**
Potassium	mg/kg	10	<10
Mercury (FIMS)	mg/kg	0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**520**
Total Nitrogen as N	mg/kg	20	**520**
Total Phosphorus as P	mg/kg	2	**73**
Reactive Phosphorus as P	mg/kg	0.1	<0.1
Total Organic Carbon	%	0.02	**0.18**
Total Metals by ICP-AES			
Arsenic	mg/kg	5	<5
Barium	mg/kg	10	**50**
Beryllium	mg/kg	1	<1
Boron	mg/kg	50	<50
Cadmium	mg/kg	1	<1
Chromium	mg/kg	2	**384**
Cobalt	mg/kg	2	**23**
Copper	mg/kg	5	**23**
Iron	mg/kg	50	**32,800**

Analyte grouping/Analyte	Unit	LOR	Concentration
Lead	mg/kg	5	<5
Manganese	mg/kg	5	**561**
Nickel	mg/kg	2	**179**
Selenium	mg/kg	5	<5
Vanadium	mg/kg	5	**48**
Zinc	mg/kg	5	**26**

3.1.3 FISH

Fish, decapods and non-fish vertebrates were sampled with a combination of nets/traps and underwater video (BRUVs). Table 3 and Figure 10 present the fish species, abundance and size distribution.

Three native omnivorous fish species were present: *Melanotaenia australis*, *Leiopotherapon unicolor and Neosilurus hyrtlii*. The most abundant species was *M. australis* which were predominantly adults (~50 mm) and estimated to be over 3 months old. The size classes present correspond with the known peak spawning period of *M. australis* from November to January. The larger size distribution of *L. unicolor* and *N. hyrtlii*, ranging from juveniles to over a year old, more clearly indicates interannual survival of these species and demonstrating evidence of successful wet season or post-wet season reproduction. However, these species may persist in downstream environments rather than Site 12 Pool throughout the drier months and migrate upstream to the pool during wet season connective flows. For example, fish were abundant during the late wet season aquatic ecology survey (June 2020) although were not observed during the previous years' late dry season site visit (December 2019). Similarly, Site 12 Pool was the only pool of five pools surveyed at North Star in June 2020 where *N. hyrtlii* was recorded (Plate 3 a), which may be due to the connectivity to downstream creeks and rivers. This species exhibits spawning migration into tributaries and the tendency to inhabit riverine habitats more frequently than off-channel lentic habitats (Pusey, B., Kennard, M., & Arthington, 2004).

Further surveys will clarify the role of environmental stress and connectivity in determining fish presence. For example, whether dry season conditions result in decreased fish abundance (suggested by no fish present in 2020 late dry season sampling), or low wet seasons restrict connectivity and therefore fish movement (suggested by fish present in 2020 late dry season sampling).

Burrowing toadlets (*Uperoleia sp.*), a genus that typically inhabits rocky creeks, were observed in the tadpole phase during December 2019 though were not observed during wet season sampling. This finding may be due to the breeding season occurring earlier and only the semi-aquatic adult stage being present at the time of sampling, which was not targeted by sampling methods.

While baited marron/box traps were used to target decapod crustaceans, none were collected or observed.

Table 3 Fish species, catch and size distribution

Species	Size class (mm)	Catch	CPUE[1]
Melanotaenia australis		**196**	**12.6**

Species	Size class (mm)	Catch	CPUE[1]
	0 – 30	0	
	30 – 60	84	
	60 – 90	112	
	> 90	0	
Neosilurus hyrtlii		**37**	**2.4**
	50 – 90	18	
	90 - 130	16	
	130 - 170	3	
Leiopotherapon unicolor		**24**	**1.5**
	30 - 60	7	
	60 - 90	10	
	> 90	7	
Total		**257**	**16.6**

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 15.5 hours.

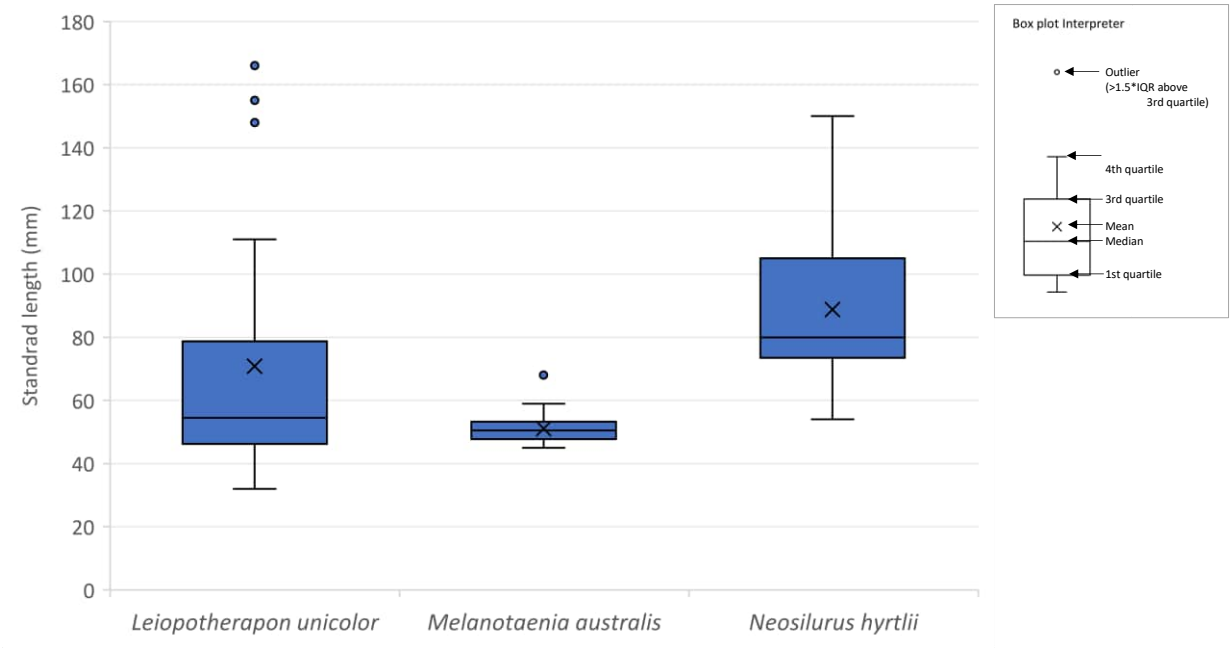


Figure 10 Size distribution (standard length mm) of fish species collected at Site 12 Pool.

3.1.4 AQUATIC MACROINVERTEBRATES

Table 4 presents the macroinvertebrate summary table and Table 5 presents the taxa abundance and SIGNAL scores for the late wet season macroinvertebrate sampling (Appendix D). Two habitat types were sampled to capture the most representative habitats at Site 12 Pool; edge habitat and macrophyte habitat. Three common macroinvertebrate biotic indices were calculated to provide an indication of waterbody condition. The key findings were as follows:

- A total of 25 families were collected during the survey with an average abundance of 84 individuals per sample.
- EPT taxa (sensitive taxa) were present in each sample (Figure 11). A total of 5 EPT taxa families were collected. The average EPT Taxonomic Richness Index = 3.5.
- Low SIGNAL 2 score (SIGNAL2 score = 3) indicates predominantly tolerant taxa and disturbed conditions (Chessman, 2003).
- No 'very sensitive' taxa were recorded (identified by SIGNAL grades 8, 9 and 10) and only 3 'sensitive' taxa were collected (SIGNAL grades 5, 6, 7).

Table 4 Macroinvertebrate summary and indices

Habitat type	Abundance	Taxonomic Richness	EPT Taxa	SIGNAL2 Score
Macrophyte	105	20	5	3.25
Edge	63	19	2	3.05
Mean	84	19.5	3.5	3 (pooled average)

Table 5 Macroinvertebrate taxa abundance and SIGNAL scores.

Order [1]	Family	Abundance (macrophyte habitat	Abundance (edge habitat)	Average abundance	SIGNAL2 Score [2]
Acarina	Acarina	14	14	14	6
Araneae	Araneae	2	1	2	N/A
Coleoptera	Hydrophilidae	0	1	1	2
	Limnichidae	0	1	1	4
	Dytiscidae	2	2	2	2
Copepoda	Copepoda	3	4	4	N/A
Diptera	Ceratopogonidae	4	2	3	4
	Stratiomyidae	2	3	3	2
	s-f Chironominae	21	3	12	3
	s-f Tanypodinae	19	15	17	4
Ephemeroptera	Baetidae	2	2	2	5
	Caenidae	1	0	1	4
Gastropoda	Lymnaeidae	0	1	1	1
	Planorbidae	3	0	2	2
Hemiptera	Micronectidae	0	1	1	2
	Pleidae	1	2	2	2
	Gerridae	2	2	2	4
	Hebridae	0	3	2	3
	Veliidae	1	0	1	3
Odonata	Coenagrionidae	7	2	5	2
	Libellulidae	2	0	1	4
Oligochaeta	Oligochaeta	4	1	3	2
Trichoptera	Hydroptilidae	3	3	3	4
	Leptoceridae	5	0	3	6
	Ecnomidae	7	0	4	4

[1] Bold font denotes EPT orders and 'very sensitivity' taxa represented by high SIGNAL 2 scores (SIGNAL 2 = 8,9,10).

[2] SIGNAL 2 scores: Red = very tolerant, yellow = tolerant, green = sensitive, blue = very sensitive.

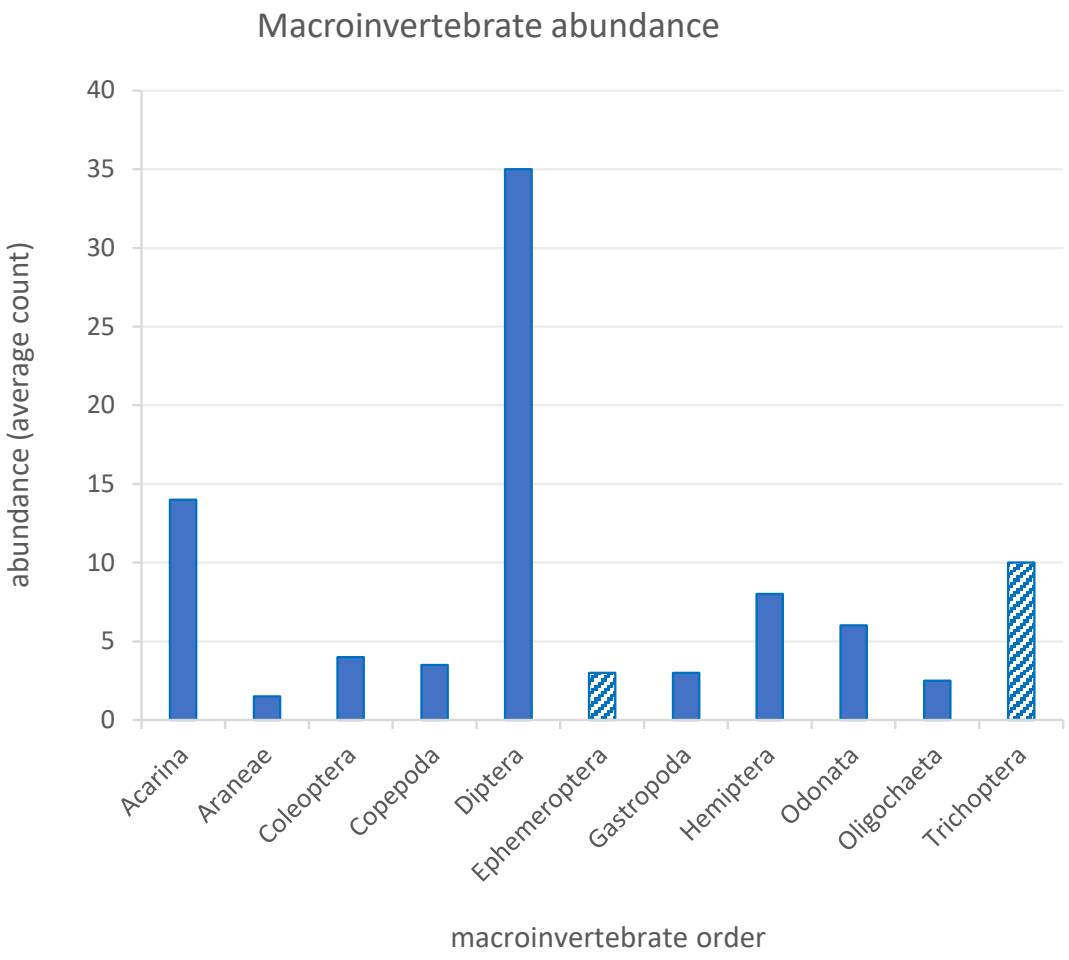


Figure 11 Macroinvertebrate abundance. Pattern fill denotes EPT orders.

3.1.5 DIATOMS

Table 6 presents the late wet season diatom species present, abundance and biotic indices. Figure 12 shows the average count by diatom species present. The key findings were as follows:

- A total of 8 diatom species were recorded and show a limited taxonomic diversity as they are from one family (Achnanthaceae) and two genuses (*Achnanthes sp.* and *Achnanthidium sp.*). The most dominant species was *Achnanthes brevipes*.
- The tolerance to environmental stress is reflected in the moderate sensitivity DSIAR scores (Table 6). Diatoms were present in very sparse abundance and had an average DSIAR score of 54.3 which is considered moderate.
- There was evidence that diatom assemblages or sensitivities were impacted by environmental stress. In Site 12 Pool there was a large number of teratological ("deformed") forms. This normally occurs as a result of environmental stress and while there are multiple possible causes (moisture stress, UV, salinity), heavy metals are typically most strongly associated with such forms (Falasco *et al.*, 2009).

Table 6 Diatom total count per species and DSIAR score as a bioassessment of waterbody health.

Species	Replicate 1	Replicate 2	Average species abundance
Achnanthes brevipes	42	112	77
Achnanthes impexa	4	24	14
Achnanthes subexigua	8	10	9
Achnanthidium exiguum	4	8	6
Achnanthidium kryophila	0	6	3
Achnanthidium lineare	0	4	2
Achnanthidium minutissimum	0	2	1
Achnanthidium minutissimum var affine	2	0	1
Total count	60	166	113
DSIAR score	54.7	53.9	54.3

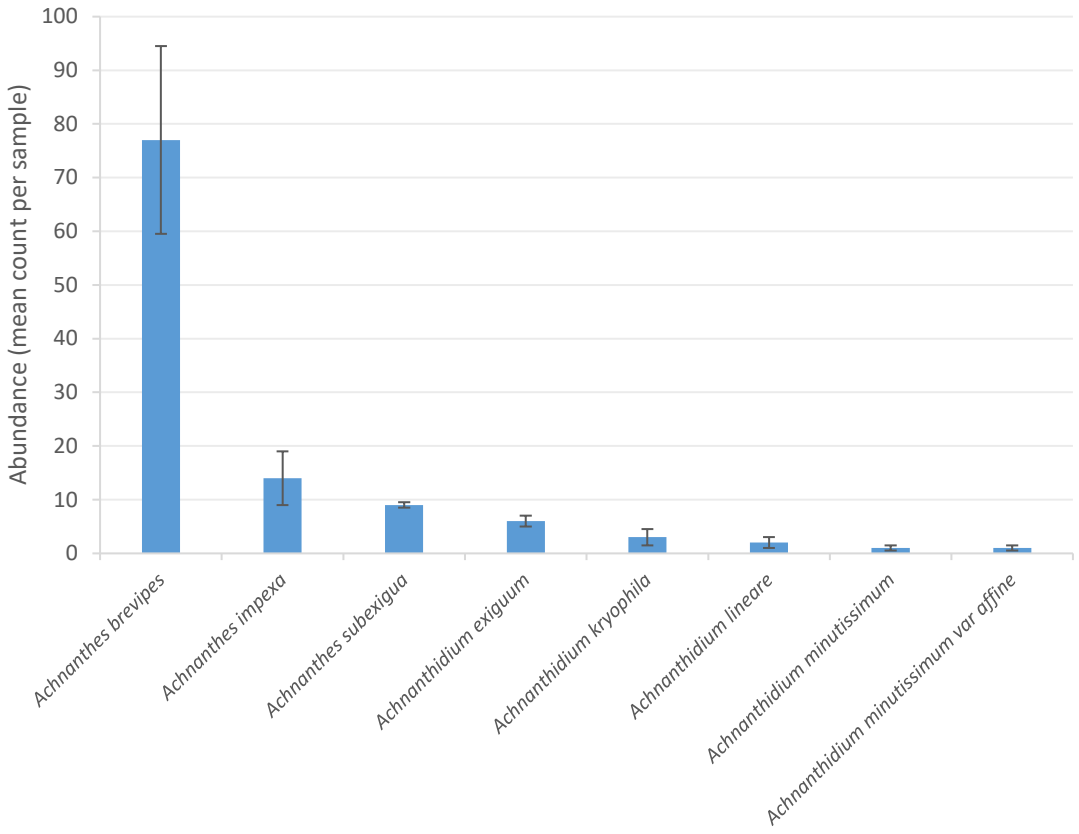


Figure 12 Diatom average abundance. Error bars show 1σ.

3.1.6 MACROPHYTES

Table 7 presents the macrophyte species and qualitative abundance during late wet season sampling. A diverse range of native flora were observed within Site 12 Pool. These comprised aquatic species and groundwater-dependent species. These species are likely not surface water dependent as the pool refills with groundwater or subsurface flows within 2 – 3 weeks following flushing events. Aquatic species were present during both late dry (December 2019) and late wet seasons. During late wet season surveying, a total of five macrophyte species were recorded including reeds (*Typha* spp.), sedges (*Juncus* spp.) as well as submerged macrophytes (*Villisneria* spp., *Myriophyllum* spp.) (Plate 3). The types and species of macrophytes present in a system are indicators of water quality and ecological health. The abundance and diversity of macrophytes at Site 12 Pool plays a key role in nutrient dynamics, indicates that water quality parameters (e.g. turbidity, salinity) have not reached levels that interfere with macrophyte growth and development, and provides habitat structure and refuges to organisms. For example, the macrophyte habitat and its' structural complexity likely provides refuge to the *M. australis* (western rainbowfish) from predation by adult *L. unicolor* (spangled perch).

Table 7 Macrophytes present at Site 12 Pool

Common name	Species name	Abundance[1]
Ribbon weed	*Vallisneria sp.*	Isolated
Charophytes	*Nitella sp.*, *Chara sp.*	Isolated
Clubrush	*Schoenoplectus sp.*	Isolated
Sedges	Cyperaceae	Isolated
Bulrush	*Typha sp.*	Isolated

[1] Abundance based on *Western Australia AUSRIVAS field sampling sheet* (DoW, 2009).



Plate 3 Site 12 Pool aquatic ecology. a) *Neosilurus hyrtlii* found at Site 12 Pool and no other surveyed pools; b) Belostomatidae, a giant water bug that typically hunts amongst macrophytes; c) bedrock covered in benchic algae; d) periphytometer used to sample diatoms shows benthic algae growth; e) and d) submerged and emergent macrophytes.

3.2 FIG POOL

Fig Pool is an isolated small acidic pool that lies at the base of a rockface (Plate 4) with a small catchment area of 0.16 km^2 (Figure 13). It is characterised by stable water levels maintained by fresh groundwater. A relatively low abundance and diversity of aquatic flora and fauna inhabit the pool, likely due to it being naturally acidic. For example, fish and macrophytes are absent in the pool. It is a bedrock dominated habitat with the primary structural complexity provided by the roots of *Melaleuca* spp (paperbark tree) roots.



Plate 4 Fig Pool is a small, acidic pool that lies below a rockface and is surrounded by *Melaleuca* spp. of which the roots are a dominant feature.

3.2.1 WATER QUALITY AND HYDROLOGY

Water quality sampling results including physico-chemical parameters, metals analysis, major ions and stable isotope analysis to characterise the surface water system and its connectivity to groundwater are presented in Appendix A. Figure 14 displays a high-resolution water level, salinity (conductivity) and temperature logger record from Site 12 Pool for the wet season of 2019/2020.

Fig Pool is a small (~20 m^3), shallow pool with water quality that varies minimally between seasons. The pool is largely sustained by groundwater and was periodically flushed with fresh surface water flows after rainfall events. It takes approximately 1 week for the groundwater to displace the surface water flows once a flushing event has occurred. Conductivity was typically fresh (~200 µS/cm) except during a surface water flow event when it would become extremely fresh (<20 µS/cm). Water levels were a maximum of ~0.06 m above the pool overflow levels during high-flow events, which typically lasted less than 24 hours before flows receded. The minimal change in water level indicates the pool remained approximately at its spill point level throughout the logging period. Due to the small catchment area (0.16 km^2) and the gradient of

Fig Pool's upstream and downstream environment it is likely the pool has very limited connectivity to surface drainage.

The water quality was clear (turbidity = <1 NTU NTU), acidic (pH = 3.4) and a sodium sulphate dominated water type (Figure 15). Although the pH at this site is low, the acidity levels are only moderate to low (16 mg/L as $CaCO_3$). Observations at the site would indicate that the low pH based on spot samples (no pH logger is installed) is potentially due to the lack of buffering capacity in the low conductivity water and is likely to be controlled by the Fe(II)/Fe(III) redox couple at a pH of ~3.5. This is potentially mediated by biological processes in the root mats which surround the pool (e.g. root zone Fe(II) oxidation).

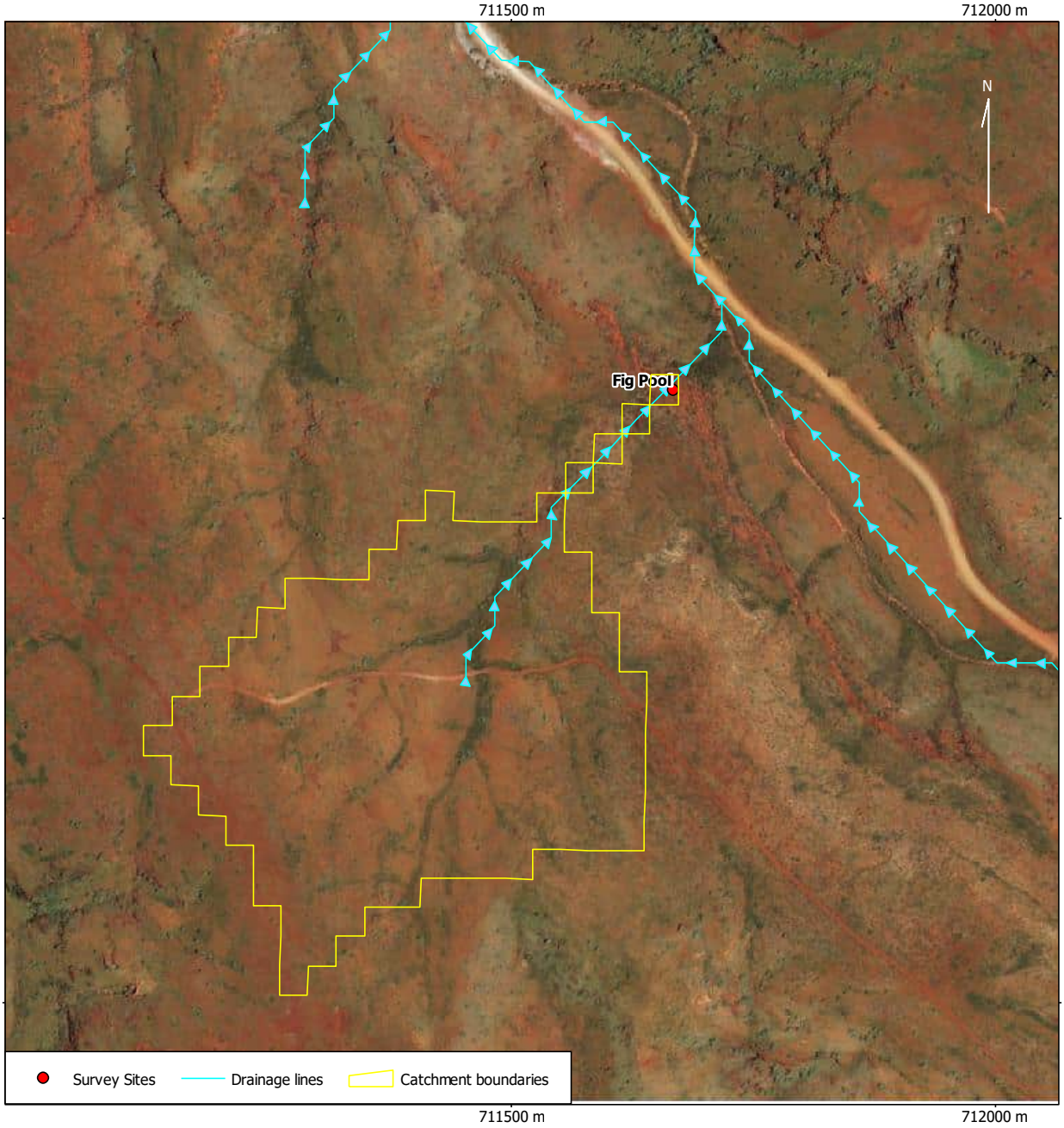


Figure 13 Fig Pool catchment area (0.16 km^2)

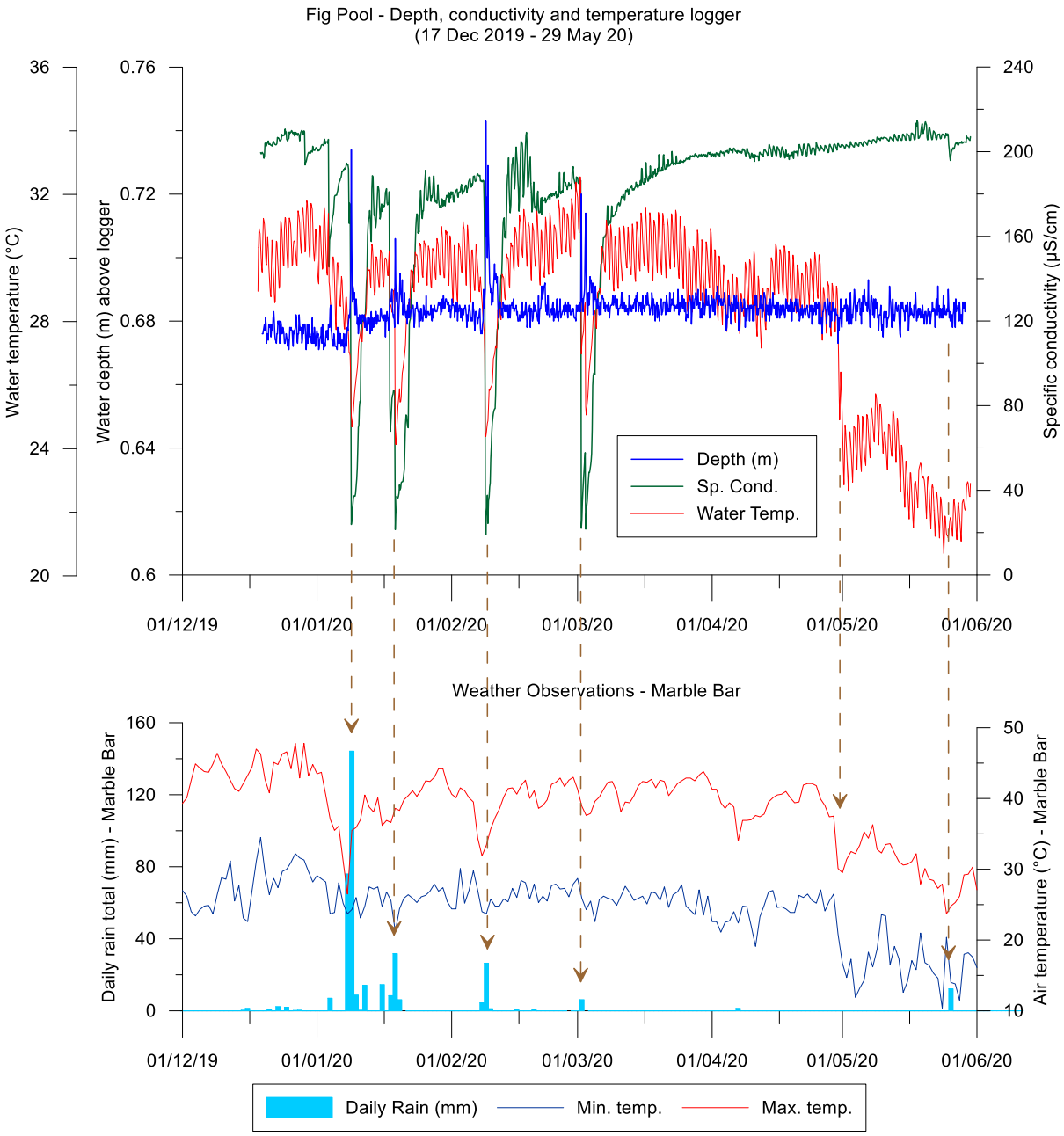


Figure 14 Depth, conductivity, and temperature logger data (above) relationship to daily rainfall (below).

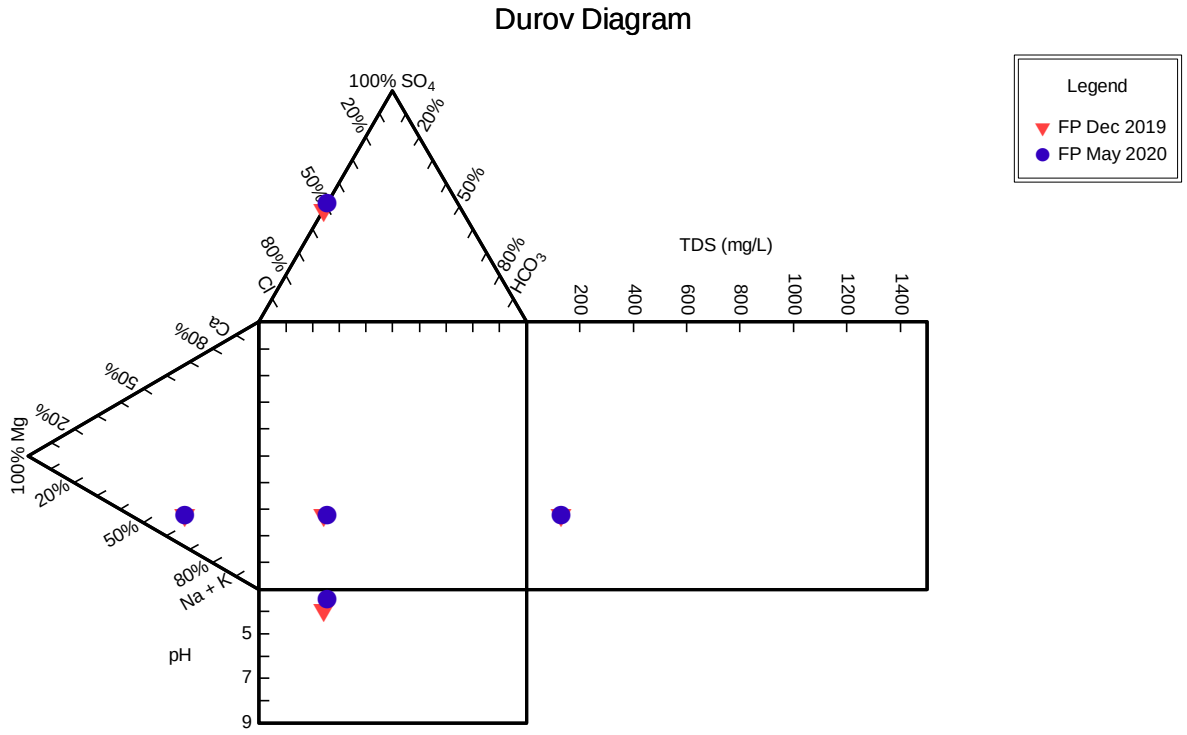


Figure 15 Durov diagram illustrates Fig Pool is a sodium-sulphate dominated water type. It is fresh, highly acidic pool with low total dissolved solids (TDS).

3.2.2 SEDIMENT QUALITY

Table 8 provides the surface sediment quality at Fig Pool during the late wet season (sample collection 30th May 2020). Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentration (143 mg/kg) exceeded the DGV but not the GV-high. Chromium naturally occurs at elevated concentrations across the Project area.

Table 8 Sediment quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	Concentration
Total Soluble Salts	mg/kg	5	**248**
Total Alkalinity as CaCO3	mg/kg	1	**2**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**2**
Carbonate Alkalinity as CaCO3	mg/kg	1	<1
Acidity	mg/kg	1	**14**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**120**
Chloride (by Discrete Analyser)	mg/kg	10	<10
Calcium	mg/kg	10	**30**
Magnesium	mg/kg	10	<10
Sodium	mg/kg	10	**10**
Potassium	mg/kg	10	**10**

Analyte grouping/Analyte	Unit	LOR	Concentration
Mercury (FIMS)	mg/kg	0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**1110**
Total Nitrogen as N	mg/kg	20	**1110**
Total Phosphorus as P	mg/kg	2	**60**
Reactive Phosphorus as P	mg/kg	0.1	<0.1
Total Organic Carbon	%	0.02	**0.30**
Total Metals by ICP-AES			
Arsenic	mg/kg	5	<5
Barium	mg/kg	10	**10**
Beryllium	mg/kg	1	<1
Boron	mg/kg	50	<50
Cadmium	mg/kg	1	<1
Chromium	mg/kg	2	**143**
Cobalt	mg/kg	2	<2
Copper	mg/kg	5	**8**
Iron	mg/kg	50	**58500**
Lead	mg/kg	5	<5
Manganese	mg/kg	5	**94**
Nickel	mg/kg	2	**6**
Selenium	mg/kg	5	<5
Vanadium	mg/kg	5	**27**
Zinc	mg/kg	5	**5**

3.2.3 FISH

Fish, decapods and non-fish vertebrates were sampled with a combination of nets/traps and BRUVs. No fish were collected by fyke nets, traps or BRUVs and no fish have been observed to inhabit the pool. Similarly, no other vertebrates (e.g. tadpoles/frogs, snakes) have been observed at the pool. It is noted that organisms that are generally highly visible (e.g. fish) would have been readily observable if they inhabited the pool due to the small size of the pool, shallowness, and water clarity.

3.2.4 AQUATIC MACROINVERTEBRATES

Table 9 presents the macroinvertebrate summary table and Table 10 presents the taxa abundance and SIGNAL scores for the late wet season macroinvertebrate sampling (Appendix D). Edge habitat type was sampled and macroinvertebrate biotic indices were calculated to provide an indication of waterbody condition. The key findings were as follows:

- Diversity and total count was low, with macroinvertebrates collected belonging to a total of 5 orders (Figure 16) and 10 families and the average count was 65.5 individuals per sample.
- EPT taxa (sensitive taxa) were absent (EPT Taxonomic Richness = 0).
- Low SIGNAL2 score (SIGNAL2 = 3) indicates predominantly tolerant taxa and disturbed conditions (Chessman, 2003).
- No 'very sensitive' taxa were recorded (SIGNAL grades 8, 9, 10). Only 1 'sensitive' family was collected (Acarina).
- The natural acidity at Fig Pool is likely to be the cause for the absence of sensitive taxa and low abundance. Additionally, macrophytes provide preferred habitats and food source to some macroinvertebrate taxa and the absence of macrophyte habitat is likely to have further reduced the abundance and diversity of macroinvertebrates the ecosystem can sustain.

Table 9 Macroinvertebrate summary and indices

Habitat type	Count	Taxonomic Richness	EPT Taxa	SIGNAL2 Score
Edge	71	8	0	2.9
Edge	60	9	0	3.1
Mean	65.5	8.5	0	3.0

Table 10 Macroinvertebrate abundance and SIGNAL scores.

Order	Family	Count – replicate 1	Count – replicate 2	Average count	SIGNAL2 Score [1]
Acarina	Acarina	10	3	7	6
Coleoptera	Dytiscidae	9	6	8	2
	Hydrophilidae	10	2	6	2
Diptera	s-f Chironominae	23	25	24	3
	Culicidae	1	4	3	1
Hemiptera	Notonectidae	2	3	3	1
	Veliidae	1	0	1	3
Odonata	Libellulidae	15	15	15	4
	Coenagrionidae	0	1	1	2
	Aeshnidae	0	1	1	4

[1] Based on SIGNAL 2 scores: Red = very tolerant, yellow = tolerant, green = sensitive, blue = very sensitive.

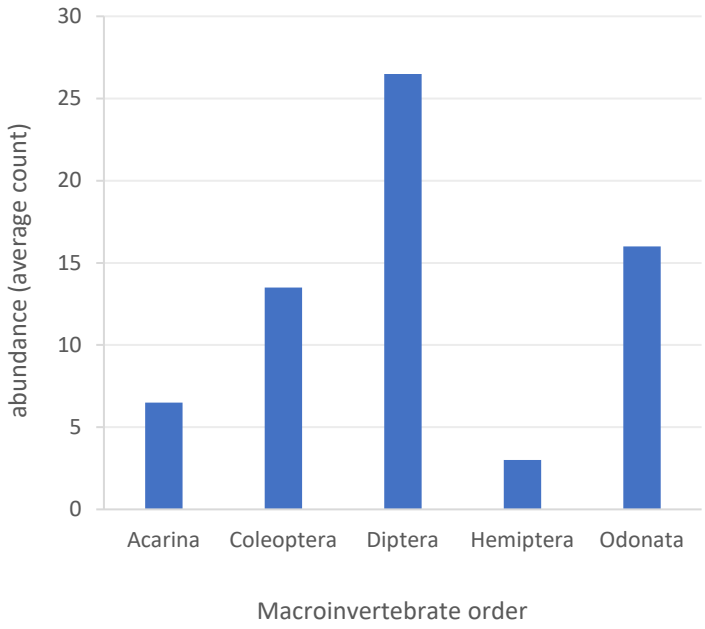


Figure 16 Macroinvertebrate count across the five orders present at Fig Pool.

3.2.5 DIATOMS

No diatom species were detected at Fig Pool during wet season sampling by quantitative artificial substrate sampling. This indicates that the water conditions did not enable reproduction of diatoms during the sampling timeframe because none colonised the new artificial substrates. It is possible that diatoms survive in the pool which had established on natural substrates during a time when conditions were more conducive to growth. Similarly, it is possible that diatoms exist in the pool that do colonise habitat though preferentially colonise other substrate types rather than the artificial substrates. A DSIAR score could not be calculated.

3.2.6 MACROPHYTES

No macrophyte species were detected at Fig Pool during wet season sampling and no macrophytes were observed during dry season 2019 site visit. The natural acidity at Fig Pool is likely to be the cause for the absence of macrophytes (Section 3.2.1 Water Quality and Hydrology). The *Melaleuca* spp extensive root mats bordered a large portion of the edge of the pool and provided habitat structural complexity typically provided by macrophytes (Plate 5). The fauna visible in Fig Pool such as Dytiscidae (dive beetles), Hydrophilidae (water scavenger beetles) and Chironominae (midges) were noted to be inhabiting the root mats.

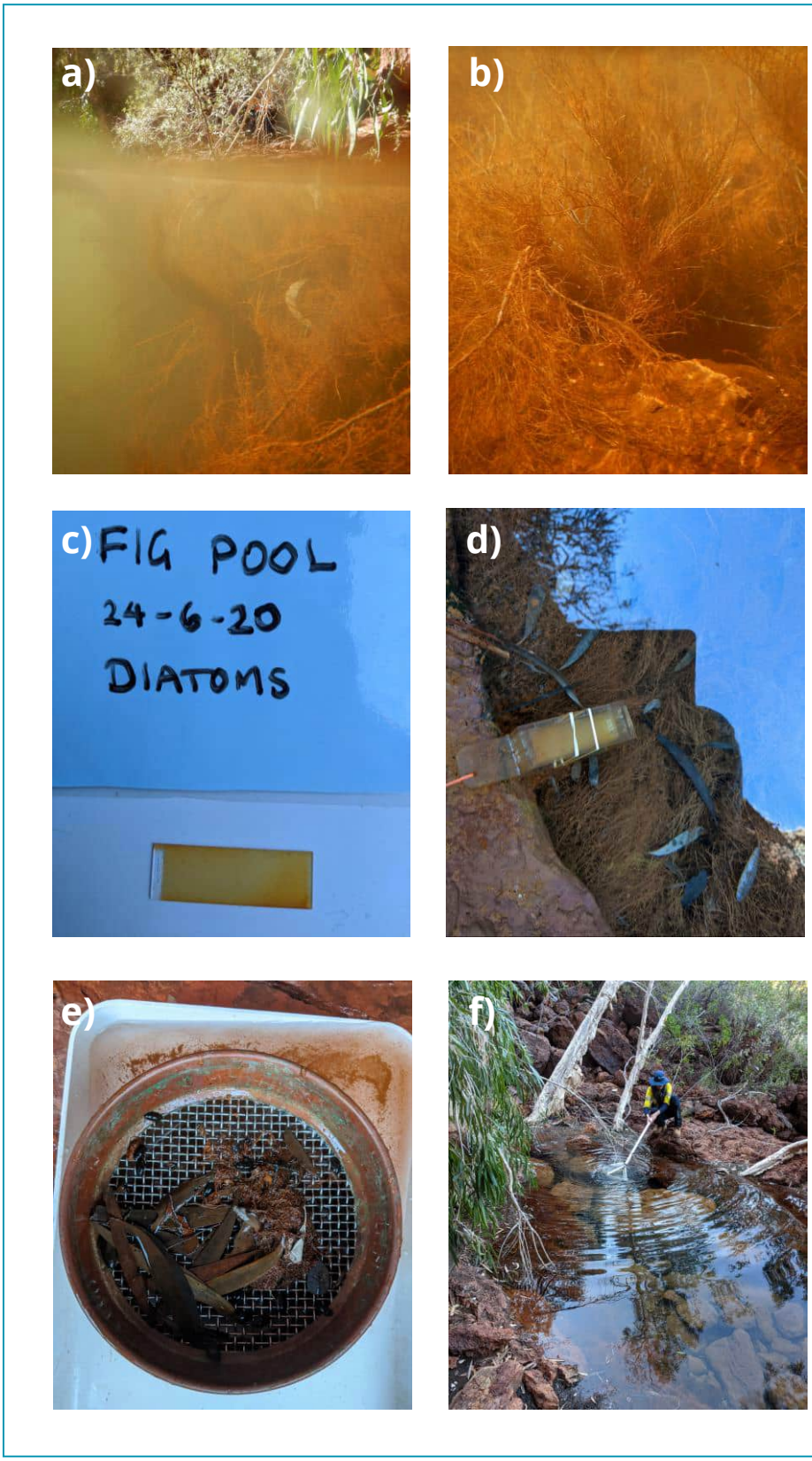


Plate 5 Fig Pool ecology. a) and b) root mats of *Melaleuca* spp extend into Fig Pool; c) and d) microscope slide used as artificial colonising habitat for diatoms appears stained by iron deposits and no algal growth; d) periphytometers to sample diatoms placed on root mats and leaf litter; e) and f) macroinvertebrate sampling found low abundance and diversity with predominantly tolerant taxa collected.

3.3 SOUTH STAR POOL

South Star pool has a catchment area of approximately 3.3 km2, draining two similarly sized basins (to the north-ease and south-east; Figure 18). Discharge from the pool flows to Cockatoo Creek and the Turner River. (see Figure 2). The likely permanent nature of the pool provides habitat to an abundance of fish, macroinvertebrates and extensive beds of macrophytes and established riparian vegetation (Plate 6).



Plate 6 South Star Pool is a permanent pool with extensive macrophyte beds and riparian vegetation.

3.3.1 WATER QUALITY AND HYDROLOGY

South Star pool is a relatively deep permanent pool located at the base of an intermittent waterfall, which appears to only flow during high rainfall events. The pool water level is controlled by a sill at the downstream edge. Water levels remain relatively consistent within the pool with the exception of short duration peaks during high rainfall events Figure 19). South Star Pool appears to be largely sustained by groundwater, however it was periodically flushed with fresh surface water flows after rainfall events. It takes approximately 3 weeks for the groundwater to displace the surface water flows once a flushing event has occurred. Conductivity was typically very slightly brackish (~850 µS/cm) except during a surface water flow event when it would become extremely fresh (<50 µS/cm). Water levels were a maximum of ~0.6 m above the pool overflow levels during high-flow events, which typically lasted less than 24 hours before flows receded. Water temperature within the pool was responsive to atmospheric temperature changes (Figure 18).

South Star pool is a clear water pool with low turbidity (0.71 NTU), low salinity (870 µS/cm) and moderate oxygenation (5.61 mg/L). No metals were recorded above ANZG (2018) and were predominantly below detection limits. Nutrients were low with Total Nitrogen at 0.5 mg/L and Total Phosphorus at 0.01 mg/L. Dissolved organic carbon (DOC) was moderate at 4 mg/L. See Appendix Appendix A for full water quality data.

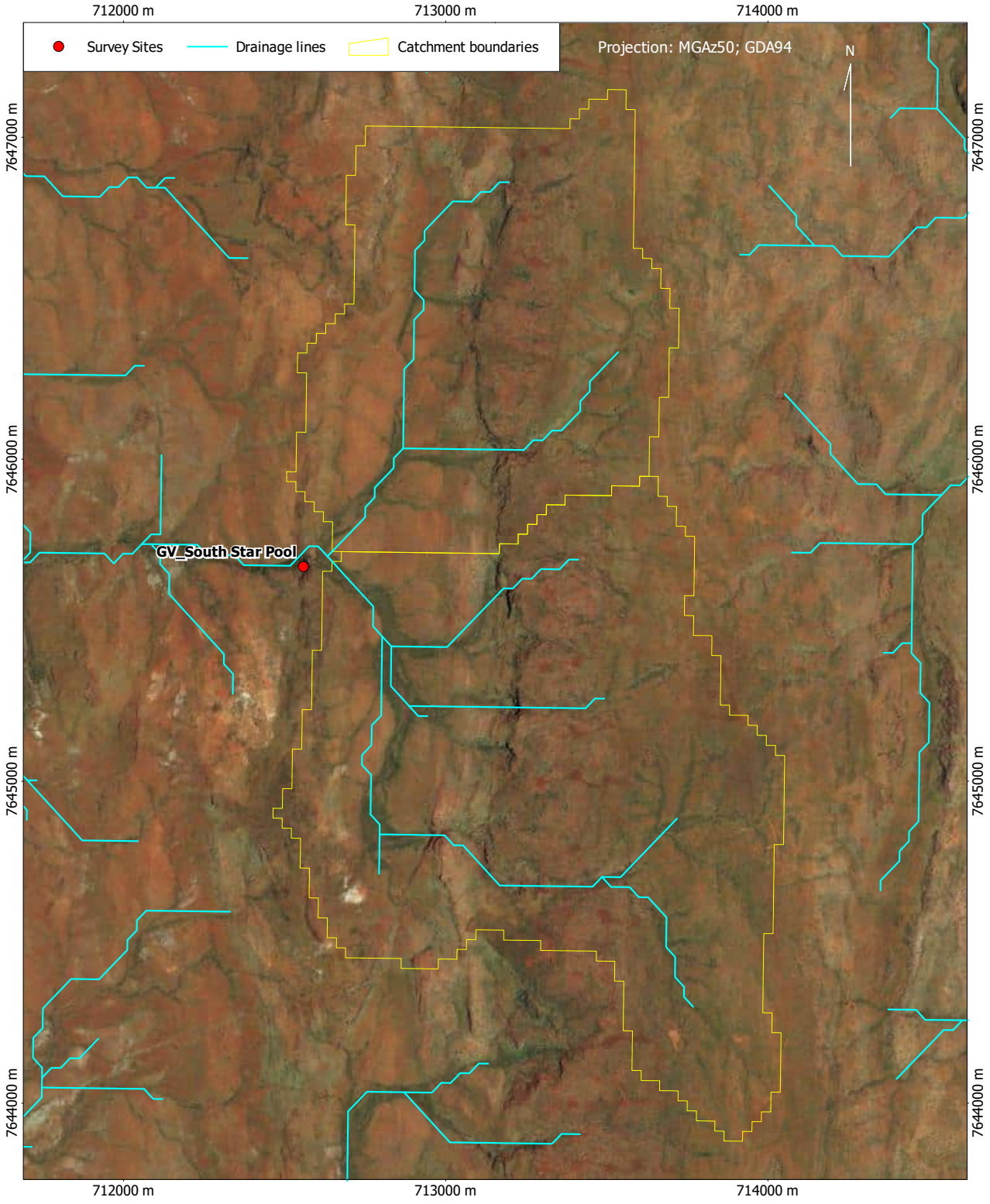


Figure 18 South Star pool catchment (3.3 km^2)

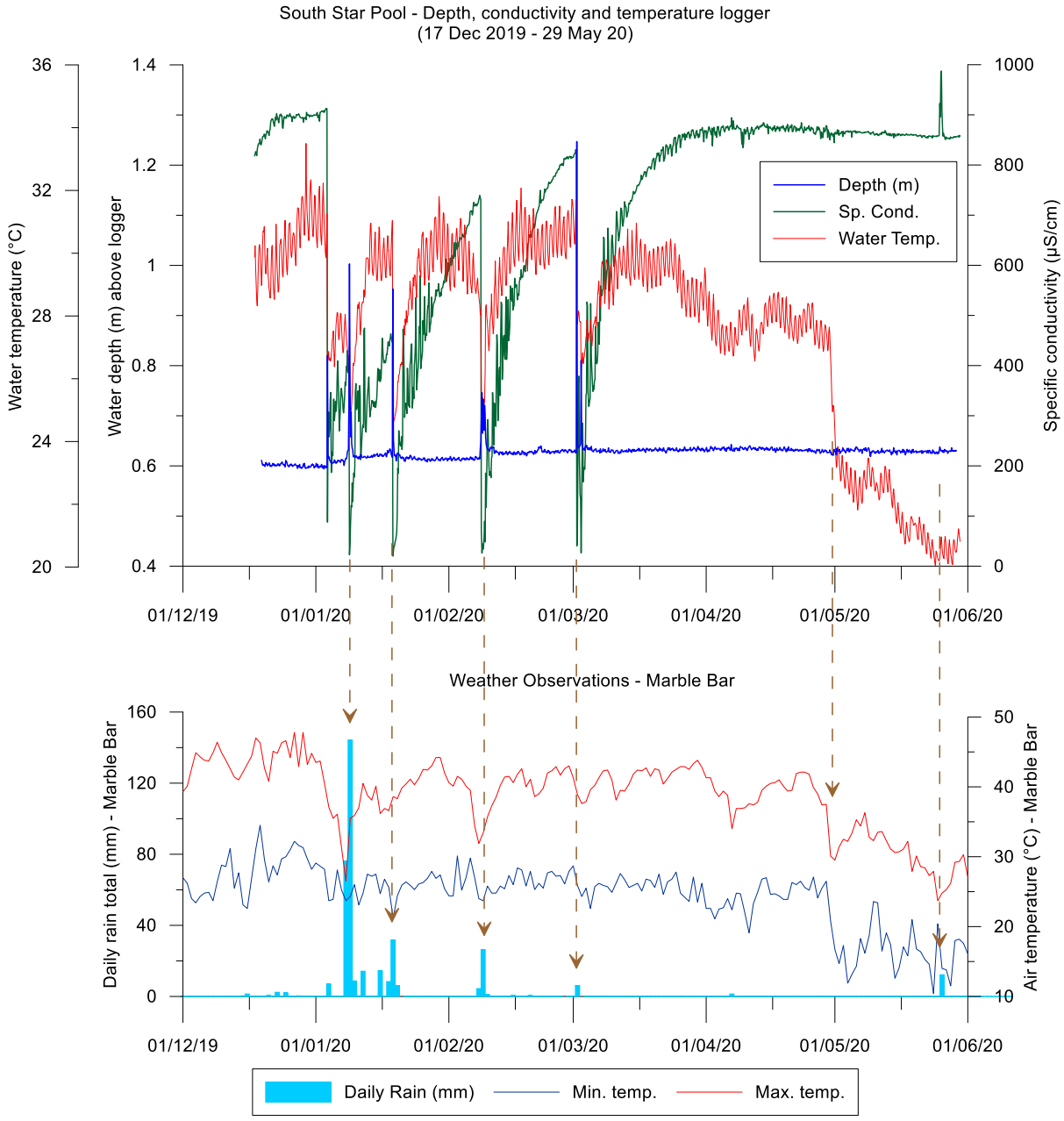


Figure 19 Water level, temperature and conductivity (salinity) at South Star Pool – Wet Season 2020

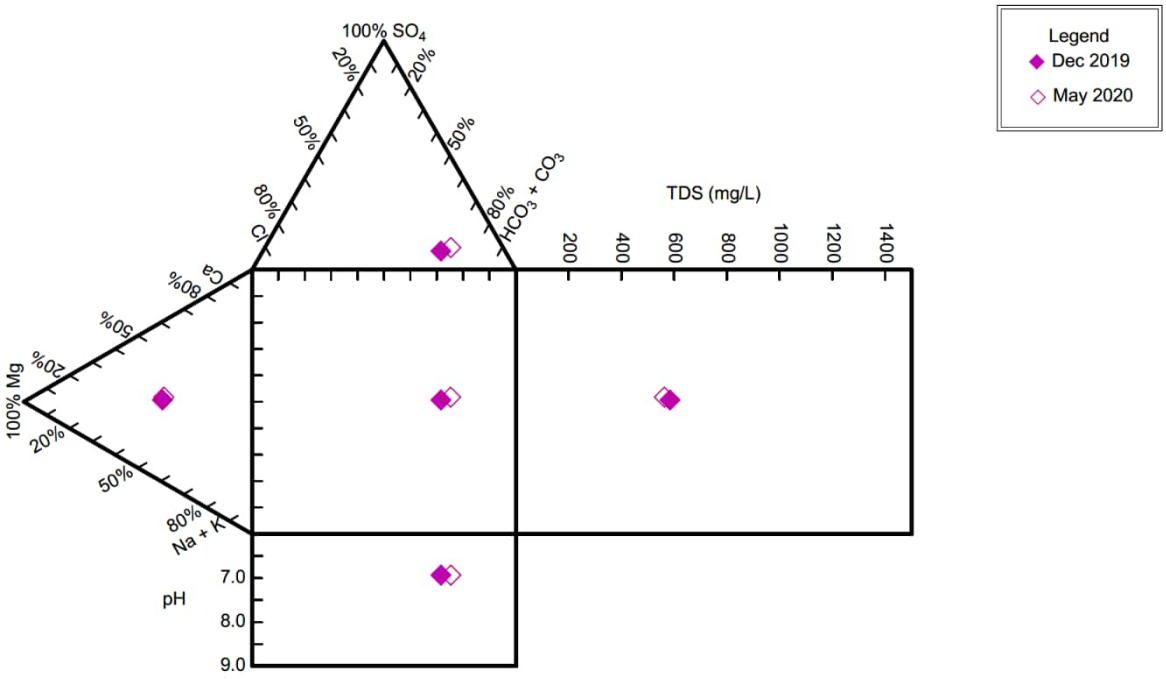


Figure 20 Durov diagram illustrates the South Star Pool major ion distribution.

3.3.2 BATHYMETRY

South Star Pool was surveyed in May 2020 using a down beam and side-scan sonar system attached to a remote-control boat. The maximum depth of the pool is approximately 3.5 m with the average depth ~2 m (Figure 21). The deepest section (3-3.5 m) is in the basin below the waterfall/rock face to the east with a shallower sill to the west at ~1 m deep (Figure 22 and Figure 23). The pool is 25 m in length (north-south) and 15 m at its widest point (east-west). The base of the pool is dominated by hard rock with gravel/sediments to the west at the pool overflow point.

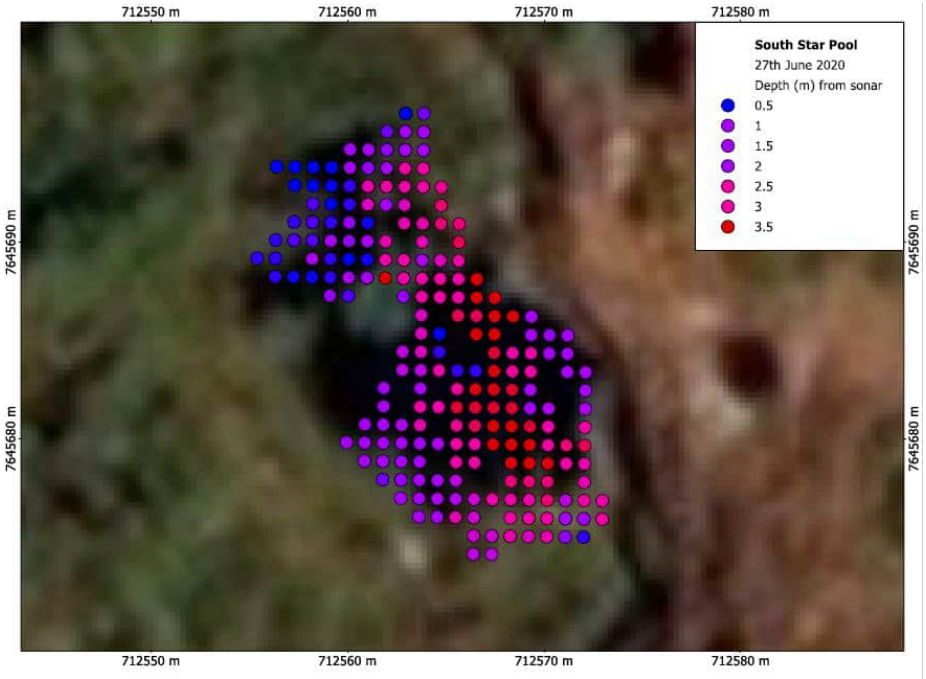


Figure 21 Bathymetry of South Star Pool

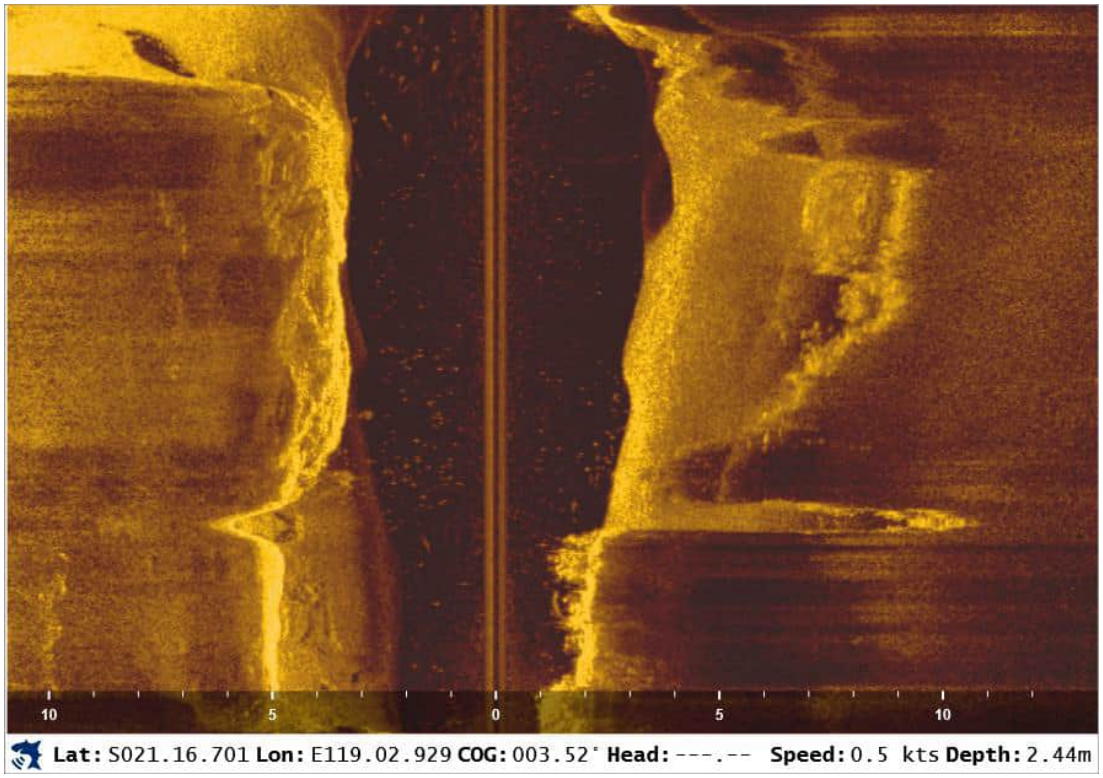


Figure 22 Side scan sonar bathymetry - cross section north-south

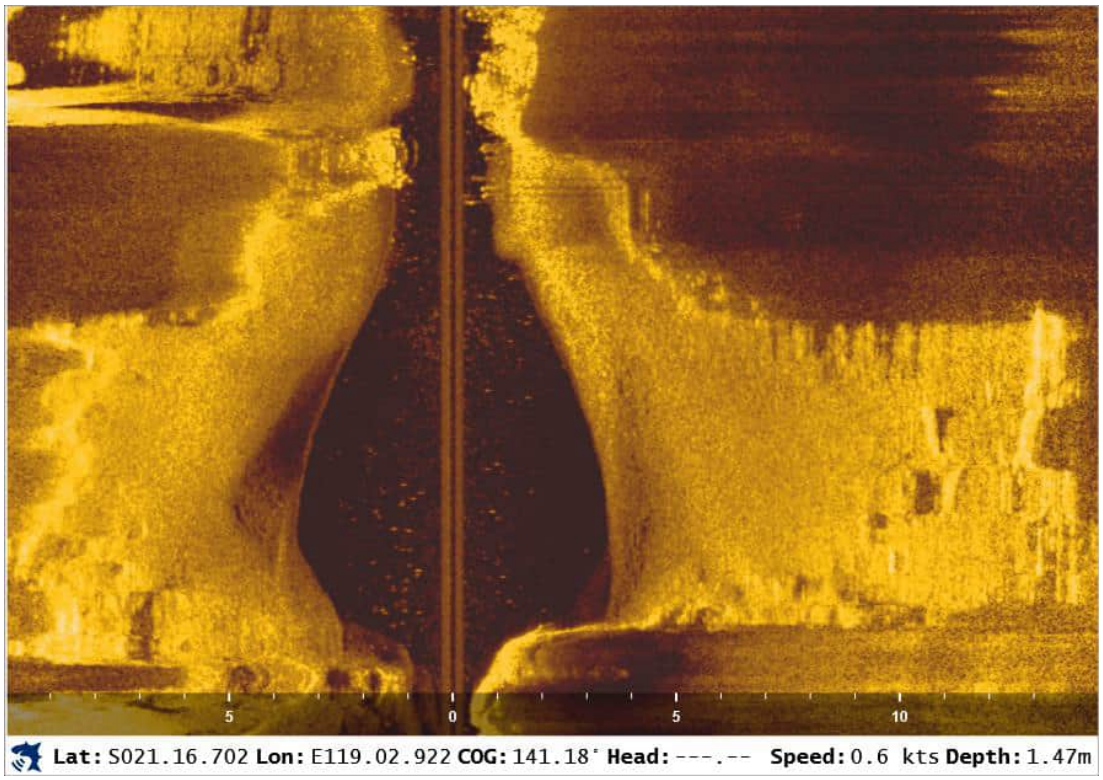


Figure 23 Side scan sonar bathymetry - cross section east-west

3.3.3 SEDIMENT QUALITY

Table 11 provides the surface sediment quality at South Star Pool during the late wet season (sample collection 30th May 2020). Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentration (169 mg/kg) exceeded the DGV but not the GV-high. Nickel concentration (79 mg/kg) exceed both the DGV and GV-high. These metals both naturally occur in high concentrations across the Project area.

Table 11 Sediment quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	Concentration
Total Soluble Salts	mg/kg	5	**693**
Moisture Content (Dried @ 105-110°C)	%	1.0	**59.7**
Total Alkalinity as CaCO3	mg/kg	1	**77**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**77**
Carbonate Alkalinity as CaCO3	mg/kg	1	<1
Acidity	mg/kg	1	**12**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**80**
Chloride (by Discrete Analyser)	mg/kg	10	**100**
Calcium	mg/kg	10	**220**
Magnesium	mg/kg	10	**110**
Sodium	mg/kg	10	**170**
Potassium	mg/kg	10	**20**
Mercury (FIMS)	mg/kg	0.1	**0.6**
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**3950**
Total Nitrogen as N	mg/kg	20	**3950**
Total Phosphorus as P	mg/kg	2	**242**
Reactive Phosphorus as P	mg/kg	0.1	<0.1
Total Organic Carbon	%	0.02	**3.15**
Total Metals by ICP-AES			
Arsenic	mg/kg	5	**9**
Barium	mg/kg	10	**40**
Beryllium	mg/kg	1	**1**
Boron	mg/kg	50	<50
Cadmium	mg/kg	1	<1
Chromium	mg/kg	2	**169**
Cobalt	mg/kg	2	**22**

Copper	mg/kg	5	**52**
Iron	mg/kg	50	**76600**
Lead	mg/kg	5	<5
Manganese	mg/kg	5	**481**
Nickel	mg/kg	2	**79**
Selenium	mg/kg	5	**5**
Vanadium	mg/kg	5	**166**
Zinc	mg/kg	5	**39**

3.3.4 FISH

Table 12 presents the fish species, catch and size distribution of fish collected during the late wet season survey. The size distribution of the subset of measured individuals is presented in Figure 24. Two fish species were present and were sampled by nets/traps and BRUVs; *M. australis* and *L. unicolor*. *M. australis* was substantially more abundant (count=212) than *L. unicolor* (count=1) when sampled with nets/traps. The low abundance of *L. unicolor* was likely due to the net being placed in habitat less frequented by this species (edge/macrophytes) and BRUVs directed towards open water captured a greater abundance of adult *L. unicolor*. The size range of L. unicolor observed demonstrated likely interannual survival and reproduction of *L. unicolor*, with some estimated at several years old (Plate 7 e). *M. australis* ranged between approximately 20 mm to 90 mm in total length. The presence of individuals less than 30 mm indicates that breeding occurred within the previous approximately 90 days (Pusey, B., Kennard, M., & Arthington, 2004). While growth rates vary considerably with changes in temperature, feeding rate and densities, it is probable the <30 mm and 30-60 mm size classes are from the most recent wet season breeding period. Baited marron/box traps were used to target decapod crustaceans, however none were collected or observed.

Table 12 Fish species, catch and size distribution

Species	Size class (mm)	Catch	CPUE[1]
Melanotaenia australis		**212**	**12.8**
	0 – 30	63	
	30 – 60	95	
	60 – 90	54	
	> 90	0	
Leiopotherapon unicolor		**1**	**0.06**
	30 - 60	0	
	60 - 90	0	
	> 90	1	
Total		**213**	**12.9**

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 16.5 hours.

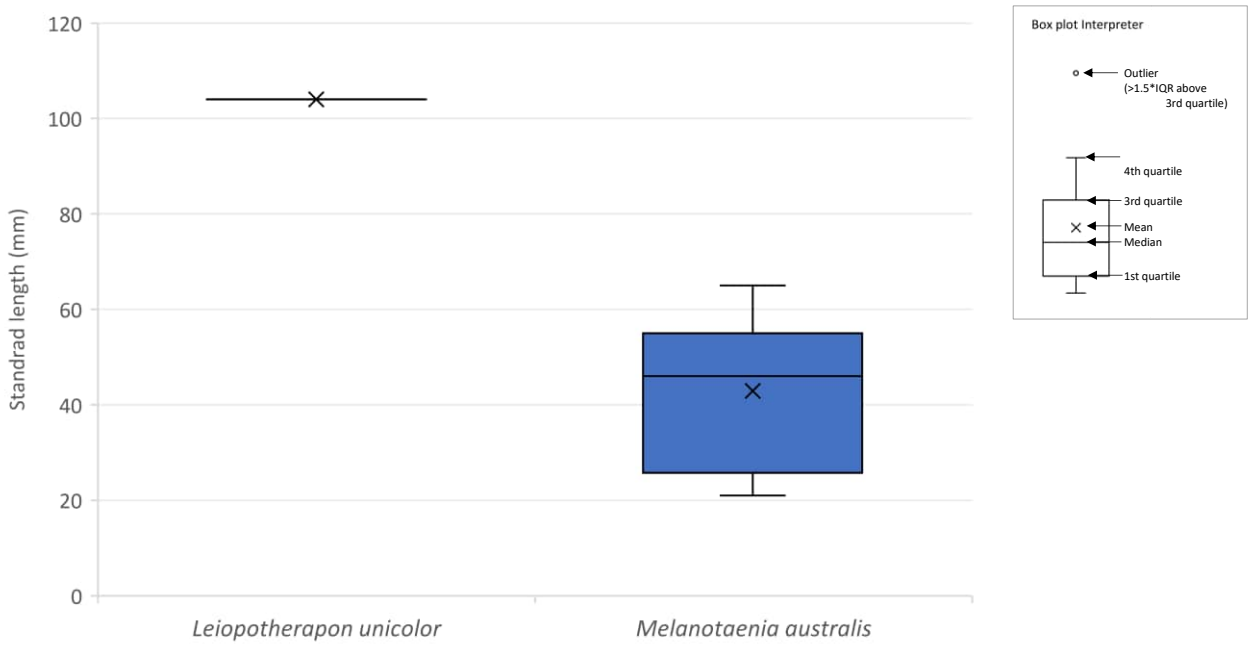


Figure 24 Size distribution (standard length mm) of fish species collected.

3.3.5 AQUATIC MACROINVERTEBRATES

Table 13 presents the macroinvertebrate summary table and Table 14 presents the taxa abundance and SIGNAL scores for the late wet season macroinvertebrate sampling (Appendix D). Macrophyte habitat type was sampled due to being the dominant habitat type, and macroinvertebrate biotic indices were derived to provide an indication of waterbody condition. The key findings were as follows:

- A high diversity and abundance of taxa were collected; a total of 27 families with an average count of 126 individuals per sample.
- EPT taxa were present in both samples. A total of 5 unique EPT families were collected. The average EPT Taxonomic Richness = 4 (Figure 25).
- A low SIGNAL 2 score (SIGNAL 2 score = 3) indicates that predominantly tolerant taxa were present (Chessman, 2003).
- 'Very sensitive' taxa were not recorded (SIGNAL grades 8, 9, 10) and 4 'sensitive' taxa were collected (SIGNAL grades 5, 6, 7).

Table 13 Macroinvertebrate summary and indices

Habitat type	Count	Taxonomic Richness	EPT Taxa	SIGNAL2 Score
Macrophyte	127	24	4	2.8
Macrophyte	126	18	4	3.2
Mean	126.5	21	4	3.0

Table 14 Macroinvertebrate abundance and SIGNAL2 scores.

Order [1]	Family	Count – replicate 1	Count – replicate 2	Average count	SIGNAL2 Score [2]
Acarina	Acarina	5	21	13	6
Araneae	Araneae	1	1	1	
Cladocera	Cladocera	2	11	7	
Coleoptera	Hydrochidae	2		2	4
Copepoda	Copepoda	6		6	
Diptera	s-f Chironominae	9	20	15	3
	s-f Tanypodinae	15	9	12	4
	Ceratopogonidae	3	2	3	4
	Culicidae		1	1	1
Ephemeroptera	Baetidae	9	13	11	5

Order [1]	Family	Count – replicate 1	Count – replicate 2	Average count	SIGNAL2 Score [2]
	Caenidae	10	1	6	4
Gastropoda	Planorbidae	3	8	6	2
	Lymnaeidae	12	4	8	1
	Ancylidae	10		10	4
Hemiptera	Pleidae	3		3	2
	Micronectidae	1		1	2
Lepidoptera	Crambidae	1	6	4	3
Odonata	Coenagrionidae	9	10	10	2
	Libellulidae	1	7	4	4
	Aeshnidae		5	5	4
	S.O. Epiproctiphora	1		1	3
	Corduliidae	1		1	5
Oligochaeta	Oligochaeta	1	1	1	2
Ostracoda	Ostracoda	15		15	
Trichoptera	Hydroptilidae		4	4	4
	Leptoceridae	4	2	3	6
	Ecnomidae	3		3	4

[1] Bold font denotes EPT orders and high SIGNAL 2 scores (SIGNAL 2 = 8,9,10).

[2] Based on SIGNAL 2 scores: Red = very tolerant, yellow = tolerant, green = sensitive, blue = very sensitive.

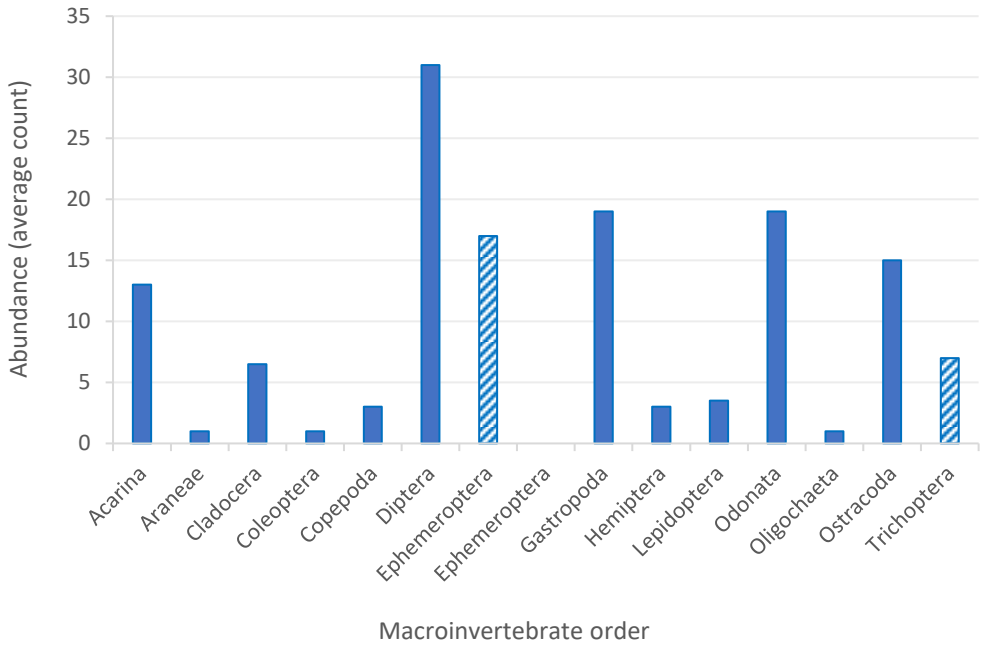


Figure 25 Macroinvertebrate abundance. Pattern fill denotes EPT orders.

3.3.6 DIATOMS

Table 15 presents the late wet season diatom species present, abundance and biotic indices. Figure 26 shows the average count by diatom species present. The key findings were as follows:

- A total of 17 diatom species were recorded and show a high taxonomic diversity ranging across multiple families.
- The most dominant species were *Achnanthidium minutissimum* (average count=197) and *Brachysira vitrea* (average count=106) (Figure 26).
- The moderate sensitivity DSIAR scores (average DSIAR = 62.7) is associated with low levels of environmental stress and diatoms valves were relatively abundant compared to other North Star Pools.

Table 15 Diatom count per species

Species	Count – replicate 1	Count – replicate 2	Average species count	Variability (St Dev)
Achnanthidium minutissimum	302	92	197	148.5
Brachysira vitrea	48	164	106	82.0
Caloneis silicula	0	2	1	1.4
Craticula halophila	2	0	1	1.4
Cymbella affinis	6	8	7	1.4
Cymbella spp	4	4	4	0.0
Diploneis parma	2	0	1	1.4
Encyonema minutum	4	0	2	2.8
Eunotia bilunaris	14	70	42	39.6
Navicula cryptocephala	6	0	3	4.2
Navicula cryptotenella	0	2	1	1.4
Navicula gregaria	4	0	2	2.8
Navicula lanceolata	4	4	4	0.0
Navicula menisculoides	8	4	6	2.8
Navicula radiosa	12	24	18	8.5
Navicula recens	4	0	2	2.8
Ulnaria ulna	0	12	6	8.5
Total abundance	420	386	403	59.3
DSIAR score	59.1	66.3	62.7	

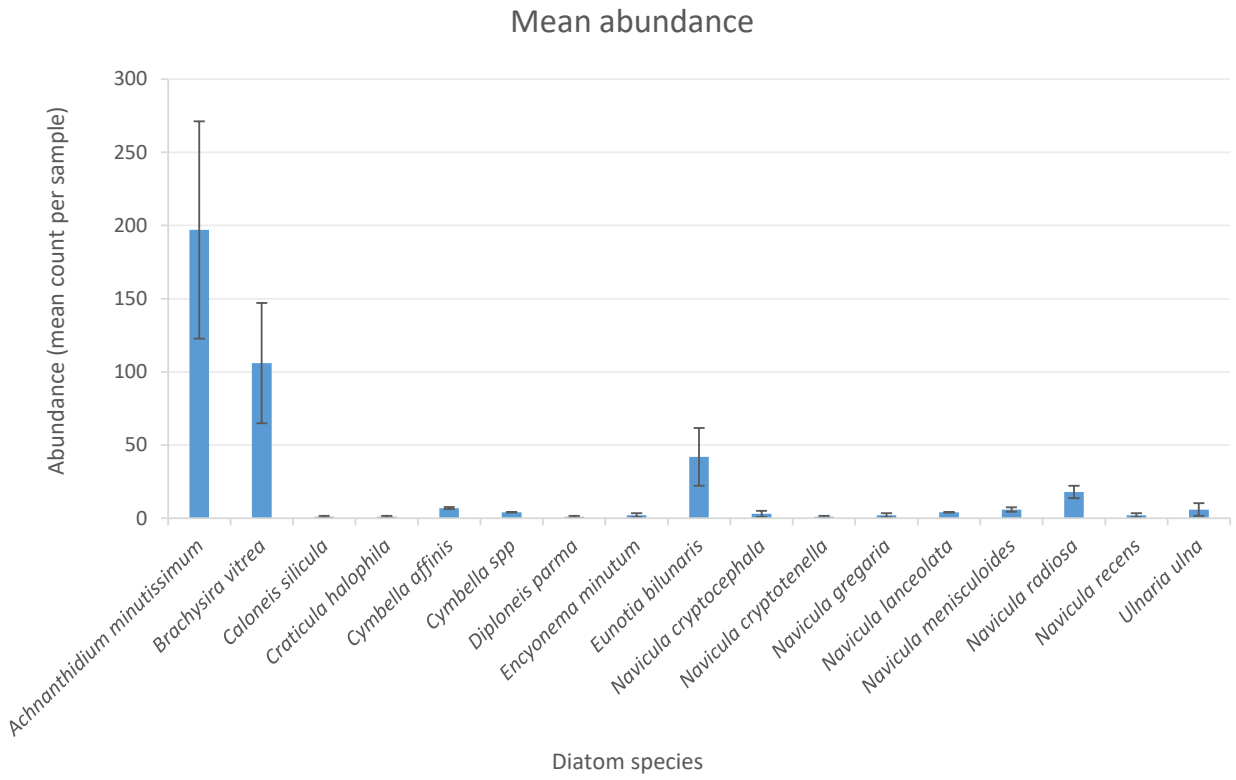


Figure 26 Diatom average abundance. Error bars show 1σ.

3.3.7 MACROPHYTES

Table 16 presents the macrophyte species and qualitative abundance during late wet season sampling at South Star Pool. The key findings were as follows:

- A total of 5 macrophyte species were recorded and show a range of emergent (bullrush, sedge and typha) and submerged (charophyte and ribbon weed) types.
- Emergent macrophytes were the dominant edge habitat, occurring in wide dense beds along the pools edge except for along the upstream eastern rockface. Submerged macrophytes occurred in scattered abundance on the bed.

Table 16 Macrophytes present at South Star Pool

Common name	Species name	Abundance[1]
Ribbon weed	*Vallisneria sp.*	Abundant
Charophytes	*Nitella sp.*, *Chara sp.*	Isolated
Clubrush	*Schoenoplectus sp.*	Abundant
Sedges	Cyperaceae	Isolated
Bulrush	*Typha sp.*	Abundant

[1] Abundance based on *Western Australia AUSRIVAS field sampling sheet* (DoW, 2009).

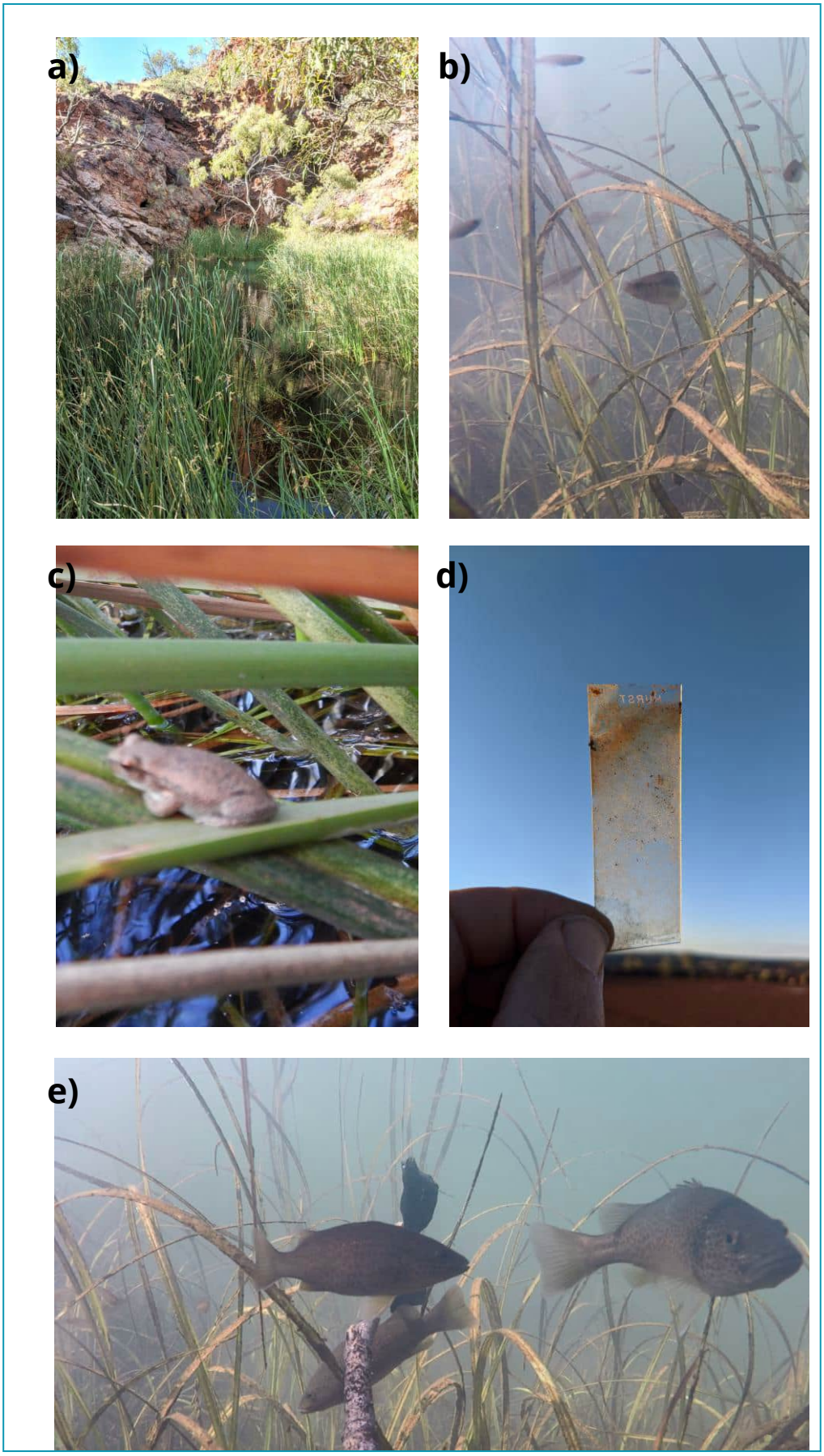


Plate 7 South Star Pool aquatic ecology. a) emergent macrophytes forms beds at the edge of the pools; b) submerged macrophytes create important habitat for an abundance of *M. australis* and *L. unicolor*; c) frog (*Littoria rubella*) utilising the macrophyte habitat; d) abundant diatom growth on slide; e) adult *L. unicolor* observed in abundance using underwater video.

3.4 CENTRAL CREEK POOL

Central Creek Pool is a shallow pool that lies on deep alluvial sediments on Cockatoo Creek, which experiences high flows in the wet season. The pool is predominantly sustained by surface water and consequently undergoes high rates of evapo-concentration and has minimal established macrophyte habitat. The water quality is relatively turbid in comparison to other North Star pools and there is evidence of cattle visitation.



Figure 27 Central Creek is a shallow pool on Cockatoo Creek that experiences substantial evapo-concentration and is likely a temporary pool.

3.4.1 WATER QUALITY AND HYDROLOGY

Central Creek Pool has a catchment area of 85.1 km2 draining to Cockatoo Creek and the Turner River (Figure 28). The surface water level logger was installed in Central Creek Pool during the wet season 2020 (May) sampling round and as such there is no direct hydrology data available for the previous wet season. However, there was a logger installed on the same creek system approximately 550 m downstream in a similar pool (MAR Cockatoo Creek; Figure 29) and it is considered that this represents a reasonable analogue for the hydrology of Central Creek Pool. This will be confirmed when the 2021 wet season data is available from both sites. The analogue MAR Cockatoo Creek site shows a typical Pilbara Creek flooding profile driven by alluvial (hyporheic) flows. There is an initial peek water level during high-rainfall events with a longer "tail" to the peak as water levels recede, driven by discharge from upper catchment alluvial

storage and groundwater. Once recharged after the first flush event, the pool water levels are maintained over the wet season, receding slowly as the alluvials dry out over the early dry season.

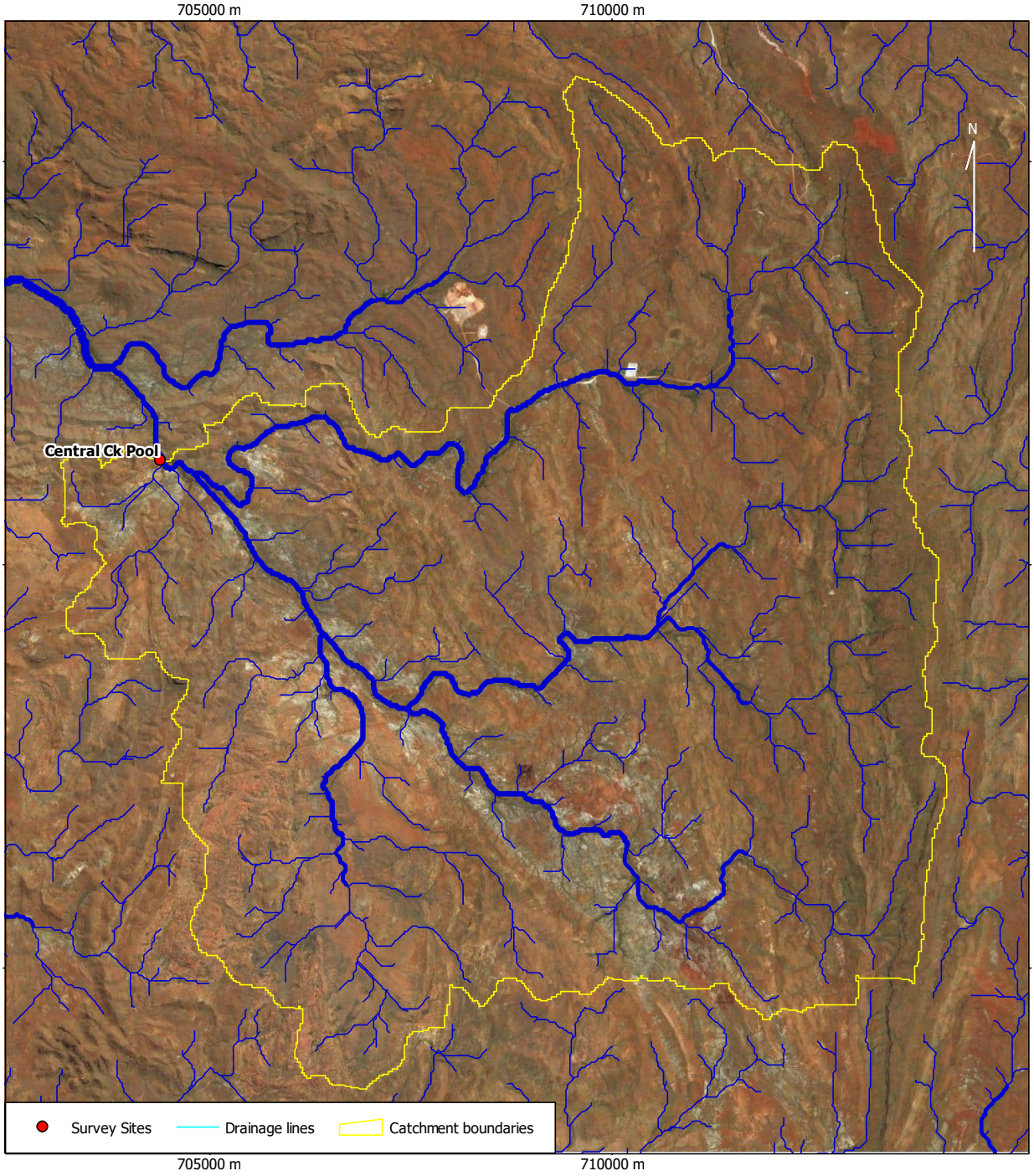


Figure 28 Central Creek Pool catchment area (85.1 km^2)

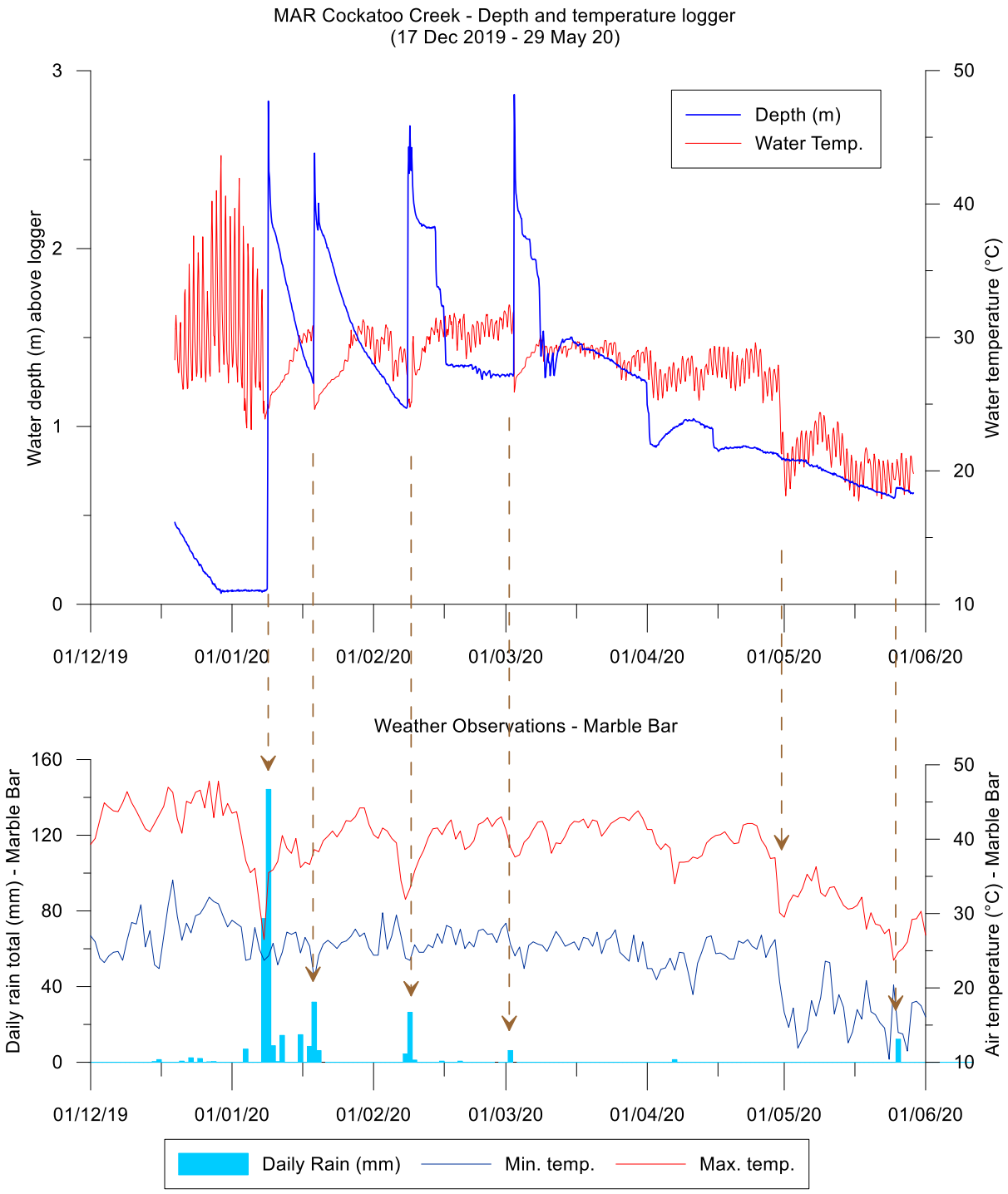


Figure 29 Water level and temperature logger data from MAR Cockatoo Creek (~550m downstream of Central Creek Pool)

Central Creek Pool displayed brackish salinity (2227 µS/cm conductivity) during the wet season sampling (May 2020), likely representing evapo-concentration effects since the last major flushing event occurred in March 2020. Water quality was representative of typical Pilbara streams with near neutral pH (7.69), low-moderate turbidity (2.54 NTU) and moderate oxygenation (92% saturation). Alkalinity was moderate-high at 406 mg/L (as CaCO3) with major ions dominated by sodium chloride (Figure 30). Dissolved arsenic levels were potentially at, or exceeding, the ANZG (2018) 99 or 95% Ecosystem Protection Levels (EPLs) at 13 µg/

however, the results represent non-speciated arsenic while the guidelines are for individual inorganic species of arsenic (III and V). No other metals or metalloids were above guideline levels.

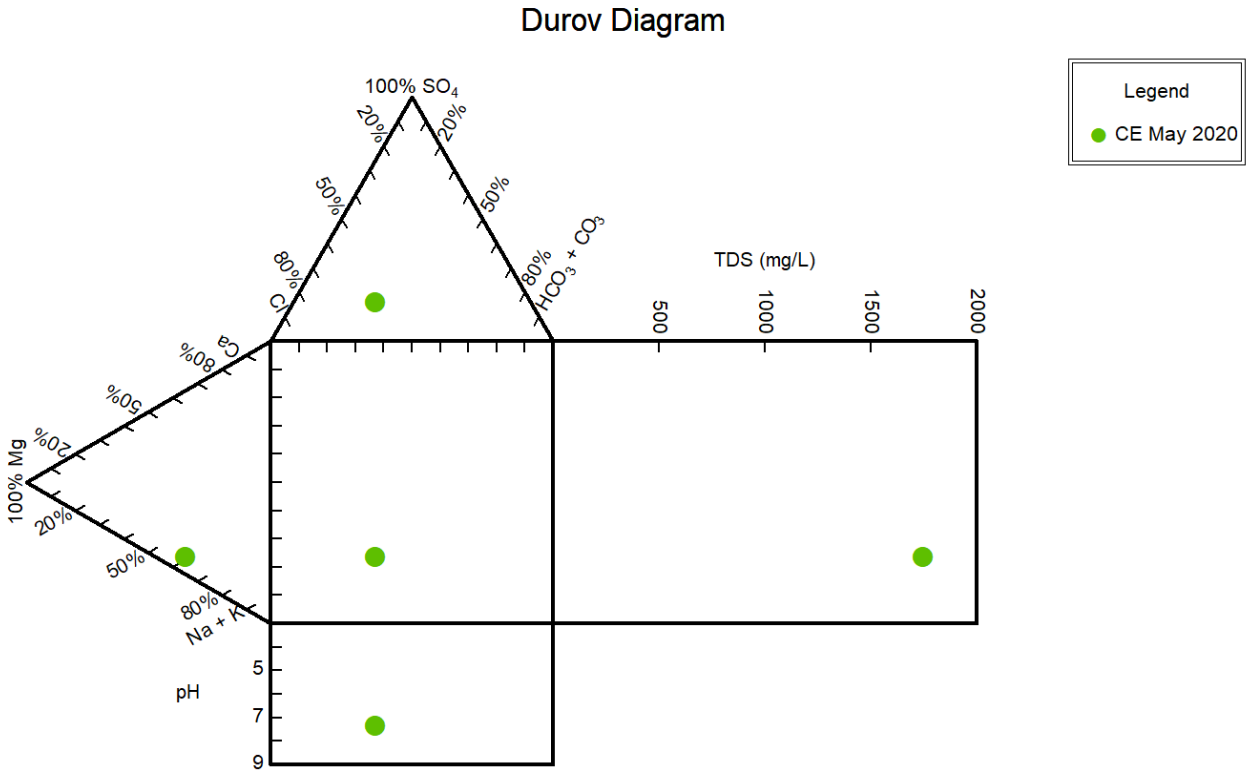


Figure 30 Durov diagram showing the Central Creek Pool major ion distribution.

3.4.2 SEDIMENT QUALITY

Table 17 provides the surface sediment quality at Central Creek Pool during the late wet season (sample collection 31st May 2020). Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentration (219 mg/kg) exceeded the DGV but not the GV-high. Nickel concentration (112 mg/kg) exceed both the DGV and GV-high. However, both chromium and nickel naturally occur in high concentrations across the Project area.

Table 17 Sediment quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	Concentration
Total Soluble Salts	mg/kg	5	**1180**
Moisture Content (Dried @ 105-110°C)	%	1.0	**29.8**
Total Alkalinity as CaCO3	mg/kg	1	**120**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**120**
Carbonate Alkalinity as CaCO3	mg/kg	1	<1
Acidity	mg/kg	1	**4**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**200**

Analyte grouping/Analyte	Unit	LOR	Concentration
Chloride (by Discrete Analyser)	mg/kg	10	**170**
Calcium	mg/kg	10	**40**
Magnesium	mg/kg	10	**70**
Sodium	mg/kg	10	**220**
Potassium	mg/kg	10	**20**
Mercury (FIMS)	mg/kg	0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**1090**
Total Nitrogen as N	mg/kg	20	**1090**
Total Phosphorus as P	mg/kg	2	**100**
Reactive Phosphorus as P	mg/kg	0.1	<0.1
Total Organic Carbon	%	0.02	**1.80**
Total Metals by ICP-AES			
Arsenic	mg/kg	5	**9**
Barium	mg/kg	10	**40**
Beryllium	mg/kg	1	<1
Boron	mg/kg	50	<50
Cadmium	mg/kg	1	<1
Chromium	mg/kg	2	**219**
Cobalt	mg/kg	2	**16**
Copper	mg/kg	5	**22**
Iron	mg/kg	50	**26600**
Lead	mg/kg	5	<5
Manganese	mg/kg	5	**476**
Nickel	mg/kg	2	**112**
Selenium	mg/kg	5	<5
Vanadium	mg/kg	5	**39**
Zinc	mg/kg	5	**35**

3.4.3 FISH

Table 18 presents the fish species, catch and size distribution. Two fish species were present; *M. australis* and *L. unicolor* and occurred at similarly high abundances for the size of the pool. The high abundance is likely a function of the high catchability due to the pool drying out rather than being due to the pool providing a preferred habitat. The high interest in bait during the BRUVs survey may be an indication of low food resources in the pool.

Over half of all *M. australis and L. unicolor* ranged between 30 mm to 60 mm in total length (Figure 31). This size class is likely associated with a 2019/2020 wet season breeding period. The presence of only one individual (*M. australis*) under 30 mm indicates breeding within the previous 3 months is unlikely to have occurred or that early life stages did not survive in recent months when the shrinking pool size increased density dependant factors such as fish predation.

Table 18 Fish species, catch and size distribution

Species	Size class (mm)	Catch	CPUE[1]
Melanotaenia australis		**171**	**9**
	0 – 30	1	
	30 – 60	113	
	60 – 90	57	
	> 90	0	
Leiopotherapon unicolor		**207**	**10.9**
	30 - 60	109	
	60 - 90	53	
	> 90	45	
Total		**378**	**19.9**

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 19 hours.

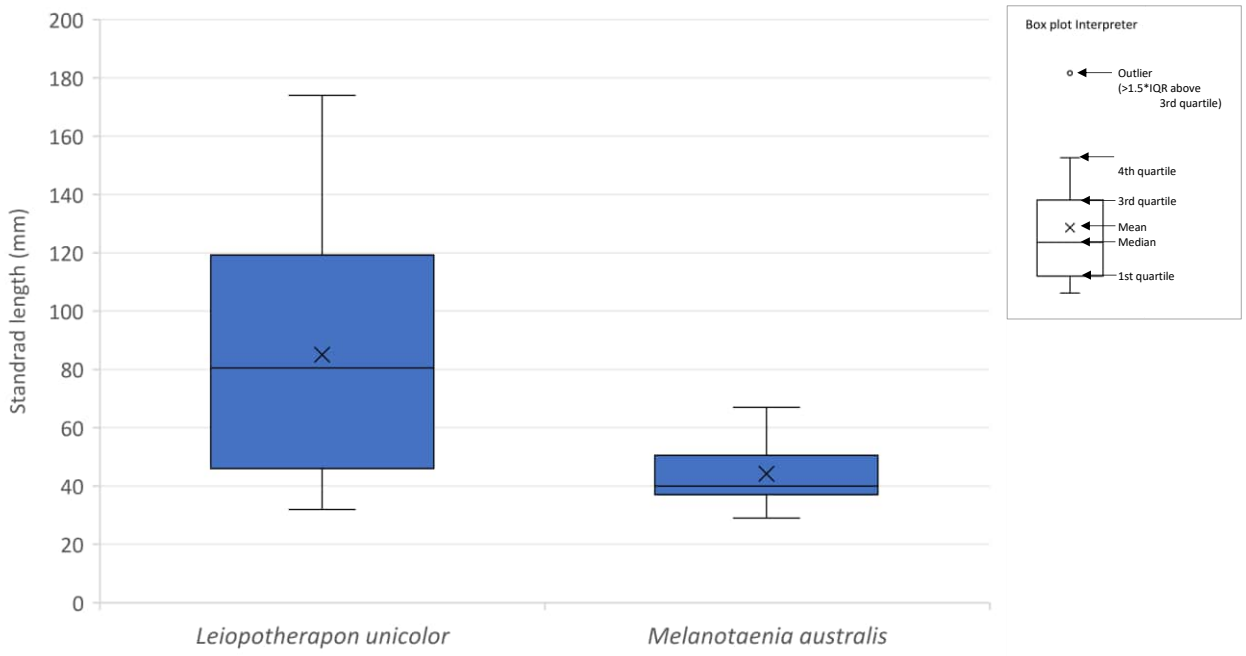


Figure 31 Species size distribution (standard length mm) of fish collected.

3.4.4 AQUATIC MACROINVERTEBRATES

Table 19 presents the macroinvertebrate summary table and Table 20 presents the taxa abundance and SIGNAL scores for the late wet season macroinvertebrate sampling (Appendix D). Edge and open pool habitat were sampled to represent the predominant habitats present and macroinvertebrate biotic indices were derived to provide an indication of waterbody condition. The key findings were as follows:

- A diverse range of taxa were collected; a total of 28 families with an average count of 96 individuals per sample.
- EPT taxa were present in each sample. A total of 3 unique EPT families were collected and the average EPT Taxonomic Richness = 3 (Figure 32).
- A low SIGNAL 2 score (SIGNAL2 grade= 3) indicates predominantly tolerant taxa were collected and the system experiences associated environmental stress (Chessman, 2003).
- 'Very sensitive' taxa were not recorded (SIGNAL grades 8, 9, 10) and 2 'sensitive' taxa were collected (SIGNAL grades 5, 6, 7).

Table 19 Macroinvertebrate summary and indices

Habitat type	Count	Taxonomic Richness	EPT Taxa	SIGNAL2 Score
Pool	87	21	3	3.11
Edge	105	22	3	3.05
Mean	96	21.5	3	3.08

Table 20 Macroinvertebrate count and SIGNAL2 scores.

Order [1]	Family	Count – replicate 1	Count – replicate 2	Average Count	SIGNAL2 Score [2]
Acarina	Acarina	2	2	2	6
Araneae	Araneae	0	1	1	N/A
Coleoptera	Dytiscidae	2	7	5	2
	Hydrophilidae	2	2	2	2
	Hydrochidae	1	2	2	4
Copepoda	Copepoda	1	5	3	N/A
Diptera	s-f Chironominae	16	26	21	3
	s-f Tanypodinae	14	11	13	4
	Ceratopogonidae	7	9	8	4
	Ephydridae	1	2	2	2

Order [1]	Family	Count – replicate 1	Count – replicate 2	Average Count	SIGNAL2 Score [2]
	Stratiomyidae	4	1	3	2
	Muscidae	0	1	1	1
	Psychodidae	0	1	1	3
	Tabanidae	0	1	1	3
	s-f Orthocladiinae	1	0	1	4
Ephemeroptera	Caenidae	7	14	11	4
Hemiptera	Pleidae	8	4	6	2
	Nepidae	1	1	1	3
	Veliidae	4	0	2	3
	Hebridae	1	0	1	3
	Mesoveliidae	1	0	1	2
Odonata	S.O. Epiproctiphora	0	1	1	3
	Coenagrionidae	7	0	4	2
	Isostictidae	3	0	2	3
Oligochaeta	Oligochaeta	0	4	2	2
Ostracoda	Ostracoda	0	1	1	N/A
Trichoptera	Leptoceridae	2	6	4	6
	Hydroptilidae	2	3	3	4

[1] Bold font denotes EPT orders and high SIGNAL 2 scores (SIGNAL 2 = 8,9,10).

[2] Based on SIGNAL 2 scores: Red = very tolerant, yellow = tolerant, green = sensitive, blue = very sensitive.

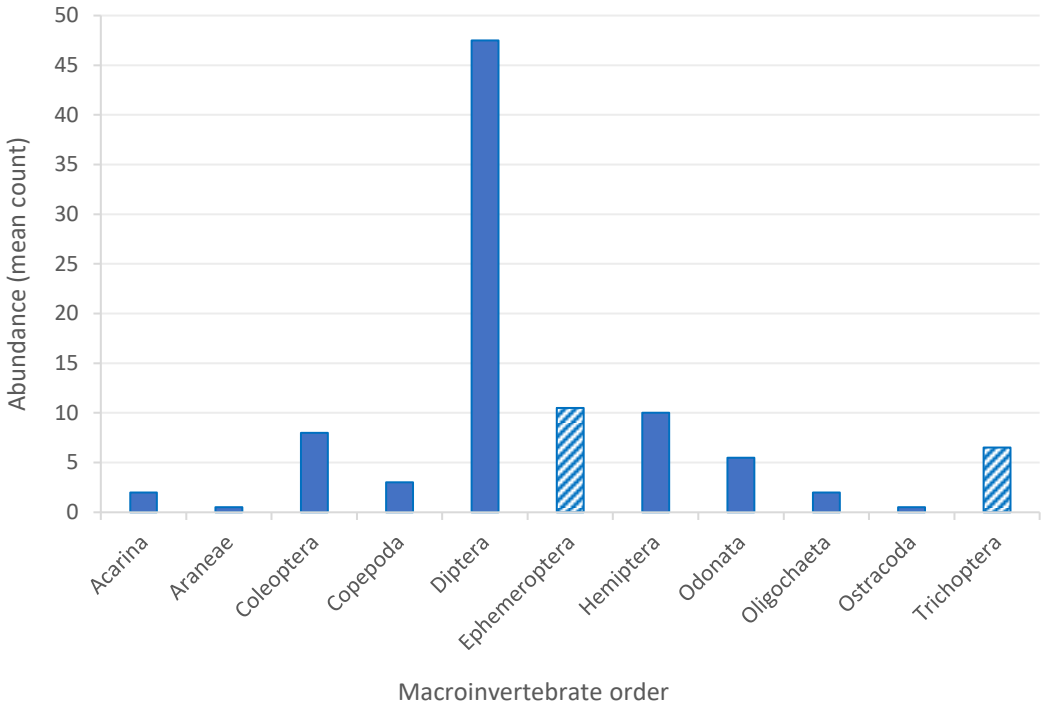


Figure 32 Macroinvertebrate counts. Pattern fill denotes EPT orders.

3.4.5 DIATOMS

Table 21 presents the late wet season diatom species present, abundance and biotic indices. Figure 33 shows the average count by diatom species present. The key findings were as follows:

- A total of 27 diatom species were recorded and show a high taxonomic diversity ranging across multiple families.
- *Achnanthidium exiguum* (average count=258) was the most abundant species. The second most abundant diatom species, *Nitzschia palea*, occurred at substantially lower abundance (average count = 28).
- The tolerance to environmental stress is reflected in the low DSIAR scores (42.0), which indicates the pool is dominated by species tolerant to degraded water quality.
- While the DSIAR score is low, no teratological forms were detected and the diversity of species is relatively high for North Star pools. The low presence or abundance of species associated with higher water quality likely reflects the environmental stress resulting from nutrient pollution from cattle visitation and declining water quality due to high evapo-concentration.

Table 21 Diatom count per species

Species	Count-Replicate 1	Count - Replicate 2	Average species count	Variability (St Dev)
Achnanthidium exiguum	246	270	258	17.0
Achnanthidium minutissimum	22	12	17	7.1
Brachysira brebissonii	0	2	1	1.4

Species	Count- Replicate 1	Count - Replicate 2	Average species count	Variability (St Dev)
Cymbella spp	0	2	1	1.4
Diploneis parma	6	2	4	2.8
Eolimna minima	2	0	1	1.4
Eunotia bilunaris	4	0	2	2.8
Fragilaria spp.	2	0	1	1.4
Hantzschia amphioxys	0	4	2	2.8
Mastogloia smithii	0	2	1	1.4
Navicula lanceolata	2	0	1	1.4
Navicula menisculus	0	4	2	2.8
Navicula phyllepta	0	2	1	1.4
Navicula radiosa	2	0	1	1.4
Navicula veneta	12	6	9	4.2
Nitzschia frustulum	10	8	9	1.4
Nitzschia graciliformis	4	0	2	2.8
Nitzschia gracilis	2	0	1	1.4
Nitzschia inconspicua	0	6	3	4.2
Nitzschia lacuum	8	4	6	2.8
Nitzschia microcephala	0	4	2	2.8
Nitzschia palea	40	16	28	17.0
Nitzschia suchlandii	0	2	1	1.4
Pinnularia legumen	0	2	1	1.4
Pinnularia spp.	0	4	2	2.8
Pleurosigma elongatum	28	0	14	19.8
Ulnaria ulna	4	0	2	2.8
Total abundance	394	352	373	49.0
DSIAR score	41.3	42.6	42.0	

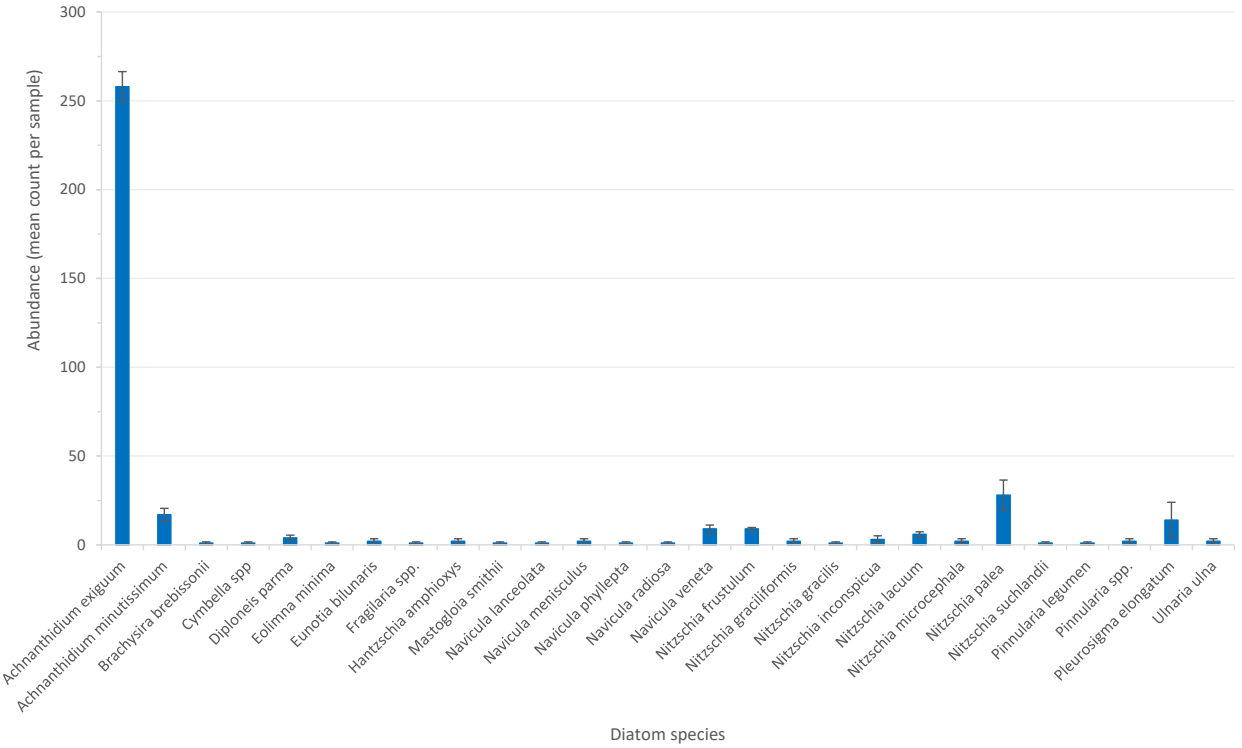


Figure 33 Diatom average count. Error bars show 1σ.

3.4.6 MACROPHYTES

There were very few and sparse macrophytes present at Central Creek Pool. These were represented by a small clump of emergent Clubrush reeds (*Schoenoplectus sp*) and a few individual sedge (Cyperacea) plants on the southern side of the pool behind a protective in-stream boulder. Less than 1% of the pool area represented macrophyte habitat.

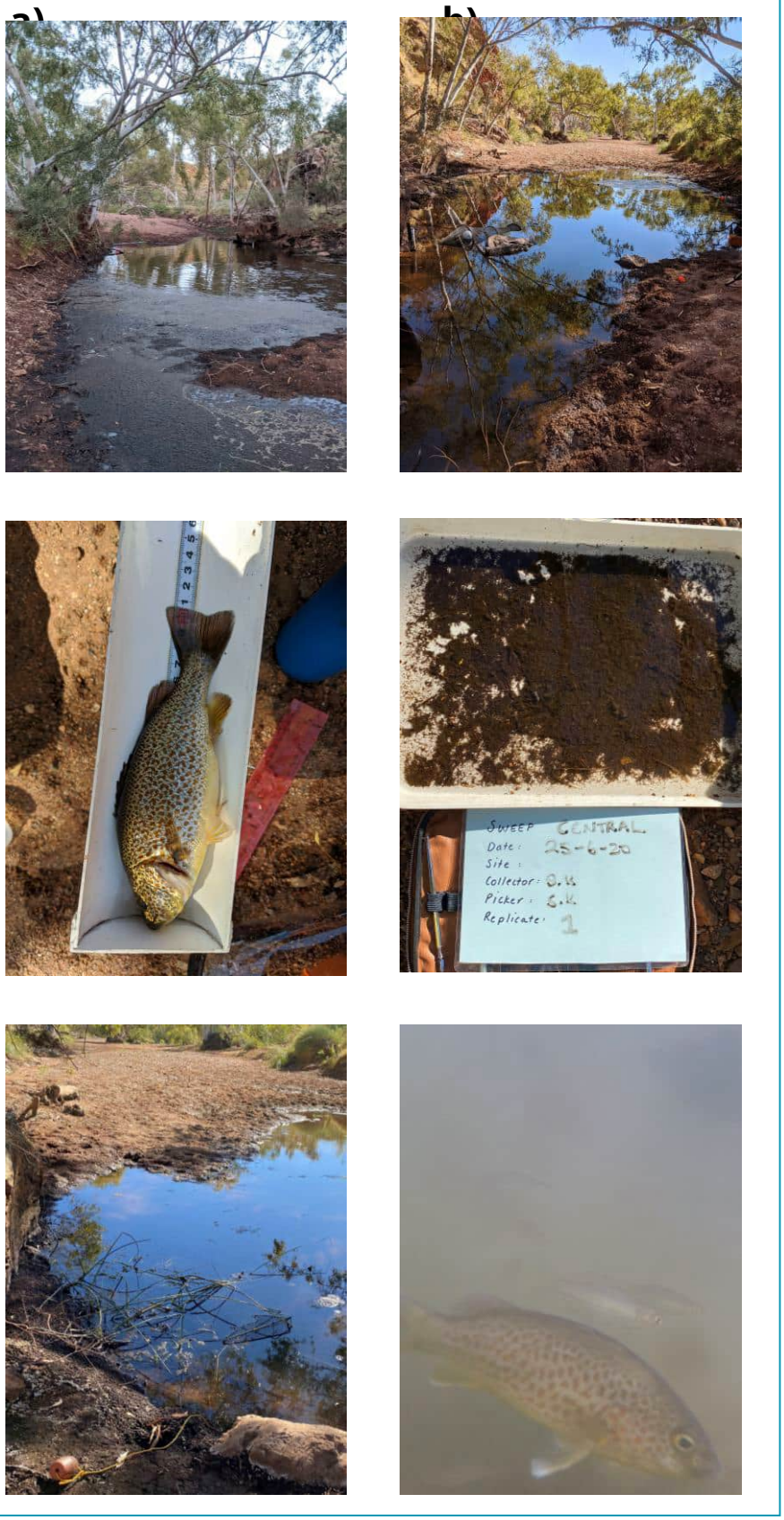


Figure 34 Central Creek Pool ecology. a) and b) the shallow pool over alluvial deposits lies on a wide creek bed; c) adult *L. unicolor* as well as juveniles were abundant; d) macroinvertebrates collected that utilise the sediment habitat; e) sparse macrophytes remain and will likely be absent by the late dry season; f) turbid waters may reduce visibility and provide a refuge from large fish predation and terrestrial predation.

3.5 COW SPRING POOL

Cow Spring Pool is a small pool confined by bedrock habitat dominated by macrophytes and benthic algal cover. The pool is likely to be sustained by groundwater and has established macrophyte habitat and an abundance of *M. australis,* despite relatively acidic water quality.



3.5.1 WATER QUALITY AND HYDROLOGY

The water level logger was installed in Cow Spring during the late wet 2020 aquatic ecology sampling and therefore there is not hydrology data available at this site at the time of reporting. However, there is a logger installed which will record the 2020 recessional and dry periods and the 2021 wet season. Cow Spring has a small surface water catchment area of 0.15 km^2 (Figure 35), draining a single ridgeline to the west. The pool is shaded by the adjacent rockface and forms a micro-climate area with dense melaleuca woodland covering the pool and the downstream drainage line for approximately 50m.

Cow Spring Pool is very clear (<1 NTU turbidity), low pH (5.72), fresh (456 µS/cm conductivity) and slightly acidic (10 mg/L as $CaCO_3$). It has a mixed, balance major ion distribution which is not dominated by any particular ions (Figure 36). No metals or metalloids exceeded the ANZG (2018) default water quality guidelines.

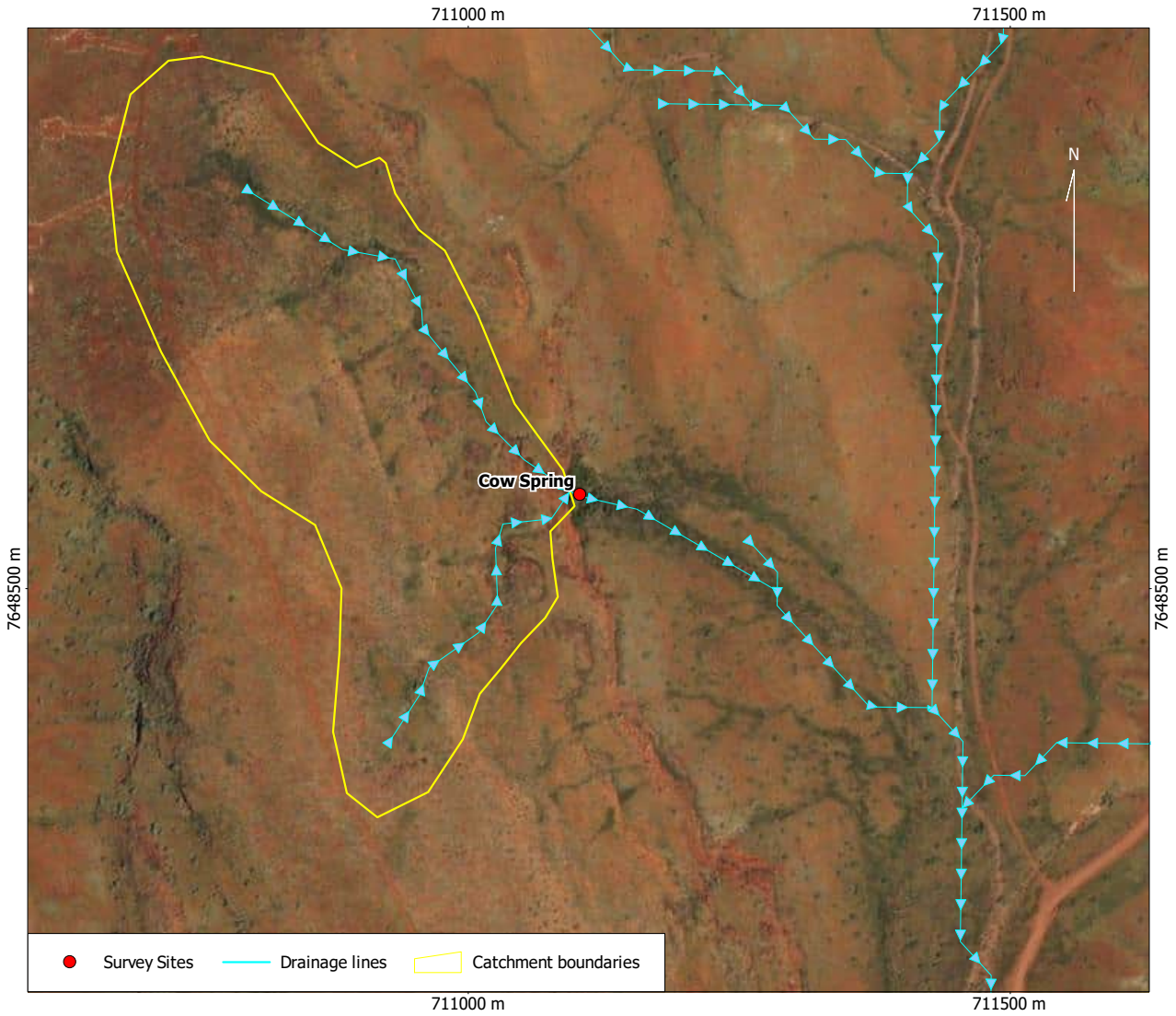


Figure 35 Cow Spring catchment area (0.15 km^2)

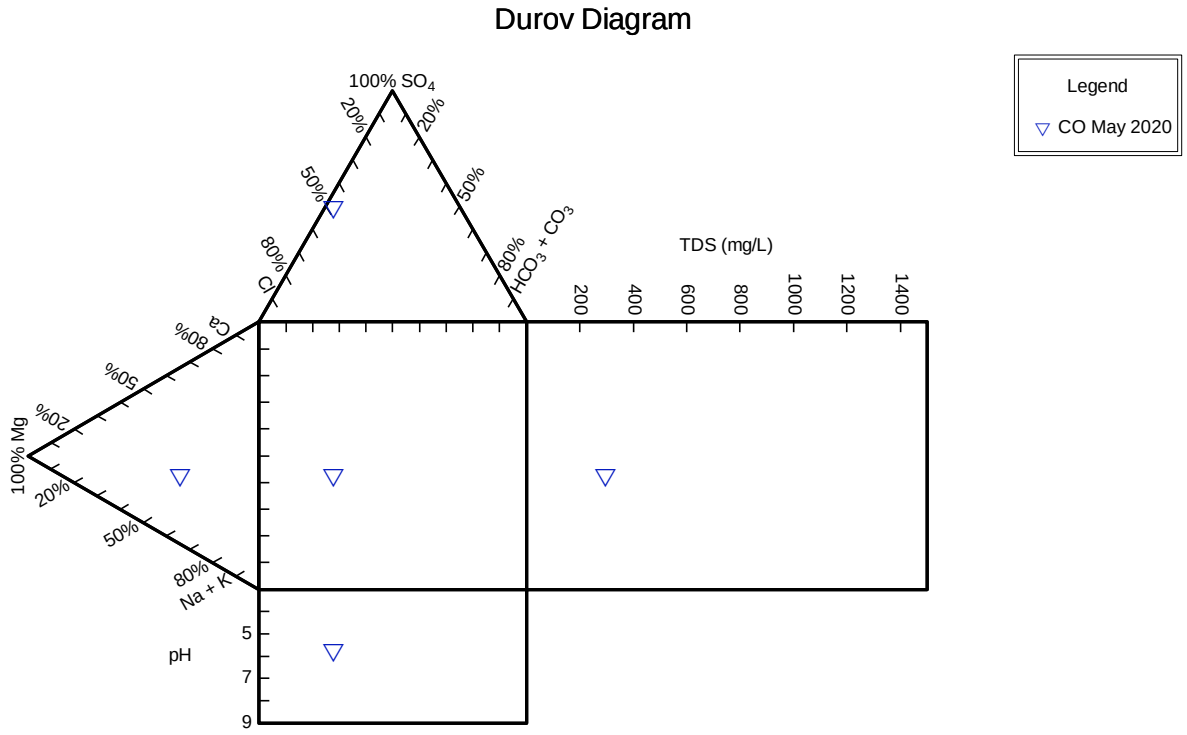


Figure 36 Durov diagram showing the Cow Spring Pool major ion distribution.

3.5.2 SEDIMENT QUALITY

Table 22 provides the surface sediment quality at Cow Spring Pool during the late wet season (sample collection 30th May 2020). Metal and metalloid concentrations were assessed against the ANZG (2018) DGVs. Chromium concentration (165 mg/kg) exceeded the DGV but not the GV-high. Chromium naturally occurs in high concentrations across the Project area.

Table 22 Sediment quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	Concentration
Total Soluble Salts	mg/kg	5	**114**
Moisture Content (Dried @ 105-110°C)	%	1.0	**23.9**
Total Alkalinity as CaCO3	mg/kg	1	**4**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**4**
Carbonate Alkalinity as CaCO3	mg/kg	1	<1
Acidity	mg/kg	1	<1
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**40**
Chloride (by Discrete Analyser)	mg/kg	10	**20**
Calcium	mg/kg	10	<10
Magnesium	mg/kg	10	<10
Sodium	mg/kg	10	**20**
Potassium	mg/kg	10	<10

Analyte grouping/Analyte	Unit	LOR	Concentration
Mercury (FIMS)	mg/kg	0.1	**4.4**
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	**0.1**
Total Kjeldahl Nitrogen as N	mg/kg	20	**750**
Total Nitrogen as N	mg/kg	20	**750**
Total Phosphorus as P	mg/kg	2	**320**
Reactive Phosphorus as P	mg/kg	0.1	<0.1
Total Organic Carbon	%	0.02	**0.22**
Total Metals by ICP-AES			
Arsenic	mg/kg	5	**9**
Barium	mg/kg	10	<10
Beryllium	mg/kg	1	<1
Boron	mg/kg	50	<50
Cadmium	mg/kg	1	<1
Chromium	mg/kg	2	**165**
Cobalt	mg/kg	2	**4**
Copper	mg/kg	5	**7**
Iron	mg/kg	50	**124000**
Lead	mg/kg	5	**9**
Manganese	mg/kg	5	**151**
Nickel	mg/kg	2	**18**
Selenium	mg/kg	5	**6**
Vanadium	mg/kg	5	**62**
Zinc	mg/kg	5	**16**

3.5.3 FISH

Table 23 presents the fish species, catch and size distribution. *M. australis* was the only fish species present in the pool. *L. unicolor* was not detected at the pool through any methods, which may due to a variety of factors such as survival, aestivation or reproduction may be limited by the naturally high acidity. Similarly, no decapod crustaceans were collected or observed.

M. australis collected ranged in size classes from less than 30 mm to over 90 mm standard length (Figure 37). The individuals less than 60 mm were likely spawned during the 2019/2020 wet season, with the <30 mm juveniles likely to have spawned post large wet season rains and indicate reproduction occurring within the pool, rather than migrating during periods of connecting flow (Pusey, B., Kennard, M., & Arthington, 2004).

Uperoleia sp. tadpoles were collected by nets/traps. Their presence or catchability in Cow Spring Pool may be in part due to the absence of the predators *L. unicolor.*

Table 23 Fish species, catch and size distribution

Species	Size class (mm)	Catch	CPUE[1]
Melanotaenia australis		**67**	**3.8**
	0 – 30	13	
	30 – 60	37	
	60 – 90	15	
	> 90	2	
Total		**67**	**3.8**

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is fyke net set for 17.75 hours.

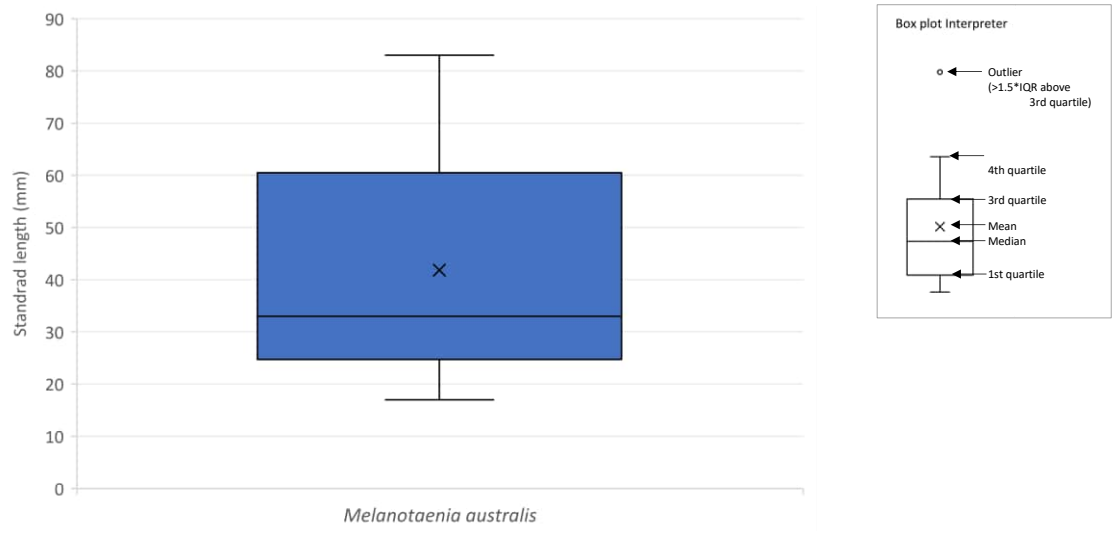


Figure 37 Size distribution (standard length mm) of *M. australis*.

3.5.4 AQUATIC MACROINVERTEBRATES

Table 24 presents the macroinvertebrate summary table and Table 25 presents the taxa abundance and SIGNAL scores for the late wet season macroinvertebrate sampling (Appendix D). Edge and macrophyte habitat were identified as the predominant habitats and a sample was collected from each habitat. Macroinvertebrate biotic indices were derived to provide an indication of waterbody condition. The key findings were as follows:

- A diverse range of taxa were collected; a total of 39 families were collected with an average abundance of 133 individuals per sample.
- EPT taxa were present in each sample. A total of 5 unique families were collected. The average EPT Taxonomic Richness = 4 (Figure 38).

- Low SIGNAL 2 score (SIGNAL2 grade= 3.4) indicates predominantly tolerant taxa and many sensitive species are unable to tolerate the conditions at Cow Spring Pool (Chessman, 2003). The naturally acidic conditions at Cow Spring Pool is likely to create environmental stress.
- No very sensitive taxa were recorded (SIGNAL grades 8, 9, 10). However, 6 sensitive taxa were collected (SIGNAL grades 5, 6, 7).
- Abundance, diversity and number of sensitive taxa were greater at the macrophyte habitat which signifies macrophytes may provide an important habitat for macroinvertebrates at Cow Spring Pool.

Table 24 Macroinvertebrate summary and indices

Habitat type	Count	Taxonomic Richness	EPT Taxa	SIGNAL2 Score
Macrophyte	200	39	5	3.10
Edge	67	13	3	3.64
Mean	133.5	26	4	3.37

Table 25 Macroinvertebrate count and SIGNAL2 scores.

Order [1]	Family	Count – Macrophyte habitat	Count – Edge habitat	Average Count	SIGNAL2 Score [2]
Acarina	Acarina	11	8	10	6
Cladocera	Cladocera	4	1	3	N/A
Coleoptera	Scirtidae	4	0	2	6
	Dytiscidae	3	2	3	2
	Hydrophilidae	3	0	2	2
	Hydraenidae	1	0	1	3
	Hydrochidae	1	0	1	4
Copepoda	Copepoda	2	2	2	N/A
Diptera	s-f Chironominae	25	22	24	3
	s-f Tanypodinae	25	4	15	4
	Ceratopogonidae	10	0	5	4
	s-f Orthocladiinae	1	0	1	4
	Culicidae	1	0	1	1
	Sciomyzidae	1	0	1	2

Order [1]	Family	Count – Macrophyte habitat	Count – Edge habitat	Average Count	SIGNAL2 Score [2]
	Stratiomyidae	1	0	1	2
	Tipulidae	1	0	1	5
Ephemeroptera	Caenidae	12	2	7	4
	Baetidae	9	12	11	5
Gastropoda	Lymnaeidae	7	0	4	1
	Ancylidae	5	0	3	4
	Planorbidae	3	0	2	2
Hemiptera	Belostomatidae	2	0	1	1
	Gerridae	2	0	1	4
	Nepidae	2	0	1	3
	Pleidae	1	1	1	2
	Mesoveliidae	1	0	1	2
	Micronectidae	1	0	1	2
	Veliidae	1	0	1	3
Hydrozoa	Hydridae	1	0	1	2
Lepidoptera	Crambidae	2	0	1	3
Odonata	Coenagrionidae	14	2	8	2
	Libellulidae	9	9	9	4
	Aeshnidae	1	1	1	4
	Corduliidae	1	0	1	5
Oligochaeta	Oligochaeta	6	0	3	2
Ostracoda	Ostracoda	16	0	8	N/A
Trichoptera	Leptoceridae	5	0	3	6
	Hydroptilidae	3	0	2	4
	Ecnomidae	2	1	2	4

[1] Bold font denotes EPT orders and high SIGNAL 2 scores (SIGNAL 2 = 8,9,10).

[2] Based on SIGNAL 2 scores: Red = very tolerant, yellow = tolerant, green = sensitive, blue = very sensitive.

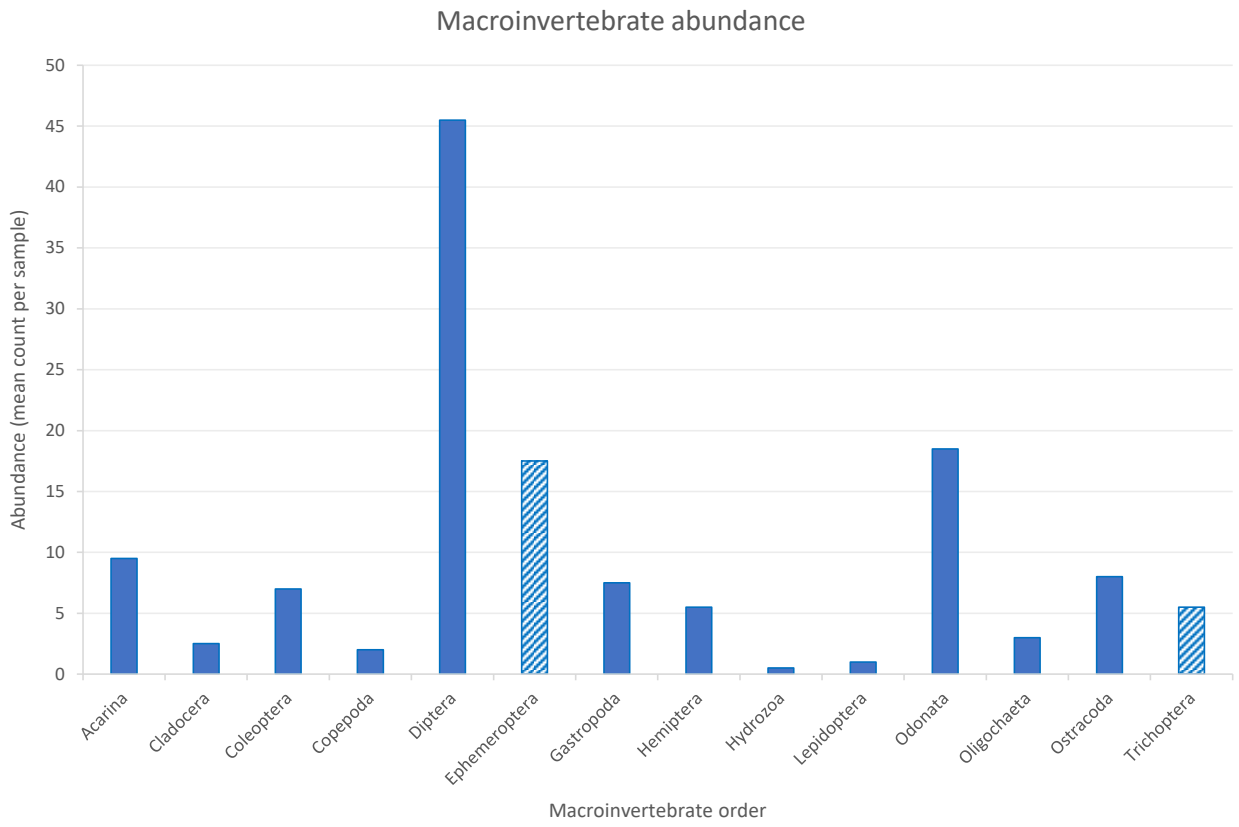


Figure 38 Macroinvertebrate counts. Pattern fill denotes EPT orders.

3.5.5 DIATOMS

Table 26 presents the late wet season diatom species present, abundance and biotic indices. Figure 39 shows the average count by diatom species present. The key findings were as follows:

- A total of 7 diatom species and 28 valves (diatom count) were recorded which indicates low diatom diversity and abundance at Cow Spring Pool.
- One sample detected no diatoms and the other sample noted very sparse abundance. The high acidity and low light conditions at Cow Spring Pool may have contributed to the relatively low diatom growth compared to other North Star pools.
- The low abundance of diatoms indicates they are able to survive, though the capacity for growth is limited under the conditions that were present during the sampling period.
- The DSIAR score (64.2) reflects the species sensitivity to environmental stress, where a higher score indicates 'better' water quality as species sensitive to environmental stress are present. This indicates the species richness is more likely limited by factors needed to grow (i.e. sunlight) rather than stressors known to cause mortality of sensitive species (e.g. high salinity).
- The slightly more abundant species (*Achnanthidium minutissimum* and *Eunotia bilunaris*) were also present at all other pools except Fig Pool. Two unique species were present – *Eunotia faba* and *Luticola mutica.*

Table 26 Diatom count per species

Species	Replicate 1	Replicate 2	Average species abundance	Variability (St Dev)
Achnanthidium minutissimum	0	8	4	2.8
Cymbella affinis	0	2	1	0.7
Cymbella spp	0	4	2	1.4
Eunotia bilunaris	0	8	4	2.8
Eunotia faba	0	2	1	0.7
Hantzschia amphioxys	0	2	1	0.7
Luticola mutica	0	2	1	0.7
Total abundance	0	28	14	
DSIAR score	N/A	64.25	64.25	

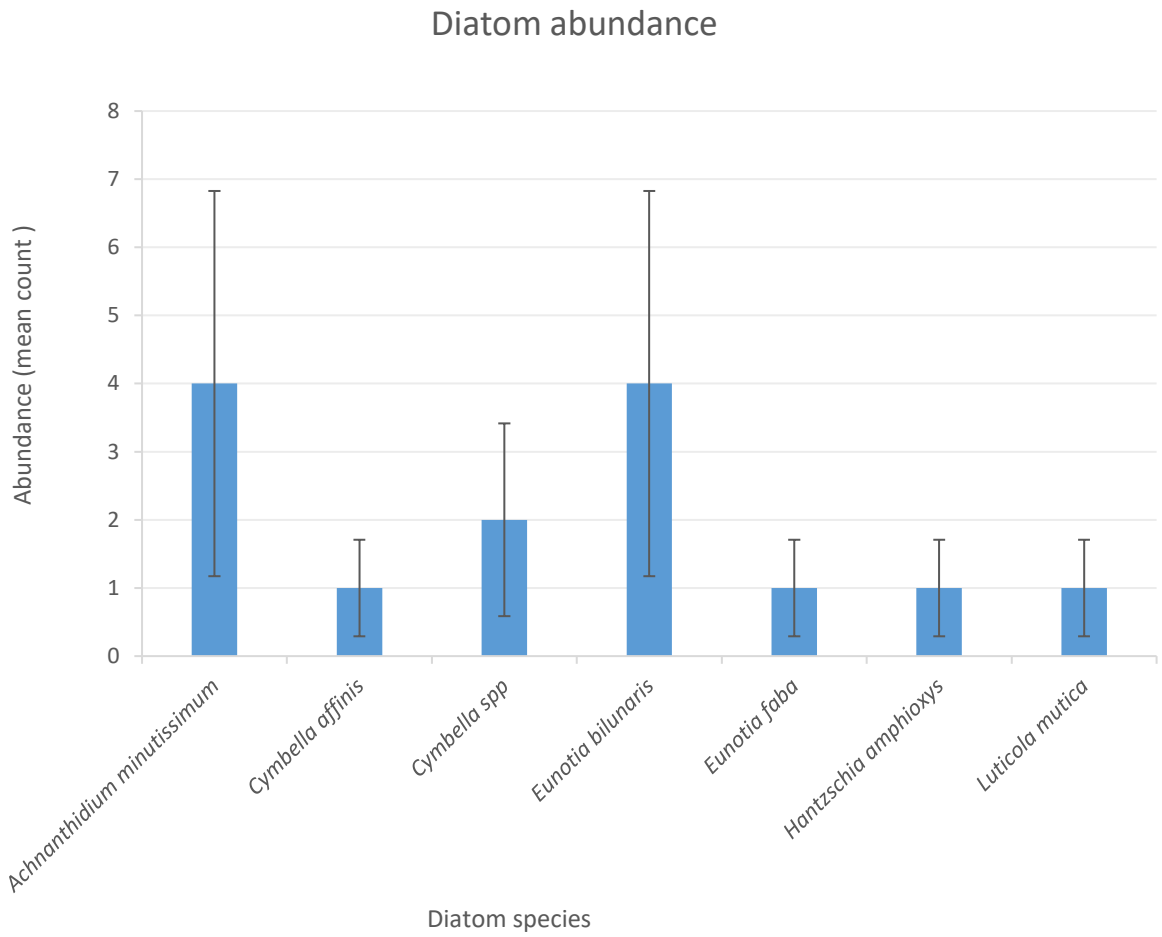


Figure 39 Diatom average count. Error bars show 1σ.

3.5.6 MACROPHYTES

Table 27 presents the macrophyte species and qualitative abundance during late wet season sampling. A diverse range of macrophyte flora were observed within Cow Spring Pool. These comprised aquatic species and groundwater-dependent species. During late wet season surveying, a total of seven macrophyte species were recorded including reeds (Clubrush, *Typha* spp.), sedges (Cyperaceae) as well as submerged macrophytes (ribbon weed, charophytes and two unidentified species of Hydrocharitaceae like appearance (the taxonomy of these species is being review at the time of reporting; Figure 40) (Plate 3). The types and species of macrophytes present in a system are indicators of water quality and ecological health. The abundance and diversity of macrophytes at Site 12 Pool plays a key role in nutrient dynamics, indicates that water quality parameters (e.g. turbidity, salinity) have not reached levels that interfere with macrophyte growth and development, and provides habitat structure and refuges to organisms. For example, the macrophyte habitat and its' structural complexity likely provides refuge to the *M. australis* (western rainbowfish) from predation by adult *L. unicolor* (spangled perch).

Table 27 Macrophytes present at Cow Spring Pool

Common name	Species name	Abundance[1]
Ribbon weed	*Vallisneria sp.*	Abundant
Charophytes	*Nitella sp.*, *Chara sp.*	Abundant
Clubrush	*Schoenoplectus sp.*	Abundant
Sedges	Cyperaceae	Isolated
Bulrush	*Typha sp.*	Isolated
Unidentified 1	Hydrocharitaceae like	Isolated
Unidentified 2	Hydrocharitaceae like	Isolated

[1] Abundance based on *Western Australia AUSRIVAS field sampling sheet* (DoW, 2009).



Figure 40 Two macrophytes pending taxonomic identification in Cow Spring Pool

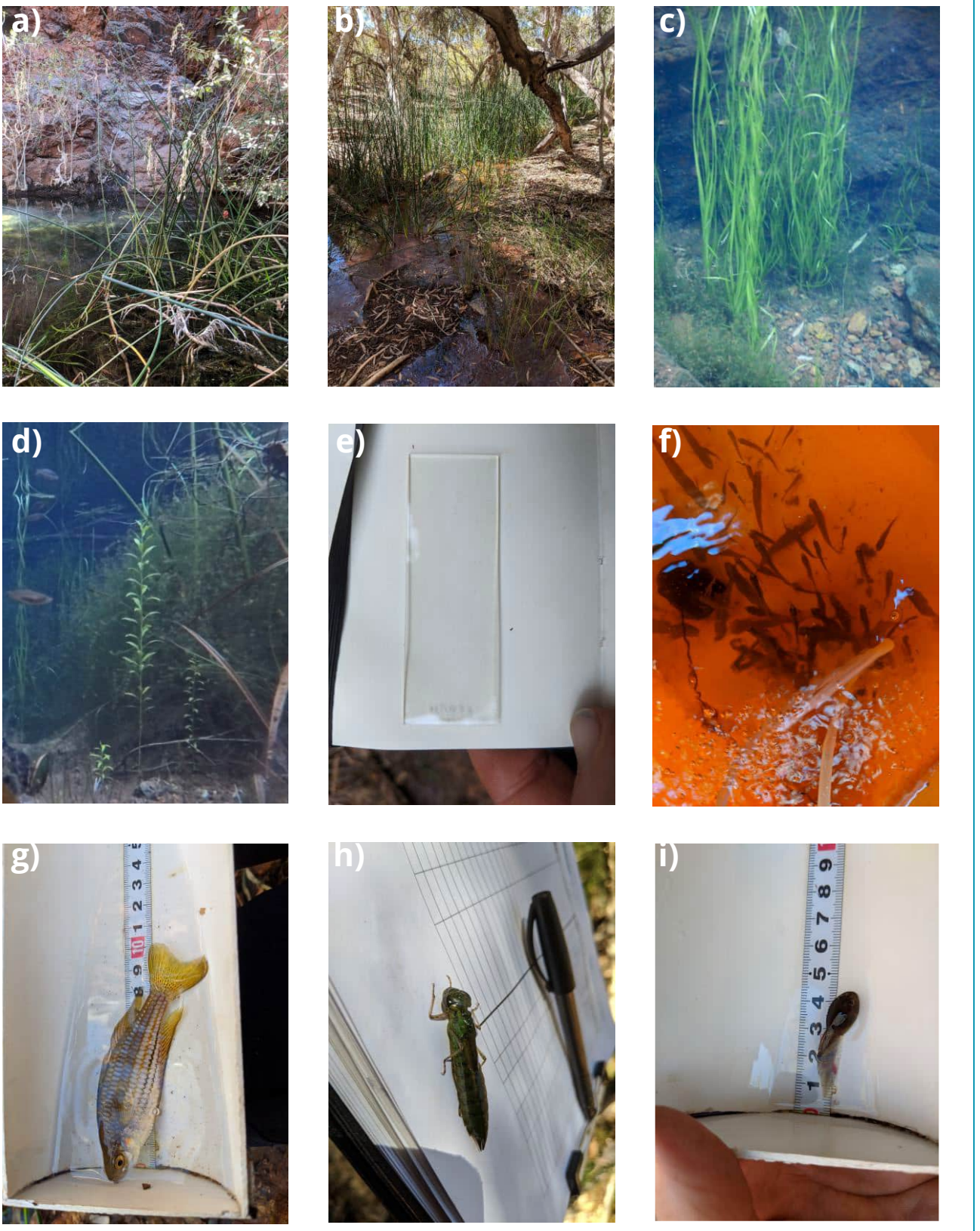


Plate 8 Cow Spring Pool aquatic ecology. a) to d) show a diversity of emergent and submerged macrophytes; e) a slide with minimal diatom colonisation; f) and g) *M. australis* present over a wide range of ages; h) Aeshnidae; an example of macroinvertebrates inhabiting macrophytes; i) tadpoles of *Uperoleia* spp.

3.6 IRON BRIDGE CREEKS

Water level and temperature loggers were installed at several sites other than the aquatic ecology sites at Iron Bridge prior to the wet season of 2020. The data from these loggers is provided below for completeness, however these are supplementary to the aquatic ecology program (and reporting) and therefore only a brief description of the results are provided. Figure 41 provides a map of the installed and planned logger locations.

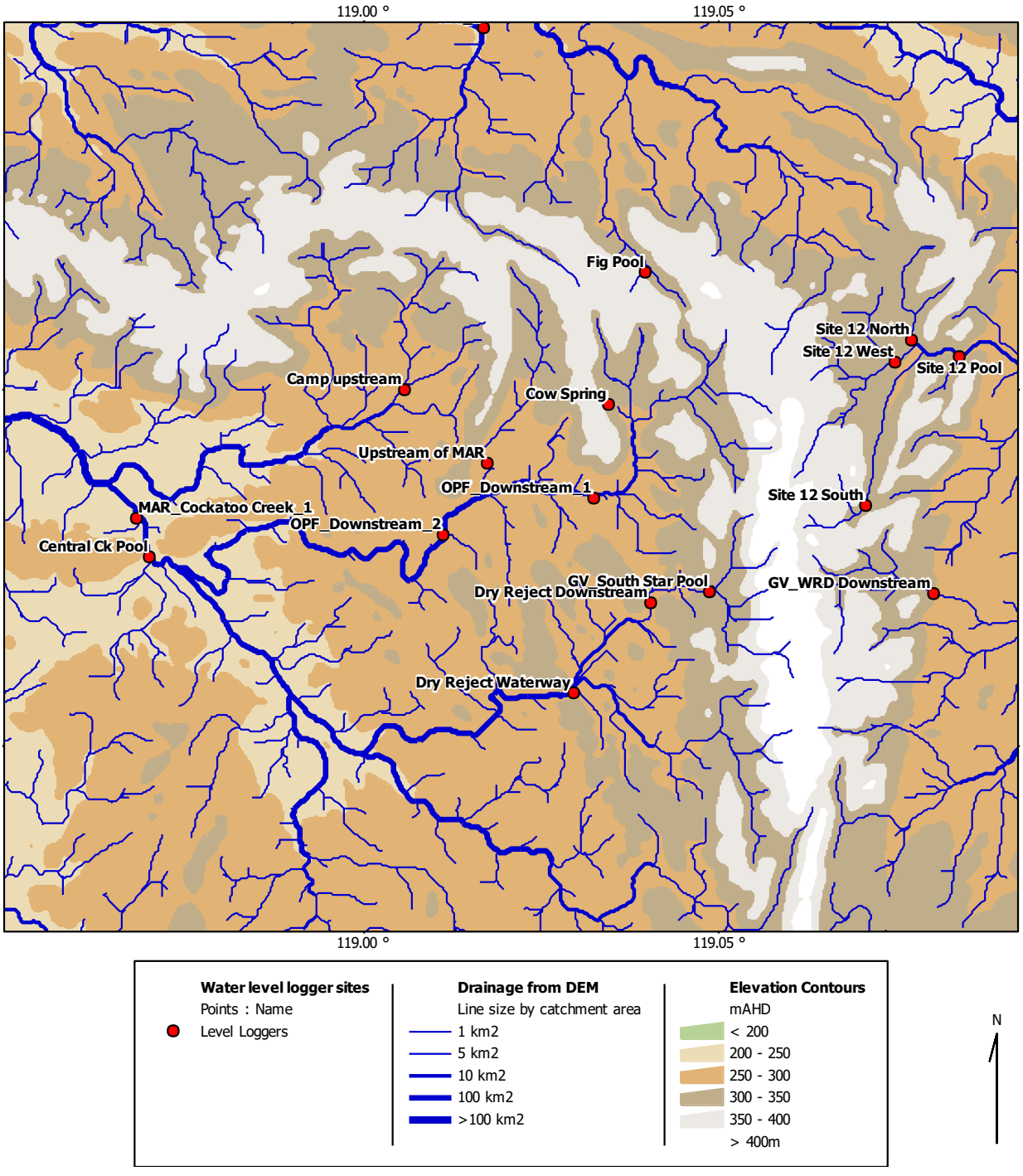


Figure 41 Map of water level logger locations (installed and planned) at Iron Bridge

The Site 12 West logger is located in a small pool and hence the water level being sustained after the first wet season flows.

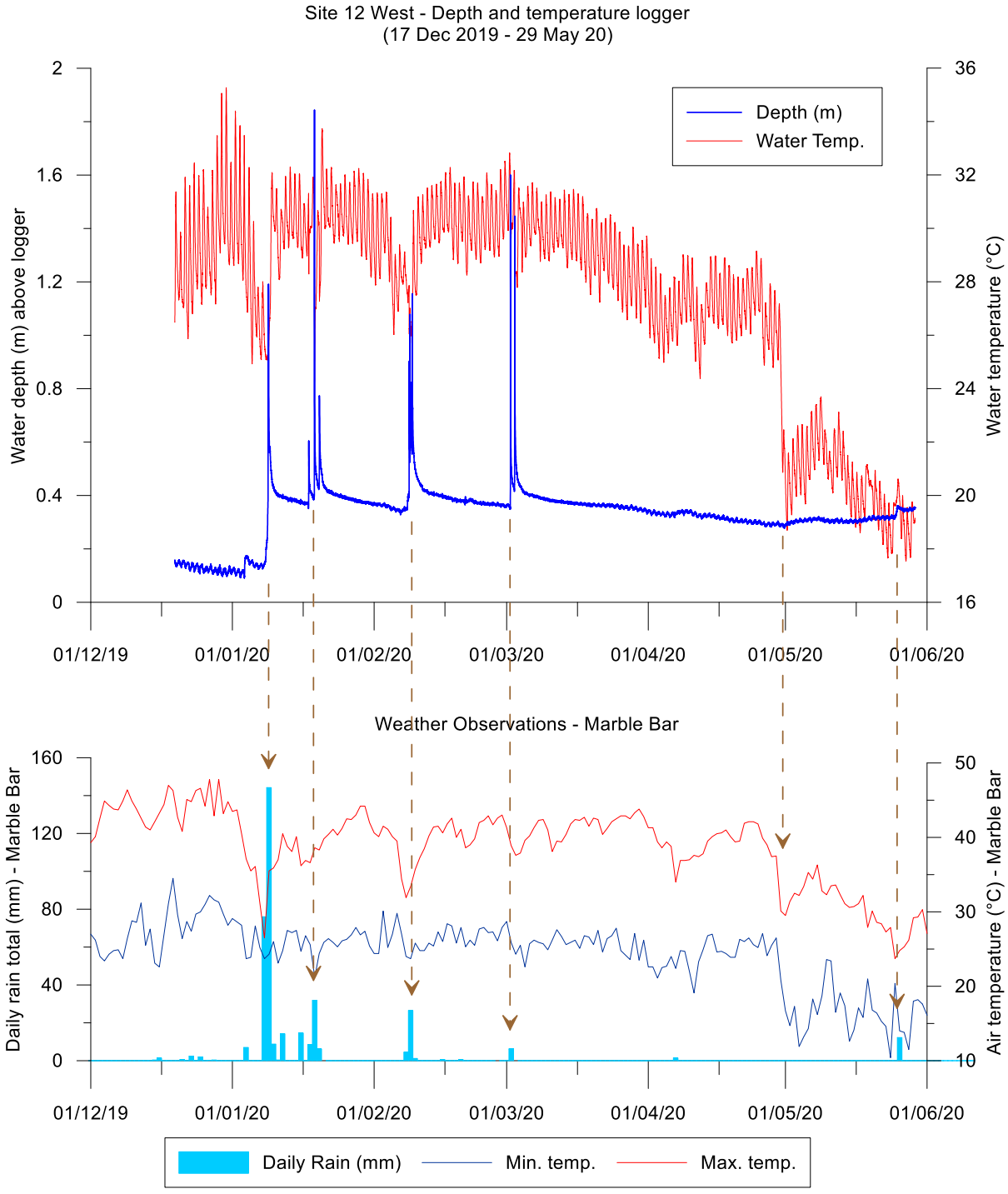


Figure 42 Site 12 West water level logger data – Dec 2019 to June 2020

The OPF Downstream 1 logger is located in a lowland creek with water levels maintained by alluvial flows. Peak flows are very flashy (short duration) indicating the relatively small catchment and lack of surface flows during much of the wet season.

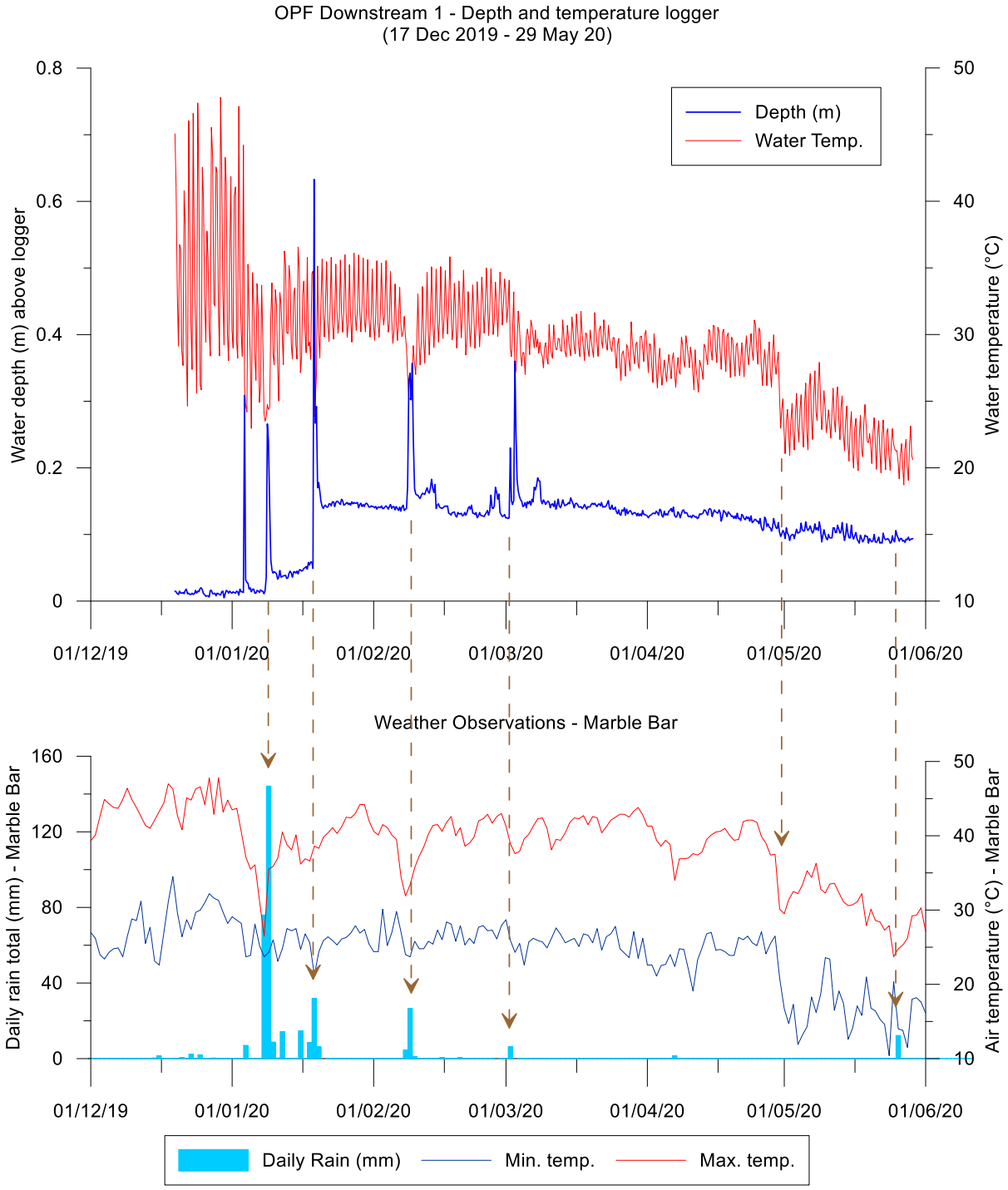


Figure 43 OPF Downstream 1 water level logger data – Dec 2019 to June 2020

The OPF Downstream 2 site is located in a slightly larger catchment position than the OPF Downstream 1 site, reflected in the longer "tail" to the flood peaks produced after high-rainfall events. There is no pooling

at this site to support higher water levels after the first flush and hence the dry riverbed defines the majority of the wet season hydrology.

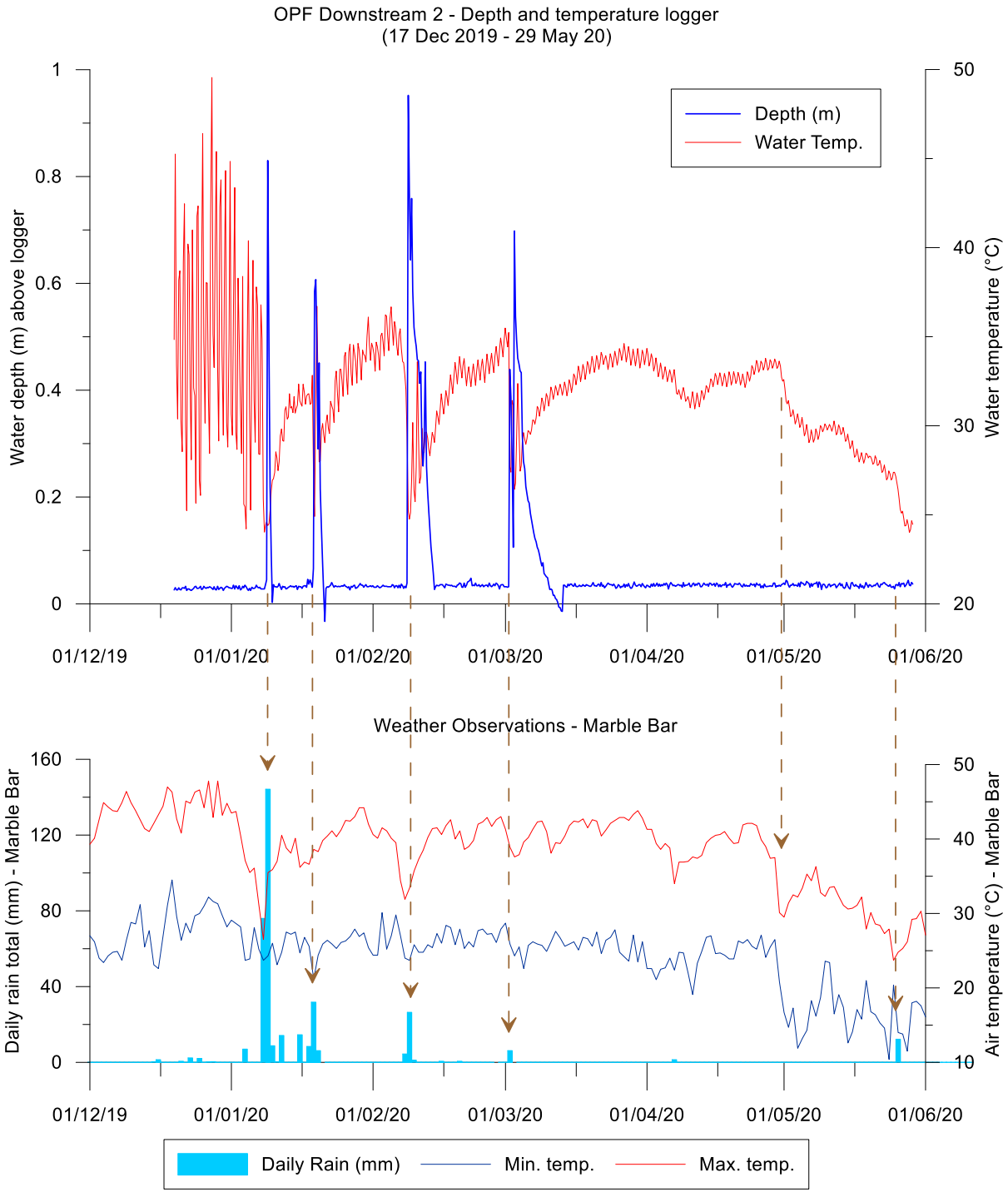


Figure 44 OPF Downstream 2 water level logger data – Dec 2019 to June 2020

The TSF-1 site is located on a creek at the base of the elevated catchment area and shows some level of continued flow after high-rainfall events. However, these last only a few days before water levels recede to dry creek bed conditions.

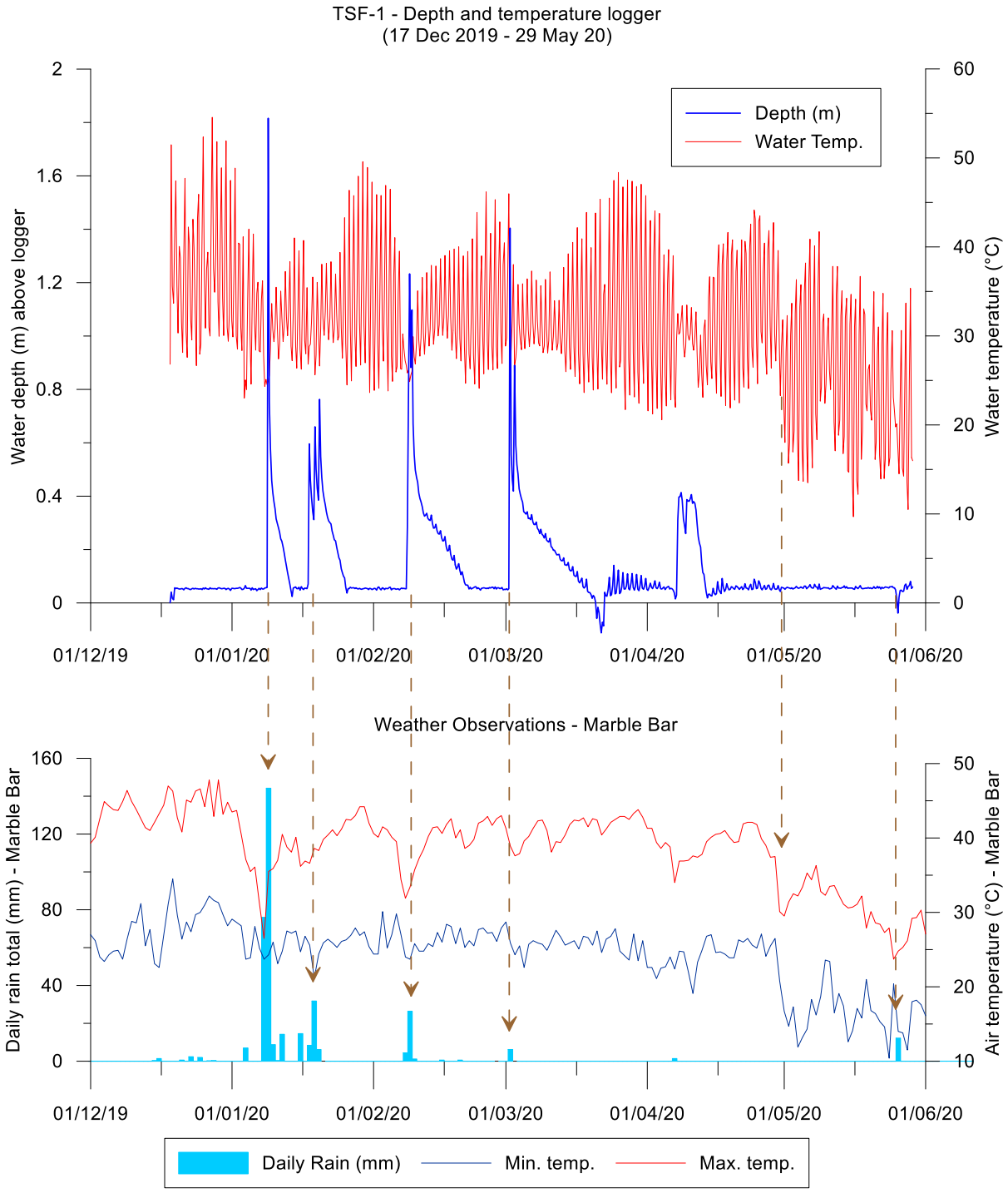


Figure 45 TSF 1 water level logger data – Dec 2019 to June 2020

The TSF-2 site is located on a slightly larger catchment to the TSF-1 site, which is reflected in a longer flow period after high-rainfall events. However, this site also returns to a dry creek bed within days to a week of high-rainfall driven flooding events.

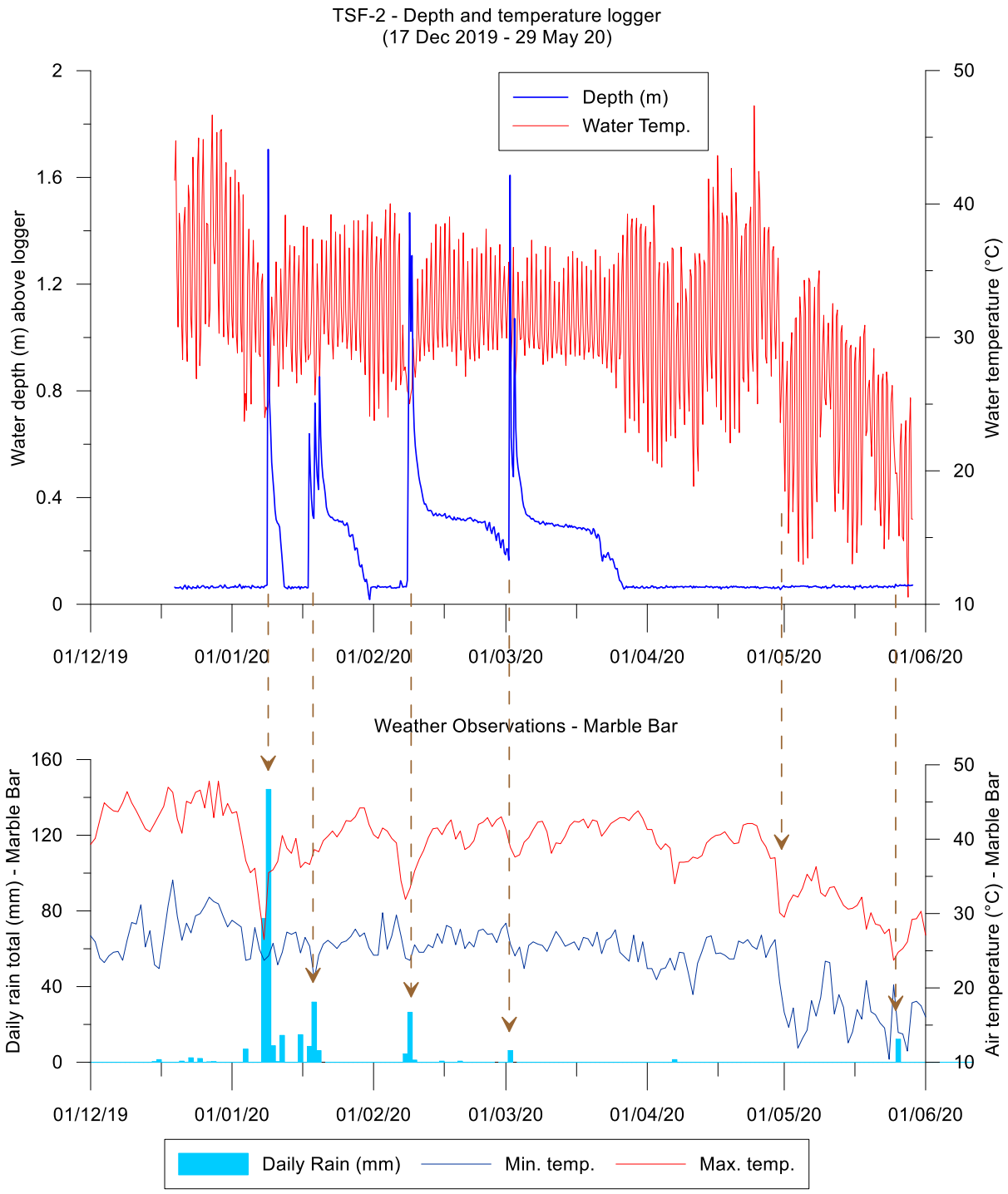


Figure 46 TSF 2 water level logger data – Dec 2019 to June 2020

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APPENDIX A. WATER QUALITY DATA

APPENDIX B. SEDIMENT QUALITY DATA

Table 28 Sediment quality data – late wet season 2019/2020. Bold font denotes values above the limit of reporting (LOR).

Analyte grouping/Analyte	Unit	LOR	South Star Pool	Cow Spring Pool	Fig Pool	Site 12 Pool	Central Ck Pool
		Sample Date	30/05/2020	30/05/2020	30/05/2020	29/05/2020	31/05/2020
		ALS Sample Number	EP2005660011	EP2005660012	EP2005660013	EP2005660014	EP2005660015
Total Soluble Salts	mg/kg	5	**693**	**114**	**248**	**408**	**1180**
Moisture Content (Dried @ 105-110°C)	%	1.0	**59.7**	**23.9**	**----**	**28.6**	**29.8**
Total Alkalinity as CaCO3	mg/kg	1	**77**	**4**	**2**	**71**	**120**
Bicarbonate Alkalinity as CaCO3	mg/kg	1	**77**	**4**	**2**	**67**	**120**
Carbonate Alkalinity as CaCO3	mg/kg	1	<1	<1	<1	**4**	<1
Acidity	mg/kg	1	**12**	<1	**14**	**4**	**4**
Sulfate as SO4 2- (soluble sulfate by ICPAES)	mg/kg	10	**80**	**40**	**120**	**20**	**200**
Chloride (by Discrete Analyser)	mg/kg	10	**100**	**20**	<10	**30**	**170**
Calcium	mg/kg	10	**220**	<10	**30**	**50**	**40**
Magnesium	mg/kg	10	**110**	<10	<10	**60**	**70**
Sodium	mg/kg	10	**170**	**20**	**10**	**40**	**220**
Potassium	mg/kg	10	**20**	<10	**10**	<10	**20**
Mercury (FIMS)	mg/kg	0.1	**0.6**	**4.4**	<0.1	<0.1	<0.1
Nitrite + Nitrate as N (Sol.)	mg/kg	0.1	<0.1	**0.1**	<0.1	<0.1	<0.1
Total Kjeldahl Nitrogen as N	mg/kg	20	**3950**	**750**	**1110**	**520**	**1090**
Total Nitrogen as N	mg/kg	20	**3950**	**750**	**1110**	**520**	**1090**

Analyte grouping/Analyte	Unit	LOR	South Star Pool	Cow Spring Pool	Fig Pool	Site 12 Pool	Central Ck Pool
Total Phosphorus as P	mg/kg	2	**242**	**320**	**60**	**73**	**100**
Reactive Phosphorus as P	mg/kg	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Total Organic Carbon	%	0.02	**3.15**	**0.22**	**0.30**	**0.18**	**1.80**
Total Metals by ICP-AES							
Arsenic	mg/kg	5	**9**	**9**	<5	<5	**9**
Barium	mg/kg	10	**40**	<10	**10**	**50**	**40**
Beryllium	mg/kg	1	**1**	<1	<1	<1	<1
Boron	mg/kg	50	<50	<50	<50	<50	<50
Cadmium	mg/kg	1	<1	<1	<1	<1	<1
Chromium	mg/kg	2	**169**	**165**	**143**	**384**	**219**
Cobalt	mg/kg	2	**22**	**4**	<2	**23**	**16**
Copper	mg/kg	5	**52**	**7**	**8**	**23**	**22**
Iron	mg/kg	50	**76600**	**124000**	**58500**	**32800**	**26600**
Lead	mg/kg	5	<5	**9**	<5	<5	<5
Manganese	mg/kg	5	**481**	**151**	**94**	**561**	**476**
Nickel	mg/kg	2	**79**	**18**	**6**	**179**	**112**
Selenium	mg/kg	5	**5**	**6**	<5	<5	<5
Vanadium	mg/kg	5	**166**	**62**	**27**	**48**	**39**
Zinc	mg/kg	5	**39**	**16**	**5**	**26**	**35**

APPENDIX C. FISH DATA

Table 29 Fish catch summary table

Species	Central Creek Pool	Cow Spring Pool	Site 12 Pool	South Star Pool	Fig Pool
Neosilurus hyrtlii	0	0	37	0	0
50 - 90 mm	0	0	18	0	0
90 - 130 mm	0	0	16	0	0
130 - 170 mm	0	0	3	0	0
Melanotaenia australis	171	67	196	212	0
< 30 mm	1	13	0	63	0
30 - 60 mm	113	37	84	95	0
60 - 90 mm	57	15	112	54	0

Species	Central Creek Pool	Cow Spring Pool	Site 12 Pool	South Star Pool	Fig Pool
> 90 mm	0	2	0	0	0
Leiopotherapon unicolor	207	0	24	1	0
30 - 60 mm	109	0	7	0	0
60 - 90 mm	53	0	10	0	0
> 90 mm	45	0	7	1	0
Total catch	378	67	257	213	0
Soak duration	19	17.7	15.5	16.5	16
CPUE	19.9	3.8	16.6	12.9	0

[1] CPUE is catch per unit effort, a measure of relative abundance. Effort is net and trap soak duration hours.

Table 30 Fish standard length and total length

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	32	37
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	36	45
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	38	47
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	37	49
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	41	49
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Leiopotherapon unicolor*	42	50
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	46	56
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	46	58
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	49	58
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	55	67
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	60	74
Central Ck Pool	Box	1	26/06/2020	16:00	10:30	Muddy	*Leiopotherapon unicolor*	66	81
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	69	85
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	75	94
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	80	97
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Leiopotherapon unicolor*	81	100
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	87	109
Central Ck Pool	Box	1	26/06/2020	16:00	10:30	Muddy	*Leiopotherapon unicolor*	94	115
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	100	125
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	107	130
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	115	139
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	119	141
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	119	142
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	120	144

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	120	145
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	127	154
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	134	160
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	134	161
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	147	173
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Leiopotherapon unicolor*	174	205
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	29	38
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	33	41
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	33	42
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	33	42
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	39	43
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	37	46
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	37	46
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	47
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	37	48
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	48
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	37	49
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	38	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	39	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	41	50
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	40	51
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	41	51
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	40	52
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	47	60
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	47	61

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	49	61
Central Ck Pool	Bait	2	26/06/2020	16:00	9:45	Muddy	*Melanotaenia australis*	49	62
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	50	64
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	52	65
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	53	65
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	53	66
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	59	75
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	65	80
Central Ck Pool	Fyke	1	26/06/2020	16:00	11:00	Pool	*Melanotaenia australis*	67	84
Central Ck Pool	Box	2	26/06/2020	16:00	10:45	Muddy	*Melanotaenia australis*	67	85
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	17	22
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	18	23
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	20	25
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	23	27
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	23	30
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	24	30
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	24	31
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	25	32
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	29	37
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	30	39
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	32	40
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	30	41
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	30	41
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	31	41
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	33	42
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	33	43

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	35	43
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	38	46
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	40	50
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	49	62
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	53	67
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	57	72
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	60	74
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	62	80
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	67	85
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	68	85
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	70	86
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	71	87
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	80	100
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Melanotaenia australis*	83	104
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Uperoleia sp.*	NA	24
Cow Spring Pool	Bait	1	29/06/2020	16:00	9:30	Marco/Edge	*Uperoleia sp.*	NA	29
Cow Spring Pool	Bait	2	29/06/2020	16:00	9:30	Reeds	*Uperoleia sp.*	NA	35
Cow Spring Pool	Fyke	1	29/06/2020	16:00	9:45	Pool	*Uperoleia sp.*	NA	36
Cow Spring Pool	Bait	1	29/06/2020	16:00	9:30	Marco/Edge	*Uperoleia sp.*	NA	40
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	32	41
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	38	50
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	43	54
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	44	55
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	45	57
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	46	57
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	47	59

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	49	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	49	62
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	52	63
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	54	63
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	54	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	55	71
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	58	73
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	59	74
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	64	79
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	70	87
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	78	92
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	79	95
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	104	122
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	111	134
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	148	162
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	155	182
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Leiopotherapon unicolor*	166	199
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	45	56
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	46	57
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	46	58
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	46	58
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	47	59
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	47	59
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	47	60
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	60
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	60

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	48	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	49	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	50	61
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	49	62
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	49	62
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	51	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	51	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	52	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	64
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	52	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	66
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	53	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	67
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	54	69
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	59	75
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	68	76
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Melanotaenia australis*	58	77
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	55	63
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	54	69
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	67	75
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	70	76
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	65	77

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	70	80
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	72	80
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	72	81
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	73	82
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	74	84
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	75	84
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	76	85
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	75	86
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	76	86
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	79	87
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	79	88
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	80	90
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	80	91
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	82	91
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	80	92
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	84	94
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	92	104
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	95	105
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	95	106
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	97	110
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	101	111
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	102	113
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	105	117
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	105	120
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	110	120
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	107	122

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	110	123
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	110	125
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	115	126
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	125	144
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	129	144
Site 12 Pool	Fyke	1	28/06/2020	17:00	8:30	Pool	*Neosilurus hyrtlii*	150	162
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Leiopotherapon unicolor*	104	126
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	21	26
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	21	26
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	23	26
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	23	27
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	23	30
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	24	31
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	25	31
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	26	32
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	26	33
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	26	33
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	41	53
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	43	53
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	55
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	45	57
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	57
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	57
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	46	58
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	48	61
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	50	62

Site Name	Gear Type	Rep-licate	Date	Time In	Time Out	Habitat Type	Species	Standard Length (mm)	Total length (mm)
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	50	63
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	54	66
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	53	67
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	55	69
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	55	70
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	57	70
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	59	74
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	63	80
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	64	80
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	63	81
South Star	Fyke	1	27/06/2020	16:00	8:30	Pool	*Melanotaenia australis*	65	82

APPENDIX D. MACROINVERTEBRATE DATA

			Site	Fig Pool	Fig Pool	Central Creek Pool	Central Creek Pool	South Star Pool	South Star Pool	Site 12	Site 12	Cow Spring Pool	Cow Spring Pool
			Habitat	Edge	Edge	Pool	Edge	Macrophyte	Macrophyte	Macrophyte	Edge	Macrophyte	Edge
			Replicate	1	2	1	2	1	2	1	2	1	2
			Date Sampled	24/06/2020	24/06/2020	25/06/2020	25/06/2020	26/06/2020	26/06/2020	28/06/2020	28/06/2020	29/06/2020	29/06/2020
			Sampled By	SK	SK	SK	SK	SK	SK	SK	SK	SK	SK
			Pick and ID By	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ	SMJ
			ID Date	27/07/2020	28/07/2020	28/07/2020	28/07/2020	29/07/2020	30/07/2020	30/07/2020	30/07/2020	30/07/2020	31/07/2020
SIGNAL2 Score	**AusRivAS taxa code**	**Order**	**Family**										
1		**Hydrozoa**	**Hydrozoa**										
3	IB029999	Hydrozoa	Oceaniidae										
2	IB019999	Hydrozoa	Hydridae									1	
		Hydrozoa	Olindiidae										
1	**KG999999**	**Gastropoda**	**Gastropoda**										
	-	Gastropoda	Ampullariidae										
4	KG069999	Gastropoda	Ancylidae					10				5	
3	KG039999	Gastropoda	Bithyniidae										
5	KG099999	Gastropoda	Glacidorbidae										
1	KG059999	Gastropoda	Lymnaeidae					12	4		1	7	
	KG109999	Gastropoda	Neritidae										
1	KG089999	Gastropoda	Physidae										
2	KG079999	Gastropoda	Planorbidae					3	8	3		3	
4	KG029999	Gastropoda	Tateidae										
4	KG049999	Gastropoda	Thiaridae										
4	KG019999	Gastropoda	Viviparidae										
2	**QO219999**	**Oligochaeta**	**Oligochaeta**				**4**	**1**	**1**	**4**	**1**	**6**	
	LP999999	**Polychaeta**	**Polychaeta**										
	-	**Araneae**	**Araneae**				**1**	**1**	**1**	**2**	**1**		
6	**MM999999**	**Acarina**	**Acarina**	**10**	**3**	**2**	**2**	**5**	**21**	**14**	**14**	**11**	**8**
		GROUP	**Microcrustacea**										
	OG999999	Cladocera	Cladocera					2	11			4	1
1	OF999999	Conchostraca	Conchostraca										
	OJ999999	Copepoda	Copepoda			1	5	6		3	4	2	2
	OH999999	Ostracoda	Ostracoda				1	15				16	
5	**QCZZ9999**	**Coleoptera**	**Coleoptera**										

3	QCAM9999	Coleoptera	Brentidae										
3	QC059999	Coleoptera	Carabidae										
2	QCAH9999	Coleoptera	Chrysomelidae										
2	QCAN9999	Coleoptera	Curculionidae										
2	QC099999	Coleoptera	Dytiscidae	9	6	2	7			2	2	3	2
7	QC349999	Coleoptera	Elmidae										
2	QC119999	Coleoptera	Georissidae										
4	QC109999	Coleoptera	Gyrinidae										
2	QC069999	Coleoptera	Haliplidae										
1	QC369999	Coleoptera	Heteroceridae										
3	QC139999	Coleoptera	Hydraenidae									1	
4	QCAO9999	Coleoptera	Hydrochidae			1	2	2				1	
2	QC119999	Coleoptera	Hydrophilidae	10	2	2	2				1	3	
1	QC079999	Coleoptera	Hygrobiidae										
4	QC359999	Coleoptera	Limnichidae								1		
4	QC089999	Coleoptera	Noteridae										
6	QC379999	Coleoptera	Psephenidae										
10	QC399999	Coleoptera	Ptilodactylidae										
6	QC209999	Coleoptera	Scirtidae									4	
2	QC119999	Coleoptera	Spercheidae										
7	QC039999	Coleoptera	Sphaeriusidae										
3	QC189999	Coleoptera	Staphylinidae										
3	**QDZZ9999**	**Diptera**	**Diptera**										
8	QD229999	Diptera	Athericidae										
10	QD049999	Diptera	Blephariceridae										
4	QD099999	Diptera	Ceratopogonidae			7	9	3	2	4	2	10	
2	QD059999	Diptera	Chaoboridae										
3	QDAZ9999	Diptera	Chironomidae										
8	QDAA9999	Diptera	s-f Aphroteniinae										
3	QDAJ9999	Diptera	s-f Chironominae	23	25	16	26	9	20	21	3	25	22
6	QDAB9999	Diptera	s-f Diamesinae										
4	QDAF9999	Diptera	s-f Orthocladiinae			1						1	
6	QDAD9999	Diptera	s-f Podonominae										
4	QDAE9999	Diptera	s-f Tanypodinae			14	11	15	9	19	15	25	4
	-	Diptera	Corethrellidae										
1	QD079999	Diptera	Culicidae	1	4				1			1	
7	QD069999	Diptera	Dixidae										

3	QD369999	Diptera	Dolichopodidae										
5	QD359999	Diptera	Empididae										
2	QD789999	Diptera	Ephydridae			1	2						
1	QD899999	Diptera	Muscidae				1						
3	QD129999	Diptera	Psychodidae				1						
6	-	Diptera	Sciaridae										
2	QD459999	Diptera	Sciomyzidae									1	
5	QD109999	Diptera	Simuliidae										
2	QD249999	Diptera	Stratiomyidae			4	1			2	3	1	
2	QD439999	Diptera	Syrphidae										
3	QD239999	Diptera	Tabanidae				1						
6	QD039999	Diptera	Tanyderidae										
7	QD119999	Diptera	Thaumaleidae										
5	QD019999	Diptera	Tipulidae									1	
9	**QE999999**	**Ephemeroptera**	**Ephemeroptera**										
7	QE049999	Ephemeroptera	Ameletopsidae										
5	QE029999	Ephemeroptera	Baetidae					9	13	2	2	9	12
4	QE089999	Ephemeroptera	Caenidae			7	14	10	1	1		12	2
8	QE059999	Ephemeroptera	Coloburiscidae										
8	QE069999	Ephemeroptera	Leptophlebiidae										
10	-	Ephemeroptera	Nesameletidae										
8	QE039999	Ephemeroptera	Oniscigastridae										
4	QE099999	Ephemeroptera	Prosopistomatidae										
9	QE079999	Ephemeroptera	Teloganodidae										
2	**QHZZ9999**	**Hemiptera**	**Hemiptera**										
	-	Hemiptera	Aphelocheiridae										
1	QH629999	Hemiptera	Belostomatidae									2	
2	QH659999	Hemiptera	Corixidae										
	-	Hemiptera	Dipsocoridae										
5	QH649999	Hemiptera	Gelastocoridae										
4	QH579999	Hemiptera	Gerridae							2	2	2	
3	QH539999	Hemiptera	Hebridae			1					3		
3	QH549999	Hemiptera	Hydrometridae										
	QH589999	Hemiptera	Leptopodidae										
2	QH529999	Hemiptera	Mesoveliidae			1						1	
2	QH659999	Hemiptera	Micronectidae					1			1	1	
2	QH669999	Hemiptera	Naucoridae										

3	QH619999	Hemiptera	Nepidae			1	1					2	
1	QH679999	Hemiptera	Notonectidae	2	3								
2	QH639999	Hemiptera	Ochteridae										
2	QH689999	Hemiptera	Pleidae			8	4	3		1	2	1	1
1	QH609999	Hemiptera	Saldidae										
3	QH569999	Hemiptera	Veliidae	1		4				1		1	
3	**QO999999**	**Odonata**	**Odonata**										
3	**QO999997**	**Odonata**	**S.O. Zygoptera**										
5	QO079999	Odonata	Argiolestidae										
	QO109999	Odonata	Calopterygidae										
	QO189999	Odonata	Chorismagrionidae										
2	QO029999	Odonata	Coenagrionidae		1	7		9	10	7	2	14	2
6	QO099999	Odonata	Diphlebiidae										
	QO019999	Odonata	Hemiphlebiidae										
9	QO069999	Odonata	Hypolestidae										
3	QO039999	Odonata	Isostictidae			3							
1	QO069999	Odonata	Lestidae										
4	QO049999	Odonata	Platycnemididae										
7	QO089999	Odonata	Synlestidae										
3	**QO999998**	**Odonata**	**S.O. Epiproctiphora**				**1**	**1**					
4	QO129999	Odonata	Aeshnidae		1				5			1	1
	QO199999	Odonata	Archipetaliidae										
10	QO279999	Odonata	Austrocorduliidae										
	QO209999	Odonata	Austropetaliidae										
9	QO219999	Odonata	Brachytronidae										
	QO289999	Odonata	Cordulephyidae										
5	QO169999	Odonata	Corduliidae					1				1	
5	QO139999	Odonata	Gomphidae										
	QO249999	Odonata	Gomphomacromiidae										
5	QO309999	Odonata	Hemicorduliidae										
4	QO179999	Odonata	Libellulidae	15	15			1	7	2		9	9
3	QO229999	Odonata	Lindeniidae										
8	QO269999	Odonata	Macromiidae										
	QO299999	Odonata	Oxygastridae										
	QO159999	Odonata	Petaluridae										
	QO259999	Odonata	Pseudocorduliidae										
2	QO239999	Odonata	Synthemistidae										

9	QO219999	Odonata	Telephlebiidae										
8	**QT999999**	**Trichoptera**	**Trichoptera**										
8	QT169999	Trichoptera	Antipodoeciidae										
7	QT239999	Trichoptera	Atriplectididae										
7	QT249999	Trichoptera	Calamoceratidae										
9	QT189999	Trichoptera	Calocidae										
7	QT159999	Trichoptera	Conoesucidae										
9	QT269999	Trichoptera	Dipseudopsidae										
4	QT089999	Trichoptera	Ecnomidae					3		7		2	1
9	QT029999	Trichoptera	Glossosomatidae										
10	QT199999	Trichoptera	Helicophidae										
8	QT179999	Trichoptera	Helicopsychidae										
10		Trichoptera	Heloccabucidae										
8	QT019999	Trichoptera	Hydrobiosidae										
6	QT069999	Trichoptera	Hydropsychidae										
4	QT039999	Trichoptera	Hydroptilidae			2	3		4	3	3	3	
3	QT209999	Trichoptera	Kokiriidae										
6	QT259999	Trichoptera	Leptoceridae			2	6	4	2	5		5	
8	QT109999	Trichoptera	Limnephilidae										
7	QT229999	Trichoptera	Odontoceridae										
8	QT129999	Trichoptera	Oeconesidae										
8	QT049999	Trichoptera	Philopotamidae										
8	QT219999	Trichoptera	Philorheithridae										
	QT119999	Trichoptera	Plectrotarsidae										
7	QT079999	Trichoptera	Polycentropodidae										
	QT099999	Trichoptera	Psychomyiidae										
	QT059999	Trichoptera	Stenopsychidae										
8	QT139999	Trichoptera	Tasimiidae										
3	**QL019999**	**Lepidoptera**	**Crambidae**					**1**	**6**			**2**	

APPENDIX E. DIATOM DATA

Table 31 Diatom species, count data and calculated DSIAR scores across the five surveyed pools at North Star.

Taxon name		Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
	Replicate Number	1	2	1	2	1	2	1	2	1	2
	Collection date	24/06/2020	24/06/2020	25/06/2020	25/06/2020	26/06/2020	26/06/2020	27/06/2020	27/06/2020	28/06/2020	28/06/2020
	Sample description	no valves	no valves					very sparse	very sparse. teratological forms	no valves	very sparse
Total Count		**0**	**0**	**394**	**352**	**420**	**386**	**60**	**166**	**0**	**28**
DSIAR Score		**NA**	**NA**	**41.3**	**42.6**	**59.1**	**66.3**	**54.7**	**53.95**	**NA**	**64.25**
Achnanthes brevipes		0	0	22	12	302	92	4	24	0	8
Achnanthes impexa		0	0	0	0	48	164	4	8	0	0
Achnanthes subexigua		0	0	4	0	14	70	8	10	0	8
Achnanthidium exiguum		0	0	2	0	12	24	0	0	0	0
Achnanthidium kryophila		0	0	0	0	8	4	0	0	0	0
Achnanthidium lineare		0	0	0	0	6	8	0	0	0	2
Achnanthidium minutissimum		0	0	0	0	6	0	0	0	0	0
Achnanthidium minutissimum var affine		0	0	0	2	4	4	0	0	0	4
Achnanthidium spp.		0	0	2	0	4	4	0	0	0	0
Actinocyclus normanii		0	0	0	0	4	0	0	0	0	0
Adlafia aff bryophila		0	0	0	0	4	0	0	0	0	0
Adlafia minuscula v. muralis		0	0	0	0	4	0	0	0	0	0
Amphicampa mirabilis		0	0	6	2	2	0	0	0	0	0

Taxon name		Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Amphipleura pellucida		0	0	0	0	2	0	0	0	0	0
Amphora delicatissima		0	0	0	4	0	0	0	0	0	2
Amphora libyca		0	0	0	0	0	0	0	0	0	2
Amphora ovalis		0	0	0	0	0	0	0	0	0	2
Amphora pediculus		0	0	0	2	0	0	42	112	0	0
Amphora spp.		0	0	0	0	0	0	0	6	0	0
Aneumastus tuscula		0	0	0	0	0	2	0	4	0	0
Anomoneis spaerophora		0	0	0	0	0	0	0	2	0	0
Asterionella ralfsii var americana		0	0	246	270	0	0	2	0	0	0
Aulacoseira ambigua		0	0	4	0	0	12	0	0	0	0
Aulacoseira crenulata		0	0	0	0	0	2	0	0	0	0
Aulacoseira granulata		0	0	40	16	0	0	0	0	0	0
Bacillaria paxillifer		0	0	10	8	0	0	0	0	0	0
Brachysira brebissonii		0	0	12	6	0	0	0	0	0	0
Brachysira styriaca		0	0	0	6	0	0	0	0	0	0
Brachysira vitrea		0	0	8	4	0	0	0	0	0	0
Caloneis aerophila		0	0	0	4	0	0	0	0	0	0
Caloneis silicula		0	0	0	4	0	0	0	0	0	0
Chamaepinnularia bremensis		0	0	0	4	0	0	0	0	0	0
Chamaepinnularia muscicola		0	0	0	2	0	0	0	0	0	0
Cocconeis pediculus		0	0	0	2	0	0	0	0	0	0

Taxon name		Fig Pool	Fig Pool	Central Ck Pool	Central Ck Pool	South Star Pool	South Star Pool	Site 12 Pool	Site 12 Pool	Cow Spring Pool	Cow Spring Pool
Cocconeis placentula		0	0	0	2	0	0	0	0	0	0
Cocconeis placentula var. euglypta		0	0	0	2	0	0	0	0	0	0
Cocconeis placentula var. lineata		0	0	28	0	0	0	0	0	0	0
Cocconeis pseudothumensis		0	0	4	0	0	0	0	0	0	0
Craticula accomoda		0	0	2	0	0	0	0	0	0	0
Craticula cuspidata		0	0	2	0	0	0	0	0	0	0
Craticula halophila		0	0	2	0	0	0	0	0	0	0

APPENDIX F. MACROPHYTE TABLE

Name	Description	Image	Site 12	Cow Spring	South Star	Central Ck
Ribbon weed (*Vallisneria sp.*)	Bright green soft ribbon fronds which float and spread across the water surface. Fronds about 0.5 cm wide.		Y	Y	Y	

Name	Description	Image	Site 12	Cow Spring	South Star	Central Ck
Charophytes (*Nitella sp., Chara sp.*)			Y			

Name	Description	Image	Site 12	Cow Spring	South Star	Central Ck
Clubrush (*Schoenoplectus sp.*)			Y	Y	Y	Y
Sedges (*Cyperus sp.*)			Y	Y	Y	Y

Name	Description	Image	Site 12	Cow Spring	South Star	Central Ck
Bulrush (*Typha sp.*)	Tall emergent ribbon like fronds with sharp margins.		Y	Y	Y	
Unidentified species 1				Y		

Name	Description	Image	Site 12	Cow Spring	South Star	Central Ck
Unidentified species 2				Y		

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Appendix 8: SRK: Stability Assessment of WRD

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Project Memo

Client:	Iron Bridge Operations Pty Ltd	**Date:**	10 April 2019
Attention:	Justin Dixon	**From:**	Jaya Mylvaganam
Project No:	FMG062	**Revision No:**	2
Project Name:	Waste Rock Dump Assessment		
Subject:	Stability Assessment of Waste Rock Dump		

1 Introduction

On 4 February 2019, SRK Consulting (Australasia) Pty Ltd (SRK) was requested by Justin Dixon of Fortescue Metals Group (FMG) to provide a proposal for the geotechnical assessments of a waste rock dump (WRD) for the Iron Bridge Project located approximately 120 km south of Port Hedland in Western Australia. The required geotechnical assessment focuses on a single large WRD, the height of which is expected to be approximately 100 m at closure. SRK was requested to conduct the study in two stages:

- Stage 1: Geotechnical characterisation of waste rock materials
- Stage 2: Stability assessments of the WRD for the final closure landform and operational lifts.

The report (FMG062_Geotechnical Characterisation of Waste Rock Materials - Iron Bridge Project_Rev0.docx) detailing the geotechnical characterisation of waste rock materials (Stage 1 Report - FMG Document Control No: 662NS-0000-RP-GE-0001) was issued to FMG on 14 March 2019. This memorandum now presents the details of WRD stability assessments (Stage 2) for the final closure landform and operational lifts.

2 Scope of Stage 2 study

The scope of the Stage 2 study includes:

1. Stability analyses for determining appropriate maximum tipping heights for various waste rock materials for operational purposes
2. Seepage/ infiltration analyses for flooding scenarios to develop pore pressures for input to stability analyses for closure designs
3. Stability analyses of closure dump designs at various design conditions
4. Provision of recommendations and reporting.

Material characterisation for the WRD foundation was not included in the scope; however, a site visit was arranged by FMG to conduct a walk-over for observation of the foundation conditions.

3 Non-linear shear strength envelopes of waste rock materials

Non-linear shear strength envelopes were developed for various waste rock materials in the Stage 1 study using the Barton-Kjaernsli criterion (Barton & Kjaernsli, 1981; Barton, 2008) method. The parameters selected for the development of non-linear strength envelopes and the process involved are summarised in the Stage 1 Report. The developed design and lower bound shear strength envelopes are presented in Figure 3-1 and Figure 3-2, respectively.

For comparison purposes, linear strength envelopes of 30°, 37° and 40° friction angles, the lower limit envelope for rockfill material proposed by Indraratna (1993), and the envelope for high strength rock fill defined by Leps (1970), are included for reference in Figure 3-1 and Figure 3-2.

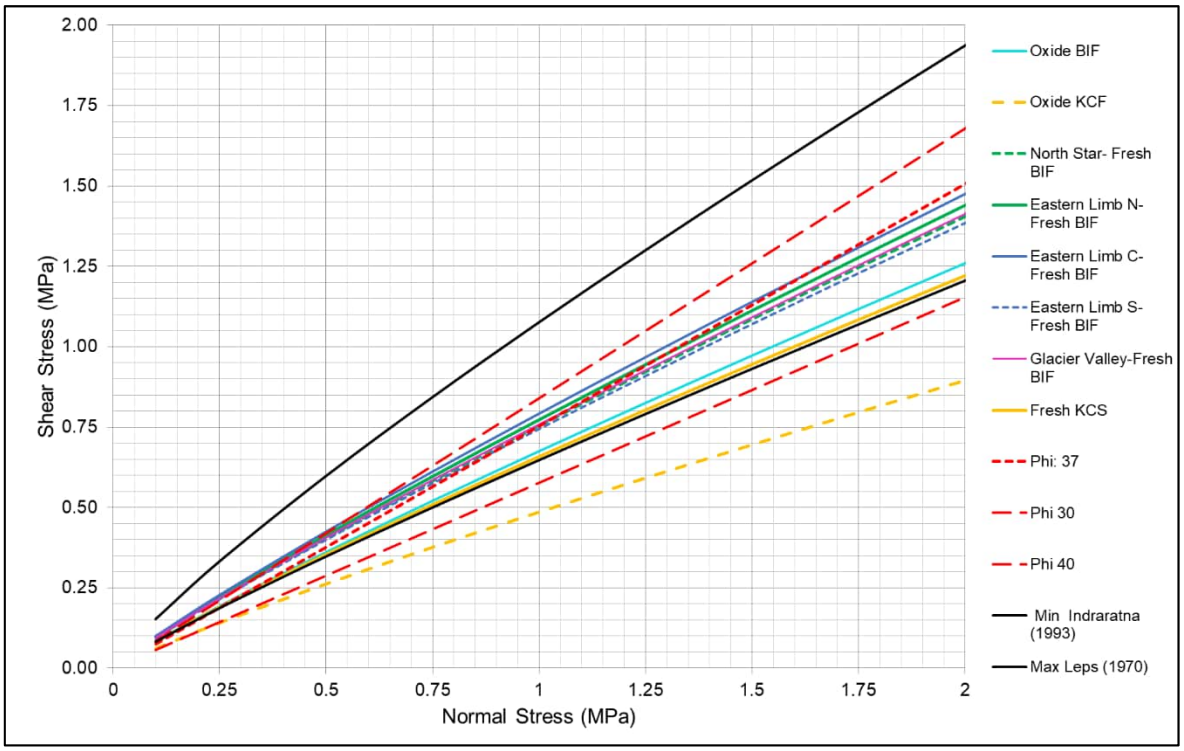


Figure 3-1: Design non-linear shear envelopes

Source: SRK, 2019

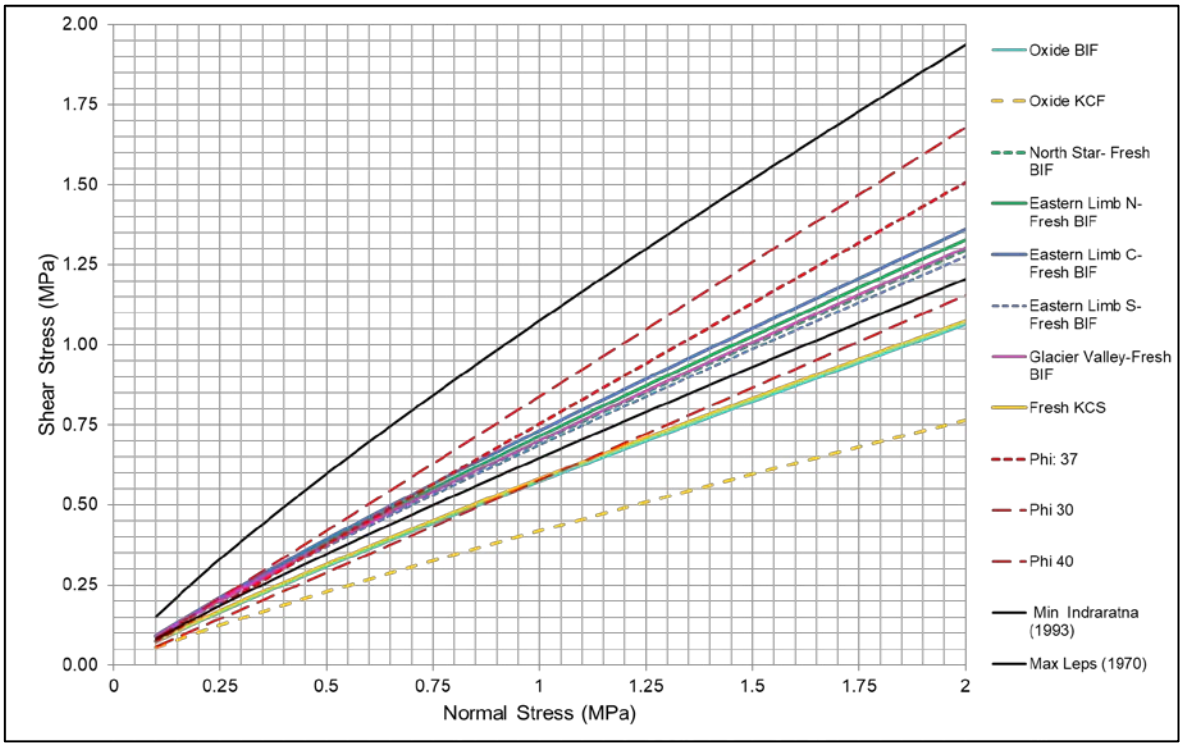


Figure 3-2: Lower bound non-linear shear envelopes

Source: SRK, 2019

4 Foundation conditions

Detailed material characterisation for the WRD foundation was not performed; however, a day site visit was conducted by SRK accompanied by FMG Geotechnical Engineers to observe the foundation conditions as much as possible. In a broad sense, the WRD foundation is constructed in gently undulating terrain (Figure 4-1 and Figure 4-2) with small stream channels present.

Figure 4-3 presents the geological mapping information extracted from Government mapping data for the WRD footprint area. As shown in the figure, the WRD footprint is largely sited over Corboy Formation; however, the western end (indicated by reddish zone in Figure 4-3) where the site visit access was difficult is sited over Pincunah Hill Formation. The oxide materials (Oxide BIF) of these formations presumably have similar shear strength characteristics. The depth of these Oxide materials is indicated to be in the range between 40 m and 60 m, based on the Base of Oxide wireframe provided by FMG (IBO_OxideBase_May_2017_Z1000.00t).

The overall observations and preliminary assessments suggest that the foundation conditions of the selected WRD are, in general, relatively competent, with an insignificant amount of loose material cover (test pitting is unlikely to be feasible), and therefore a site investigation for characterisation of foundation materials was not considered necessary at this stage. Example photographs of foundation materials are shown in Figure 4-4.

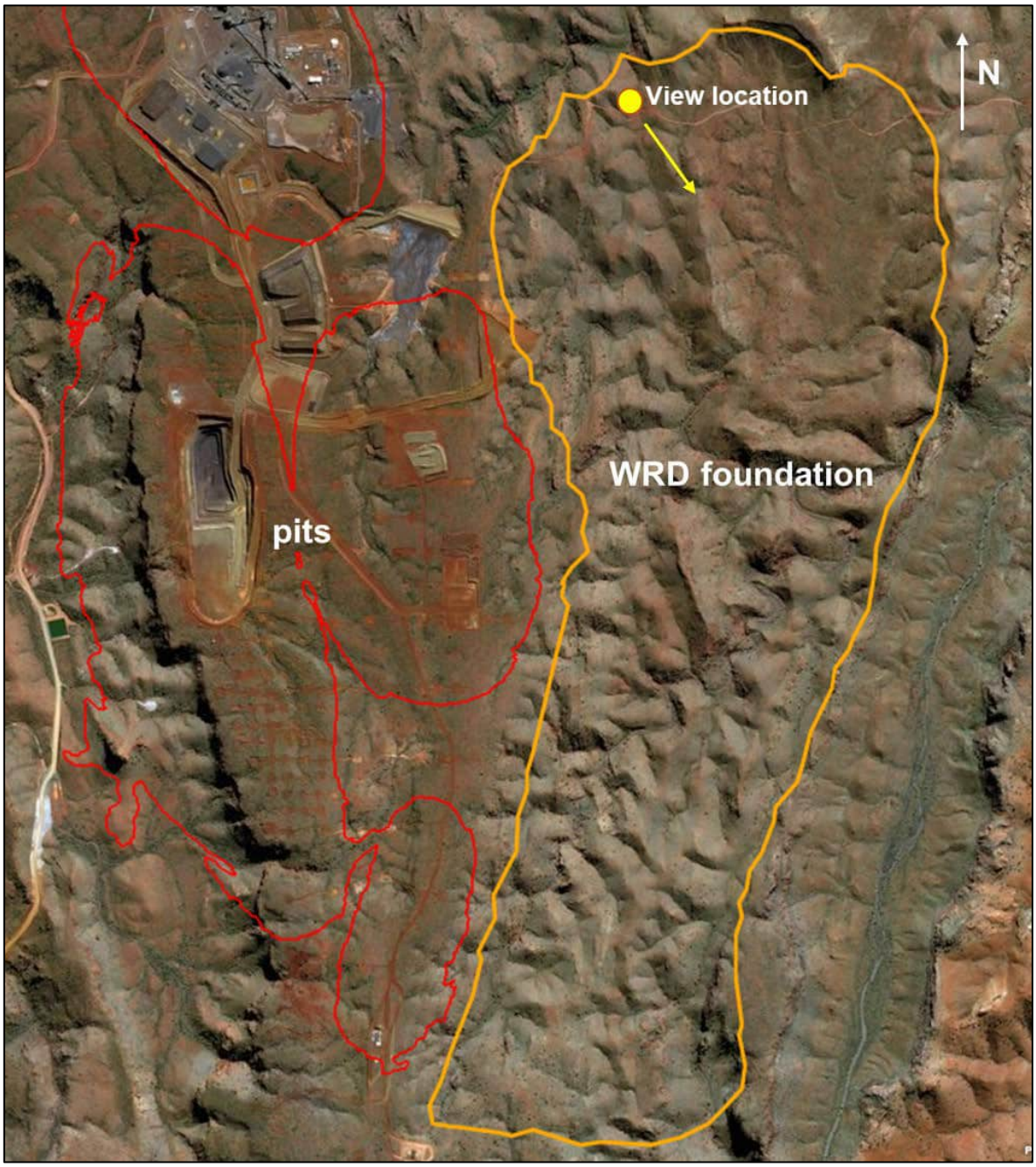


Figure 4-1: Location of WRD foundation and its terrain



Figure 4-2: A view of foundation terrain

Note: View location and the direction is shown in Figure 4-1 by a yellow arrow.

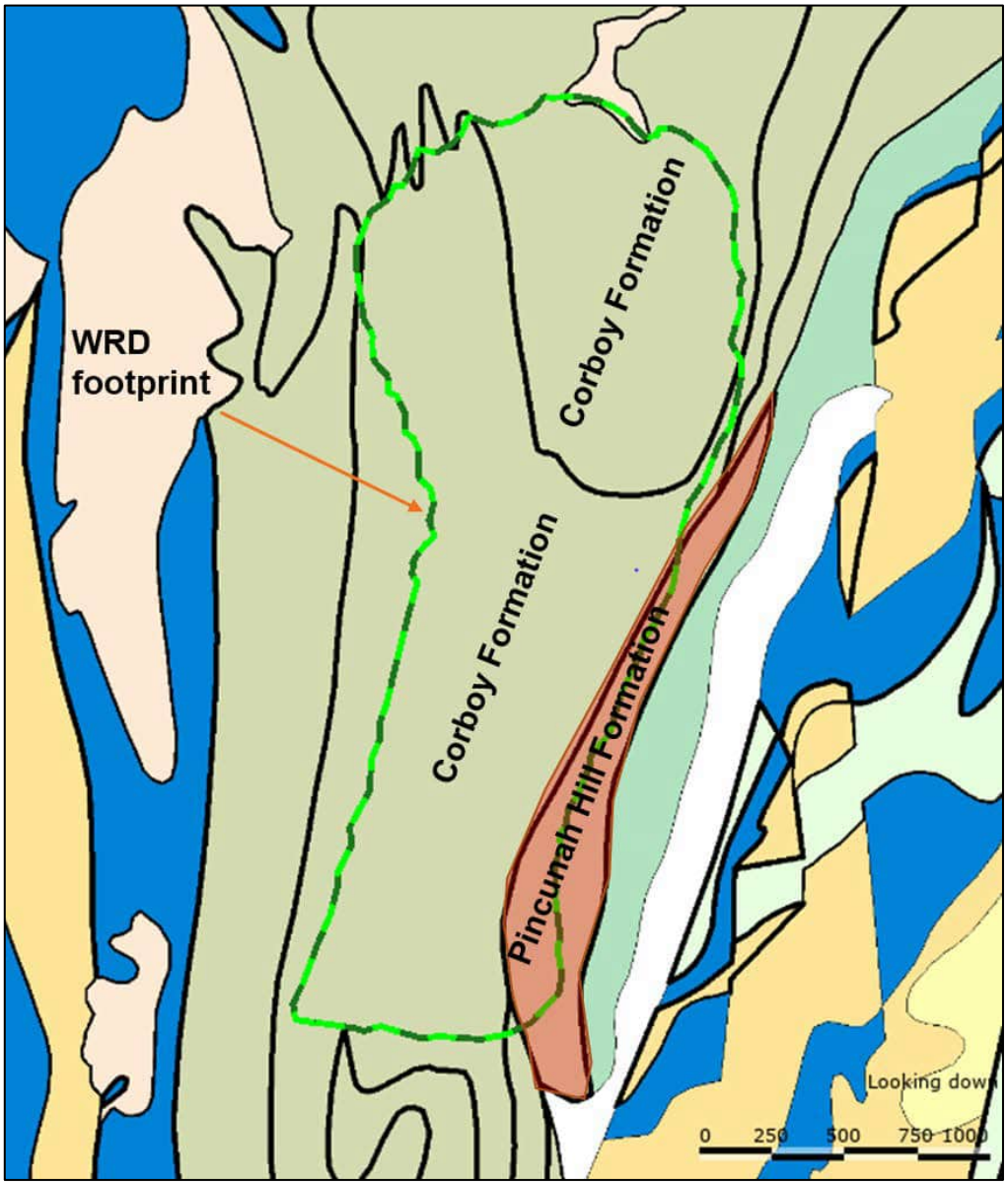


Figure 4-3: Geological mapping of WRD footprint area

Note: Government mapping data source

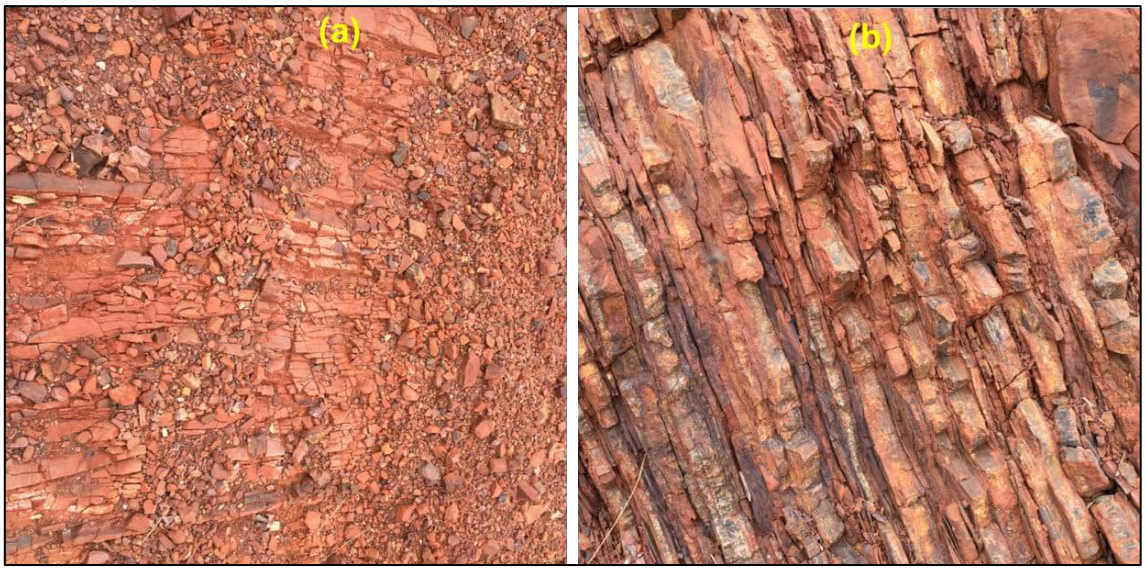


Figure 4-4: Photographs showing foundation conditions

Note: View location is shown in Figure 4-1 by yellow circle; a) floor; b) road cut)

In the absence of site-specific data, SRK used information available for the design of surrounding pits such as geological and structural interpretation wireframes and the rock mass parameters developed by AMC (2019). Rock mass parameters for the expected foundation materials in WRD footprint areas are presented in Table 4-1. No data is available for the foundation materials sited on the western side of the WRD. Shear strength parameters for the weak Oxide BIF or any other representative weak materials are considered important in the assessment, whereas parameters of relatively hard rock beneath the footprint area are less important. For the purposes of this stability assessment, lower bound rock mass parameters of Oxide BIF (highlighted in orange in Table 4-1) was considered appropriate to use at this stage. However, if any materials significantly weaker than the lower bound Oxide BIF are identified in any influential zones, revisions of material parameters and review of the WRD stability may then be required.

Table 4-1: Possible foundation parameters

Units	Density (kN/m^3)	Rock mass shear strength					
		Design			Lower bound		
		GSI	UCS (MPa)	m*i*	GSI (25th percentile)	UCS (MPa) (25th percentile)	m*i*
Oxide BIF	31	48	35.9	15	40	22	15
Fresh BIF	33	72	167	20	63	134	20

Source: AMC, 2019

5 Design Considerations

5.1 Analysis considerations

5.1.1 Potential failure modes

The terrain in which the WRD will be founded is gently undulating in a broad sense, and the closure design dump slope angles are very shallow (overall slope angle 15°–20°). These suggest that failure through foundation material is less likely unless very weak materials or adversely oriented structures are present. Apart from the dump surface ravelling (as the bench faces are generally at the angle of repose), shallow or deep-seated instability mechanisms were considered within dump materials.

5.1.2 Dump settlement

It is expected that a significant part of the potential settlement of loosely placed waste rock will occur during WRD construction due to overburden weight and the loading from haul truck trafficking and other equipment. The magnitude of post-rehabilitation settlement of WRD surfaces (at closure) is expected to be minimal and the impact of this settlement on the overall stability of the WRD is considered insignificant.

5.1.3 Seismic assessment and liquefaction potential

The Iron Bridge project site is not situated in a seismically active area, and the possibility of large earthquakes occurring is minimal. However, the potential for earthquake-induced instabilities has been assessed using a pseudo-static analysis method, where a horizontal loading associated with earthquake-induced acceleration is applied in the model analyses. Due to the constant application of the horizontal loading in this method (which is a conservative approach), only a partial peak ground acceleration (PGA) of the earthquake event is applied (generally one third to one half of the PGA).

Liquefaction-induced instability is considered unlikely in this assessment. Soil susceptible to liquefaction should be nearly fully saturated and loose (e.g. sandy soils). Figure 5-1 presents the gradation curves of waste materials considered in this study in comparison with liquefaction susceptibility limits presented in CSIRO (2017). Figure 5-1 shows that most parts of the grading curves are outside the limits, which indicates that liquefaction susceptibility is insignificant. Furthermore, nearly fully saturated conditions within the dumps or foundation (weak influential zones) in the study area are unlikely. Therefore, detailed liquefaction assessments were excluded from this study.

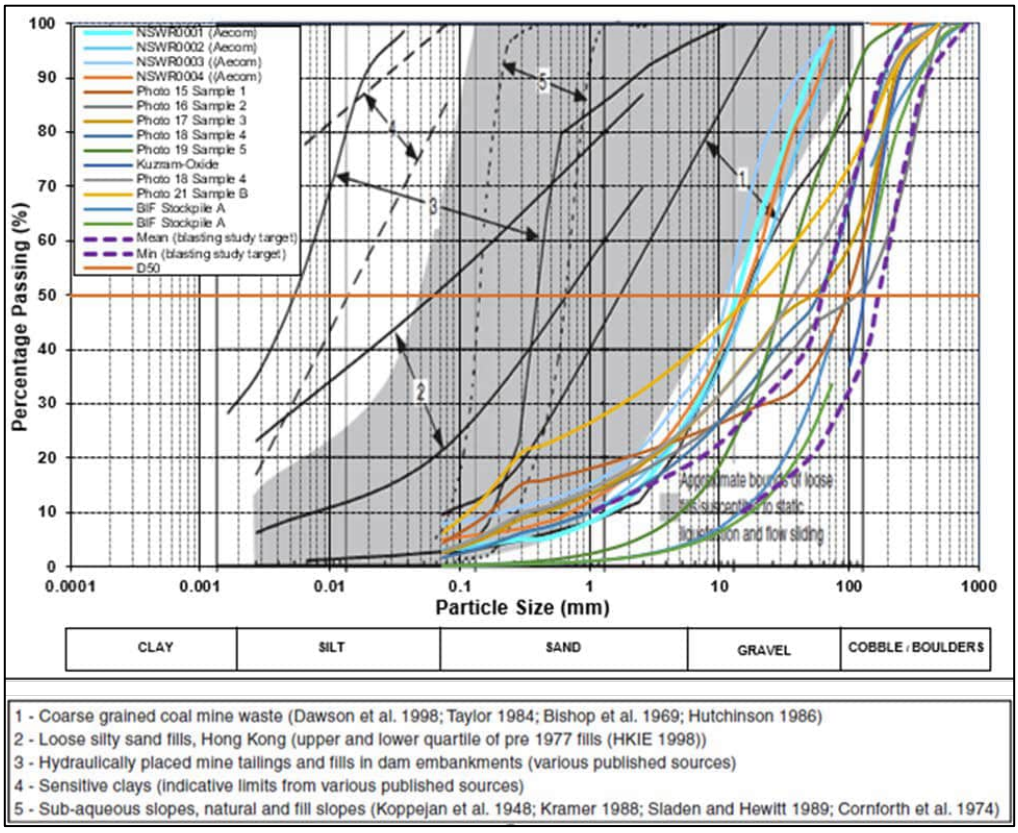


Figure 5-1: Range of gradation of soils which exhibited flow slide behaviours

Source: Modified after CSIRO, 2017

5.1.4 Storm event assessment

Surface water modelling conducted by FMG confirmed that water ponding occurs on designed WRD berms for 1 in 100-year and 1 in 500-year 24-hour storm events and for a potential maximum precipitation (PMP) 72-hour storm event. The potential impact on the geotechnical stability associated with an increased phreatic surface or pore pressure (PP) has been assessed using a conservative approach.

5.1.5 Geological structures in WRD foundation

Specific structural interpretations and structural mapping data for the WRD footprint area are not available. However, fault model and bedding plane information developed for surrounding pit design studies was extrapolated to identify any possible impact on the WRD stability. Faults that possibly intersect or strike across the WRD footprint area are presented in Figure 5-2, and they are subvertical. Based on the geological wireframes provided by FMG, bedding is expected to be dipping eastward at an angle of approximately 65°. Assessments indicated that the impact of these faults and bedding on the WRD stability is insignificant.

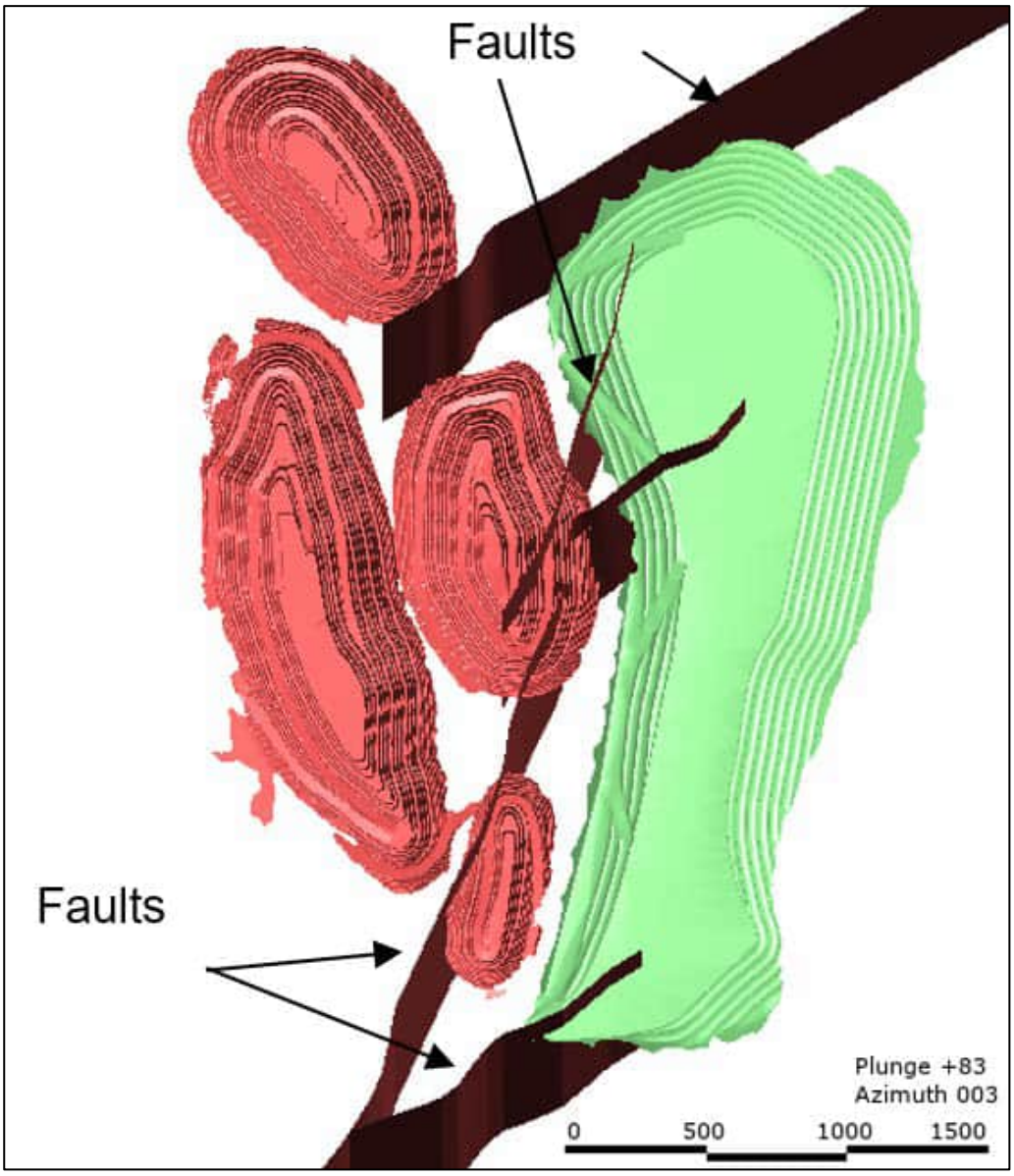


Figure **5**-2: Faults possibly intersecting the WRD footprint area

5.2 Acceptance criteria

Table 5-1 summarises design acceptance criteria considered for various analysis scenarios based on CSIRO (2017) recommendations.

Table 5-1: Model scenarios and acceptance criteria

WRD slope	Loading	Pore pressure (PP)	Minimum FoS requirement
Operational profile (short term)	Static	Dry	1.1–1.3
Closure profile (long term)	Static	1:500-year PP	1.5
		PMP PP	1.1
		Dry	1.5
		Fully saturated	1.1
	Pseudo-static OBE	Dry	1.1
	Pseudo-static MCE	Dry	>1.0

OBE - Operating basis earthquake; MCE - Maximum credible earthquake

Figure 5-3 shows the suggested design sequence for accepting the stability criteria in Table 5-1.

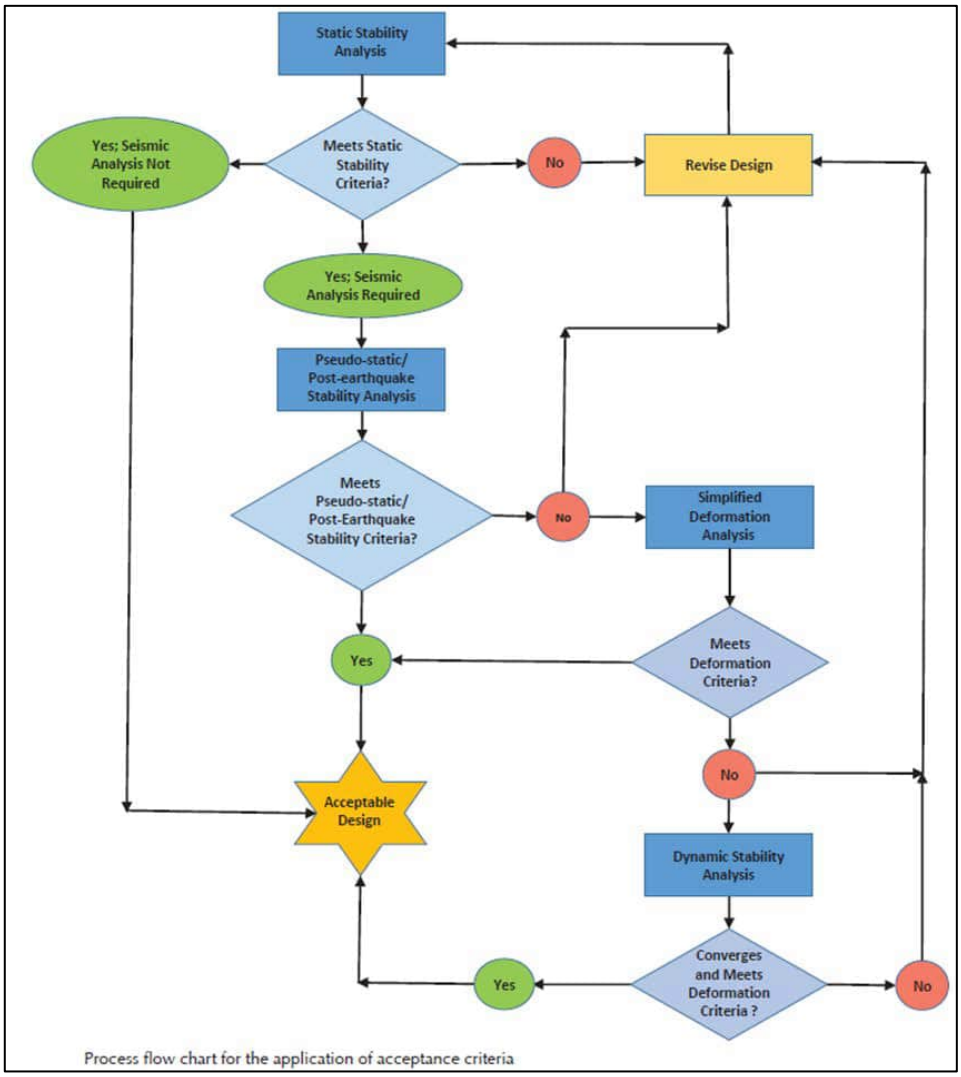


Figure 5-3: Process flow chart for the application of acceptance criteria

Source: CSIRO, 2017

5.3 Waste dump stability rating and hazard classes

Figure 5-4 illustrates the waste dump and stockpile stability rating and hazard classification (WSRHC) system (CSIRO, 2017) used to identify the hazards and risk associated with the designs. Based on this system, the WRD stability ratings and hazard classes were assessed for Iron Bridge WRD. The outcome of this assessment is presented in Table 5-2, which shows that the instability hazard is Moderate to Low. The ratings for construction and performance (Table 5-2) were selected in conjunction with ratings used by FMG for the Frederick WRD (FMG, 2017a).

Table 5-2: Iron Bridge WRD stability rating and hazard class

Index	Factor	Lower Bound	Upper Bound
Engineering Geology Index (EGI)	Regional settings	5	5.5
	Foundation conditions	10.5	14
	Material quality	9	15
Design and Performance Index (DPI)	Geometry and mass	6	8
	Stability analyses	7	10
	Construction	13	13
	Performance	7.5	7.5
Waste dump and stockpile rating (WSR)		58	73
Waste dump and stockpile hazard classification (WHC)		III	II
Instability hazard		Moderate Hazard	Low Hazard

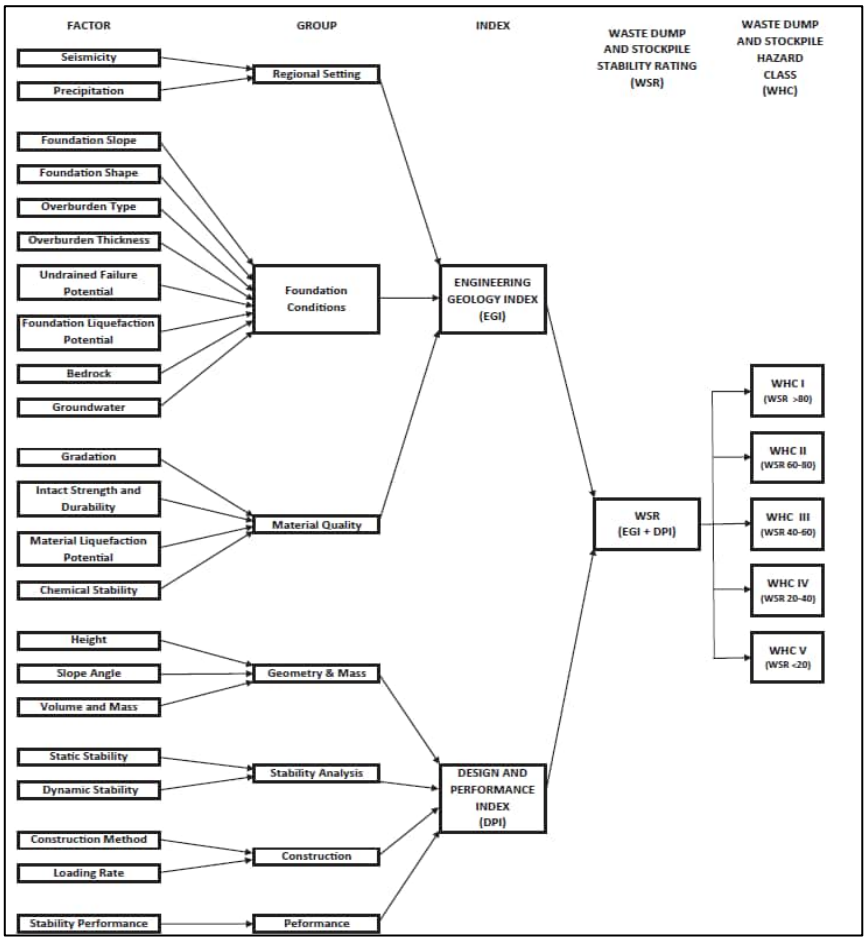


Figure 5-4: Structure of waste dump and stockpile stability rating and hazard classification (WSRHC) System

Source: CSIRO, 2017

6 Stability Assessment

The stability assessments were conducted using Slide v7 software (Rocscience, 2016) in the context of various waste rock parameters, seismicity, and pore pressure conditions. Slide is a 2D limit equilibrium slope stability program for assessing circular or non-circular slip surfaces in terms of factor of safety (FoS). Pore pressure inputs for the stability assessment as required were developed using the seepage and infiltration analysis feature in Slide. Stability assessments were conducted for short-term operational and long-term closure design.

6.1 Stability analysis inputs

6.1.1 Waste rock and waste rock dump foundation parameters

Non-linear shear strength parameters of waste rock materials, as presented graphically in Figure 3-1 and Figure 3-2, were assigned in Slide through the shear-normal function feature. The suggested envelopes for the design and sensitivity assessments are presented in Table 6-1. Fresh BIF of Eastern limb S has the lowest shear strength of all the fresh BIF materials available, and the shear strength envelope of Eastern limb S was therefore used for stability assessment of Fresh BIF scenarios. Where necessary, high strength BIF material (Eastern limb C) was also considered in the assessments.

As described in Section 4, lower bound rock mass parameters of Oxide BIF (highlighted in orange in Table 4-1) were assigned for the WRD foundation in the assessments.

Table 6-1: Suggested envelopes for the stability assessment

Design Profile	Suggested envelopes for Design	Suggested envelopes for Sensitivity Assessment
Closure	Oxide BIF (Design) Fresh BIF (Design)	Oxide BIF (lower bound) Fresh BIF (lower bound) Phi=37° & C=0 kPa (General)
Operation (lift height)	Oxide BIF (Design) Oxide KCS (Design) Fresh BIF (Design) Fresh KCS (Design)	Phi=37° & C=0 kPa (General) Phi=37° & C=5 kPa (General)

6.1.2 Seismic coefficient

A site-specific probabilistic seismic hazard assessment has not been completed for Iron Bridge site. Therefore, the seismic hazard assessment data conducted for Solomon site was considered representative and the probabilistic PGA values for typical return periods are presented in Table 6-2, as reported by FMG (2017a). In this study, a PGA of 0.06g associated with a 1 in 475-year return period event was considered for operating basis earthquake (OBE) analyses. As used by FMG (2017a), a maximum credible earthquake (MCE) of 0.34g was considered for sensitivity analyses, which was assessed based on deterministic seismic analyses of a 1 in 10,000-year return period event.

As the earthquake-induced instabilities are assessed using a pseudo-static analytical method where a horizontal loading associated with PGA was constantly applied, a partial PGA (half the PGA) of the earthquake events was applied.

Table 6-2: Probabilistic peak ground acceleration for typical return periods

Percentage in 50 years (%)	Annual exceedance	Return period (years)	PGA (g)
63	0.02	50	0.03
39	0.01	100	0.03
10	0.002	475	0.06
5	0.001	975	0.07
0.5	0.0001	9975	0.18

Source: FMG 2017a

6.1.3 Groundwater and pore pressure input

FMG provided groundwater levels for the site spatially as points, to be applied to the WRD foundation. This information indicates that the GWL in the WRD foundation is approximately 40–50 m below surface. Pore pressure developed by infiltration into the WRD during storm events was assessed using seepage and infiltration analyses for input to stability assessments. The details regarding the infiltration analyses are described in Section 6.3.1.

6.2 Operational Design

During operation, the WRD is constructed by loose dumping in successive lifts to a maximum height possible (ensuring safe mining operations) depending on waste rock characteristics, foundation conditions and equipment loading, while not impeding the ability to achieve final closure profile requirements. The toe position of each successive lift is stepped in an optimal bench design distance that will provide the required overall landform slope at closure (Figure 6-1).

To assist with WRD operational construction, maximum tipping height assessments were conducted for slopes with a face angle of 37° under static drained conditions. A sample Slide analysis section is presented in Figure 6-2. As advised by FMG, a truck standoff distance of 5 m from the bench crest was assumed, and the truck wheel pressure (537 kPa) and related dimensions shown in Figure 6-2 were chosen for the haul truck equivalent to CAT 793F to be used at the Iron Bridge operation as provided in FMG (2017b).

A series of Slide stability analyses were conducted for various waste rock materials, as well as two general case materials for comparison (ϕ=37° & c=0 kPa and ϕ=37° & c=5 kPa), by varying the slope height from 10 m to 60 m in 10 m increments. It is noted that simulating the truck wheel pressure in 2D analyses is conservative as the pressure does not represent plane strain conditions. The FoS results obtained from these analyses are presented in Table 6-3, and graphically depicted in Figure 6-3. During operations, the maximum tipping heights shall be chosen by IB Operations using the results shown in Figure 6-3to align with geotechnical acceptance criteria outlined in the site Ground Control Management Plan. The FoS for Oxide KCS (Kangaroo Cave Shale) is significantly below zero even for 10 m height and therefore, paddock-dumping is recommended for this material.

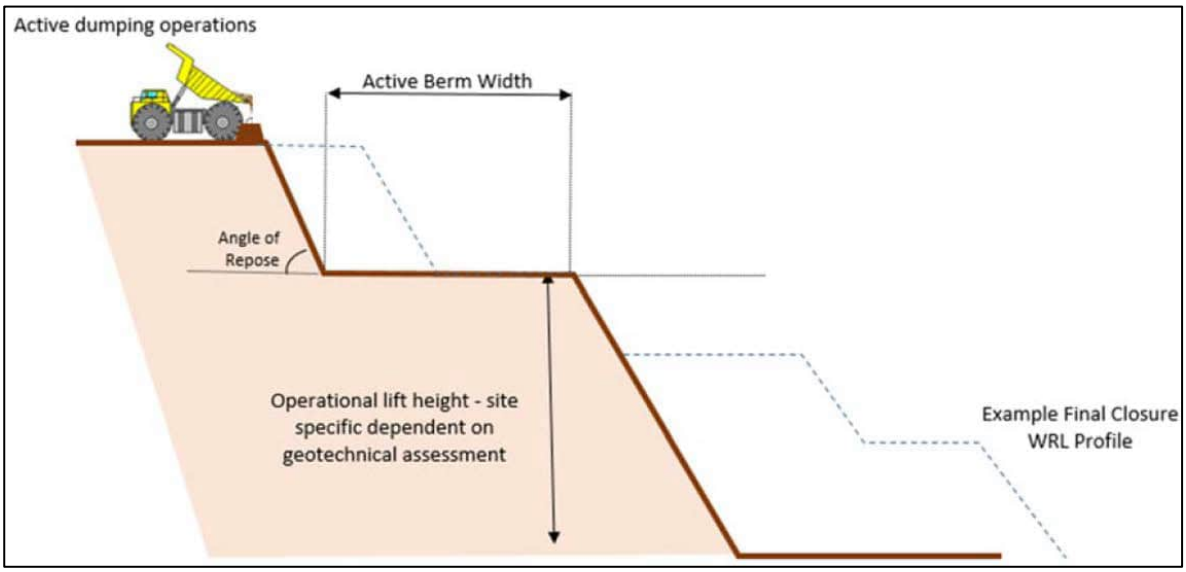


Figure 6-1: Simplified illustration of waste rock dumping operation

Source: FMG 2017a

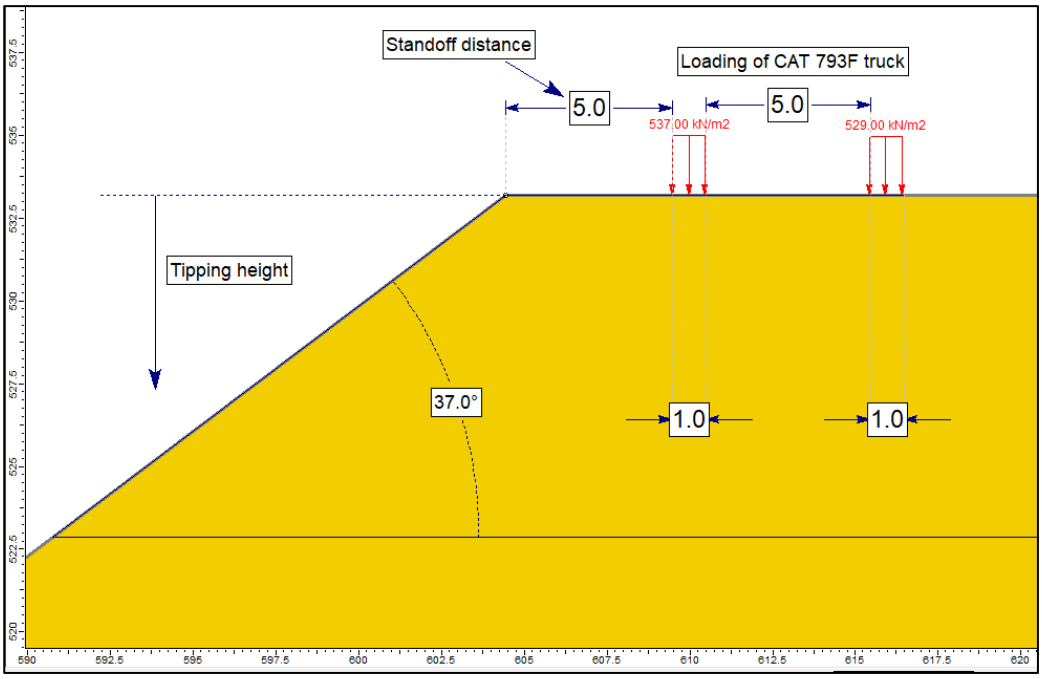


Figure 6-2: Slide section for tipping height analyses

Table 6-3: Results of tipping height analyses

Tipping height (m)	Factor of Safety (FoS)					
	Oxide BIF (Design)	Oxide KCS (Design)	Fresh BIF (Design)	Fresh KCS (Design)	Phi=37° c=0 (kPa)	Phi=37° c=5 (kPa)
10	1.35	0.9	1.52	1.34	1.24	1.34
20	1.25		1.4	1.24	1.13	1.23
30	1.2		1.34	1.2	1.09	1.18
40	1.17		1.3	1.17	1.06	1.15
50	1.15		1.28	1.15	1.05	1.13
60	1.14		1.26	1.14	1.04	1.12

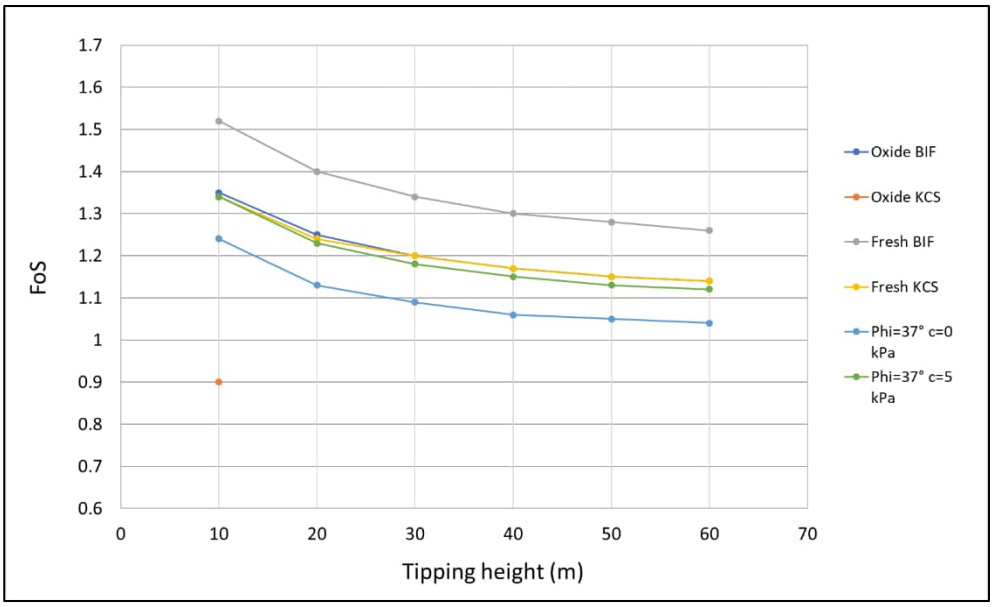


Figure 6-3: Results of tipping height analyses for a 5 m truck standoff distance

6.3 Closure design assessment

Waste rock dumps for closure are designed to ensure that they are physically safe to humans and animals, and geotechnically stable. Two sections were chosen for the closure design stability analyses. These sections represent the steepest and highest overall slope, and therefore will provide worst-case instability scenarios. The locations of the stability analysis sections, and the corresponding Slide sections, are shown in Figure 6-4 and Figure 6-5, respectively. Section 2 was selected mainly to analyse the bottom inter-ramp slope (60 m high slope at angle of 37° as shown in Figure 6-4b) which spans relatively locally. Finer geometrical details of individual benches (e.g. rock buttressing at closure) have not been included in the model as these will have a negligible impact on the overall stability.

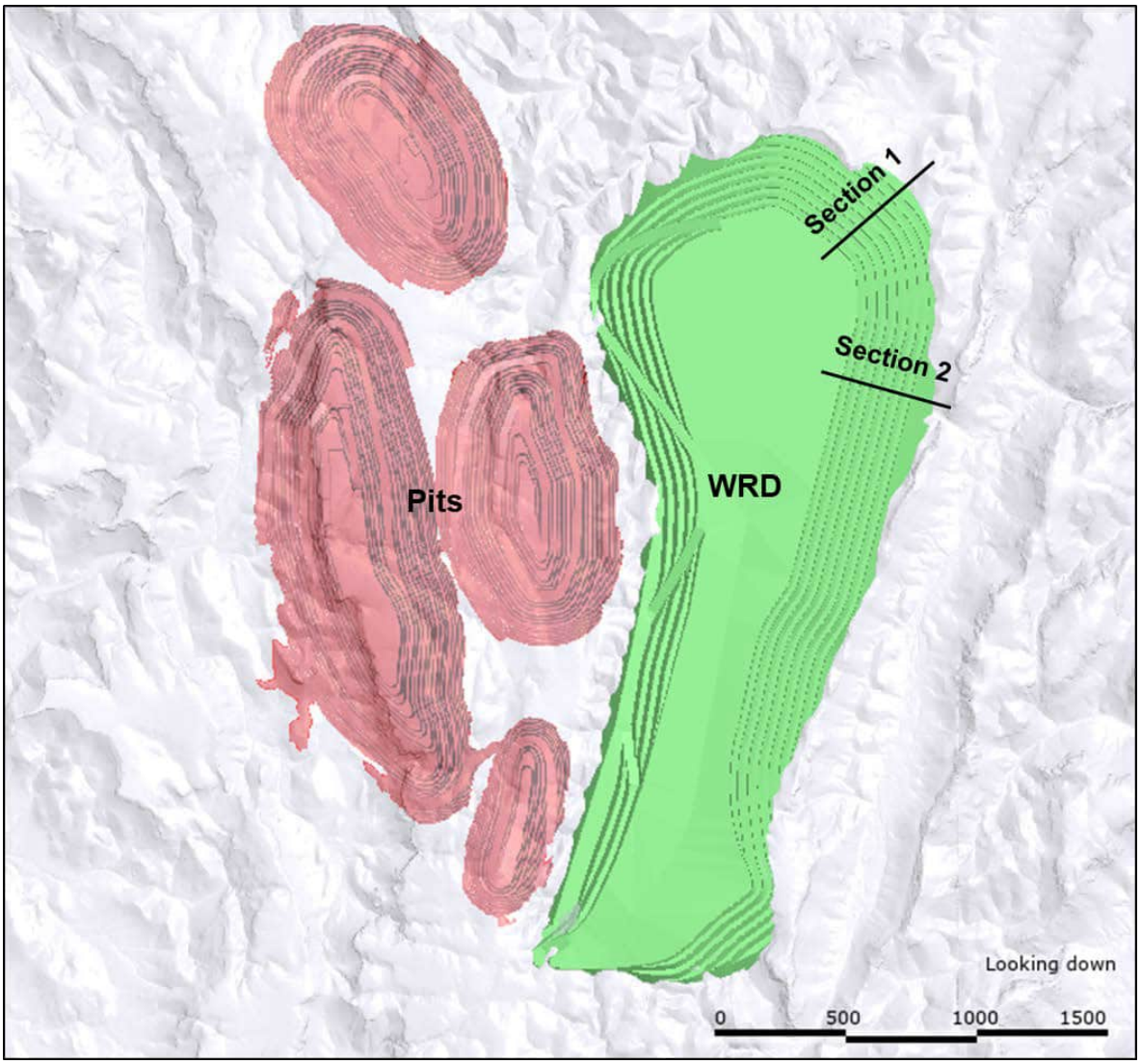


Figure 6-4: Plan view showing Slide section locations

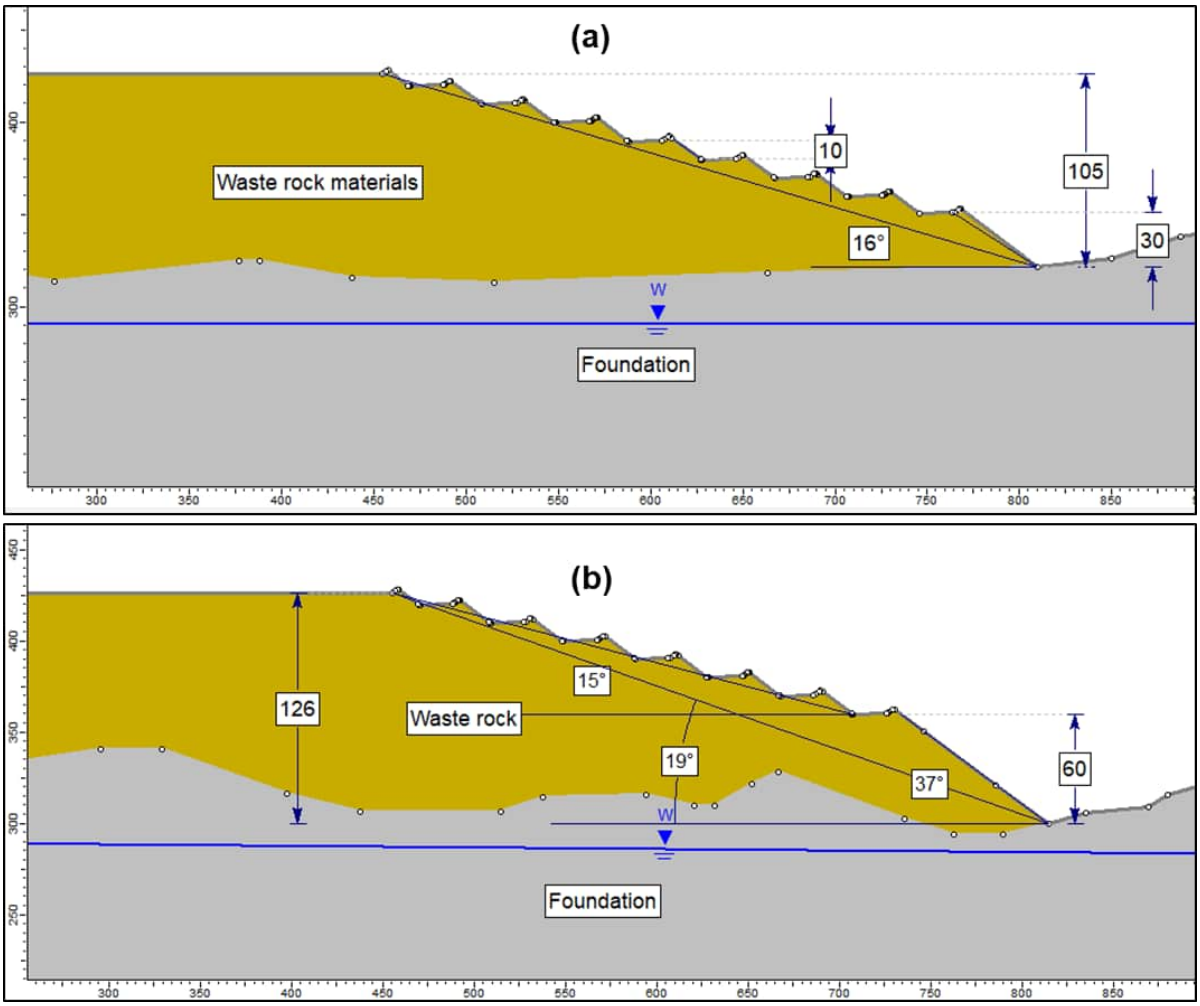


Figure 6-5: Slide analysis sections: a) Section 1; b) Section 2

6.3.1 Infiltration and seepage analyses

The analyses were conducted using Slide under unsaturated transient conditions to produce pore pressures (PP) within the WRD due to storm event infiltration. The hydraulic parameters adopted for this analysis are presented in Table 6-4. Saturated hydraulic conductivity values for Oxide and Fresh BIF were assessed based on PSD data for an assumed porosity of 25% (SRK, 2019), and due to the difficulties in obtaining other data at this stage, reasonable assumptions were made based on engineering judgements.

Table 6-4: Waste rock hydraulic parameters adopted

Material	Volumetric saturated moisture content	K (saturated) (m/s)	Volumetric residual water content
Oxide BIF	0.25	1 × 10-3 - 4 *	0.05
Fresh BIF	0.25	1 × 10-2 - 4 *	0.05
Sensitivity for Oxide and Fresh BIF	0.25	1 × 10-5	0.05
Foundation	0.2	1 × 10-6	0.02

* Interpreted using PSD data

In this study, a 1 in 500-year 24-hour storm event is adopted as the design case, whereas a PMP 72-hour event is considered for sensitivity analyses. Figure 6-6 presents the pond water heights assessed by FMG's surface water modelling for PMP and 1 in 500-year storm events. Pond water heights of approximately 1.1 m and 2.8 m were considered for the 1 in 500-year and PMP events, respectively.

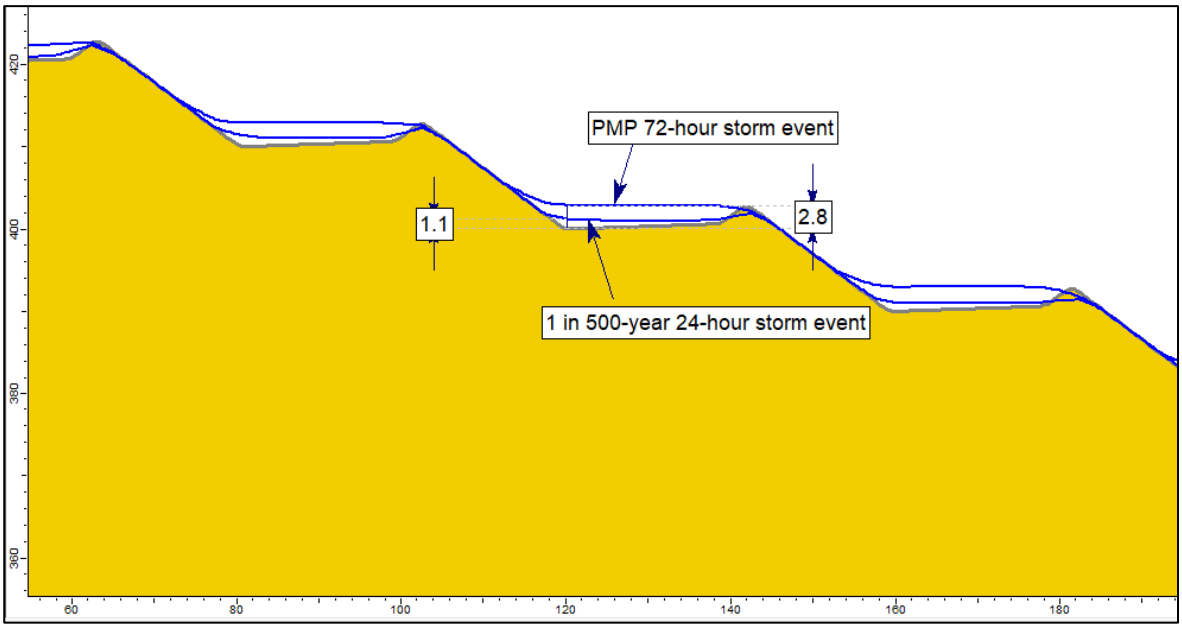


Figure 6-6: Pond height of storm events

Preliminary analyses were conducted using estimated hydraulic conductivity values for conservative infiltration rates of 0.1 m/day and 0.43 m/day. A sample section (Section 1) illustrating the hydraulic boundary conditions (infiltration rate of 0.43 m/day) is shown in Figure 6-7. These analyses yielded insignificant pore pressure development, and similar FoS values for instability to that of a drained scenario were therefore obtained.

A sensitivity assessment was then conducted using a hydraulic conductivity value of 1×10^{-5} m/s with a conservative infiltration rate of 0.43 m/day. For the pore pressure input to stability analyses, two and six days of infiltration was simulated conservatively for the 1 in 500-year and PMP events, respectively. These analyses are very conservative in producing pore pressure in terms of hydraulic conductivity as well as infiltration rate and time period.

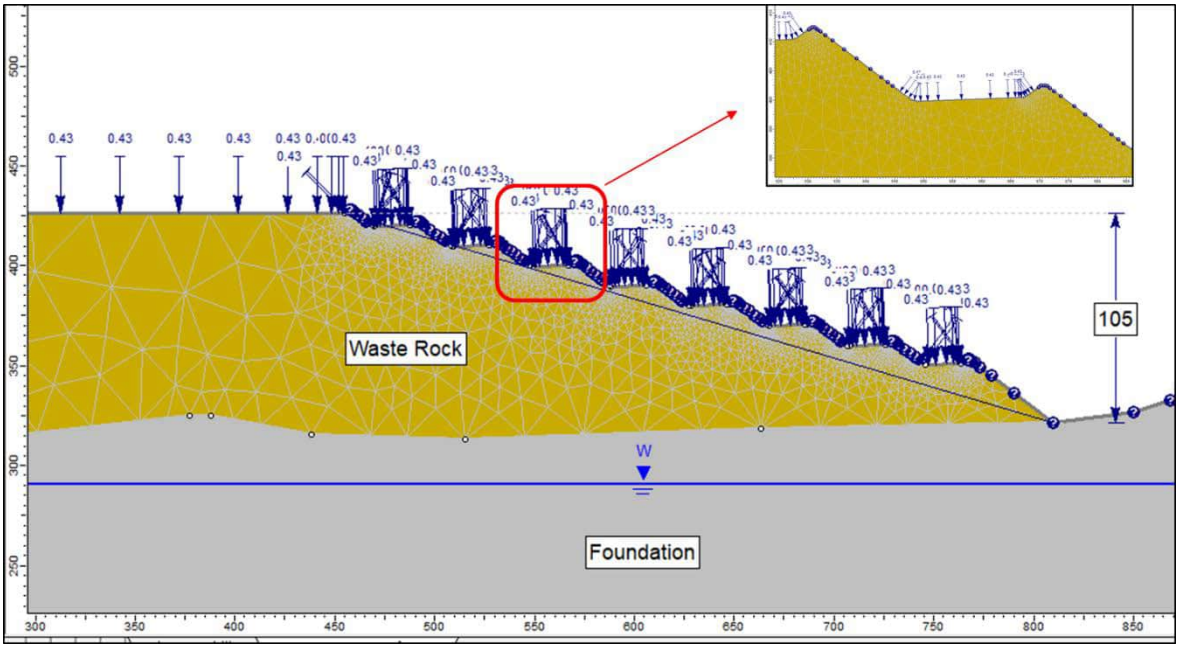


Figure 6-7: Sample analysis section for closure design seepage and stability analyses (Section 1)

6.3.2 Stability analyses

Deterministic stability analyses were undertaken for circular and non-circular slip surfaces using various search options to assess inter-ramp and overall slope instabilities. The lower inter-ramp slope section in Section 2 was assessed for stability due to relatively steep high slope design. Instabilities associated with WRD foundation interactions were also assessed for the design waste rock units. The non-circular slip surface used the GLE/ Morgenstern-Price slice method, considered the most analytically rigorous method, was chosen for the final analyses as it provided the lowest minimum FoS. Analyses were conducted for the following scenarios:

- Drained – Static
- Using pore pressure of 1 in 500-year 24-hour storm event – Static
- Using pore pressure of PMP 72-hour storm event – Static
- Drained – Pseudo-static (OBE)
- Drained – Pseudo-static (MCE).

Waste material units and shear strength envelopes selected for the design case and sensitivity analyses are presented in Table 6-1.

6.3.3 Results of analyses

The results of the stability analyses for overall slope slip surfaces within WRD materials are presented in Table 6-5 for each scenario considered, and graphically presented in Figure 6-8. The reported FoS values are well in exceedance of the acceptance criteria for both the design and sensitivity analysis scenarios, due to the shallow overall slope angles of the WRD designs. The results (plots) for design cases analyses of Section 1 and 2 are presented from Figure 6-9 through to

Figure 6-12.

Table 6-6 presents the stability results for lower inter-ramp slope sections under various scenarios. As presented, the design acceptance criteria were not met for either of the design materials. A sensitivity analysis with high strength Fresh BIF (Eastern limb C fresh BIF as shown in Figure 3-1) indicates that the stability of the slope is reasonably acceptable due to its limited span in the overall dump footprint.

The FoS results of slip surfaces interacting with foundation materials are presented in Table 6-7. The FoS values in each scenario analysed far exceed the acceptance criteria and are higher than FoS of the corresponding analyses of slip surfaces through WRD materials.

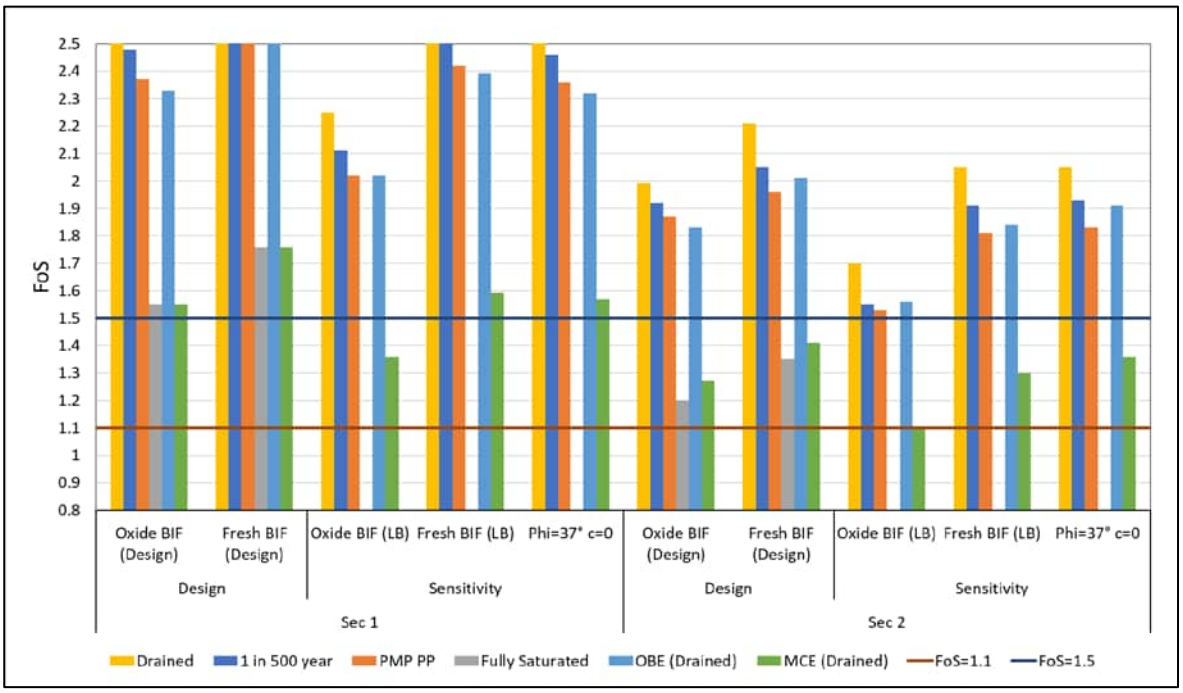


Figure 6-8: Results of stability analyses

Table 6-5: Stability analysis results for overall slope – Slip surfaces within WRD materials

Section	Analyses case	Material	FoS – Static				FoS – Pseudo-static	
			Drained	1 in 500-year PP	PMP PP	Fully Saturated	OBE (Drained)	MCE (Drained)
Sec 1	Design	Oxide BIF (Design)	2.62	2.48	2.37	1.55	2.33	1.55
		Fresh BIF (Design)	2.87	2.75	2.62	1.76	2.58	1.76
	Sensitivity	Oxide BIF (LB)	2.25	2.11	2.02	-	2.02	1.36
		Fresh BIF (LB)	2.66	2.53	2.42	-	2.39	1.59
		Phi=37° c=0 kPa	2.59	2.46	2.36	-	2.32	1.57
Sec 2	Design	Oxide BIF (Design)	1.99	1.92	1.87	1.2	1.83	1.27
		Fresh BIF (Design)	2.21	2.05	1.96	1.35	2.01	1.41
	Sensitivity	Oxide BIF (LB)	1.7	1.55	1.53	-	1.56	1.1
		Fresh BIF (LB)	2.05	1.91	1.81	-	1.84	1.3
		Phi=37° c=0	2.05	1.93	1.83	-	1.91	1.36

Table 6-6: Stability analysis results for lower inter-ramp slope section (Section 2)

Section	Material	FoS – Static			FoS – Pseudo-static	
		Drained	1 in 500-year PP	PMP PP	OBE (Drained)	MCE (Drained)
Sec 2	Oxide BIF (Design)	1.15	-	-	1.08	0.83
	Fresh BIF (Design)	1.28	-	-	1.23	0.93
	High strength Fresh BIF (Design)	1.36	1.36	1.35	1.28	~1 (1.1*)

* FoS value if one third of PGA is used

Table 6-7: Stability analysis results - foundation interaction

Section	Material	FoS – Static		FoS – Pseudo-static	
		Drained	Fully Saturated	OBE (Drained)	MCE (Drained)
Sec 1	Oxide BIF (Design)	2.87	1.93	2.64	1.88
	Fresh BIF (Design)	3.15	2.1	2.86	2.02
Sec 2	Oxide BIF (Design)	2.28	1.63	2.15	1.63
	Fresh BIF (Design)	2.41	1.75	2.26	1.74

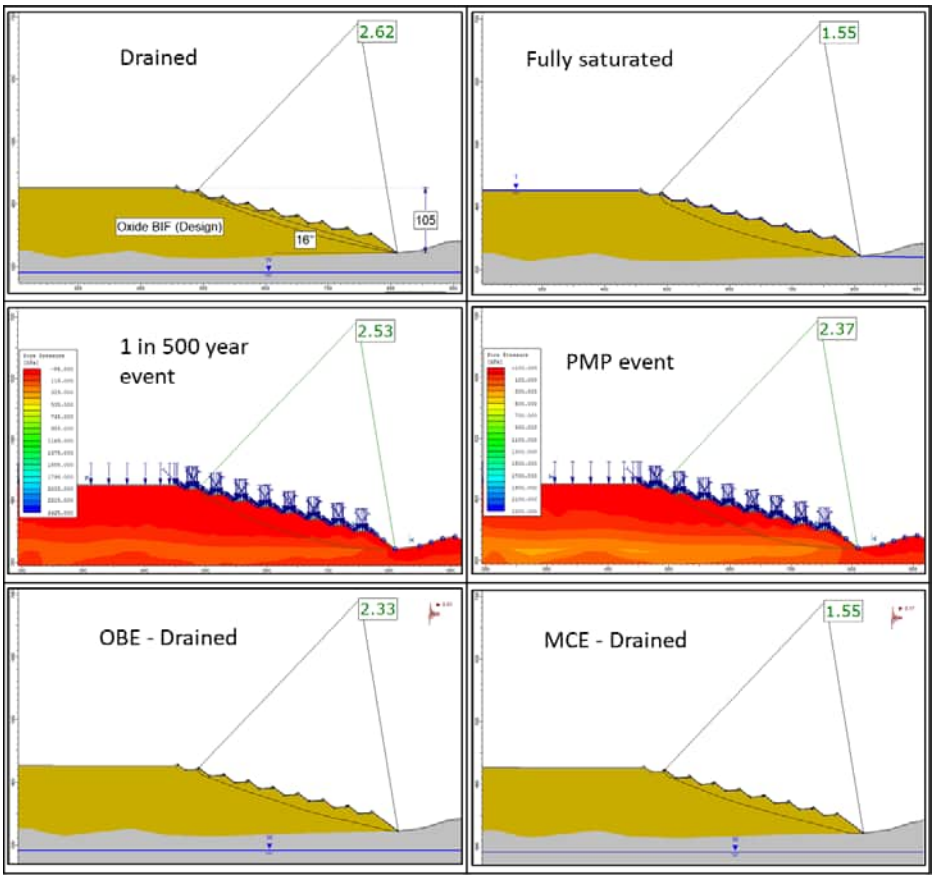


Figure 6-9: Results (plots) of various analysis scenarios for Oxide BIF− Section 1

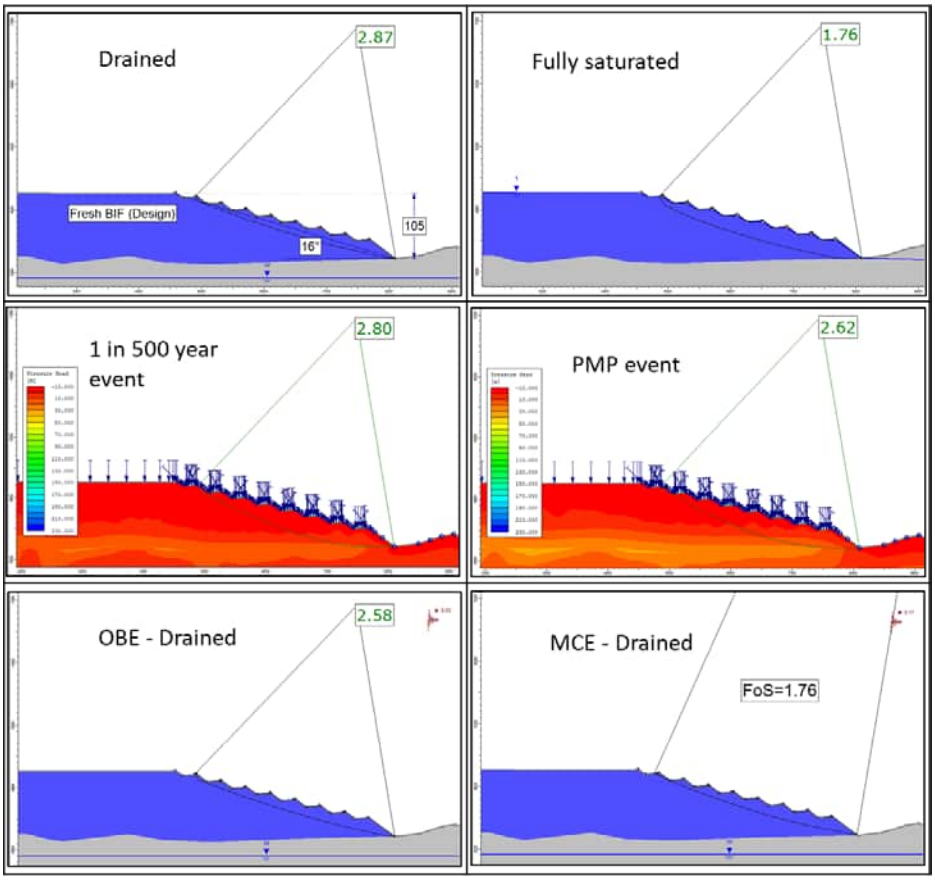


Figure 6-10: Results (plots) of various analysis scenarios for Fresh BIF− Section 1

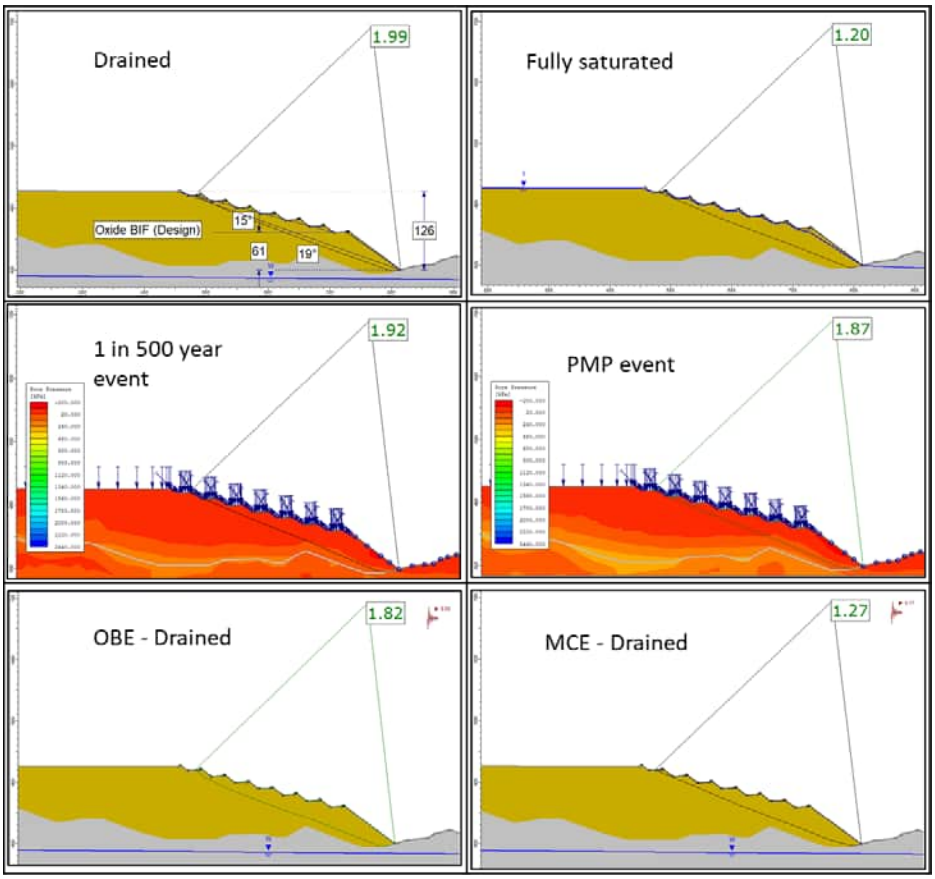


Figure 6-11: Results (plots) of various analysis scenarios for Oxide BIF− Section 2

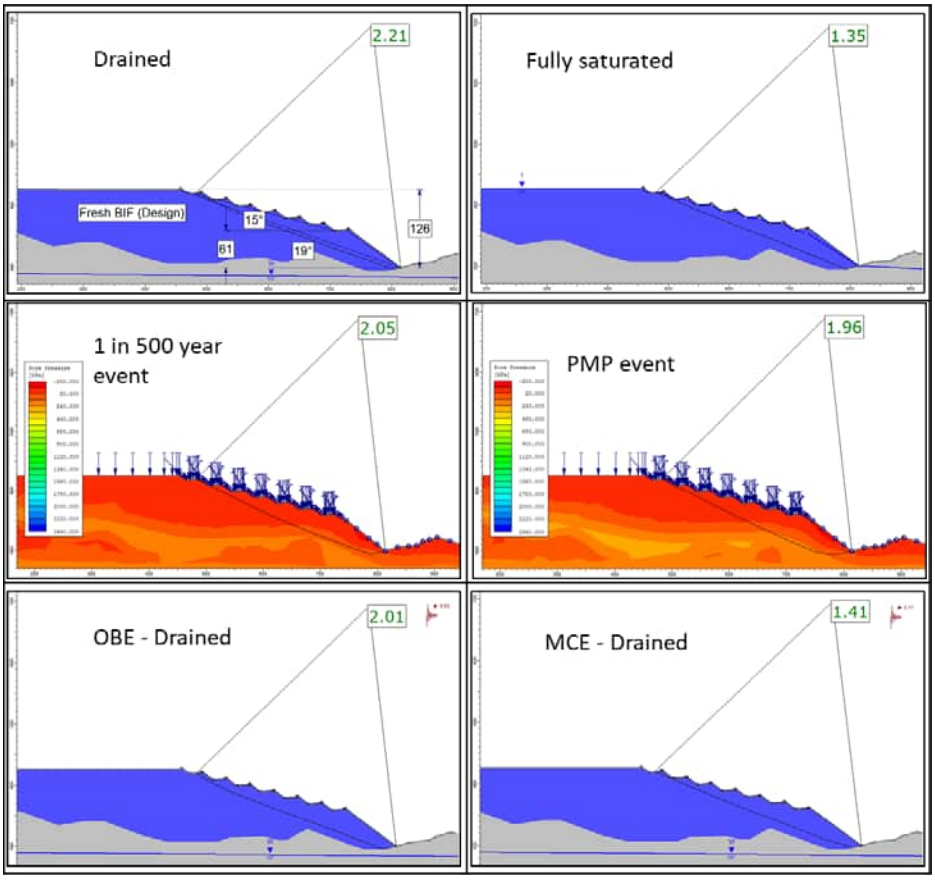


Figure 6-12: Results (plots) of various analysis scenarios for Fresh BIF− Section 2

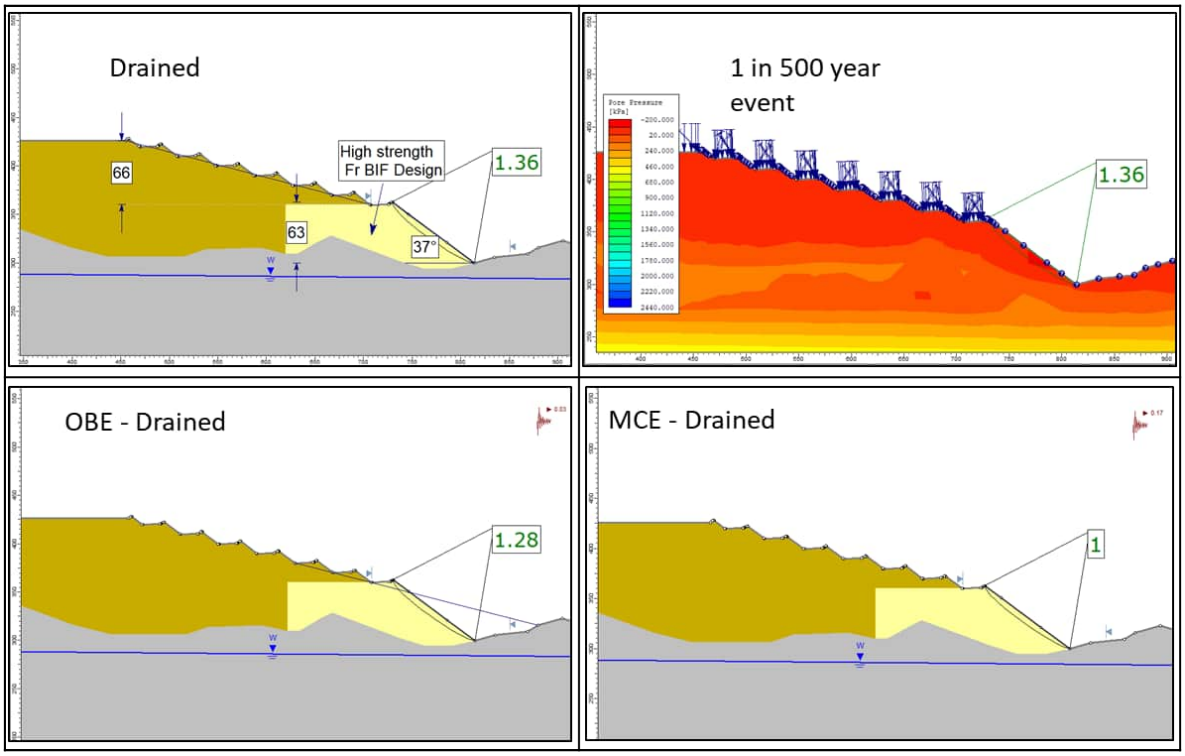


Figure 6-13: Results plots for lower inter-ramp (Section 2); a) Fresh BIF (High Strength)

7 Conclusion

As part of the Stage 1 study, non-linear shear strength envelopes were developed characterising various waste rock materials for the Iron Bridge WRD, and the developed envelopes facilitated effective closure design assessments using representative (design) and conservative (lower bound) material strength parameters. The assessments using lower bound strength provided increased confidence in the outcomes of the study.

Detail material characterisation for the WRD foundation was not performed; however, overall observation of the WRD foundation conditions (made during a one-day site visit by SRK and from the topographical wireframe review) suggests that they are in general competent, with minimal loose material cover. Therefore, a site investigation for characterisation of foundation materials was not considered necessary at this stage due to its insignificant impact on the WRD stability.

Geotechnical stability assessments of the Iron Bridge WRD were conducted for the closure designs and operational conditions. The infiltration and stability assessments conducted for all possible scenarios, including extreme events (e.g. MCE and PMP flood events) indicated a very stable closure landform, with FoS for the overall slopes far exceeding the required stability acceptance criteria. Along a limited span of the overall WRD footings, lower inter-ramp slope sections were designed as a continuous slope of height ranging from 30 m to 60 m, and these slope segments present inadequate stability for the materials properties considered for the analyses. However, the slope assessment using high strength BIF materials (Eastern limb C fresh BIF) present acceptable stability results. For operational construction of the WRD, tipping height analyses incorporating truck weight resulted in a guiding chart being compiled from which IB Operations can select maximum operational lift heights for various waste rock units.

8 Recommendations

A number of assumptions were made in the process of developing the non-linear shear strength envelopes of various waste rock materials. It is therefore recommended that the design parameters of waste rock materials and the stability requirements be reviewed and updated during operations, as necessary. Performance of waste materials in the actual WRD during operations will be used for verification of the study outcomes. Based on operational slope performance, stability for the maximum tipping height should be re-assessed due to expected variability of free-tipping slope angles (angles of repose).

Based on SRK's limited site observation and topographical review, the foundation conditions were suggested to be competent. For the purpose of stability assessment, lower bound rock mass parameters of Oxide BIF were used at this stage. However, if any materials significantly weaker than the lower bound Oxide BIF is identified in any influential zones, reviews of material parameters through site investigations and updated stability assessment may then be required.

Along limited spans of the overall WRD footing, lower inter-ramp slope sections were designed as continuous slope of height ranging from 30 m to 60 m. It is strongly recommended that these parts of the slope be constructed using very high strength BIF materials (e.g. Eastern limb C fresh BIF) to achieve reasonably acceptable stability. The developed shear strength parameters of high strength BIF need to be verified when the material is available. Limiting the slope height to 30 m or less is considered to be a better option.

It is recommended that any significantly weak waste materials (e.g. Oxide Kangaroo Cave Shale) be paddock-dumped and encapsulated away from the WRD slope structure to prevent instability issues arising. Encapsulating any material identified as inappropriate for exposure due its physical nature (e.g. PAF waste) within the interior of the WRD is also recommended.

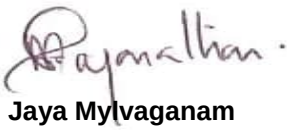
As waste rock particles tend to break due to increased confinement, large-scale testing on blasted samples will generally allow better representation of the likely field performance. The height of the Iron Bridge WRD is approximately 100 m, and associated confining pressures are not expected to be exceptionally high. In addition, the overall stability of the dump significantly exceeds the design acceptance criteria, and therefore, large-scale testing is not required at this stage. However, if the dump heights are significantly more than planned, then large-scale testing may be necessary.

Many instability development warnings such as increased rate of deformation, cracking, bulging, seepage on the face in the WRD can be observed visually, and therefore routine or periodic visual inspection is recommended for identifying any developing instability. In addition to visual monitoring, displacement monitoring using instrumentation and surface water and groundwater monitoring can be implemented, as required. The slope performance monitoring should be carried out periodically during operation, rehabilitation and after closure to ensure operational and long-term slope stability, safety, the absence of any significant erosion or settlement, and environmental protection. If observed, it will be necessary to remediate defects or cracks, to avoid major uncontrollable erosion or slope failures precipitated by erosion.

Yours faithfully

SRK Consulting (Australasia) Pty Ltd

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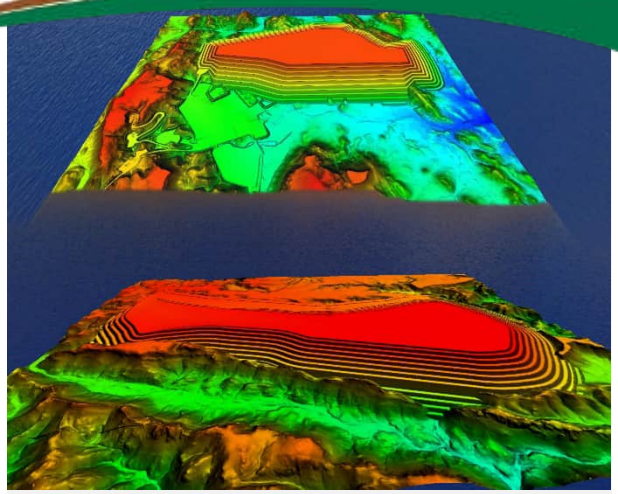
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Appendix 9: Landloch: Landform Evolution Modelling



LANDFORM EVOLUTION MODELLNG – NORTH STAR WASTE ROCK DUMP & DRY REJECTS LANDFORMS

Iron Bridge Operations Pty Ltd

19 October 2020

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Client: Iron Bridge Operations Pty Ltd

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1 INTRODUCTION

Landloch Pty Ltd (Landloch) were engaged by Iron Bridge Operations Pty Ltd (Iron Bridge) to undertake SIBERIA landform evolution modelling for two rehabilitation landform designs at the North Star Project (North Star) including:

- Waste Rock Dump (WRD) which sits in a landscape block ~3.5km x 1.7km; and
- Dry Rejects Landform (DRL) which sits in a landscape block ~3.0km x 1.4km.

North Star is located approximately 110km south-east of Port Hedland. This report presents the outcomes of the SIBERIA modelling for the two landform designs.

1.1 Background

Landloch completed a study of the physical properties of Iron Bridge's waste materials including the dry rejects, oxide wastes (oxides), and tailings (Landloch 2018). Erodibility parameters for the WEPP model were derived for the oxides as part of this study. These parameters were used to develop a range of rehabilitation batter designs for closure. The results of the 2018 study indicated:

- The oxides are sensitive to slope length and gradient. For angle of repose slopes, the predicted long-term erosion rates decrease dramatically as slope length reduces. For linear (uniform gradients) lifts of similar height, erosion rates reduce as gradients decrease.
- The oxides respond favourably to the use of concave slope profiles, with batter heights up to 30m being assessed to be erosionally stable (when the appropriate concave gradients are used).
- The effective hydraulic conductivity of the dry rejects is similar to that of the oxides. As such, the risk that the oxides will slip from a surface underlain by dry rejects during large rainfall events is low.
- For the recommended batter profiles to be stable and sustainable, it will be crucial to retain runoff on the top of the rehabilitated landforms.
- To achieve long-term stability of the batter slopes it is critical that flow concentration be minimised.

Iron Bridge has reviewed the options for closure of the WRD and DRL in light of the outcomes of the 2018 study. As a result, Iron Bridge are considering using oxide to cover the waste landforms at North Star. The objective of this study is to use existing oxide waste characterisation information and existing modelling results to derive input parameters for the SIBERIA landform evolution model. These parameters were then used to model long-term performance of closure landform design options for the WRD and DRL.

2 LANDFORM DESIGNS

2.1 North Star – WRD

The modelled North Star WRD design used a bench/batter design with each batter approximately 12m in height (including a 2 m crest bund), with a 37° linear slope (Figure 1). Benches were typically 20m wide with a 2° backslope with a 5 m wide (base-width) crest bund. Crest bunds were located on the outer edge of each bench and on the outer edge of the landform top. The top of the WRD was sloped towards the centre at a uniform 1° gradient. Other features of the design included several access ramps, and a large flat section on the western side that fills in the valley between the WRD and the active mine areas and will be used as a staging area for mining purposes.

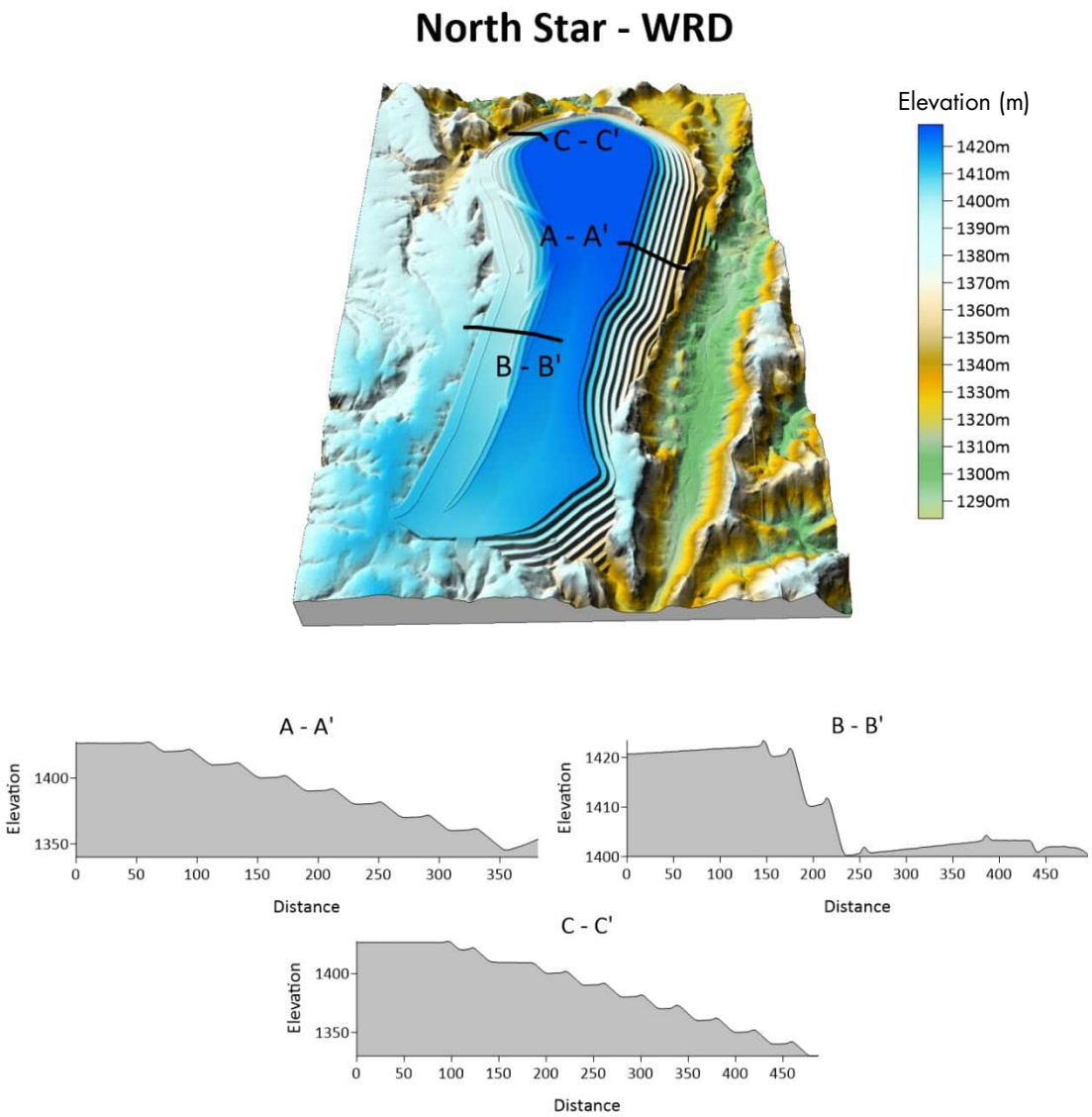


Figure 1: North Star WRD modelled design.

2.2 North Star – DRL

The North Star DRL is intended to be encapsulated in waste rock to achieve the long-term closure design. This is expected to involve the tipping of waste rock around the outside of the DRL before reshaping or otherwise managing the waste rock (not the dry rejects) to achieve the closure design. Thus, the performance of slopes on the DRL will be the same as the WRD slopes when the same bench/batter configurations are used. The North Star DRL was, therefore, designed to evaluate and compare the performance of materials left at angle of repose (i.e. the WRD 37° linear slope) against a 'typical rehabilitation' 18° linear slope.

The northern edge of the modelled North Star DRL design used a bench/batter design with each batter approximately 12m in height (including a 2 m crest bund), with an 18° linear slope (Figure 2). The same design configuration using a 37° linear slope was used on the other sides of the North Star DRL design. Benches were typically 18m wide with a 2° backslope and 10m wide (base-width) crest bund. Crest bunds were located on the outer edge of each bench and on the outer edge of the landform top. The top of the DRL was flat (zero gradient).

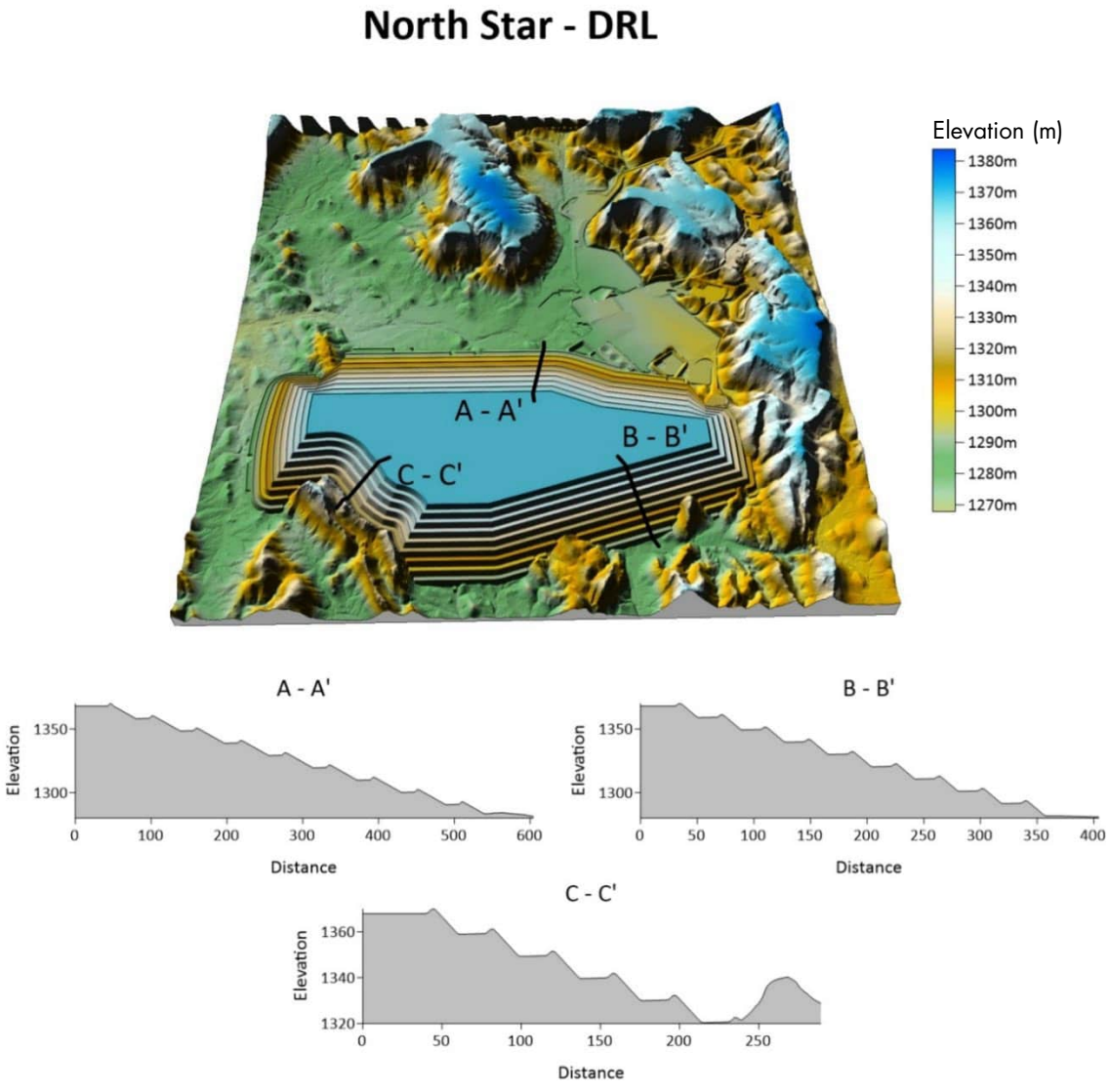


Figure 2: North Star DRL modelled design.

3 SIBERIA LANFORM EVOLUTION MODEL

The SIBERIA landform evolution model is a 3-dimensional topographic model that predicts the long-term development of channels and hillslopes in a catchment on the basis of runoff, erosion, and deposition. The location and speed with which rills and gullies develop is controlled by a channelisation function. SIBERIA does not input actual rainfall or material erodibility parameters. Rather, the input parameters define this channelisation function that is related to both runoff and soil erodibility (Willgoose *et al.* 1989) and must be derived for each particular material at each particular site. SIBERIA solves for two variables:

1. Elevation, from which slope geometries are determined, and
2. An indicator function that determines where channels exist.

Channel growth is governed by an activation threshold that is dependent on discharge and slope gradient. When the activation threshold is exceeded, a channel is predicted to develop. In this way, it is possible for a modelled surface to initially have no gullies, and for channels to develop when the activation threshold is exceeded over time.

The model is equally applicable to any climatic regime as its input parameters are derived by calibration to runoff and erosion data. Input parameters can be derived from output from the WEPP model using methods developed by Landloch in consultation with the developers of SIBERIA.

SIBERIA has been successfully applied to explain aspects of geomorphology of natural landforms (Willgoose 1994) and has been extensively used in the context of mining and subjected to extensive validation. In general, the validation work indicates that provided the model is adequately calibrated, SIBERIA predictions of landform development appear to be reasonable (Hancock *et al.* 2000, Hancock *et al.* 2002, Hancock *et al.* 2003). In addition, Hancock (2004) notes that rates of erosion predicted by SIBERIA for a catchment in the Northern Territory compared favourably with estimates of erosion derived using the Caesium-137 method. As the two methods used completely independent input information, the agreement is particularly significant.

The SIBERIA model has been widely used for assessment of the development of constructed landforms on a range of mine sites across Australia and overseas (Willgoose 1995, Willgoose and Riley 1993, Boggs *et al.* 2000, Hancock *et al.* 2003, Hancock and Willgoose 2004, Hancock 2004, Mengler *et al.* 2004, Hancock and Turley 2006).

3.1 SIBERIA input parameters

SIBERIA predicts the annual change in elevation of a point by predicting the volume of sediment lost from a node. The rate of sediment transport through a node is determined by the equation:

$$q_s = \beta_1 \times q^{m_1} \times S^{n_1} \qquad 1)$$

where q_s in sediment transport rate (m^3/y), β_1 is the sediment transport rate coefficient, q is discharge (m^3/y), m_1 is the discharge exponent, S is the slope gradient (m/m), and n_1 is the slope exponent.

SIBERIA does not directly model discharge, but uses sub-grid effective parameterisation which relates discharge to area draining through a point as:

$$q = \beta_3 \times A^{m_3} \qquad 2)$$

where q is discharge (m^3/y), β_3 is the coefficient between discharge and area, A is area (m^2), and m_3 is the exponent of the discharge area.

To run SIBERIA, the parameters β_1, m_1, n_1, β_3, and m_3 are needed. All these parameters interact with each other, with the result being that an almost infinite number of parameter sets will give the same rate of erosion, though aspects of the pattern of erosion that is predicted will vary. For this reason, fixed values of n_1, β_3, and m_3 are often adopted for mining landforms calibrated from erosion model data (as is the case for this project). If the surface geometry to be modelled is the same as the geometry for which erosion data are available for calibration, m_3 and β_3 can be taken as 1.0. A value of 1.5 can be used for n_1 for situations where slope gradient does not affect slope erodibility (i.e. armouring). Where steeper slopes are subject to greater armouring, the exponent n_1 may be as low as 0.7 (Evans *et al.* 1998).

Therefore, the two remaining parameters requiring calibration are β_1 and m_1. The β_1 parameter can be thought of as an erosion rate parameter, as it strongly influences the rate of sediment movement. The m_1 parameter primarily controls slope length responses.

3.2 Deriving SIBERIA input parameters

The β_1 and m_1 input parameters for SIBERIA are derived by fitting the SIBERIA model equations to time series data of runoff and erosion. However, in most instances, sufficiently long series of these paired data are not available for the landforms of interest. This is particularly true for landform design planning where the landforms do not yet exist, as is the case for North Star. Therefore, Landloch has developed an alternative approach for developing the required SIBERIA input parameters. The general approach is to:

a) Make measurements of runoff and erosion on materials using laboratory-based flumes to derive calibrated WEPP runoff/erosion model parameters.
b) Run the WEPP model for batter geometries consistent with the geometries used in the landform design under consideration. Generate data sets of runoff and erosion for batter geometries and materials of interest using long (100-years), site specific climate sequences that contain a wide range of rainfall events, including rare and extreme events.
c) Analyse the WEPP runoff and erosion model output and fit to the SIBERIA model equations to derive values for β_1 and m_1.

The input parameters for the North Star oxide waste rock were developed from the laboratory-based assessments of infiltration and erodibility (Landloch, 2018). The key parameters are given in Table 1. These parameters are specific to the oxides at Iron Bridge and cannot be used to represent the erodibility of different materials at Iron Bridge or oxides at sites other than Iron Bridge.

Table 1: SIBERIA parameters for the oxide at Iron Bridge.

Material	β_1	m_1
Oxide waste	0.00046	1.9305

3.3 Model settings

Digital terrain models (DTMs) were provided to Landloch by Iron Bridge for the WRD and DRL. SIBERIA modelling was undertaken for the WRD and the DRL assuming an oxide waste cover. Both the WRD and DRL were run with the oxide parameters applied to the entire surface (including the surrounding natural landscape). It should be noted that predicted erosion of the surrounding natural landscape in the model output figures is unlikely to be consistent with the erosion of the oxides. The intent of this modelling exercise is to consider erosion of the WRD and DRL surfaces only, including the interface between the constructed batters and the natural landscape.

The following SIBERIA outputs were produced:

- Visual outputs showing the evolved DTM and erosion/deposition locations at year 50, 100, 200 and 300;
- Average erosion (t/ha/y) for each output year;
- Cumulative erosion (mm) for the simulated period; and
- Maximum (largest ~5% excluding outliers) depth of gullies at each output year (minimum depth of 0.3m used to define a gully).

The output from the SIBERIA model runs were processed to produce a series of visualisations for each model run. For each model run, visualisations of the erosion and deposition on the modelled surface are given, with scaling to show erosion/deposition ±0.25m in yellow, deposition >0.25m in blue, erosion 0.25-0.5m in red, and erosion >0.5m in cyan.

4 RESULTS

4.1 WRD

Results for the WRD simulations conducted with oxide model parameters applied to the surface are provided in Table 2 and Figures 3 and 4.

Table 2: Maximum gully depth, average erosion, and cumulative erosion for the WRD with oxide wastes applied to the surface.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
50	<0.3	2.8	9.6
100	<0.3	2.8	19
200	0.6	3.0	39
300	1.0	3.2	61

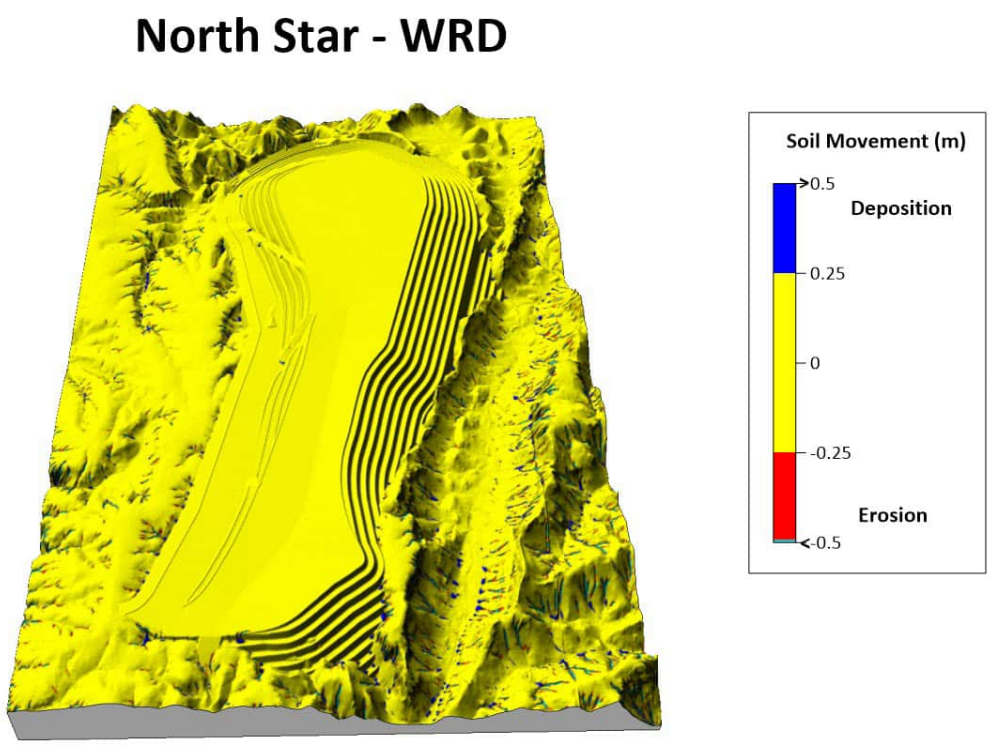


Figure 3: WRD after 50 years (top image) and 100 years (bottom image) of simulation with erosion >0.25m in red, erosion >0.5m in cyan, and deposition >0.25m in blue.

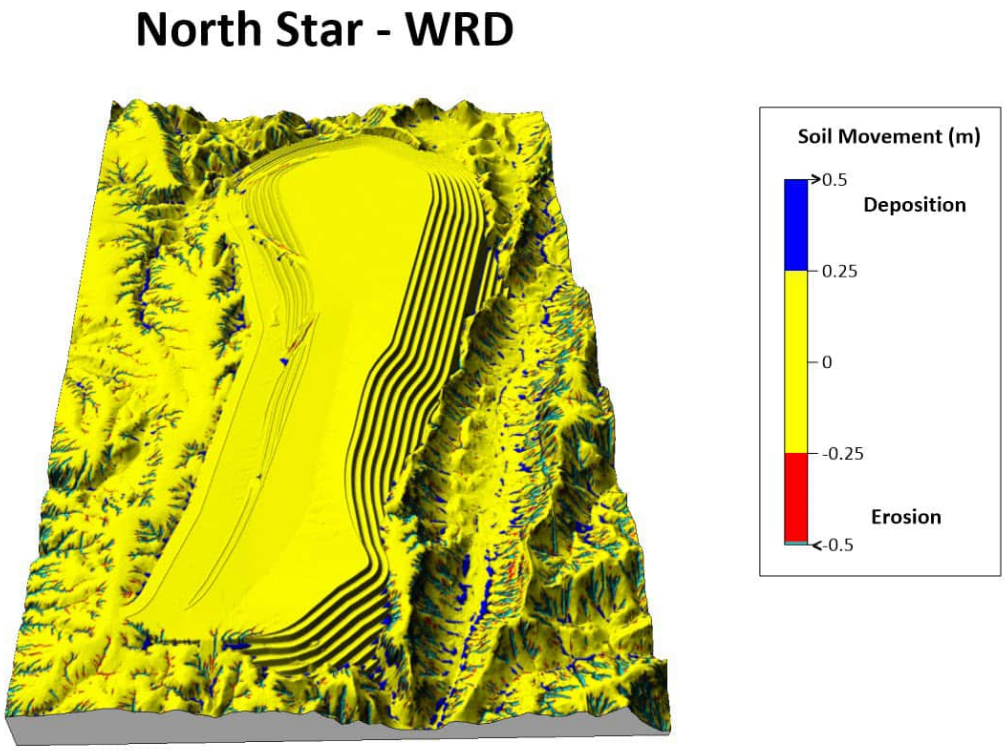


Figure 4: WRD after 200 years (top image) and 300 years (bottom image) of simulation with erosion >0.25m in red, erosion >0.5m in cyan, and deposition >0.25m in blue.

4.2 DRL

Results for the DRL simulations conducted with oxide model parameters applied to the surface are provided in Table 3 and Figures 5 and 7.

Table 2: Maximum gully depth, average erosion, and cumulative erosion for the DRL with oxide wastes applied to the surface.

Simulation year	Maximum gully depth (m)	Average erosion (t/ha/y)	Cumulative erosion (mm)
50	0.3	3.0	9.9
100	0.5	2.9	20
200	0.8	2.9	39
300	1.0	2.8	57

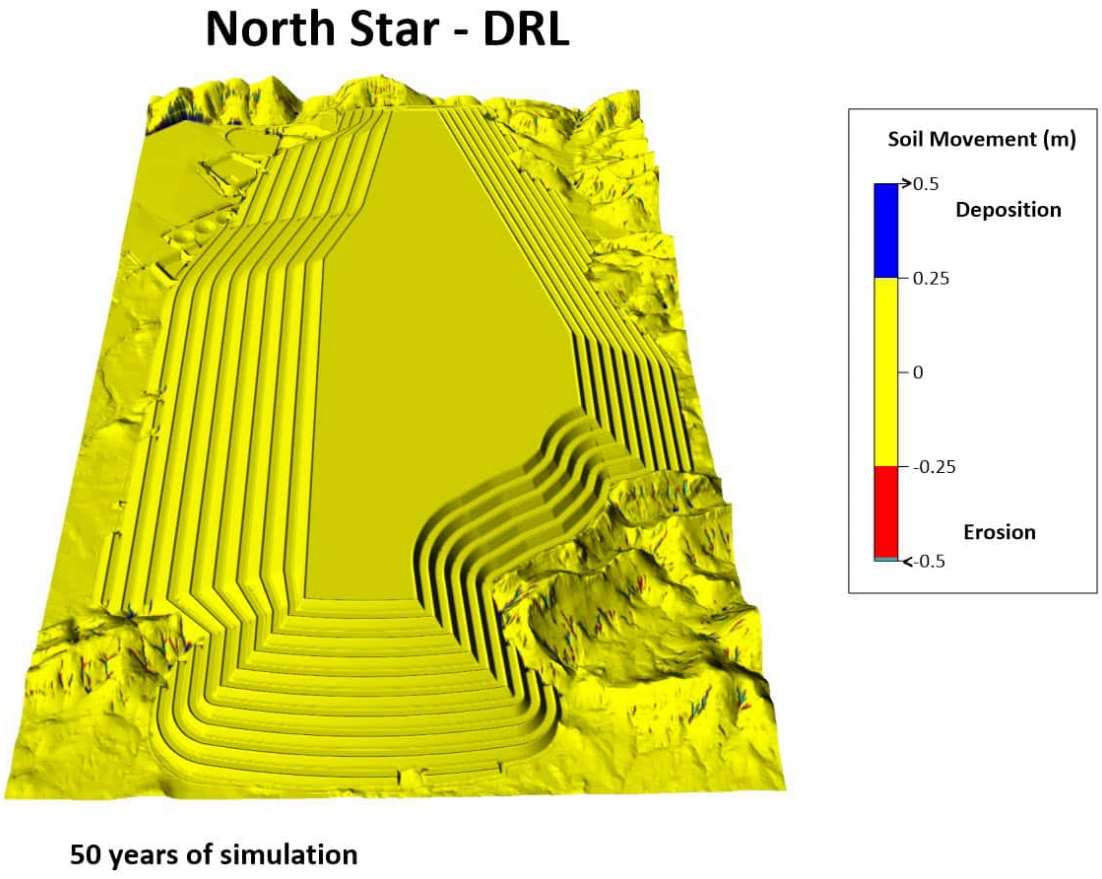
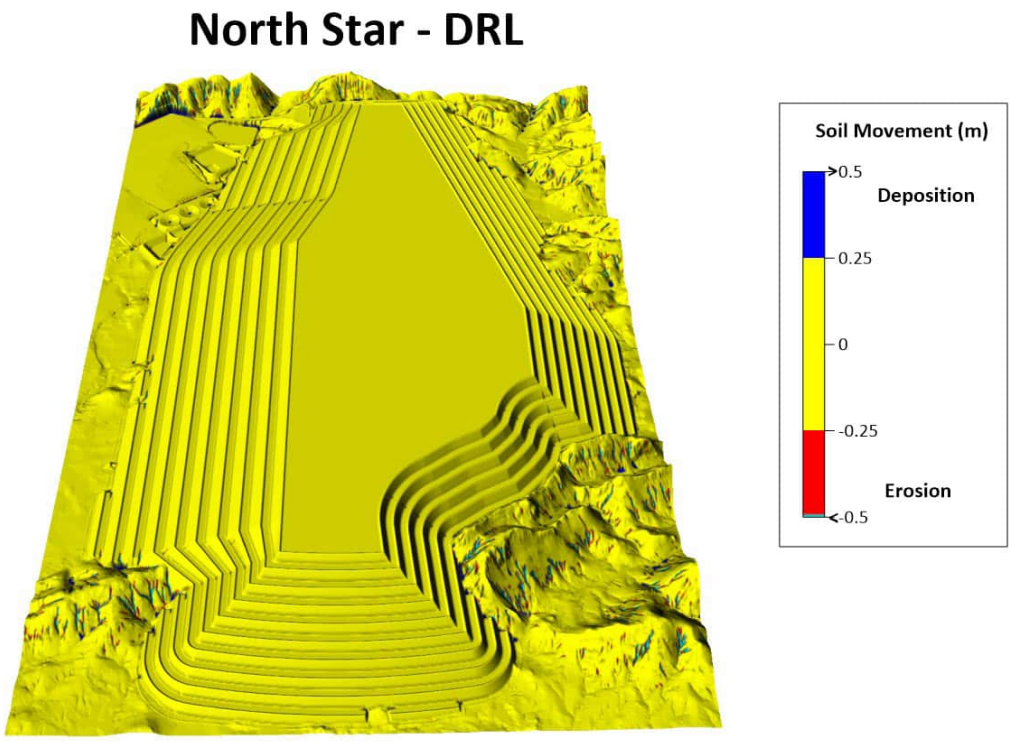
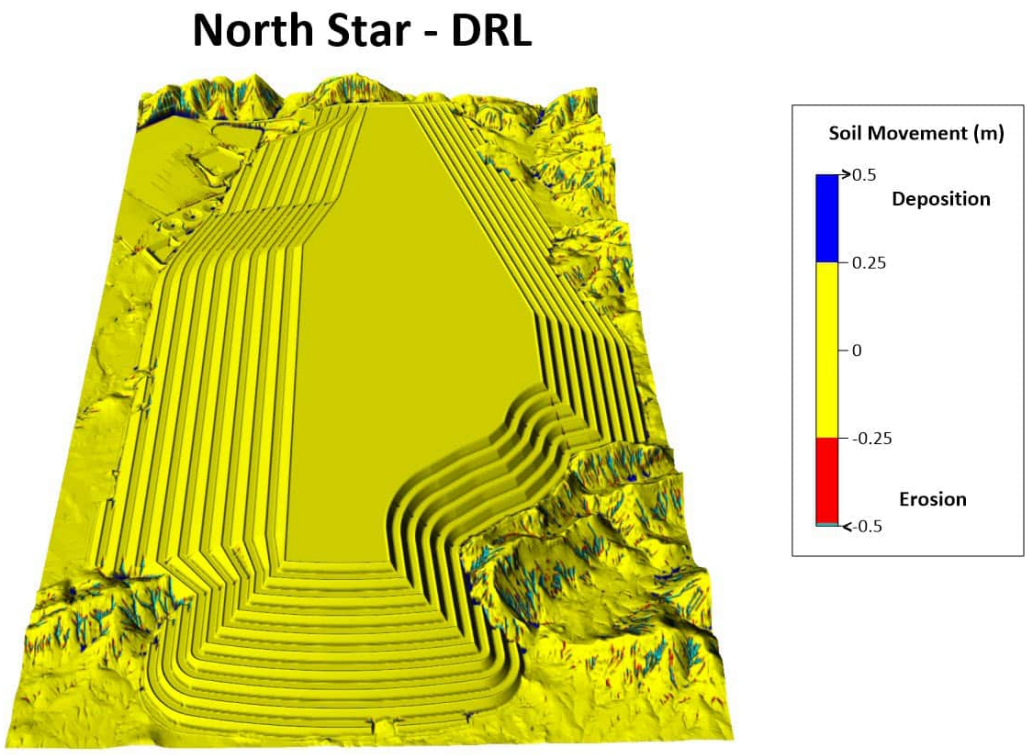


Figure 5: DRL after 50 years of simulation with erosion >0.25m in red, erosion >0.5m in cyan, and deposition >0.25m in blue. 18° linear slope to the left and 37° linear slope to the right.



100 years of simulation



200 years of simulation

Figure 6: DRL after 100 years (top image) and 200 years (bottom image) of simulation with erosion >0.25m in red, erosion >0.5m in cyan, and deposition >0.25m in blue. 18° linear slope to the left and 37° linear slope to the right.

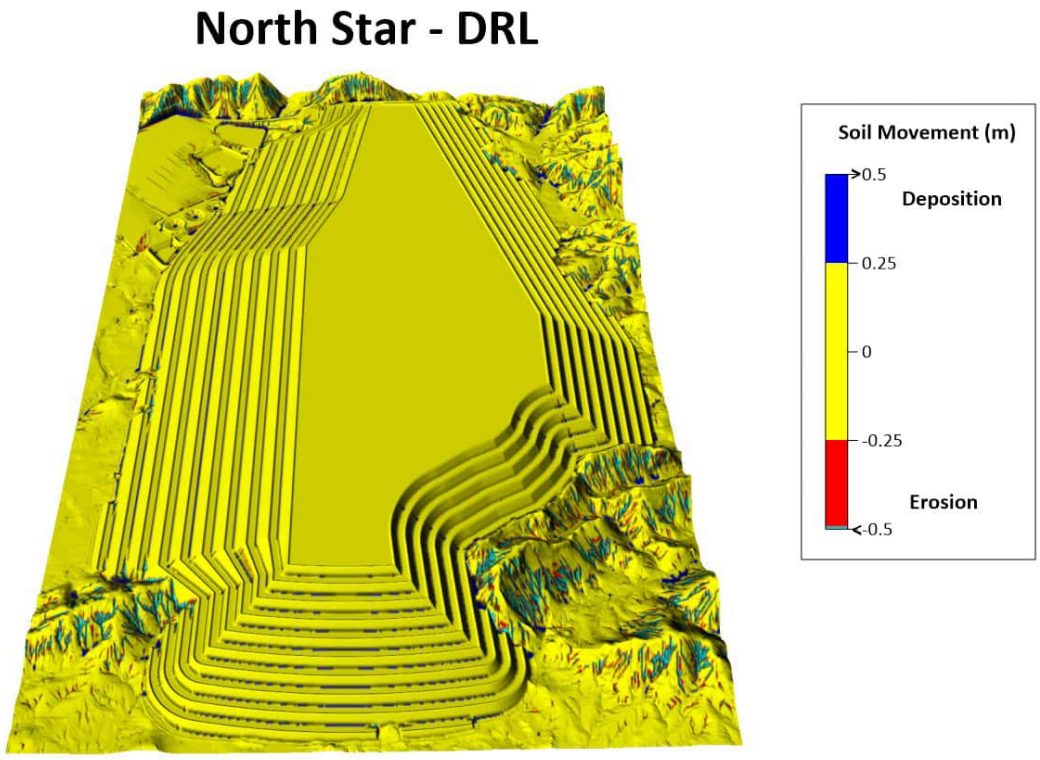


Figure 7: DRL after 300 years of simulation with erosion >0.25m in red, erosion >0.5m in cyan, and deposition >0.25m in blue. 18° linear slope to the left and 37° linear slope to the right.

5 DISCUSSION

5.1 WRD

The average erosion rate was 2.8t/ha/y at year 50 and increased to 3.2t/ha/y by year 300. Gullies developed by year 200 at a depth of 0.6m and increased to 1.0m by year 300. Prior to year 200, no gullies greater than 0.3m deep were predicted to occur. An average soil loss of the batter slopes (i.e. excluding the WRD top and the surrounding landscape) of 61mm was predicted by year 300.

The top of the WRD was free of erosion features except for the southern edge, where gullies formed on the interface between the top of the WRD and the natural landscape. The formation of an extensive gully network at this location (Figure 8) was likely to be driven by surface water flow concentration.

Aside from isolated locations (e.g. around the ramps), there was no evidence of rill or gully formation on the batter slopes. The modelled batter and bench design with crest bunds successfully trapped all water and sediment on the bench, contributing to an overall low rate of erosion.

Crest bunds were missing from the access ramps on the western side of the WRD. By year 300, long and deep gullies had formed on the ramps as a result. In some areas, this also impacts on the nearby batter slopes with gully erosion occurring from the interaction between the ramp and batters (Figure 9).

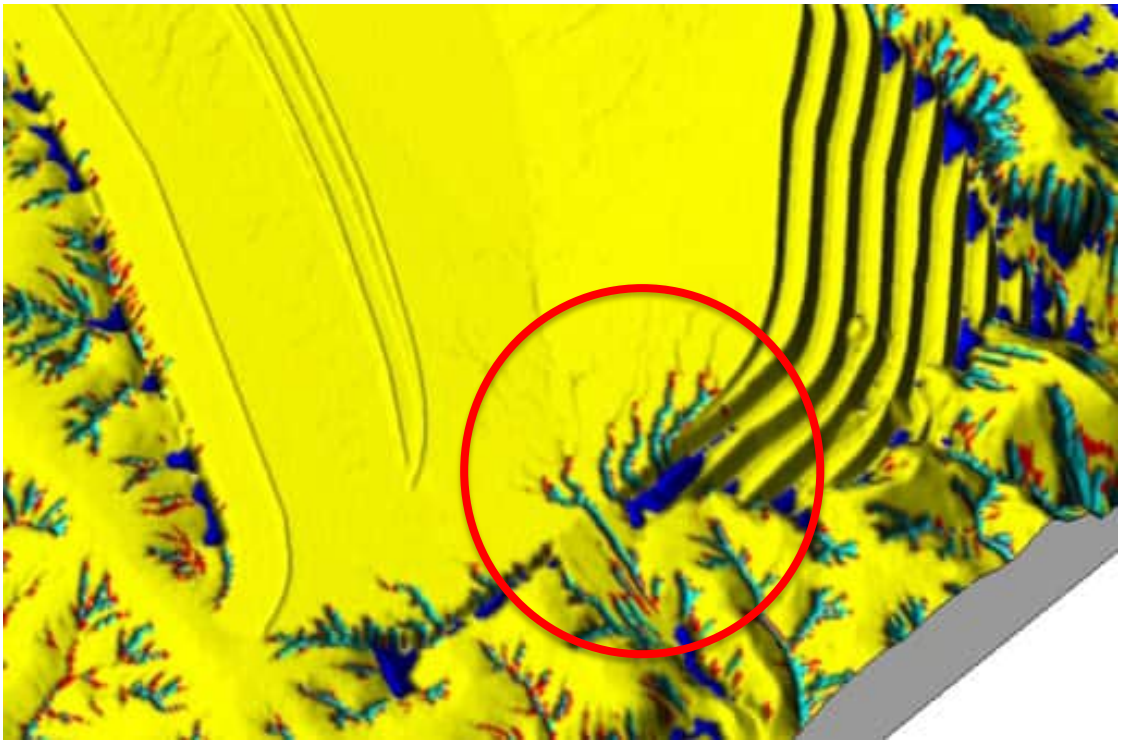


Figure 8: Gully network development on the southern section of the WRD top.

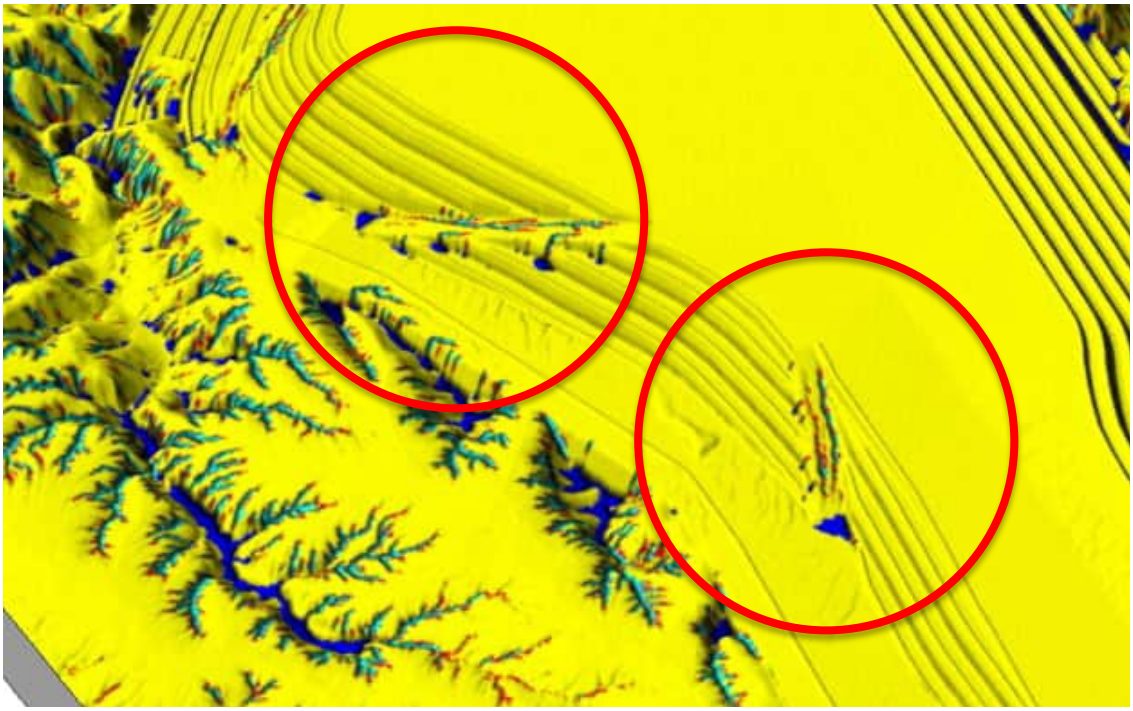


Figure 9: Gully network development on the two western ramps on the WRD.

5.2 DRL

The average erosion rate was 3.0t/ha/y at year 50 and decreased to 2.8t/ha/y by year 300. Gullies developed by year 50 at a depth of 0.3m and increased to 1.0m by year 300. An average soil loss of the batter slopes (i.e. excluding the DRL top) of 57mm was predicted by year 300.

The batter slope options performed similarly and were stable regardless of the batter angle used.

The top of the DRL was free of erosion features and appeared to be performing well.

Gully erosion was predicted to occur in locations associated with localised changes in landform shape:

- There were erosion features present at the toe of the slope on the interface between the 18° batter slope and the existing infrastructure (Figure 10).
- There were also some erosion features visible in Figure 10 directly upslope of the infrastructure areas. These features were investigated and found to be artefacts of the DTM gridding and should be disregarded.
- Erosion features occurred on the interface between the batter slopes and the natural surface (Figure 11) and in convergent zones of the landform (Figure 12) that concentrated surface water flows (e.g. sections with concave plan curvatures[1]).

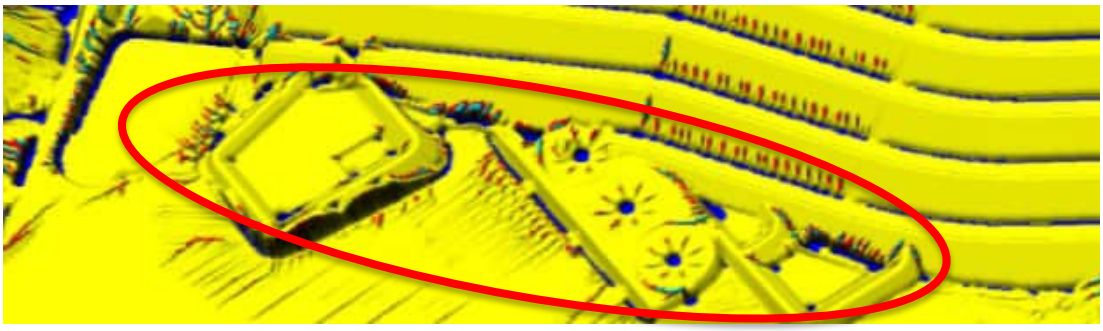


Figure 10: Gully network development on 18° batter slopes located near to the existing infrastructure on the DRL.

[1] Appendix A provides a visual classification scheme for 3D landform shapes.

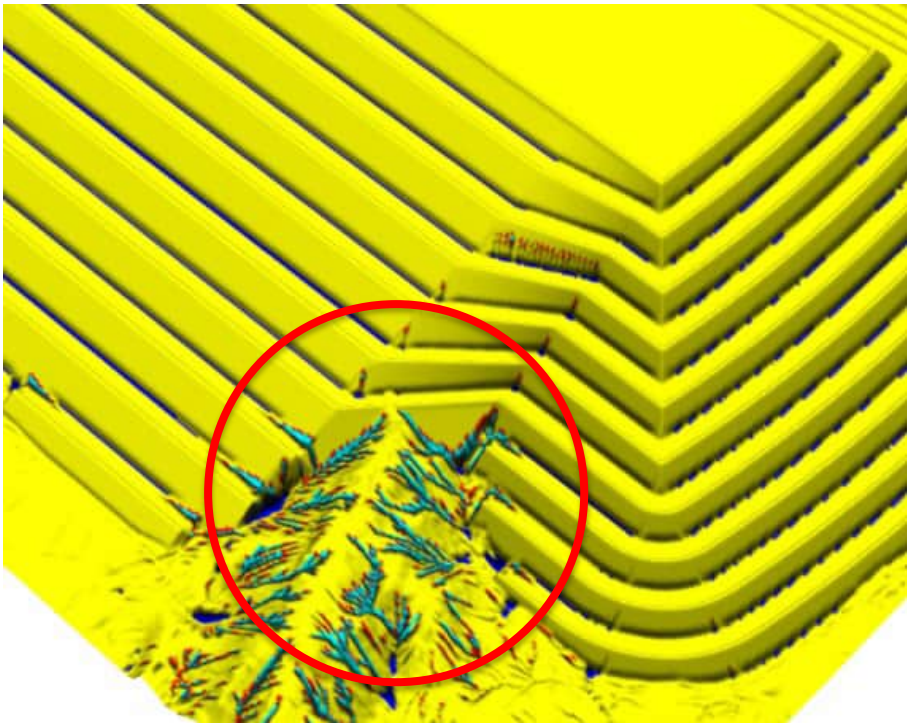


Figure 11: Gully network development on the interface between the 37° linear batter slopes and the natural landscape on the DRL.

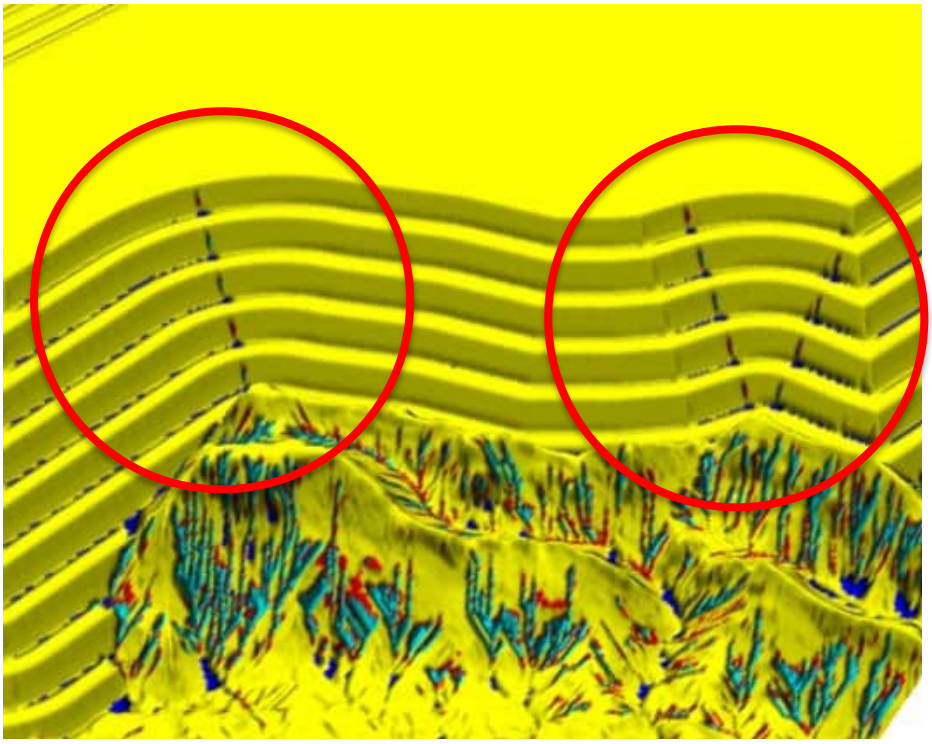


Figure 12: Gully network development on the slope arising due to the convex cross-sectional profile curvature of the DRL landform design.

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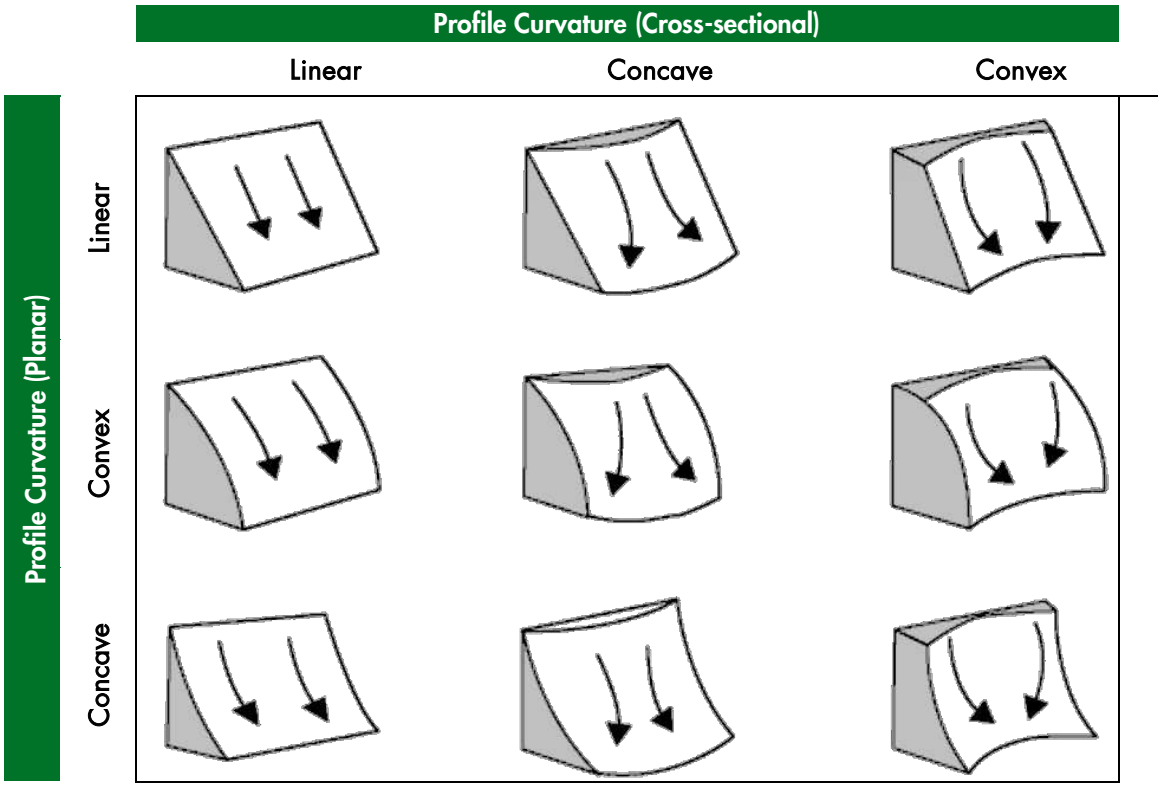
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APPENDIX A: LANDFORM SHAPE CLASSIFICATION SCHEME

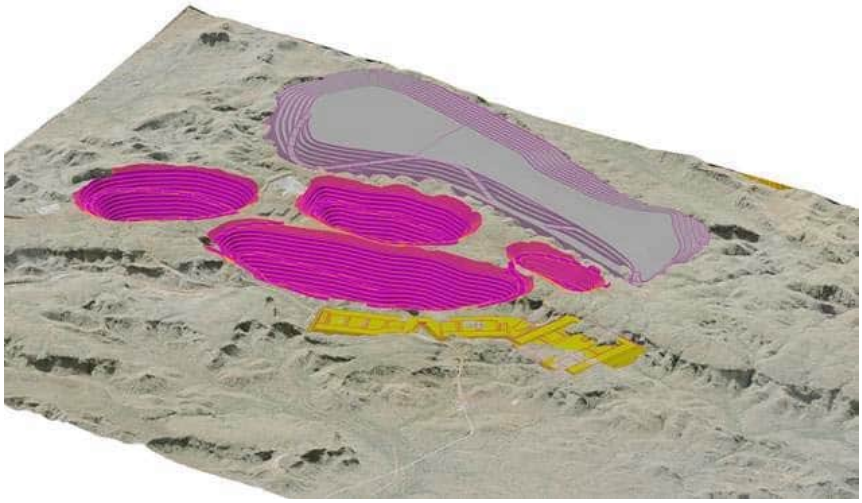


Appendix 10: SRK: Waste Rock Dump Runoff Water Quality Predictions

North Star Magnetite Project – Waste Rock Dump Runoff

Report Prepared for

Iron Bridge Operations



Report Prepared by

SRK Consulting (Australasia) Pty Ltd

FMG060, Report FMG060-4/4

April 2019

North Star Magnetite Project – Waste Rock Dump Runoff

Iron Bridge Operations

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April 2019

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Executive Summary

The North Star Magnetite Project is in the early stages of development. Geochemical studies have been undertaken to support assessment of potential water quality impacts from mining. This report describes geochemical modelling of dump runoff chemistry.

The dump will contain potentially acid forming (PAF) and non acid forming (NAF) waste material. However, the outer surfaces of the dump will comprise only NAF materials. In a companion study documenting modelling of dump seepage quality (SRK, 2019a), solute production rates for PAF and NAF materials were quantified using results from laboratory testing – kinetic (column) tests.

Laboratory-derived reaction rates were scaled or extrapolated for application to the field-scale dump. Runoff chemistries were estimated by:

- Calculating the mass of solute produced on the dump surface in the time elapsed since the last runoff event (two elapsed times were considered: 4 and 52 weeks)
- Dissolving the solute produced in an estimated runoff volume; two runoff extremes were considered – 5 mm and 150 mm – intended to place bounds on the range that might be applicable within a typical year
- Accounting for any relevant mineral and gas interactions, e.g. equilibration with CO_2 in pore gas, precipitation of minerals, reaction of neutralising minerals in contacting mineral assemblages (carbonate- and silicate-based minerals were considered).

Sensitivity calculations examined the influence of scaling factors and macroscopic dump properties on model outcomes.

Based on the modelling, acidic conditions are considered unlikely, on the basis that the dump surface will comprise NAF materials. Even if some small quantities of PAF material contaminate the surface, it is likely that carbonate- and/or silicate-based neutralisation potential would be available to maintain near-neutral pH conditions.

Under extreme conditions, i.e. extended dry periods since the last storm event, combined with low runoff volumes leads to the potential for runoff to contain solutes at concentrations in excess of baseline surface water. However, for most conditions, it is expected that the runoff chemistry will fall within the ranges observed within the water quality monitoring datasets.

For most parameters, 10 times dilution within the downstream environment would be sufficient to bring dissolved concentrations in line with baseline averages for the North Star Magnetite Project.

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Appendix A: SRK memo - Data Review and Gap Analysis

Disclaimer

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

1 Introduction

Stage 1 of the development of the North Star Magnetite Project by Iron Bridge (IB) Operations is in the early stages of development and is focused on mining and processing oxide material. Stage 2 will progress deeper into the orebody with the mining and processing of ore from below the oxide zone.

IB Operations commissioned SRK Consulting (Australasia) Pty Ltd (SRK) to undertake geochemical studies to assess pit water quality and waste rock dump runoff and seepage quality for the proposed mining development. Outcomes of these studies have been documented in a series of reports as follows:

- Waste rock dump seepage assessment
- Dump runoff water quality assessment (this report)
- Pit lake water balance and quality assessment.

A data gap analysis was also completed as part of the overall assessment. The data gap analysis is presented in Appendix A.

This report focuses on modelling of the dump runoff water quality.

2 Project Description

The North Star Magnetite Project includes expansion of the existing North Star (NTS) pit and development of the Eastern Limb North, Central and South pits, a waste rock dump (WRD), tailings storage facility (TSF), low grade ore stockpile (LGOS), crushing and screening hub, magnetic separation processing plant, roads and other associated mine infrastructure. Figure 2-1 shows the current planned layout of the mine area.

The NTS pit is expected to be the deepest pit and the currently proposed pit shell will intersect potentially acid forming (PAF) rock. As mining will take place below the groundwater table, lakes are expected to form within the pits at cessation of operations. Modelling of the long-term hydrogeology near the pits has been completed by IB Operations and indicates that the lakes will represent permanent groundwater sinks in the local hydrogeological environment.

Surface water features of interest are shown in Figure 2-2. The WRD will be designed to shed water runoff water to the south. An assessment of the runoff water quality from the WRD is required to support impact assessments at the downstream pools.

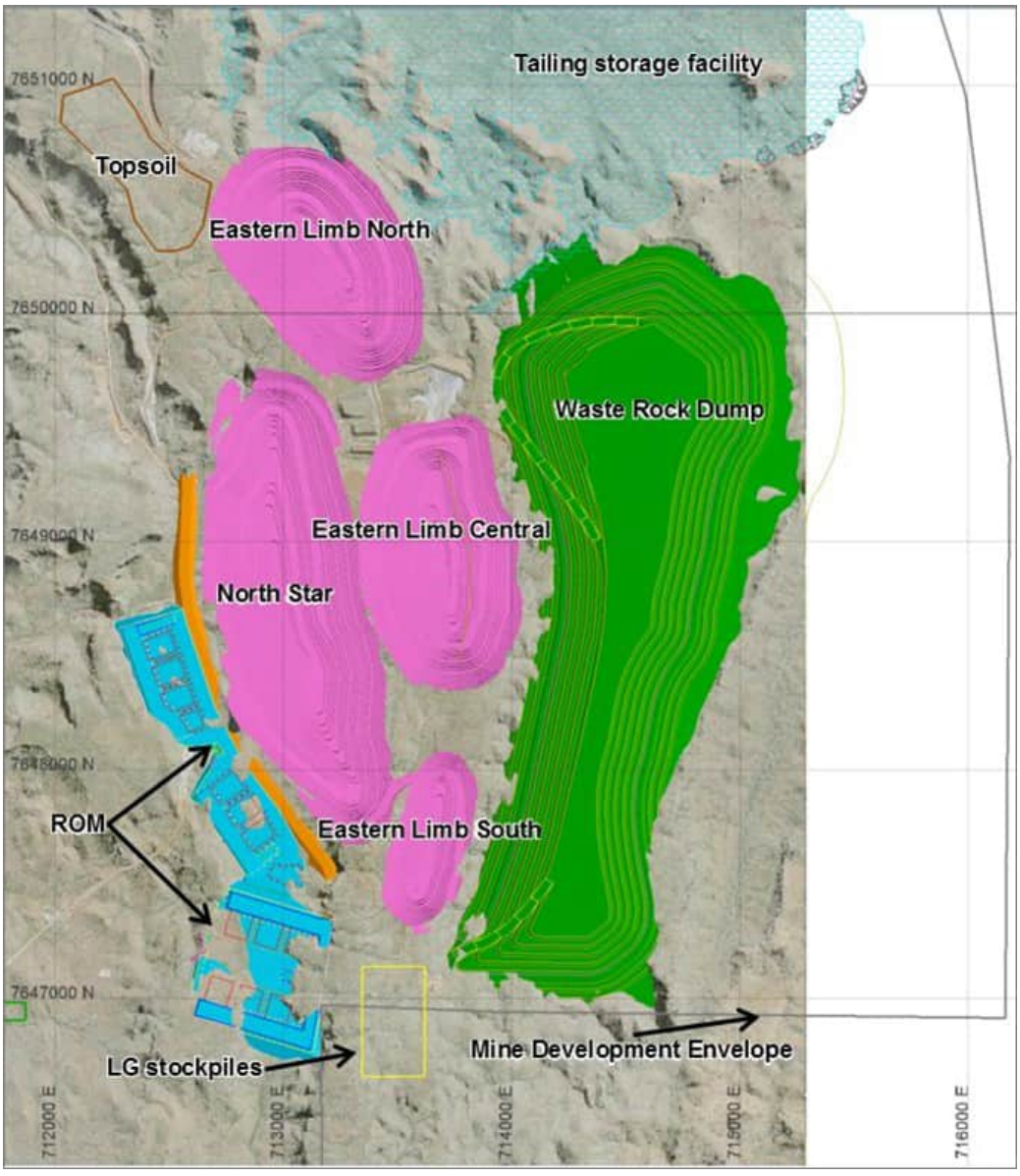
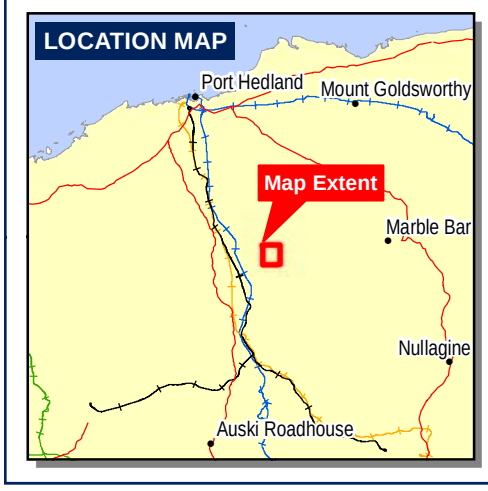


Figure 2-1: Schematic showing current planned layout of the mine area (conceptual only)

Source: IB Operations.





LEGEND

- Pools
- 50k Drainage
- Sub Catchments

Iron Bridge Stage 2

- Roads
- Camp
- Canning Basin Pipeline
- Explosives Facility
- Landfill
- OPF
- Pits
- Topsoil Stockpile
- Dry Rejects
- Return Water
- TSF
- Waste Dump

Data Sources:
Drainage, DoW.
Aerials, FMG and Landgate.
Other data FMG, 2019.

N

0 0.5 1 1.5 2
Kilometres

Figure 2-2: Iron Bridge
Infrastructure and Hydrology

Requested By: C. Burgers
Drawn By: S. Costello
Revised By: scostello
Approved By: S. Costello
Scale: 1:40,000
Coordinate System: GDA 1994 MGA Zone 50
Document Name: 662NS_0000_MP_OP_0003.002_r1

Date: 17-Apr-19
Size: A3P
Revision: 1
Confidentiality: 0

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Iron Bridge

3 Waste Rock Dump Design and Runoff Management

Over a projected mine life to 2036, over 420 Mt of waste rock is expected to be produced, and a WRD will be located to the east and south east of the pits, Figure 2-1.

The composition of the waste rock and schedules of annual production according to acid and metalliferous drainage (AMD) classification[1] have been described in a companion report (SRK, 2019a). Disposal options being considered by IB Operations for the management of potentially acid forming (PAF) waste material, include: (i) co-disposal, where PAF material is randomly interspersed (as dictated by the production schedule) within non acid forming (NAF) materials in the dump, and (ii) selective placement of PAF material within a cell encapsulated within NAF material.

Irrespective of the PAF management option adopted, the outer 10 m of the dump will comprise NAF material. The majority of this outer material is expected to contain low sulfur; however, NAF materials that contain sulfur may be present within this layer and therefore may be exposed at surface. Depending on the closure and rehabilitation strategy, these materials may be covered with a soil layer which would further reduce the exposure of reactive materials.

A conceptual closure design for the waste rock dump is presented in Figure 3-1. According to the design, dump berms will be designed to store water. Runoff will be prevented by the presence of crest bunds. Any solute (or sediment) generated by weathering and erosion at these locations on the dump surface will be retained in place. Over the long term, the relative proportion of fine material on berms is expected to increase as fine particles are washed down from adjacent batter slopes. These circumstances are anticipated to encourage growth of vegetation on the berms.

The upper surface (the top lift) of the dump has been designed to shed water, channelled via drainage features toward the south (Figure 3-2). Erosion rates have been estimated to range up to 3 t/ha/yr (Landloch, 2018). Erosion and transport of fines may result in suspended solids being present in the runoff.

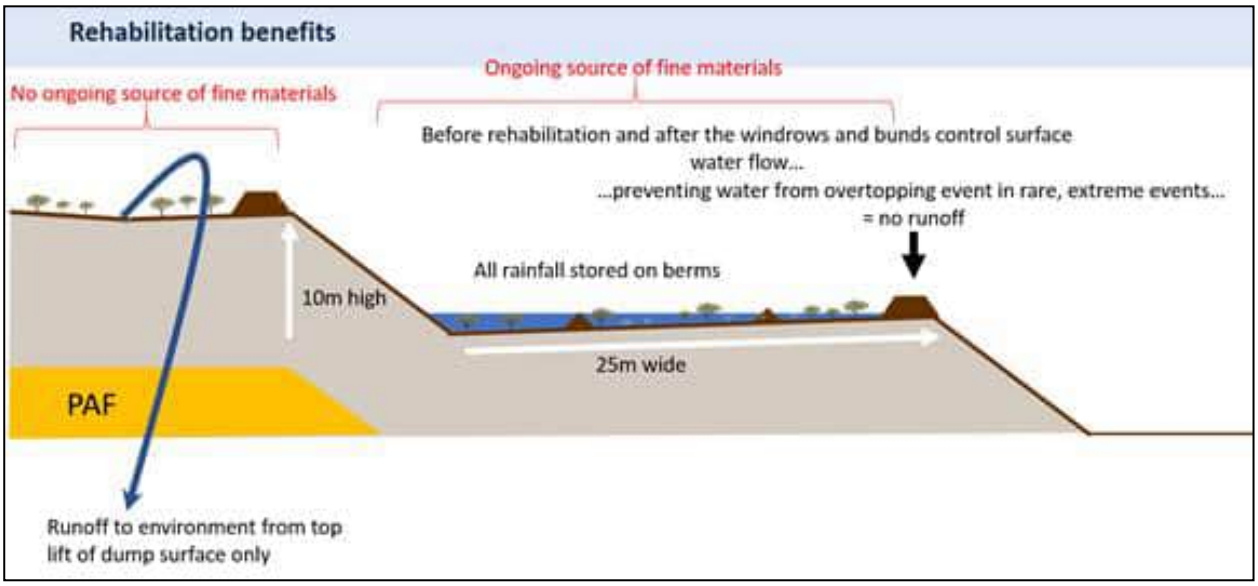


Figure 3-1: Conceptual closure design for the waste rock dump

Source: IB Operations.

[1] Waste rock mineralogy, geochemistry and the basis for the AMD classification are described in Appendix A

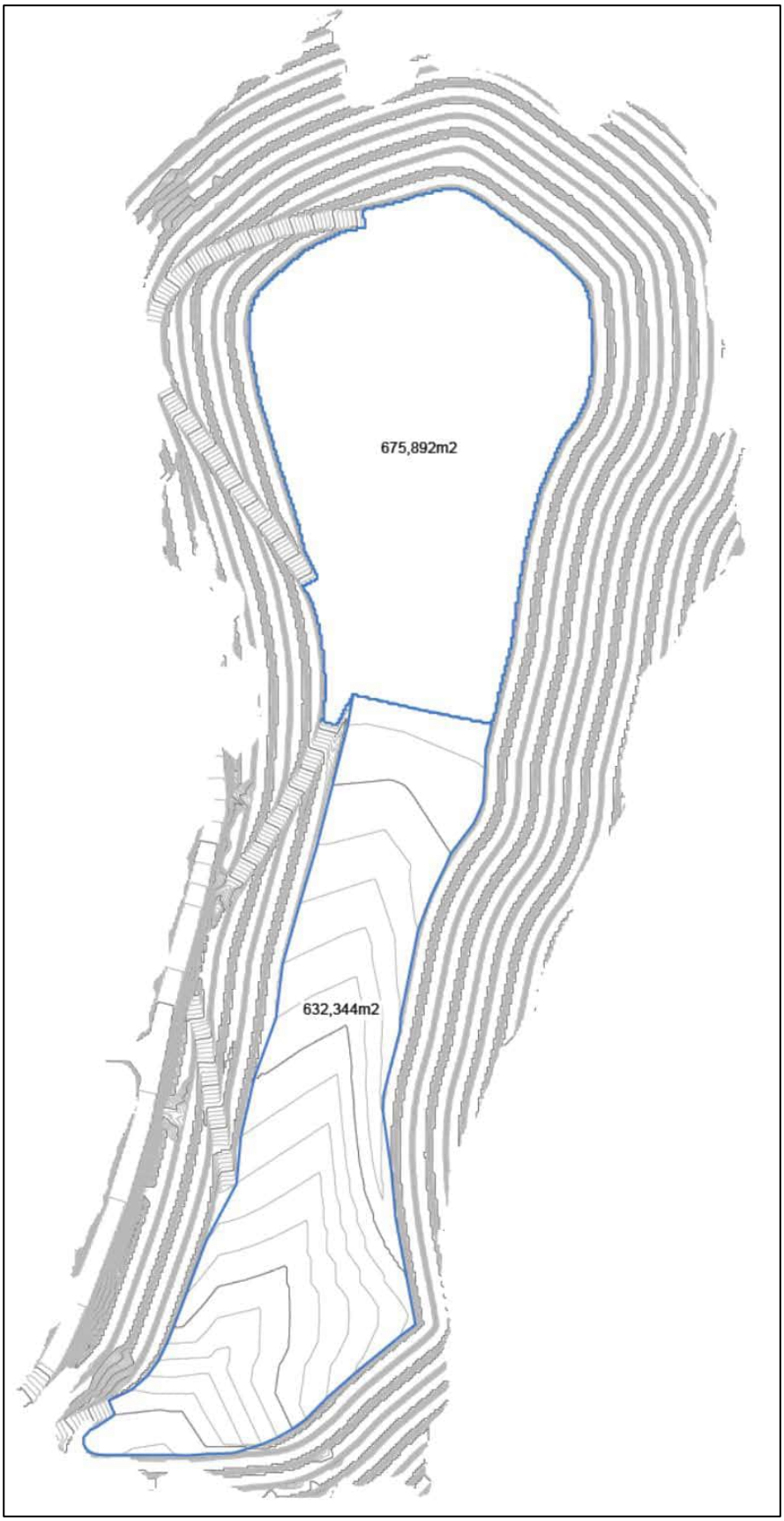


Figure 3-2: Shape of final dump surface

4 Runoff Chemistry – Conceptual Model and Input Parameters

4.1 General

Solutes generated within the near-surface waste rock of the WRD may be transported upwards due to capillary action resulting in salt wicking to the surface. Wicking occurs within the zone of evaporative influence, the depth of which is a function of physical material properties such as particle size distribution, hydraulic conductivity, and matric suction. For most materials the zone of influence would be expected to be between 0.5 m and 1 m in depth. Should a soil cover be placed, the depth of influence would be affected.

Salt accumulating on or near the dump surface will remain in place until a runoff event occurs. Runoff is generated following intense rainfall, once the capacity of the surface materials to take up water (recharge) has been exceeded. The chemistry during a runoff event will depend, amongst other things, on:

- Rates of solute production within the zone of influence
- Volume of water that infiltrates before runoff commences (moves salts back into the dump)
- Volume of water in the runoff event.

The most saline runoff chemistry would be expected for a relatively short, high intensity rainfall event following a prolonged dry period. Under such circumstances, significant salt mass may have accumulated at the dump surface to be dissolved in a relatively low volume of water.

4.2 Solute production and release

Solute production rates have been quantified using results from laboratory testing – kinetic (column) tests (described in Appendix A). These results provide an indication of release rates as a function of a material attribute, such as the sulfur content, or AMD classification.

For modelling purposes, three general material types were defined: PAF-HC, PAF-LC and a general 'NAF' category to represent the remainder of the mined wastes. The NAF category, which will dominate dump surface materials, is of most relevance in determining runoff chemistry. The other categories have been included in runoff modelling, to facilitate assessment of scenarios where PAF material contaminates the dump surface.

For each material type, derivation of solute production terms is documented in a companion report (SRK, 2019a).

In summary:

- Most solutes were considered to result from sulfide oxidation and production rates were related to sulfate production. Release of other solutes was derived on the basis of mass ratios relative to sulfate release. For each model category, the sulfur content and laboratory-derived sulfate production rates are presented in Table 4-1.
- Na and K release were treated separately to reflect a silicate source within the materials. Laboratory-scale Na production rates of 0.0001 mg/kg/week, 0.001 mg/kg/week and 1 mg/kg/week were assigned to PAF-HC, PAF-LC and 'NAF' categories, respectively. K release was calculated by utilising the mass ratios relative to Na release, as guided by the relevant column data.

Table 4-1: Material types represented in the model

Material	Initial S content (%) [1]	SO_4 production rate (laboratory) (mg/kg/week)
PAF-HC	1.91	224
PAF-LC	1.14	4
'NAF'	0.11[2]	0.4

Notes:

[1] Based on averages calculated from the IB Operations assay database differentiated according to AMD class (C. Burgers, personal communication).

[2] Weighted average for the multiple material classes represented in this category.

Laboratory-derived solute production rates require scaling or extrapolation for application to the field-scale dump. No quantitative site specific data are available upon which to base scaling factors, and ranges of value were therefore assessed based largely on professional judgement and in discussion with IB Operations. Adopting scaling factors is acknowledged to be a simplification and does not account for spatial or temporal variability in solute production within the full-scale facility. However, the approach is considered appropriate for the illustrative calculations being undertaken as part of the current study.

Table 4-2: Scaling factors and assumptions

Description	Factor	Comment
Surface area correction	0.15–0.3	Field-scale material is coarser-grained than material tested at laboratory scale
Fraction solute flushed by rainfall/ infiltration	0.5–1	To represent incomplete flushing at field-scale (e.g. preferential flows). For runoff, a major proportion of solute is assumed to have relocated to near the surface and will be readily accessible for removal in runoff
Depth of influence	0.5–1 m	A function of the capillarity of the materials (as a control on the upward movement of solute, i.e. salt wicking)

Note:

For material located near the surface, no scaling factors were considered necessary to allow for temperature adjustment and/ or incomplete oxygenation of the material.

4.3 Macroscopic dump properties

The proposed dump shape is shown in Figure 3-2; the total dump surface area is estimated at around 320 ha. However, runoff from only the top surface and the southern drainage slopes, a combined area of approximately 131 ha, will be released off the WRD (Section 3).

For the purposes of modelling, macroscopic properties of dump materials are assumed to be homogenous; values for some key characteristics were agreed with IB Operations as follows:

- Porosity – 0.25 (guided by geotechnical studies)
- Bulk density – 2,300 kg/m^3. This value is calculated by combining the porosity with the average of estimates of in situ density for oxide, Kangaroo Caves and Pincunah Fresh (3,100 kg/m^3, 2,800 kg/m^3 and 3,300 kg/m^3, respectively)
- Water-filled porosity – 0.05 to 0.15 (corresponds to 2%–7% w/w% water content).

4.4 Estimation of runoff: volumes and frequency

Runoff generated during intense rainfall events is expected to equate to between 15% and 30% of mean annual rainfall, i.e. between 54 mm/yr and 110 mm/yr.

The runoff will not be spread evenly throughout the year; instead it would occur erratically, triggered

by intense rainfall events. Not all rainfall events will result in runoff. The first increment of water falling on a surface will infiltrate and where the rainfall rate exceeds the infiltration rate, ponding on the surface would occur. Therefore, runoff will occur only when total rainfall exceeds this threshold, i.e. resulting in ponding. Theoretical models, such as the Green-Ampt model, allow estimation of initial infiltration and runoff volumes as a function of rainfall intensity, duration and material properties:

$$I = \frac{[(\theta_s - \theta_i)\psi_f]}{[(p/K_s - 1)]} \quad [1]$$

where:

I is the total amount of water infiltrated (cm)

p is the rainfall rate (cm/s)

K_s is the saturated hydraulic conductivity (cm/s)

Ψ_f is the matric suction at wetting front

θ_i is the initial moisture content (dimensionless)

θ_s is the saturated moisture content (dimensionless).

The Bureau of Meteorology (BOM) provides statistical data on rainfall characteristics for the North Star Project site. These are summarised in Table 4-3. A corresponding table with some estimates of infiltrated versus runoff volumes are presented in Table 4-4. Note that for many of the longer duration, but less intense, storm events no infiltration or runoff is predicted. For these cases, incident rainfall would be lost to a combination of evaporation and consumption as the surface materials 'wet up' and lost to recharge beyond the depth of influence. Under these circumstances, salts generated within the evaporative zone will be 'lost' to net percolation and will not be available for release to the next runoff event.

The estimates in Table 4-4 should be considered illustrative as the estimates are based on assumed values for the material properties. However, they do give insight to the possible volumes of runoff that might be generated during a single event. Conceptually, the average annual runoff mentioned above, 54 mm/yr to 110 mm/yr, could comprise several short, very intense, events (e.g. 5-minute storms, 63% probability of recurring within a year) combined with perhaps one or two longer events (e.g. storms lasting an hour or longer, at lower probabilities of recurrence within a year).

Table 4-3: Precipitation volumes (mm) for different types of storm event

Annual exceedance probability (AEP)	Equivalent return period (years)	Storm duration (hours)						
		0.083	1	6	12	24	48	72
63.2%	1	6.6	24.3	37.2	43.4	51.3	61.0	67.0
18.13%	5	10.9	40.5	64.7	77.7	94.5	115.0	127.0
10%	10	12.7	47.5	77.4	94.1	116.0	142.0	158.0
5%	20	14.7	54.9	91.3	112.0	140.0	174.0	193.0
2%	50	17.2	64.6	110.0	138.0	174.0	216.0	240.0
1%	100	19.1	71.8	125.0	158.0	201.0	250.0	277.0
0.2%	500	25.6	96.2	167.0	211.0	269.0	339.0	370.0
0.1%	1000	28.6	108.0	187.0	237.0	301.0	381.0	414.0

Note:

Taken from information presented on the Bureau of Meteorological website (www.bom.gov.au) for location: easting 714421, northing 7648669, zone 51.

Table 4-4: Estimated infiltration versus runoff volumes using Green-Ampt method

Annual exceedance probability (AEP)	Equivalent return period (years)	Storm duration (hours)						
		0.083	1	6	12	24	48	72
		Initial Infiltration (mm)						
63.2%	1	1.8	17.5	> Rainfall	> Rainfall	> Rainfall	> Rainfall	> Rainfall
18.13%	5	1.0	4.9	> Rainfall	> Rainfall	> Rainfall	> Rainfall	> Rainfall
10%	10	0.8	3.7	> Rainfall	> Rainfall	> Rainfall	> Rainfall	> Rainfall
5%	20	0.7	3.0	> Rainfall	> Rainfall	> Rainfall	> Rainfall	> Rainfall
2%	50	0.6	2.4	> Rainfall	> Rainfall	> Rainfall	> Rainfall	> Rainfall
1%	100	0.5	2.0	38.9	> Rainfall	> Rainfall	> Rainfall	> Rainfall
0.2%	500	0.4	1.4	11.2	> Rainfall	> Rainfall	> Rainfall	> Rainfall
0.1%	1000	0.3	1.2	8.4	62.9	> Rainfall	> Rainfall	> Rainfall
		Ponding or Potential Runoff (mm) = Total Precipitation - Initial Infiltration						
63.2%	1	4.8	6.8	NP	NP	NP	NP	NP
18.13%	5	9.9	35.6	NP	NP	NP	NP	NP
10%	10	11.9	43.8	NP	NP	NP	NP	NP
5%	20	14.0	51.9	NP	NP	NP	NP	NP
2%	50	16.6	62.2	NP	NP	NP	NP	NP
1%	100	18.6	69.8	86.1	NP	NP	NP	NP
0.2%	500	25.2	94.8	155.8	NP	NP	NP	NP
0.1%	1000	28.3	106.8	178.6	174.1	NP	NP	NP

Notes:

'NP' denotes no ponding i.e. infiltration exceeds rainfall and therefore no runoff would be expected, see main text.

Inputs adopted for the Green-Ampt formula were as follows:

- Saturated hydraulic conductivity: 18 mm/h (range suggested by surface water modelling, 8-24 mm/h (18 mm/h considered a best estimate).
- Matric suction: 0.3 kPa or 30.6 mm (based on published Van Genuchten parameters for sandy gravel, Perkins and Nimmo, 2009).
- Saturated moisture content (~porosity): 0.25, See Section 4.3.
- Available storage: 0.2 (porosity minus existing moisture content, 0.05, see Section 4.3.

5 Predicted Runoff Quality

5.1 Assessment scenarios

The dump surface will comprise NAF material and the majority of calculations have used solute production terms based on the characteristics of this material type. A series of sensitivity calculations were performed to examine the influence of scaling factors and macroscopic dump properties on outcomes; the inputs adopted are summarised in Table 5-1, and results are presented in Section 5.4.1. Some additional calculations examined the possible consequences should PAF materials contaminate the near-surface volumes of the dump (Section 5.4.2).

Table 5-1: Sensitivity calculations – scaling factors/ macroscopic properties

Description	Scaling factors/ Properties				Comment
Option #	1	2	3	4	
Surface area correction	0.15	0.3	0.15	0.15	Field-scale material is coarser-grained than material tested at laboratory scale
Fraction solute flushed in runoff	1	1	0.5	1	To represent incomplete flushing at field-scale (e.g. preferential flows)
Depth of influence, m	0.5	0.5	0.5	1.0	

Note:

Grey highlight denotes the series of factors considered to be the 'base case'. Red text indicates the factor varied.

5.2 Calculation basis

Most calculations focused on estimation of the mass of solute produced within a one-dimensional column of waste rock (area 1 m^2; depth varied according to the assume depth of influence). Solute production times would vary depending on time elapsed since the last storm event. For illustrative calculations described herein, timeframes ranging from one month to a year were examined.

The resulting solute mass would be apportioned between infiltrating water and runoff. (Note that salt loss resulting from net infiltration associated with interim events that do not result in runoff, but cause net infiltration, were conservatively neglected in the calculations). From Table 4-4, it appears that for most storms, the proportion of infiltrating water is low, usually less than 10%. Thus, for the calculations it was (conservatively) assumed that all solute could be dissolved in the runoff volume. Runoff volumes vary according to the intensity and duration of the storm event; according to Table 4-4, runoff would most likely be in the 5–10 mm range (5–10 L/m^2 equivalent), but could range up to a maximum of order 250 mm (250 L/m^2 equivalent). For the current calculations, low and high bound runoff volumes of 5 mm and 110 mm were adopted (the high bound being equivalent to the upper end of annual average runoff provided by IB Operations).

Using the modelling code, PHREEQC (Parkhurst and Appelo, 2013), the calculated chemistry was adjusted to account for potential mineral and gas interactions.

For all calculations, the following interactions were considered:

- Equilibration with CO_2 in air. The runoff was equilibrated with air (0.03v%) (saturation index -3.5)
- Precipitation of minerals such as:
  - Oxides and hydroxides - gibbsite, ferrihydrite, MnOOH, amorphous silica
  - Sulfates - gypsum, barite
  - Hydroxysulfates - jarosite, jurbanite, alunite
  - Carbonates - calcite, dolomite, malachite.

Geochemical modelling also examined equilibration with potential neutralising minerals present in contacting mineral assemblages. Two options were considered:

- Carbonate-based neutralisation adopting dolomite as the dominant carbonate. While dolomite has not been identified within the North Star materials, it was selected to reproduce release of both Ca and Mg in response to acid generation (as has been observed in kinetic testing).
- Silicate-based neutralisation. Uncertainty exists as to the identity of the mineral providing effective neutralisation capacity; possible candidates are:
  - Stilpnomelane: $(K,Na,Ca)_{0\text{-}1.4}(Fe,Mg,Al,Mn)_{5.9\text{-}8.2}[Si_8O_{20}](OH)_4(O,OH,H_2O)_{3.6\text{-}8.5}$
  - Stilbite: $(Ca,Na_2,K_2)[Al_2Si_7O_{18}].7H_2O$.

Thermodynamic data for stilpnomelane were not available. A Na,Ca-rich stilbite was present in the database. Several potential neutralising phases were examined: Ca,Na-stilbite, analcime and phlogopite ($KAlMg_3Si_3O_{10}(OH)_2$), as a possible analogue for a Mg-rich stilpnomelane, and kaolinite. Al released as aluminosilicate react can be reprecipitated as Al hydroxide and/ or Al hydroxysulfate. Only those combined reaction stoichiometries that result in net consumption of protons, after accounting for precipitation of Al-bearing products, will result in effective neutralisation. In the current work, Ca,Na-stilbite and phlogopite dissolution were effective at influencing pH, while the others were not. For the current study, phlogopite was selected as this reaction resulted in Mg release and therefore reproduces trends observed in kinetic testing.

Suspended sediment loadings were calculated on the basis of the sediment production rate, 5,800 mg/m^2/week (recalculated from the erosion rate, 3 t/ha/yr; Section 3); however, not all of the sediment release would be transported away from the WRD. The majority of the sediments would be expected to be deposited in sediment ponds or in alluvial deposits at the toe of the WRD where flows slow down particles will settle out of the water column. Important additional model assumptions were:

- Solute sources were present in the surface materials. Over time, weathering and leaching would deplete solute sources from the near-surface environment. Depletion of the sources was not represented in the model calculations.
- Solute production continues at a constant rate. Rates would decrease with time due to processes such as armouring, or reductions in reaction surface area as the source is depleted.

5.3 Base Case runoff water quality

Water quality estimates for base case runoff calculations are presented in Table 5-2. The following comments can be made:

- Where reactive neutralisation potential is present, the calculated solutions are near-neutral to mildly alkaline. Even in the absence of such minerals, the solution pH is expected to remain near-neutral, between 6 and 7.
- Major cation and anion concentrations are typically calculated to be below that of baseline water quality. Exceptions are for cases where low runoff volumes are combined with long elapsed times since the last runoff event; in these circumstances, it is possible that dissolved concentrations could exceed water quality thresholds and result in moderately saline drainage.
- Trace metal and metalloid concentrations are calculated to be low. Excepting solutions with lower pH values (less than 7), solubility limits apply for elements such as Fe, Al, Mn. [It should be noted that many trace components were not included in the NAF source term as they did not leach at detectable concentrations from NAF materials during kinetic testing].

While total suspended solids concentrations will be related to the estimated rate of erosion, the actual concentrations will vary from event to event, and will be proportional to the magnitude of the event,

i.e. the larger the event, the higher the flow velocities, the higher the total suspended solids (TSS) concentrations are likely to be. However, as noted before, suspended particles will be deposited at the toe of the WRD where velocities are expected to slow once it leaves the steep batters. Furthermore, control structures such as sedimentation or retention ponds can be implemented to further control TSS concentrations. Furthermore, the rate of erosion would be expected to be influenced by the establishment of a vegetation cover and other rehabilitation strategies to stabilise the surface of the WRD. While these measures should be taken into consideration when assessing the TSS concentrations in the runoff, it is beyond the scope of the current assessment.

5.4 Sensitivity calculations

5.4.1 Influence of scaling factors and assumed dump properties

Outcomes from sensitivity calculations are presented in Figure 5-1. The main point to note is that variability in the calculated outcomes arising from different scaling factors or assumed depths of influence is minimal in comparison to the effect of changing the elapsed times between events and the runoff volumes generated from any given event.

5.4.2 PAF contamination of dump surface materials

To examine the possible consequences of PAF material exposure or contamination of the near-surface materials on the WRD, illustrative calculations were undertaken where the surface material included small proportions of PAF-HC and PAF-LC materials at fractions of 0.05 and 0.02, respectively. These proportions were based on the overall proportions of these materials present within the volume to be mined.

Calculated runoff chemistries are presented in Table 5-3. As would be expected, the calculated solute concentrations in runoff for this scenario is significantly greater than calculated for NAF materials. This is considered to be an unlikely scenario given that management strategies will be in place to ensure that only NAF material is placed in the near-surface regions of the dump.

Table 5-2: Calculated runoff chemistry – Base Case assumptions

Scaling factors		No neutralisation				Carbonate-based neutralisation				Silicate-based neutralisation				Averages from IB Operations WQ monitoring datasets		IB Operations Interim Trigger Values	
		Scaling factors – Base Case (Table 5-1); Depth of influence: 0.5 m															
Time elapsed since last storm event, weeks		4		52		4		52		4		52		Groundwater	Surface water	Groundwater	Surface water
Runoff volume, mm		5	110	5	110	5	110	5	110	5	110	5	110				
pH	pH unit	5.8	5.7	6	5.8	8.3	8.4	8.1	8.3	7.9	7.8	7.9	7.9	7.8	8.3	8.3	9
Alkalinity	mg $CaCO_3$/L	0.1	0.053	0.23	0.083	61	64	43	63	24	18	30	24	420	428	580	600
Acidity calc.	mg $CaCO_3$/L	-	-	-	-	-	-	-	-	-	-	-	-				
SO_4	mg/L	57	2.6	740	34	57	2.6	740	34	57	2.6	740	34	119	55	250	100
Cl	mg/L													221	128	500	200
Ca	mg/L	14	0.65	180	8.4	21	14	110	18	13	0.0077	180	7.2	44	31	70	60
Mg	mg/L					11	7.8	55	9.2	5.9	4.2	7.7	5.7	104	110	180	160
Na	mg/L	140	6.3	1800	82	140	6.3	1800	82	140	6.1	1800	81	136	68	300	100
K	mg/L	17	0.75	210	9.7	17	0.75	210	9.7	20	3	220	13	5	2	12	4
Al	mg/L	0.00007	0.000077	0.000038	0.000073	9.1E-06	0.000018	0.0000042	0.00001	0.000011	0.00034	0.0000035	0.000015	0.01	0.07	0.03	0.2
As	mg/L													0.01	0.002	0.02	0.01
Be	mg/L													0.001	0.001	0.001	0.001
Ba	mg/L													0.03	0.02	0.08	0.05
Cd	mg/L													0.0001	0.0001	0.003	0.003
Cr	mg/L													0.001	0.001	0.05	0.04
Co	mg/L													0.003	0.001	0.007	0.0014
Cu	mg/L													0.006	0.001	0.023	0.020
Pb	mg/L	0.00034	0.000015	0.0044	0.0002	0.00034	0.000015	0.0044	0.0002	0.00034	0.000015	0.0044	0.0002	0.001	0.001	0.15	0.15
Mn	mg/L	0.076	0.0035	0.99	0.045	0.000017	0.000011	0.00015	0.000014	0.00024	0.00037	0.00043	0.00023	0.1	0.03	1.2	1.2
Ni	mg/L													0.01	0.002	0.18	0.16
V	mg/L													0.04	0.01	0.08	0.02
Zn	mg/L	0.11	0.0052	1.5	0.067	0.11	0.0052	1.5	0.067	0.11	0.0052	1.5	0.067	0.1	0.03	0.13	0.12
Fe	mg/L	0.014	0.00063	0.012	0.0082	0.007	0.00063	0.0067	0.007	0.0066	0.00063	0.0067	0.0066	0.1	0.13	0.3	0.3
Hg	mg/L													0.0001	0.0001	0.0001	0.0001
Se	mg/L													0.01	0.01	0.01	0.01
TDS	mg/L	230	10	2900	130	300	95	3000	220	260	34	3000	160	897	676	1450	900
Ion balance	%	72	70	75	72	57	9.3	74	48	65	25	75	61				
Solubility controls	Neutralising mineral[2]	None				Dolomite ($CaMg(CO_3)_2$)				Phlogopite ($KAlMg_3Si_3O_{10}(OH)_2$) – as an analogue for Mg-rich stilpnomelane							
	Other minerals	K-jarosite, amorphous silica (SiO_2), kaolinite, Ca,Na-stilbite				$Fe(OH)_3$, amorphous silica (SiO_2), MnOOH, calcite, Ca,Na-stilbite				$Fe(OH)_3$, amorphous silica (SiO_2), kaolinite, MnOOH, Ca,Na-stilbite							

Orange highlight indicate values in excess of interim trigger limits

TDS = total dissolved solids.

Blanks in table indicate instances where the solute was not represented in the source.

Notes:

1. In low volume runoff events, it is unlikely that such high suspended sediment loads would be mobilised; the value presented in the table are therefore over-estimates.
2. The selected neutralising mineral was assumed present in quantities sufficient to provide effective neutralisation of seepage.
3. Redox conditions were assumed to be relatively oxidising, and pe was fixed at +10 (~Eh = +590 mV).
4. The calculations were performed assuming that the system is open to exchange with CO_2 in air: 0.03v%.
5. Positive ion imbalances probably relate to overestimation of Na production within the 'NAF' material. Further work is required to better constrain the Na source term. [Cl release was not represented in the NAF source and this may also have contributed to the imbalance. Kinetic testing indicated that some materials released Cl on an ongoing basis, but generally levels that were too low (on a molar equivalent basis) to represent a key anion source within the materials.]

Table 5-3: Calculated runoff chemistry – PAF contamination within surface materials (unlikely scenario)

Scaling factors		Carbonate-based neutralisation				Silicate-based neutralisation				Averages from IB Operations WQ monitoring datasets		IB Operations Interim Trigger Values	
		Scaling factors – Option #1 (Table 5-1); Depth of influence: 0.5 m PAF proportions present 0.05 (PAF-HC) and 0.02 (PAF-LC)											
Time elapsed since last storm event, weeks		4		52		4		52		Groundwater	Surface water	Groundwater	Surface water
Runoff volume, mm		5	110	5	110	5	110	5	110				
pH	pH unit	6.7	7.6	6.8	7	5.7	6.7	5.8	6	7.8	8.3	8.3	9
Alkalinity	mg $CaCO_3$/L	17	16	17	13	2.6	1.7	20	1.7	420	428	580	600
Acidity calc.	mg $CaCO_3$/L	-	-	-	-	-	-	-	-				
SO_4	mg/L	600	73	920	730	1200	73	15000	690	119	55	250	100
Cl	mg/L	0.43	0.02	5.7	0.26	0.43	0.02	5.7	0.26	221	128	500	200
Ca	mg/L	21000	970	12000	13000	21	0.98	41	13	44	31	70	60
Mg	mg/L	13000	590	13000	8200	22000	1000	20000	14000	104	110	180	160
Na	mg/L	110	5.2	1500	67	130	5.8	1600	75	136	68	300	100
K	mg/L	15	0.7	25	8.9	12000	540	9500	7400	5	2	12	4
Al	mg/L	0.00000059	0.0000059	0.00000052	0.0000011	0.000082	0.000041	0.000072	0.00006	0.01	0.07	0.03	0.2
As	mg/L	0.0066	0.0003	0.087	0.0039	0.0066	0.0003	0.086	0.0039	0.01	0.002	0.02	0.01
Be	mg/L	0.011	0.00051	0.14	0.0065	0.011	0.00051	0.14	0.0065	0.001	0.001	0.001	0.001
Ba	mg/L	0.028	0.0013	0.16	0.017	0.028	0.0013	0.0088	0.017	0.03	0.02	0.08	0.05
Cd	mg/L	0.0058	0.00027	0.077	0.0035	0.0058	0.00027	0.076	0.0035	0.0001	0.0001	0.003	0.003
Cr	mg/L	1.1	0.049	14	0.64	1.1	0.049	14	0.64	0.001	0.001	0.05	0.04
Co	mg/L	1.1	0.05	14	0.64	1.1	0.05	14	0.64	0.003	0.001	0.007	0.0014
Cu	mg/L	0.11	0.0087	0.087	0.074	0.33	0.015	4.3	0.2	0.006	0.001	0.023	0.020
Pb	mg/L	0.7	0.032	5	0.42	0.7	0.032	3.9	0.42	0.001	0.001	0.15	0.15
Mn	mg/L	0.82	0.0046	0.43	0.28	14	0.64	180	8.3	0.1	0.03	1.2	1.2
Ni	mg/L	5.7	0.27	76	3.4	5.7	0.27	75	3.4	0.01	0.002	0.18	0.16
V	mg/L	0.022	0.001	0.29	0.013	0.022	0.001	0.29	0.013	0.04	0.01	0.08	0.02
Zn	mg/L	1.8	0.081	23	1	1.8	0.081	23	1	0.1	0.03	0.13	0.12
Fe	mg/L	0.013	0.0072	0.011	0.01	0.018	0.018	0.003	0.021	0.1	0.13	0.3	0.3
Hg	mg/L	0.00003	0.0000014	0.00039	0.000018	0.00003	0.0000014	0.00039	0.000018	0.0001	0.0001	0.0001	0.0001
Se	mg/L	0.0033	0.00015	0.043	0.0019	0.0033	0.00015	0.043	0.0019	0.01	0.01	0.01	0.01
TDS	mg/L	34000	1700	27000	22000	35000	1600	46000	22000	897	676	1450	900
Ion balance	%	100	98	100	99	100	98	99	100				
Solubility controls	Neutralising mineral[1]	Dolomite ($CaMg(CO_3)_2$)				Phlogopite ($KAlMg_3Si_3O_{10}(OH)_2$) – as an analogue for Mg-rich stilpnomelane							
	Other minerals	Gypsum ($CaSO_4.2H_2O$), $Fe(OH)_3$, amorphous silica (SiO_2), kaolinite, MnOOH, pentasalt ($Ca_5K_2(SO_4)_6:H_2O$), Ca,Na-stilbite, tenorite (CuO), barite ($BaSO_4$), $PbCO_3$				K-jarosite, $Fe(OH)_3$, amorphous silica (SiO_2), kaolinite, MnOOH, pentasalt ($Ca_5K_2(SO_4)_6:H_2O$), barite ($BaSO_4$), $PbSO_4$							

Orange highlight indicate values in excess of interim trigger limits

TDS = total dissolved solid

Notes:

1. The selected neutralising mineral was assumed present in quantities sufficient to provide effective neutralisation of seepage.
2. Redox conditions were assumed to be relatively oxidising, and pe was fixed at +10 (~Eh =+590 mV).
3. The calculations were performed assuming that the system is open to exchange with CO_2 in air: 0.03v%.
4. Positive ion imbalances probably relate to overestimation of Na production within the 'NAF' material. Further work is required to better constrain the Na source term.

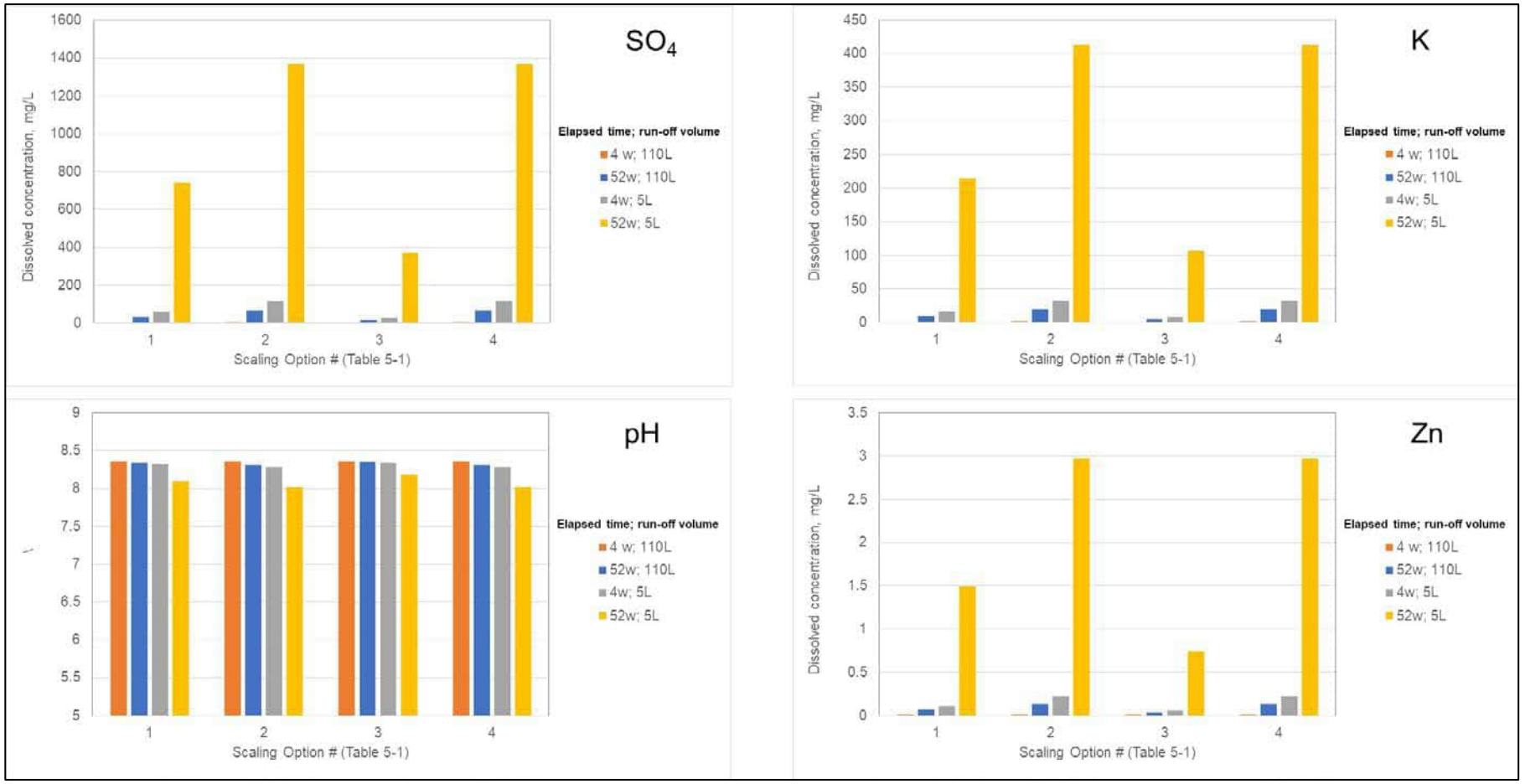


Figure 5-1: Sulfate, K, pH and Zn in seepage, as a function of scaling factors and macroscopic dump properties (co-mingled dump)

Note: For the calculations represented, effective carbonate-based neutralisation within the dump was assumed.

6 High-level Runoff Impact Assessment

As part of the current scope, a high level assessment was completed to estimate the likelihood of downstream impacts. [Detailed downstream impact assessments are being conducted by IB Operations as part of ongoing studies].

Dump-impacted runoff would encounter, and mix with, surface water along flow paths away from the source. The assessment performed herein is based on comparison of calculated runoff water quality with baseline surface water quality and determination of the degree of dilution that would be required to reduce concentrations in WRD-impacted flows to be in line with baseline values. Where estimated dilution ratios are large, the likelihood of downstream impact is greater.

Figure 6-1 presents estimated dilution factors for the Base Case assessment, in the case of some the 'worst-case' runoff chemistries, namely low volume runoff events. Two elapsed times are presented – 4 weeks and 52 weeks. The baseline reference chemistries used were average groundwater and surface water quality taken from the IB Operations' water quality monitoring datasets.

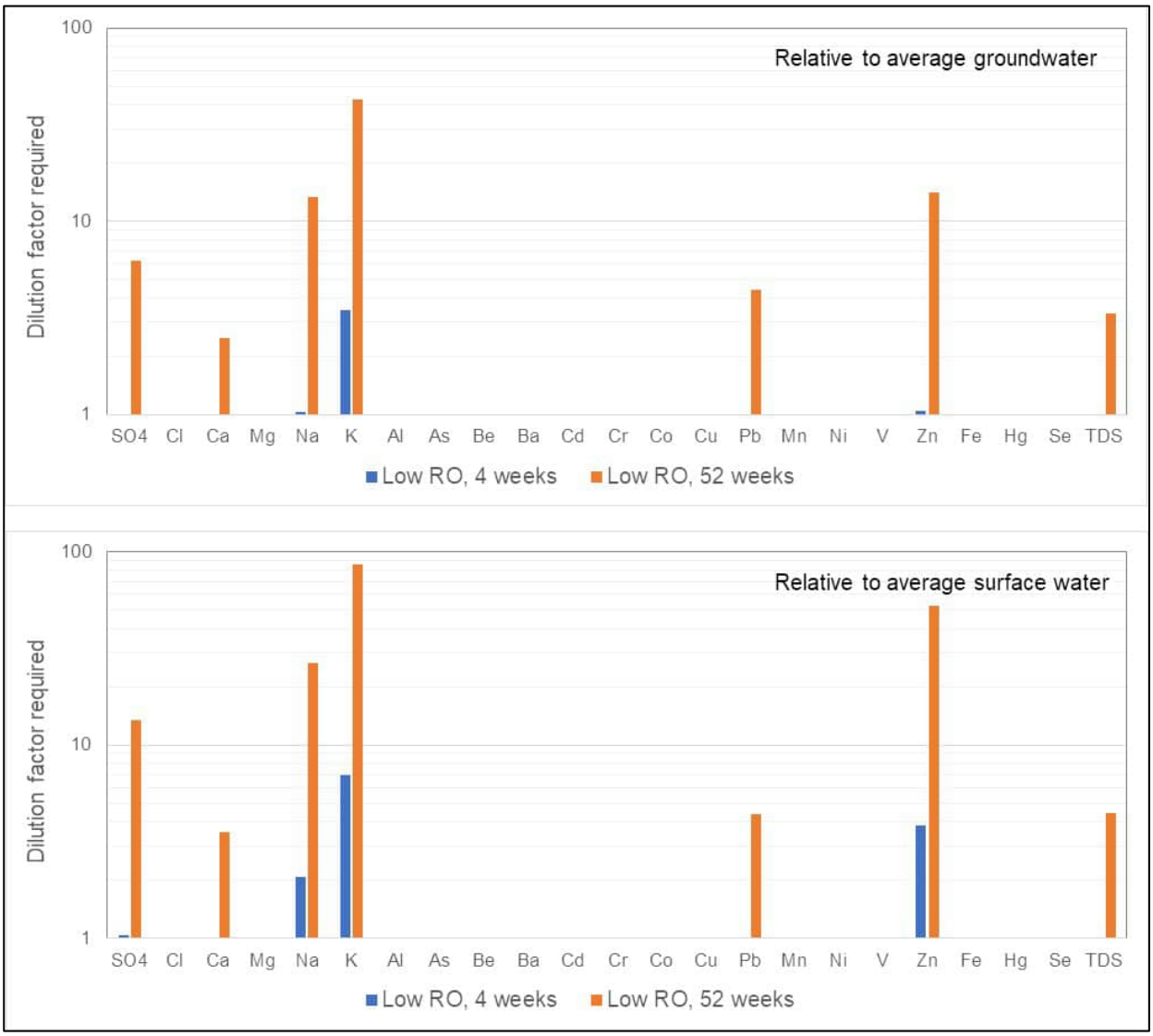


Figure 6-1: Dilution factors required to reduce impacted runoff concentrations to baseline groundwater or surface values

While some parameters may require dilution exceeding a factor of 10, many fall within the 1–10 range. The significance of these dilution factors should be considered in the context of the magnitude of runoff flow during a storm event, and the downstream water flows during that event. Note that compared to interim trigger values for surface water, only Ca, Na, and Zn concentrations would exceed the IB Operations trigger values.

The combined surface area of the top surface and the southern drainage slope is approximately 131 ha. For this surface area, the total runoff volumes for a 5 mm and 150 mm event would be between 7 ML and 200 ML.

IB Operations is currently performing surface water and groundwater modelling which will inform estimates of the ranges of surface and groundwater flows that may apply for different storm events, and whether the required degree of dilution can be expected for the different scenarios represented.

7 Conclusions

A runoff water quality model was developed based on solute production from PAF-HC, PAF-LC and NAF waste materials that may be exposed on the surface of the North Star dump. Using this model, and completing illustrative runoff event scenarios, runoff water qualities have been calculated. The results from the modelling indicated the following:

- Acidic conditions are unlikely, on the basis that the dump surface will comprise NAF materials. Even should some small quantities of PAF contaminate the surface, it is likely that carbonate- and/ or silicate-based neutralisation potential would be available to maintain near-neutral pH conditions.
- Under extreme conditions, i.e. extended dry periods since the preceding storm event, combined with low runoff volumes leads to the potential for runoff to contain solutes at concentrations in excess of baseline surface water. However, for most conditions, it is expected that the runoff chemistry will fall within the ranges observed within the water quality monitoring datasets.
- For most parameters, 10 times dilution within the downstream environment would be sufficient to bring dissolved concentrations in line with baseline averages for the North Star Magnetite Project.

The estimated water qualities will however be subject to the final closure and water strategy management strategy. Placement of soil covers and revegetation will lead to a substantial reduction in solute production which would be expected to result in runoff water quality not dissimilar to background values. With respect to TSS concentrations, it is expected that some mitigation and control measures such as sedimentation ponds would likely be required to limit TSS concentrations in water released from the site.

8 Recommendations

The conceptual models developed herein provide a preliminary assessment of the potential dump runoff water quality. The modelling, however, has adopted a number of simplifying assumptions, is reliant on the available data (e.g. geochemical solute production rates), and may not consider the full range of conditions and interactions that could occur.

It is therefore recommended that the following activities take place to facilitate refinement of the model:

- Further kinetic testing to represent the range of sulfur and ANC contents that might occur within the dump, and to enable derivation of kinetic parameters for oxidation and alkalinity release specific to these materials, and specifically, closer examination of the role of reactive silicate minerals, should be completed. The tests should be operating for time periods sufficiently long (possible many years) to allow for the potentially long lag times to acidification that may apply. The analyte list should be extended to include Si, Sb and Li.
- Further study of neutralising mineral capacity should be undertaken; modified acid-base characteristic curve (ABCC) testing, with full analysis of the final titrated solutions, could give valuable insight to the identity of minerals reacting to neutralise acid added.

Compiled by



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Principal Geochemist

Peer Reviewed by



John Chapman

Principal Consultant

9 References

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SRK Consulting, 2019b. North Star Magnetite Project – Pit Lake Modelling, SRK Project FMG060, Report FMG060-2/4.

Appendices

Appendix A: SRK memo - Data Review and Gap Analysis

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Project Memorandum

Client:	Iron Bridge (IB) Operations	**Date:**	24 April 2019
Attention:	Sylvie Ogier-Halim, Colleen Burgers	**From:**	Claire Linklater/ Russell Staines
Project No:	FMG060	**Revision No:**	2
Project Name:	Geochemical Studies – North Star Magnetite Project		
Subject:	Data Review and Gap analysis - Report FMG060-1/4		

1 Introduction

Iron Bridge (IB) Operations contracted SRK Consulting (Australasia) Pty Ltd (SRK) to complete assessments of pit water quality and waste rock dump runoff and seepage water quality in support of preparation of a Mining Proposal for the North Star Magnetite Project.

An initial activity comprised a review of previous geochemical studies with the objectives of:

i) Assessing the representivity and applicability of the available data

ii) Verifying the quality of the available data

iii) Determining whether previous conclusions remain valid for the planned mining activities and in the light of the latest available geochemical datasets.

This memorandum summarises outcomes of the review, data gaps that have been identified, and their significance with respect to the planned modelling studies.

2 Data Review Outcomes

2.1 Geology

The geological stratigraphy in the vicinity of the North Star Magnetite Project is shown in Figure 2-1. Figure 2-2 is a schematic showing the steeply folded main geological units at depth, and the presence of weathered oxide material near the surface. Sulfide mineralisation is documented to occur within the Western Shale.

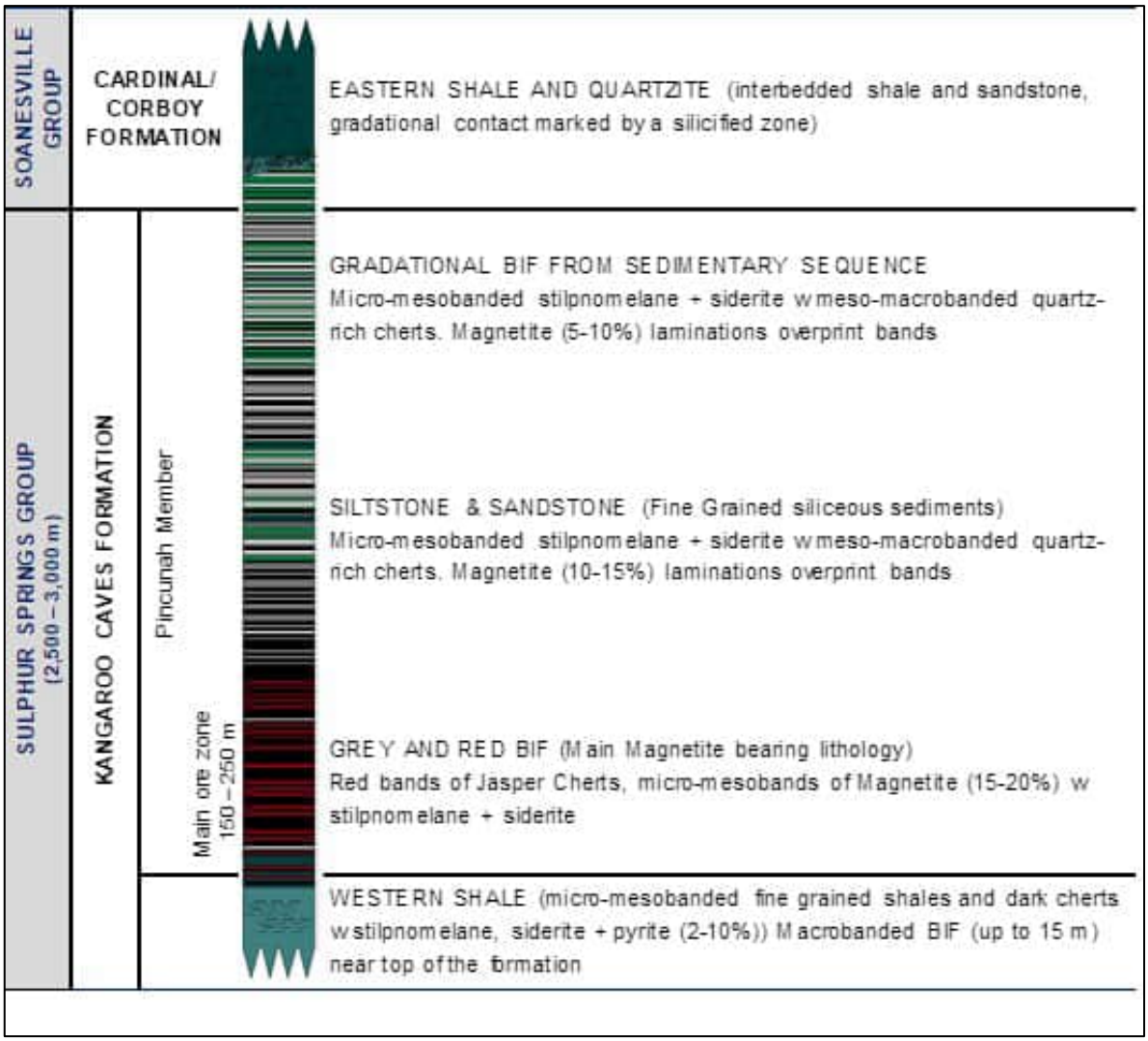


Figure 2-1: North Star Project – Stratigraphy

Source: IB Operations request for proposal (RFP) documentation.

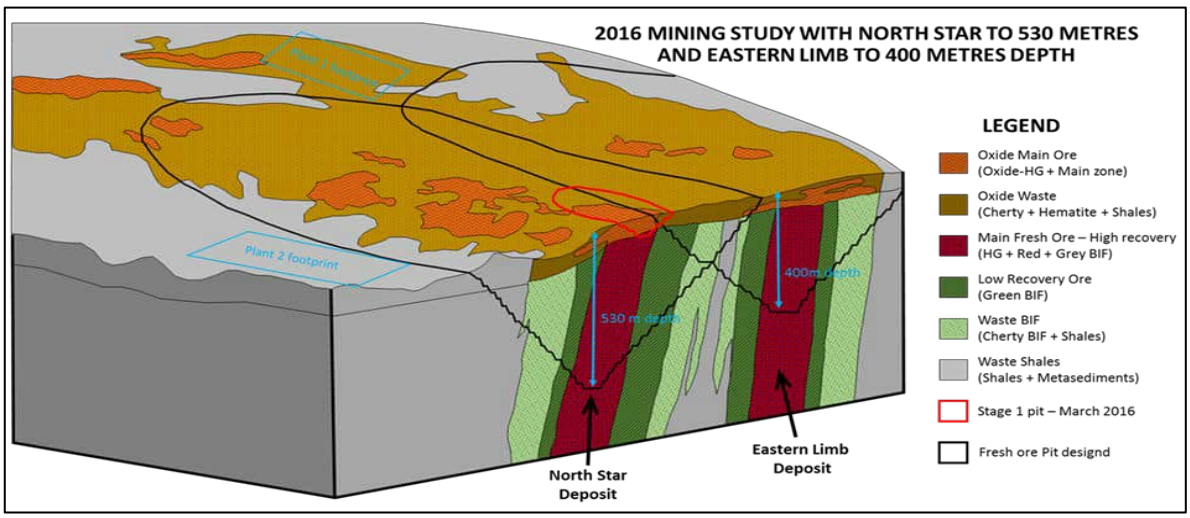


Figure 2-2: North Star Project – Geology

Source: IB Operations request for proposal (RFP) documentation.

2.2 Potential for acidic or neutral mine drainage (AMD or NMD) from waste rock

Several geochemical characterisation programs have been conducted (WorleyParsons, 2011; GHD, 2012; 2014; Golder, 2015). It is noted that sampling for these programs has focused on the deeper units, and consequently the near-surface oxide units are not well represented within the datasets.

2.2.1 Potential for acid generation

Assay data from the IB Operations drill hole database suggests that, in general, sulfur content is low; more than 90% of ore grade samples and around 80% of waste rock samples contained sulfur at levels below 0.4% (Figure 2-3). The results for the ore samples are skewed toward the lower end of the sulfur range, with a median of about 0.05% S. The results for the waste rock showed a bimodal distribution, with the peak of the primary population coinciding with the median sulfur content of 0.06% determined for the entire population. A peak sulfur content of 0.9% is indicated for the secondary minor population. The calculated average sulfur contents, differentiated by stratigraphy, ore or waste categories, and AMD classification, are presented in Table 2-1.

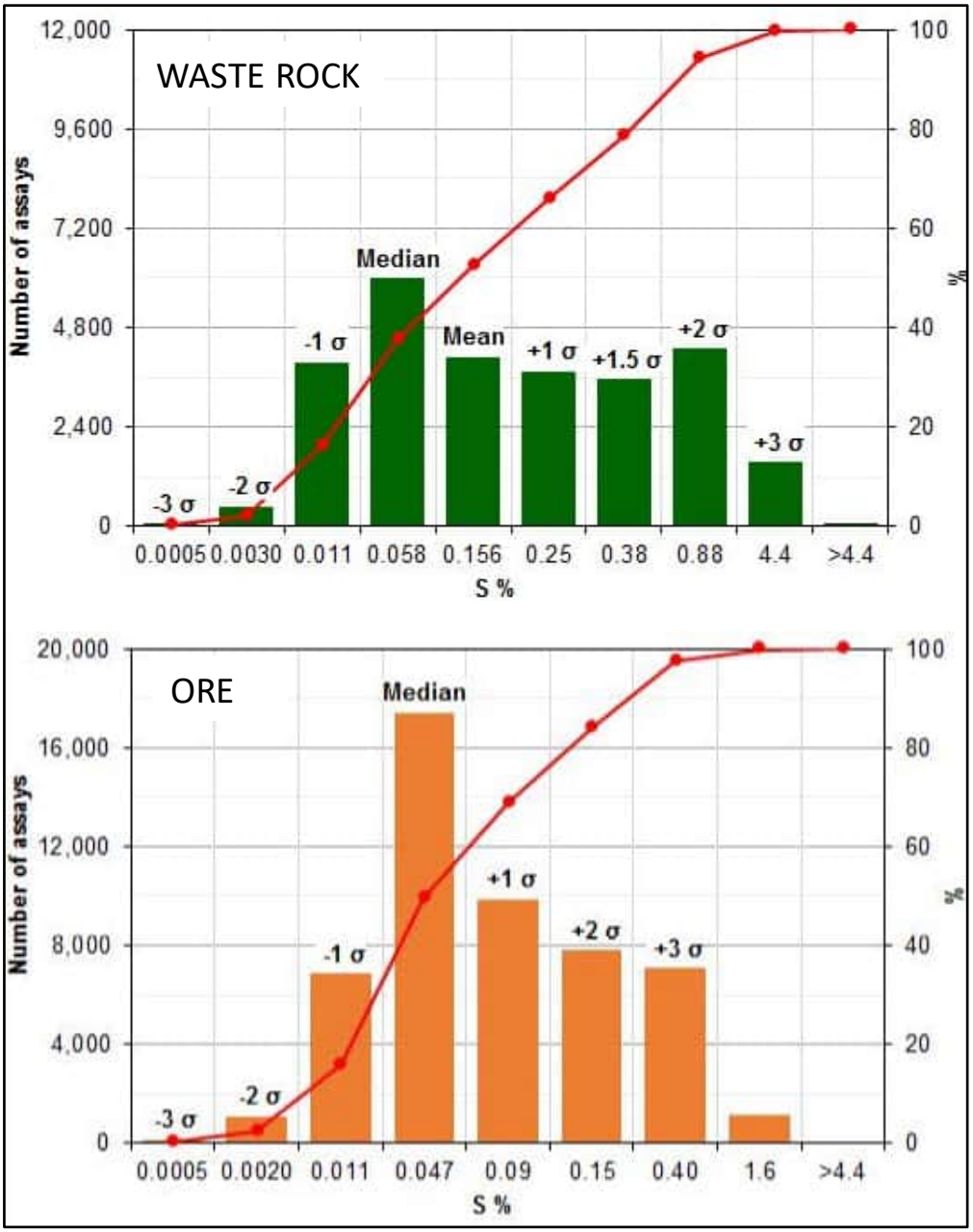


Figure 2-3: Sulfur distribution, North Star Magnetite Project

Source: IB Operations, 2019; XRF-based assay data, n=27,768 samples (waste rock) and 51,477 samples (ore)

The Golder study (2015) included some sulfur speciation studies (KCl-extractable sulfur testing) and concluded that the majority of sulfur present was sulfide. Total sulfur has therefore been adopted by IB Operations as a proxy for sulfide content and estimates of acid potential (AP). Based on Figure 2-3, median AP would be low, around 3 kgH_2SO_4/t (based on 0.1% S).

[KCl extraction of sulfates may underestimate Fe- and Al-hydroxy-sulfate contents and thus using the S(T) to estimate AP may be overly conservative; there may be value in some additional sulfur speciation testing using combinations of HCl-extractable sulfur and chromium-reducible sulfur (CRS) testing to verify the sulfide sulfur content.]

Table 2-1: Average sulfur content of waste rock and ore

Description	Stratigraphy	Average S %	Assay count	Category
Oxide Ore	POX-HG	0.011	8,224	Ore
Pincunah BIF Red	PBR	0.075	29,961	
Pincunah Chert Grey	PCG	0.156	13,196	
Oxide/ Cherty waste NAF	POXc	0.017	8,390	NAF Waste
Pincunah Chert Green	PCN	0.222	12,160	
Pincunah Cherty BIF Grey	PFG	0.314	3,119	
Corboy Formation quartzite NAF	CBq	0.238	734	
Kangaroo Caves Formation quartzite NAF	KCq	0.263	394	
Oxide/ shaley waste	POXs	0.295	273	PAF Waste
Pincunah Shale Green	PSN	1.353	538	
Pincunah Shale Cherty	PSC	1.297	949	
Corboy Formation shale PAF	CBs	0.792	716	
Kangaroo Caves Formation shale PAF	KCs	2.153	591	
		Total assay count	**79,245**	

2.2.2 Acid neutralisation capacity

Most materials tested contained modest acid neutralising capacity (ANC). The results presented in the Golder study indicated ANC to range from 1 H_2SO_4/t to 120 kg H_2SO_4/t, with a median of 38 kg H_2SO_4/t. Acid-base characteristic curve (ABCC) tests indicated that for many samples the readily available neutralisation capacity (probably dolomitic based on plateaus around pH 6) formed only a proportion of the total ANC (often less than half). The remainder of the ANC was inferred to be due to contribution from silicates reactive at low pH values.

Poor correlations are observed between measured ANC and typical proxies such as total inorganic carbon, Ca and Mg content. Following a wider mathematical correlation analysis, IB Operations proposed the following alternative scheme for approximating ANC (FMG, 2017):

$$ANC_{Clay}, \text{ kg } H_2SO_4/t = (\text{wt \% CaO} \times 17.5) + (\text{wt \% } Na_2O \times 15.8) + (\text{wt \% Fe} \times 1.58) \quad (1)$$

The Fe component of the calculation is based on 9% of total assayed Fe content. The inclusion of Na_2O and Fe in the scheme is intended to reflect the role of alternative potentially ANC-contributing minerals such as Na-bearing carbonates and/ or silicates.

The information provided does not state the error range for the ANC calculation by this method, and whether it is more accurate for one material type over another. SRK considers it would be worthwhile to explore the potential correlation between mineralogical composition and ANC further, and also integrate the results from the ABCC tests to ensure that the ANC estimation by this method is conservative. SRK also recommends that where Na-related ANC may be present, the rates of ANC consumption should be assessed. Should ANC leach rapidly it may not be available for long-term neutralisation of sulfide minerals, i.e. a possible acid-base imbalance may occur at a later date.

2.2.3 Material classification

Figure 2-4 (taken from FMG, 2017) shows the Golder study data plotted on a geochemical classification system based on the NAG–NAPP relationship. IB Operations generated mathematical equations to represent the curves defining lower and upper bounds within which most measured data occur, as shown on the plot. Based on the zones defined in this figure, IB Operations has proposed the material classification scheme presented in Figure 2-4. This scheme has been implemented in the IB Operations block model by using MPA (from total S) and ANC_{Clay} (Eq. 1) values to calculate $NAPP_{Clay}$. $NAPP_{Clay}$ is used to estimate a NAGpH value (conservatively) using the lower bound curve.

The scheme is acknowledged to be an approximation and verification testing is still underway.

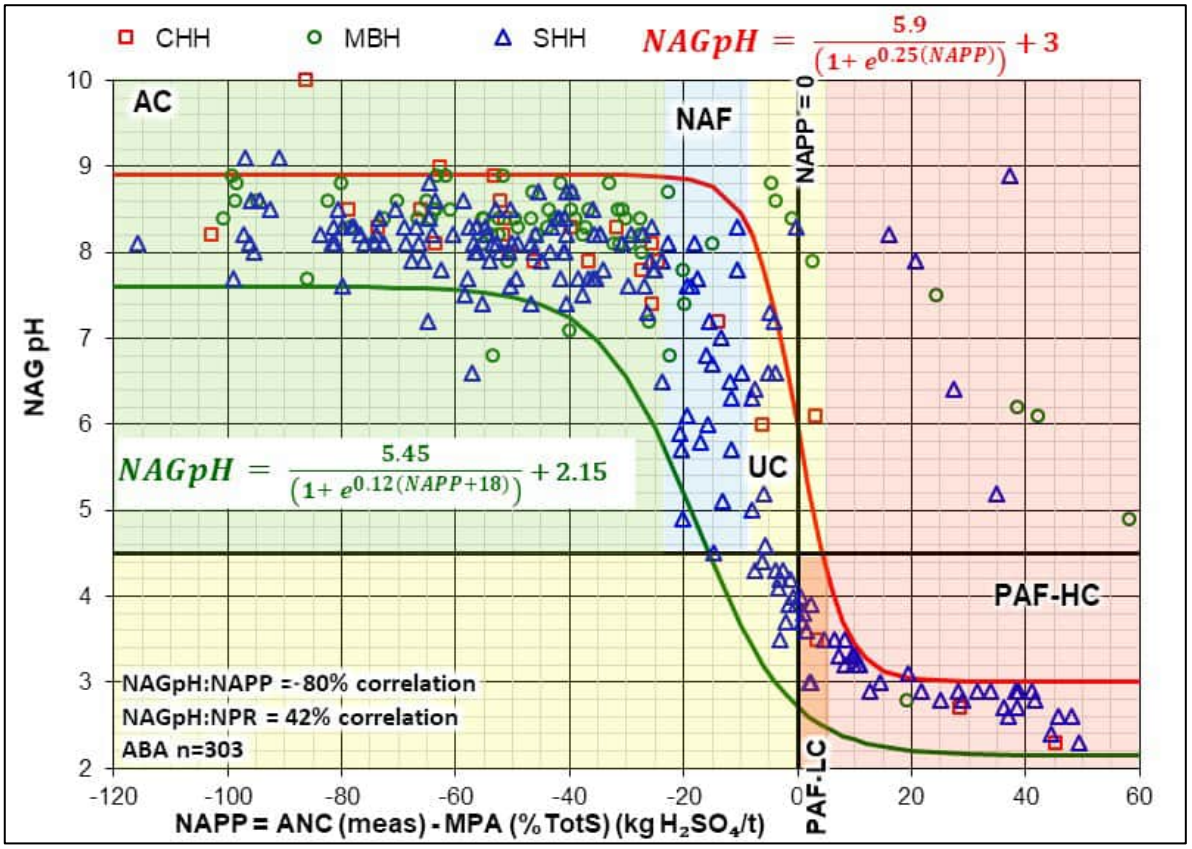


Figure 2-4: Geochemical classification plot

Source: FMG, 2017; measured data shown from the Golder study (2015).

Note: Note: CHH = hard chert; MBH = hard magnetic BIF; SHH = Shale.

Table 2-2: Material classification – North Star Magnetite Project

Bin	Classification	$NAPP_{Clay}$ (kg H_2SO_4/t)	Calc NAGpH Lower	NPR_{Clay}
0	NAF-Ox	(based solely on weathered profile)		
1	AC	-	-	≥3
2	NAF	≤ -7.5	≥4.5	≥2
3	UCU	-15.7 ≤5	-	≥2
4	UCL	≤ -15.7	-	<2
5	PAF-LC	-15.7 ≤5	<4.5	<2
6	PAF-HC	>5	-	-

2.2.4 Characteristics of tailings products

Most data generated to date represent tailings samples generated from the processing of ore sourced from oxide materials. However, the Golder study included samples of tailings representative of

processing of fresh ore material, but the origin of the ore was not defined. In general, due to the low total sulfur content, tailings do not represent a significant potential for AMD generation. Tailings sourced from oxide material were found to have negligible ANC. Tailings from fresh materials contained significant ANC (50–120 kg H_2SO_4/t) and were classed as acid consuming.

2.3 Potential for contaminant leaching

2.3.1 Available datasets

Table 2-3 summarises the leach data referred to in the available reports and provides commentary on data quality and completeness. A subset of these datasets has been provided by IB Operations in the form of Excel spreadsheets.

2.3.2 Insights from static test data

For waste rock samples, Figure 2-5 shows results of ASLP (Australian Standard Leach Procedure) leachates and NAG liquors presented in the Golder study, plotted as a function of pH. Contact water pH in ASLP tests is invariably near-neutral to alkaline. As would be expected for these pH conditions, the dissolved concentrations of many trace elements are low. Notably, Na and Si (and Li, not shown in the figure) show trends toward higher dissolved concentrations as the pH increases.

The dissolved concentrations of many elements increase in the NAG test liquors – the combined influence of more acidic pH and the presence of oxidation products generated during the tests. A notable exception is Sb, which ranges to the highest dissolved concentrations in the ASLP tests.

For tailings (Golder data), ASLP leachates and NAG liquors were neutral to alkaline, and dissolved concentrations of many trace elements were low.

The GHD datasets are subject to data quality issues that could not be resolved in this review. IB Operations is currently undertaking data reconciliation activities to address these issues, where possible. When the reconciled data are available, the verified data will be collated with the Golder data and reviewed.

Table 2-3: Summary of available leach test data

Study	Method	Comments on data quality and completeness
GHD, 2012	Australian Standard Leach Procedure (ASLP)	Documentation of the leach conditions is not provided. It is not clear whether de-ionised (I) water or acetic acid was used. The list of analytes did not include major cations or anions. It is noted that the dissolved Fe and Al concentrations are extremely high (for the near-neutral to alkaline conditions observed). It is understood that there may have been an issue with filtration at the laboratory, and that therefore the result may be affected by the presence of particulates.
GHD, 2012	NAG tests (analysis of final liquors)	While mentioned in the report text, data were only found for small number of tailings samples.
GHD, 2014	Free-draining columns (AMIRA)	Documentation of operational detail is incomplete. Leaching was according to the standard AMIRA method: 0.4 L/kg monthly, and a smaller volume of water (100 mL) during intermediate weeks (to moisten the sample). Monthly analytical suites included major cations, anions and trace elements. No baseline characterisation was completed on the column samples. The samples were composites, usually mixtures of two individual samples, but the masses used to prepare the composites were not reported. While data describing the composition of individual samples are available, assumptions must be made in order to estimate the composition of the mixed composites tested.
Golder, 2015	ASLP leach	The operational details were recorded: 10:1 de-ionised water: solid contact ratio; 18 hours contact time. The datasets are complete (major cations, anions and trace elements are represented).
Golder, 2015	NAG tests (analysis of final liquors)	For a subset of samples submitted for NAG testing, analysis of the final NAG liquor was conducted. The datasets are complete (major cations, anions and trace elements are represented).

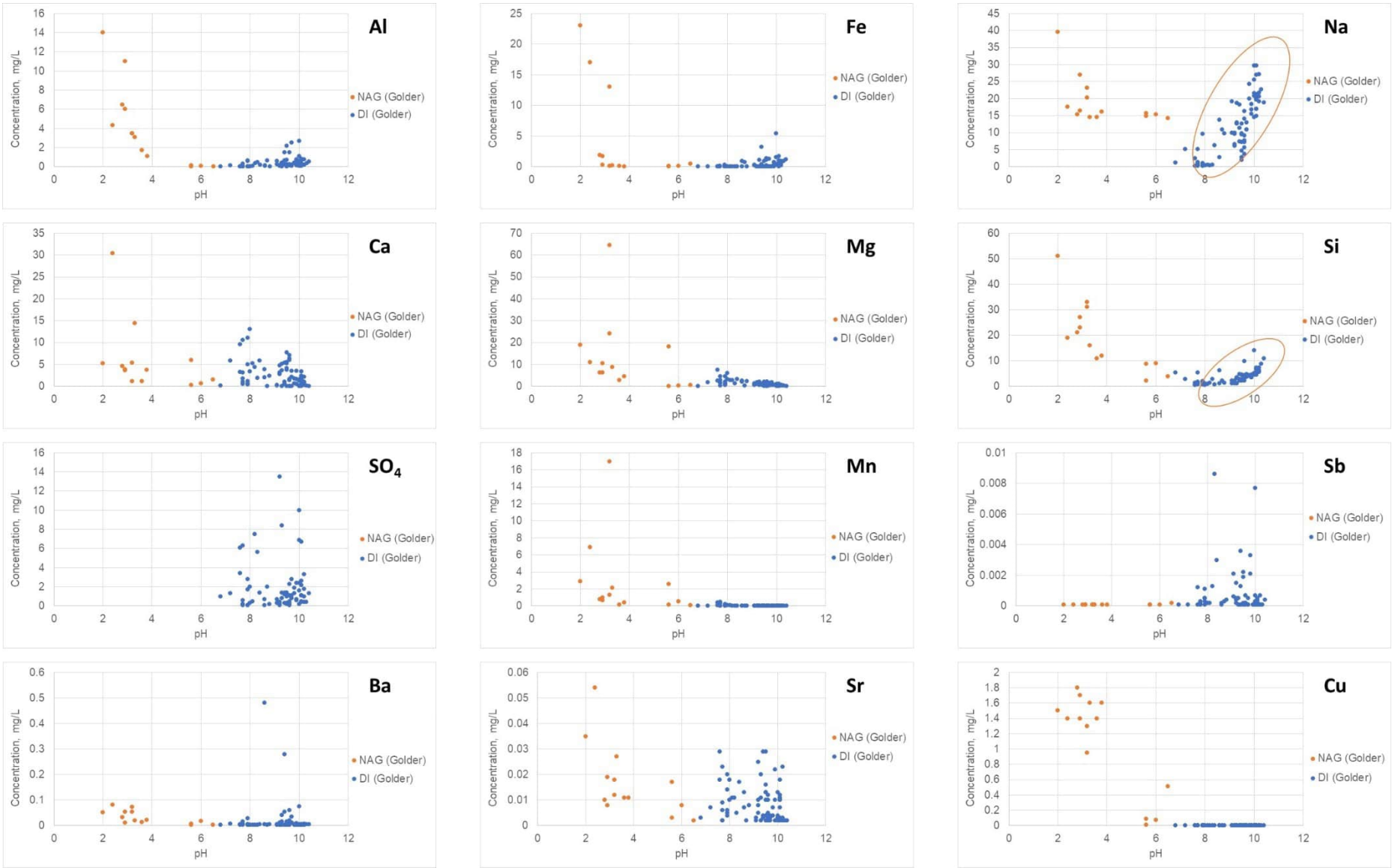


Figure 2-5: Dissolved concentrations of selected solutes, as a function of pH (from Golder datasets)

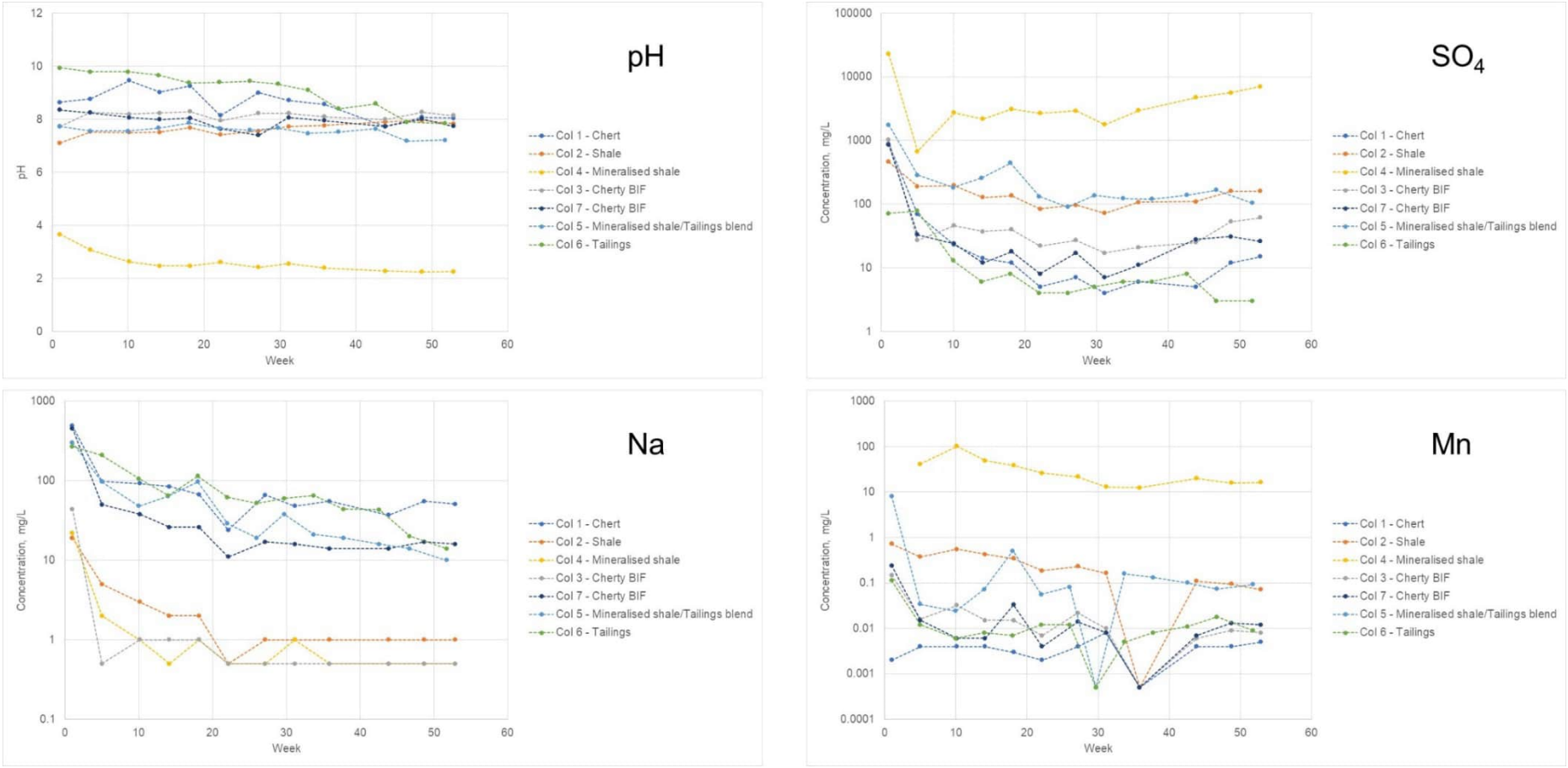


Figure 2-6: Solution pH, dissolved SO_4, Ca and Na as a function of time (from GHD column data)

Table 2-4: Kinetic test results - average solute release rates

Parameters	Units	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
		Chert	Shale	Cherty BIF	Mineralised Shale	Mineralised Shale/ Tailings Blend	Tailings	Cherty BIF
%S	%	0.44	1	0.56	3.3	1.2	0.17	0.81
ANC	kgH_2SO_4/t	5.5	23	10	1.3	8.6	20	2.6
Week test stabilises[1]		10	14	5	10	22	14	5
pH[2]	pH unit	8.3	7.7	8.1	2.4	7.4	8.4	7.8
SO_4	mg/kg/week	0.56	7.2	2.1	220	6.1	0.23	1.1
Cl	mg/kg/week	0.036	0.082	0.091	0.042	0.27	0.029	0.03
Ca	mg/kg/week	0.064	0.48	0.42	1.1	0.93	0.025	0.11
Mg	mg/kg/week	0.04	1.9	1.3	8.8	0.75	0.035	0.37
Na	mg/kg/week	3.2	0.072	0.038	0.042	0.97	2.4	1.2
K	mg/kg/week	0.34	0.074	0.044	0.032	0.26	0.3	0.15
Al	mg/kg/week	0.017	0.00085	0.00083	12	0.0031	0.004	0.0063
As	mg/kg/week	0.00026	0.000031	0.00003	0.00096	0.000068	0.000096	0.000043
Be	mg/kg/week	0.00062	0.00058	0.00066	0.0014	0.00062	0.00064	0.00056
Ba	mg/kg/week	0.0053	0.0048	0.007	0.0021	0.0038	0.0052	0.0057
Cd	mg/kg/week	0.0000027	0.0000031	0.000003	0.00086	0.0000024	0.0000022	0.000003
Cr	mg/kg/week	0.000069	0.000031	0.00003	0.16	0.000032	0.000024	0.000033
Co	mg/kg/week	0.000036	0.000031	0.00003	0.16	0.000024	0.000024	0.00004
Cu	mg/kg/week	0.00011	0.000031	0.00003	0.049	0.00005	0.000078	0.000055
Pb	mg/kg/week	0.000065	0.001	0.000088	0.1	0.0014	0.000068	0.0001
Mn	mg/kg/week	0.00021	0.011	0.00074	2	0.0045	0.00039	0.00062
Ni	mg/kg/week	0.000033	0.000034	0.000038	0.85	0.000042	0.000022	0.00013
V	mg/kg/week	0.00047	0.00031	0.0003	0.0031	0.00024	0.00022	0.0003
Zn	mg/kg/week	0.0014	0.0023	0.00077	0.24	0.0023	0.00057	0.001
Fe	mg/kg/week	0.019	0.0015	0.0016	54	0.0032	0.0048	0.016
Hg	mg/kg/week	0.0000027	0.0000031	0.000003	0.0000032	0.0000024	0.0000022	0.000003
Se	mg/kg/week	0.00003	0.00002	0.000035	0.00047	0.000056	0.000014	0.000041

Notes: [1] Week after which trends in the leachate chemistry were judged to be stable. [2] Average pH at stability calculated from the average H^+ concentrations.

2.3.3 Interpretation of kinetic test data

GHD completed very limited interpretation of data obtained from the column tests. The raw datasheets were provided and SRK has evaluated the results.

Figure 2-6 shows selected outcomes from the tests:

- Solution pH as a function of time: Only one of the column tests developed acidic conditions during testing (Column 4 – a Hanging Wall shale sample with a high sulfur content and classed as PAF-HC). Several other tests were classed as PAF but did not develop acidic conditions during the tested period (1 year).
- Dissolved SO_4 and Na profiles as a function of time: Initially concentrations are relatively high, reflecting leaching of pre-existing salts from the sample. After this initial stage, the profiles for both parameters tend towards a steady concentration – considered representative of ongoing production within the column (for example, sulfide oxidation and acid neutralisation taking place within the column). Many other parameters show analogous trends.
- Dissolved Mn profiles as a function of time: Significantly higher concentrations of Mn are observed in leachates from the test generating acidic conditions. Many other trace parameters show analogous trends.

SRK used the steady concentrations observed in latter portions of the tests to calculate steady-state oxidation related production rates for solutes (Table 2-4). These rates will form the basis of estimating solute production from waste material exposed on pit walls and within waste rock dumps.

Figure 2-7 shows steady-state SO_4 production rates plotted as a function of estimated sample sulfur content. A positive correlation is shown. [As mentioned in Table 2-3, baseline characterisation of the column samples was not undertaken. The sulfur content was estimated by assuming that the composite sample was prepared using equal measures of the individual samples. This approach gave reasonable agreement with data provided in the GHD spreadsheets for most – but not all – column samples.]

However, it is important to note that the samples studied in kinetic testing program were biased high when compared to the range of sulfur contents presented in Figure 2-3. The kinetic testing results may not represent the bulk of the waste rock. As a result, solute release related to oxidation could be overestimated, and solute release associated with weathering processes other than sulfide mineral oxidation could be underestimated.

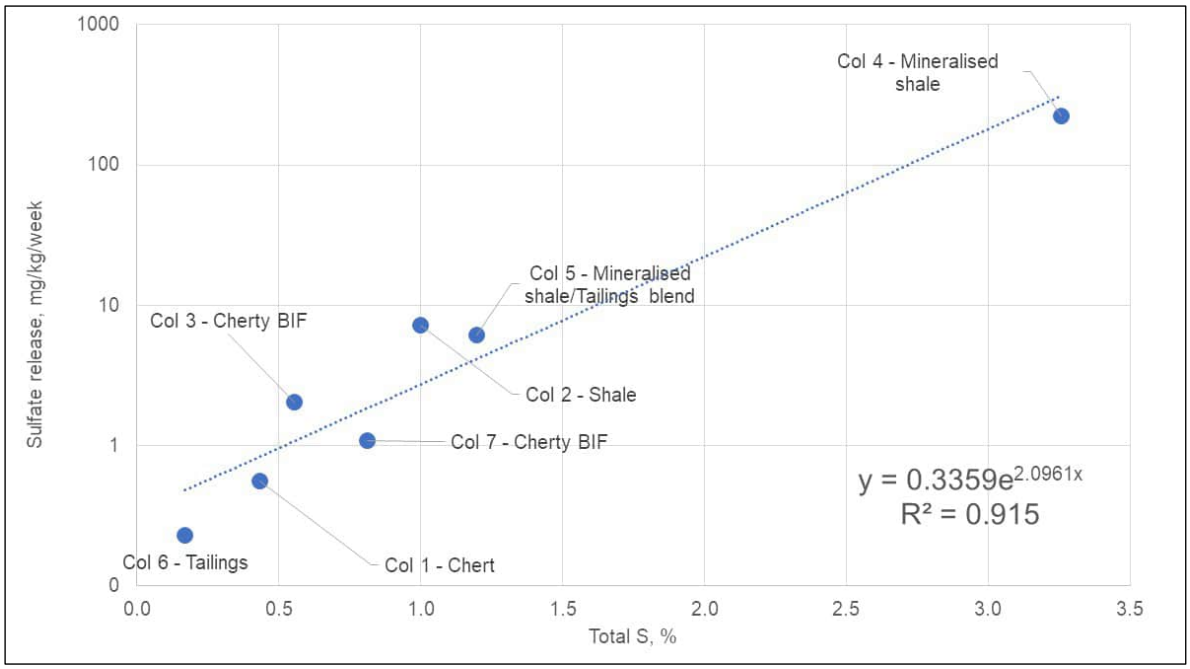


Figure 2-7: Average SO_4 production rate plotted as a function of (estimated) sample sulfur content (calculated from GHD column data)

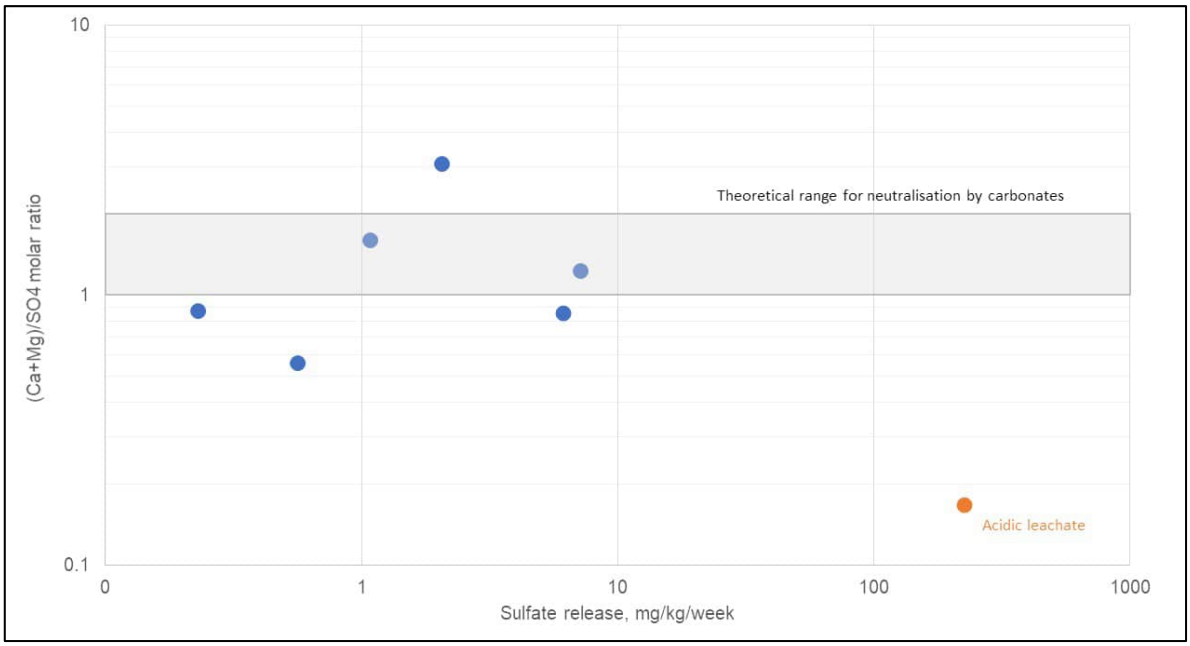


Figure 2-8: Molar (Ca+Mg)/SO_4 ratios as a function of sulfate release (calculated from GHD column data)

Figure 2-8 shows (Ca+Mg)/SO_4 molar ratios plotted as a function of SO_4 production rates. For neutralisation dominated by Ca- or Mg-bearing carbonates, (Ca+Mg)/SO_4 molar ratios in leachate are expected to lie between 1 and 2. Several of the tests give ratios falling outside this range. This observation, combined with the ongoing release of Na from the tests, gives weight to the interpretation that a Na-bearing mineral (silicate?) contributes to neutralisation in North Star materials.

For selected elements, Figure 2-9 shows elemental release as a function of sulfate release. The elements shown all show release positively correlated with sulfate release – indicative of release controls linked to sulfide oxidation, either release from the matrix of the dissolving sulfide (Zn, Pb?) or from minerals reacting in response to the acidity generated (Ca, Mg, Mn?).

Na and K release are not correlated with sulfate release; for the tests operating at near-neutral pH, release of both elements is relatively constant – generally between 1 mg/kg/week and 3 mg/kg/week for Na, and at less than 0.6 mg/kg/week for K. Thus, it appears that the mineral source for these elements is not necessarily reacting in response to acid generation, but instead dissolving in response to contact with water. The continued release of these elements over the duration of testing suggests that dissolution may be subject to a kinetic control – possibly a reactive silicate mineral.

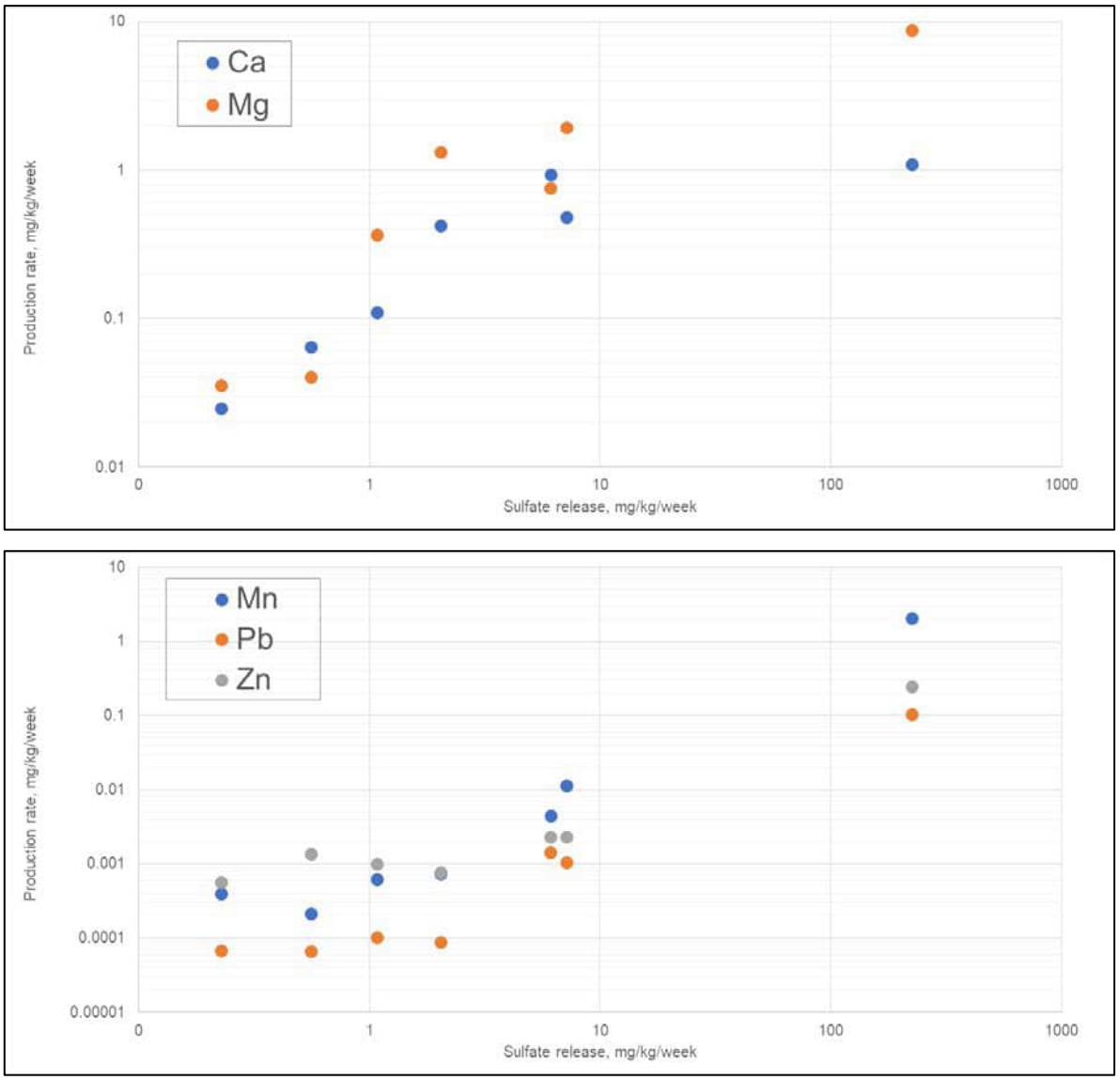


Figure 2-9: Elemental release (Ca, Mg – top; Mn, Pb, Zn – bottom) as a function of sulfate release (calculated from GHD column data)

2.3.4 Mineral solubility controls (laboratory tests)

Leachate data has been processed using PHREEQC to determine possible mineral solubility controls that have applied in the laboratory tests.

The following possible controls were identified:

- Carbonates – calcite, dolomite, rhodochrosite
- Fe and Al hydroxides
- Mn oxides and hydroxides – manganite (MnOOH), pyrolusite (MnO_2)
- Amorphous silica
- Barite
- Aluminosilicates - stilbite (zeolite): $(Ca,Na_2,K_2)[Al_2Si_7O_{18}].7H_2O$ and petalite: $Li[AlSi_4O_{10}]$
- Hydroxysulfates - jarosite and jurbanites [Acid conditions only].

2.4 Descriptions of mine features to be modelled

2.4.1 Pit shells and pit wall composition

Table 2-5 presents the proportions of exposed pit wall according to AMD classification category. Figure 2-10 shows an image of the pit shell.

Table 2-5: Composition of pit walls

Pit	PAF-HC %	PAF-LC %	UCL %	NAF %	Total area (m²)
Eastern Limb Central	-	0.30	0.21	99.5	1,268,000
Eastern Limb North	-	0.56	0.49	98.9	1,310,000
Eastern Limb South	-	0.12	-	99.9	357,346
North Star	7.6	1.7	0.85	89.8	2,183,000
Total	**7.6**	**2.7**	**1.6**	**95.2**	**5,118,346**

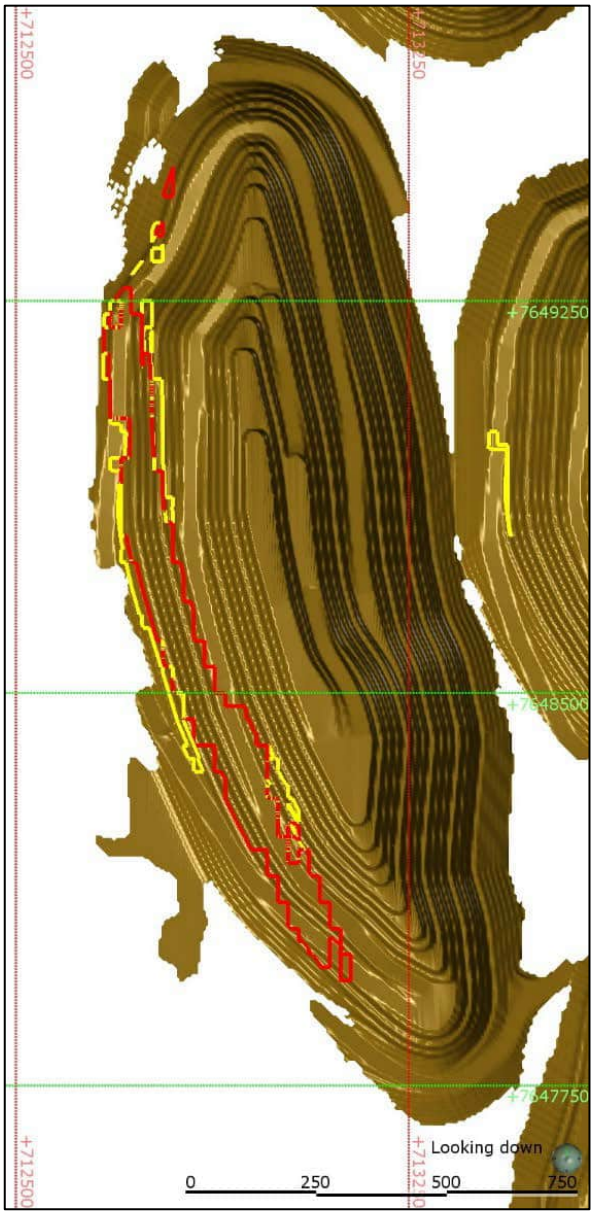


Figure 2-10: Distribution of material types that would be exposed on the North Star pit wall

Note: PAF-HC wall area outlined in red, PAF-LC in yellow

2.4.2 Waste dump designs and composition

Mine scheduling information provided by IB Operations included the estimated mass of ore and waste production per year, per AMD classification. IB Operations also provided the calculated average total S, Ca, Fe and Na content of the waste materials scheduled for each year.

Figure 2-11 shows the estimated masses of waste material per year. While NAF-oxide dominates in earlier years, later years are dominated by acid consuming (AC) waste. PAF-HC waste is scheduled during the period, 2025–2030.

Figure 2-12 shows the average total sulfur content of the waste material types as calculated from the block model. Notably, the average sulfur content for NAF and UCL classed waste is greater than 0.5% over the duration of mining.

Going forward, these data will be processed in more detail so that an overall acid-base account for the waste can be determined – to build confidence in the current working assumption that there is a low likelihood of acid generation (low proportion of PAF-HC combined with high proportions of AC-classed waste). The relatively high sulfur content of NAF material suggests that saline drainage could be likely.

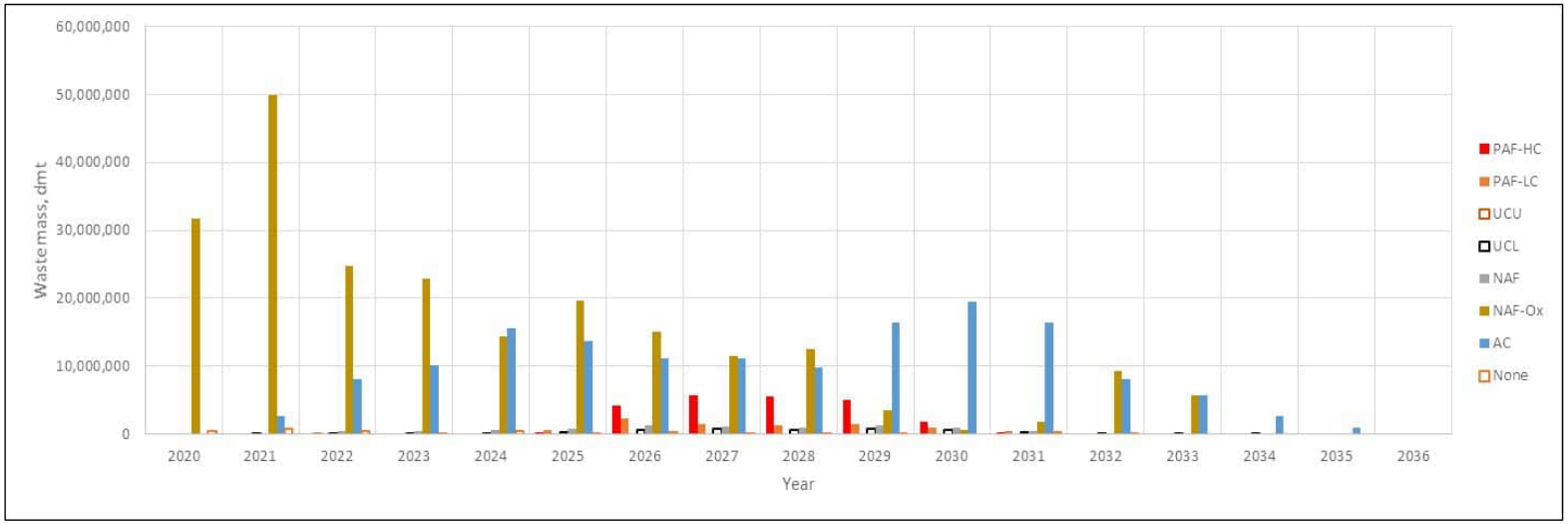


Figure 2-11: Schedule of waste masses, differentiated by AMD class

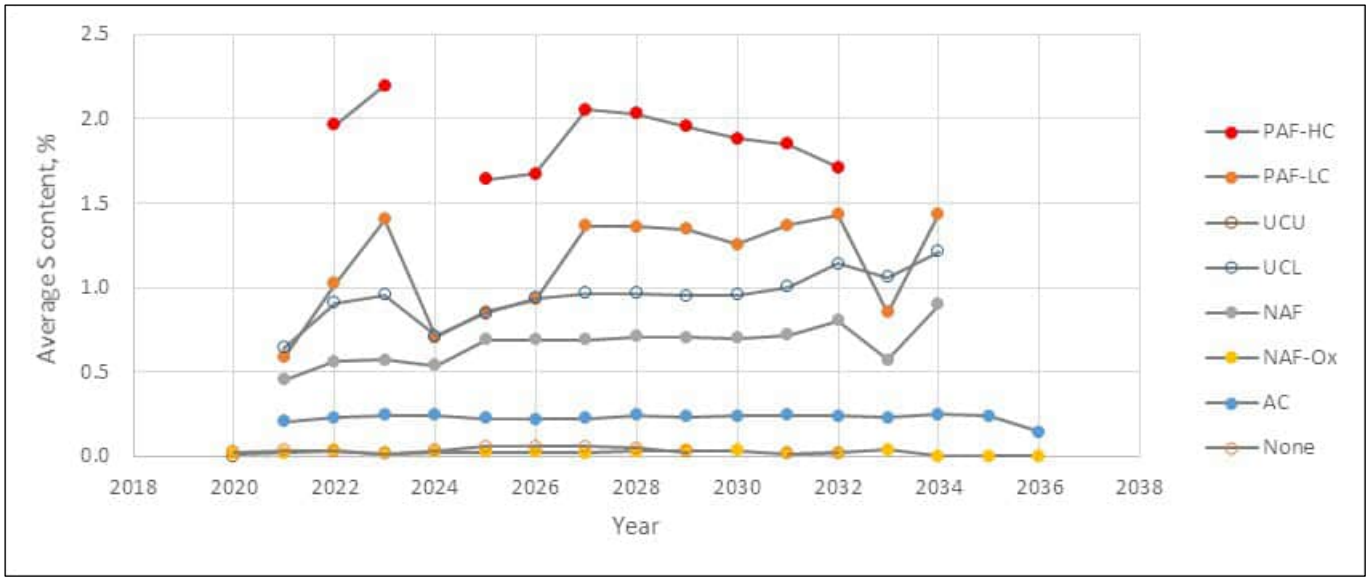


Figure 2-12: Average total sulfur content in the waste as scheduled, differentiated by AMD class

2.5 Inputs to water balance modelling

A water balance will be constructed using GoldSim software to simulate physical processes occurring in the North Star pit lake system (climatic, hydrological and hydrogeological). Modelling will be based on the following inputs as provided by FMG:

- The pit shell, which has PAF materials exposed on the walls/ benches
- A footprint area within the closure bund to be used for the rainfall capture catchment area
- A SILO (Scientific Information for Land Owners) database of daily rainfall and evaporation records for the North Star site for the period, 1918–2017
- Groundwater inflow rates.

The SILO rainfall records will be processed to create stochastic rainfall sequences in GoldSim using the WGEN method. WGEN is a stochastic weather generation method originally developed in the 1980s at the US Department of Agriculture Agricultural Research Service (Richardson and Wright, 1984). WGEN uses historical monthly and annual statistics to generate daily time-series of precipitation and assumes that precipitation follows a gamma probability distribution. The method is a first-order Markov chain model, i.e. the probability of rain on a given day is dependent on the wet or dry status of the previous day. A total of 100 individual daily rainfall sequences (realisations) will be created, and statistics from these will be checked against the SILO record to ensure that data are suitable for the purposes of modelling.

Runoff coefficients for the pit walls will be agreed with FMG prior to use, as will evaporation factors to be used for conversion of the SILO pan evaporation data to simulate evaporation from the lake surface.

A detailed water balance for the WRD will not be constructed. Geochemical modelling for the WRD will incorporate the following physical inputs, provided by FMG:

- Net dump infiltration rates, as a percentage of annual rainfall
- Runoff rates (volumes, durations and frequencies) for water and sediment will be derived from modelling carried out by Landloch.

3 Role of the TSF as contaminant source for the pit lake

Available data are somewhat biased to tailings formed from oxide materials. However, the Golder dataset included tailings formed from fresh material. With respect to potential to generate acidity and/ or solutes, no significant difference between the tailing types was noted. This outcome is consistent with expectations, given the BIF-dominated geology of ore host rock. However, other processes such as evapo-concentration could lead to elevated solute concentrations in the tailings process and porewater in the longer term and should be assessed as part of the operational water balance, coupled with solute production determined from the kinetic testing.

From a geochemical perspective alone, it is considered that the tailings may not represent a significant contributor with respect to either acidity or solute loadings and that the TSF should not represent a significant contaminant source for the pit lake. However, verification of process water quality and the effects of evaporation on TSF pond (and tailings porewater quality) is required.

4 Gap analysis

The outcomes of the gap analysis have been summarised in Table 4-1. While data gaps and limitations have been identified, it is considered that there are sufficient data to continue developing models of water and solute balances for the North Star Magnetite Project.

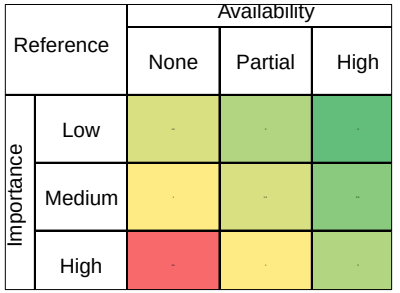


Table 4-1: Gap analysis outcomes

Feature	Description	Data limitations, gaps	Rating	Comments/ Implications
Waste rock geochemistry	Oxide – material considered to be NAF	Very limited geochemical characterisation data		Unlikely to host sulfide mineralisation and probably already significantly leached; does not comprise a significant proportion of waste rock dump volume
	Fresh rock – majority NAF but some sulfide mineralisation in Western Shale Hanging Wall unit	Acid generating and neutralising characteristics relatively well understood, and sufficient data available to determine solute production potential		
Tailings geochemistry	NAF – classed, considered either NAF or acid consuming (AC)	Sample numbers are relatively low, and somewhat biased toward oxide tailings		
	Impacts of process/ porewater quality drain-down	Tailings process/ pond water quality		
Ongoing solute production rates	Kinetic test data describing rates of acid and solute generation	Baseline characterisation of test samples did not take place		To fully utilise the datasets, assumptions regarding initial chemistry of the test samples will be necessary
	Representativity of kinetic test samples	Samples selected for kinetic testing are biased towards relatively high sulfur contents and may also be biased high in solute release rates; may not address solute release from non-mineralised waste rock		Solute release rates associated with sulfate production may be overestimated for most of the waste rock if based on current dataset
Baseline groundwater	Low solute content, neutral to alkaline water	Some uncertainty as to reliability and representativity of available analysis		Unlikely to represent most significant contributor to solute loads in pit lake – but might contribute alkalinity and neutralising potential; sensitivity studies will be necessary to determine possible influence on lake chemical conditions

Feature	Description	Data limitations, gaps	Rating	Comments/ Implications
Waste rock dump composition	Estimates of material proportions by AMD class are available – supported by summaries of key parameters (average S, NAPP, Ca, Na, Fe)	Scheduling of the material types		
	ANC availability/ kinetics	Limited ABCCs; short-term testing, incomplete interpretation of the kinetic test data		Should ANC deplete before sulfides, the likelihood of acid generation in the long-term may be misjudged
Pit shells and pit wall composition	Pit shells have been provided, along with estimates of exposed areas, by AMD class	No summary of averages for key parameters (average S, NAPP, Ca, Na, Fe)		Assumptions regarding appropriate values for sulfur content for different areas on exposed walls will be necessary
Climate data	SILO records for daily rainfall and evaporation records for the North Star site for the period 1918–2017			
Groundwater inflow/ outflow from pit	Outputs from IB Operations hydrogeological modelling			Any uncertainties in the hydrogeological model will have an impact on geochemical modelling
Dump hydrology	Dump runoff flow and estimates of net infiltrations to dump interior	To be provided based on outputs from surface water modelling		

Project Number: FMG060

Memo Title: Geochemical Studies – North Star Magnetite Project
Data Review and Gap analysis

Yours faithfully

SRK Consulting (Australasia) Pty Ltd

Signed by:



Claire Linklater
Principal Geochemist

Signed by:



John Chapman
Principal Consultant

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SRK Report Client Distribution Record

Project Number: FMG060

Report Title: North Star Magnetite Project – Waste Rock Dump Runoff

Date Issued: 24 April 2019

Name/Title	Company
Sylvie Ogier-Halim	Iron Bridge Operations

Rev No.	Date	Revised By	Revision Details
0	03/04/2019	Claire Linklater	Draft Report
1	24/04/2019	Claire Linklater	Final Report

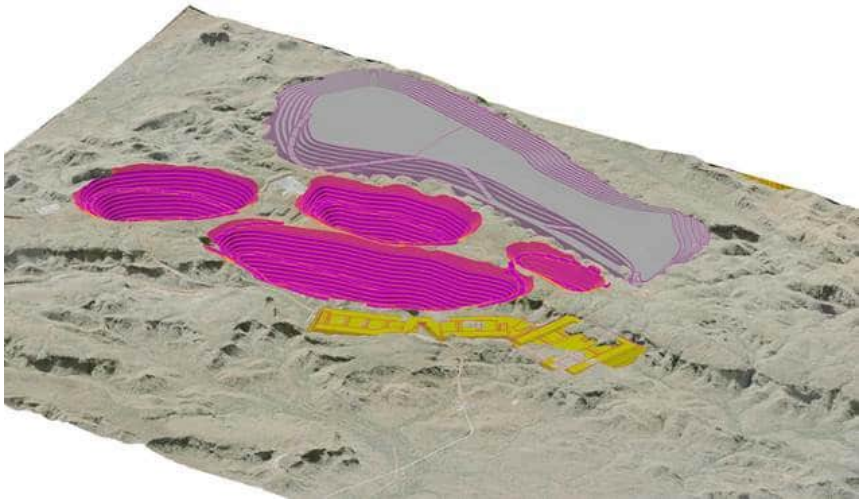
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Appendix 11: SRK: Waste Rock Seepage Water Quality Predictions

North Star Magnetite Project – Waste Rock Dump Seepage (Update)

Report prepared for

Iron Bridge Operations



Report prepared by

SRK Consulting (Australasia) Pty Ltd

FMG084

December 2020

North Star Magnetite Project – Waste Rock Dump Seepage (Update)

Iron Bridge Operations

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Executive Summary

Iron Bridge Operations (IBO) is in the process of developing the North Star Magnetite Project. Geochemical studies have been undertaken to support assessment of potential water quality impacts from waste rock that will be produced and placed in a waste rock dump (WRD) during mining of the deposit. In 2019, modelling of WRD seepage was undertaken based on waste classifications and WRD designs under consideration at the time. Since 2019, geochemical classification of waste rock materials has been revisited and the WRD design has changed.

The revised waste rock classifications comprise three main categories, as follows:

i). non-acid forming (NAF) (representing 74% of the waste rock)

ii). NAF with elevated sulfur (NAF_S) (representing 6 % of the waste rock)

iii). potentially acid forming (PAF) (representing 20% of the waste rock).

The conceptual WRD design incorporates internal 'PAF' cells (containing co-mingled PAF, NAF_S and NAF material) encapsulated within NAF basal and cover layers. The WRD footprint area is estimated at approximately 270 ha, of which 180 ha (in plan) may contain PAF cells (concentrated towards the north of the WRD footprint). To simplify the assessment of WRD seepage quality, the WRD was divided into two distinct zones, the PAF cell area and the NAF-only area. As outlined in Table ES-1, three cases were assessed for the PAF cell area, to address the possible variability and quantity of the PAF materials, while a single case was assessed for the NAF-only material.

Table ES-1: Cases assessed

Case	Proportion of material class (%)			Description
	PAF	NAF_S	NAF	
PAF cell area (co-mingled materials), 180 ha				
1. Base Case	25	8	67	Co-mingled internal cell (60 m) based on average proportions from mine schedule; basal (10 m) and cover (10 m) layer 100% NAF
2. Best case (lower bound)	25	-	75	As for base case but NAF_S is not reactive
3. Worst case (upper bound)	33	-	67	As for base case but NAF_S is PAF
NAF-only area, 90 ha				
Base case	-	-	100	Comprises NAF only

For each material type (NAF, NAF_S and PAF), solute production rates were quantified using results from laboratory kinetic (column) tests. Laboratory-derived reaction rates were extrapolated based on sulfur content and then scaled to represent field conditions in the WRD.

Seepage quality was estimated by:

- calculating the mass of solute that may be generated from oxidation and kinetically controlled processes, and then dissolved in the volume of contacting water (infiltration from rainfall); most calculations examined timeframes equivalent to the water residence time within the WRD
- accounting for likely mineral and gas interactions (e.g. reaction of neutralising minerals contacting seepage, such as carbonate- and silicate-based minerals; equilibration with CO_2 in pore gas; and precipitation/dissolution of secondary minerals).

Sensitivity calculations were completed to evaluate the influence of scaling factors and assess macroscopic WRD properties on modelling outcomes.

It is considered unlikely that acidic conditions would develop, as sufficient carbonate- and/or silicate-based neutralisation potential would be available along seepage flow paths within the WRD. Irrespective of pH, seepage has the potential to become moderately saline, with elevated concentrations of dissolved sodium, calcium, magnesium, and sulfate. Calculated dissolved concentrations of some metals and metalloids could reach concentrations in excess of interim trigger limits for the site, even when accounting for mineral solubility.

For some parameters, estimated concentrations in seepage were more than 100 times higher than in baseline groundwater or surface water (e.g. chromium, cobalt, lead, and nickel). In such cases, dilution within the downstream environment – at factors of 1,000 or more – would be required to lower dissolved concentrations to values in line with baseline averages.

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Disclaimer

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1 Introduction

The North Star Magnetite Project being developed by Iron Bridge Operations (IBO) is in the early stages of development. Stage 1 of the development is focused on mining and processing oxide material, while Stage 2 will progress deeper into the orebody to mine ore from below the oxide zone.

In 2019, IBO commissioned SRK Consulting (Australasia) Pty Ltd (SRK) to undertake geochemical studies to assess potential waste rock dump (WRD) seepage quality for the proposed mine development. The outcomes of these studies were documented in a series of reports:

- WRD seepage assessment (SRK, 2019a)
- WRD run-off water quality assessment (SRK, 2019b)
- Pit lake water balance and quality assessment (SRK, 2019c).

Based on these assessments, it was concluded that WRD run-off and pit lake water quality would pose a low risk of impact to the downstream environment. However, under some conditions, seepage from the WRD could be released and would be considered a risk. Although acidic seepage was considered unlikely, there is a potential risk that seepage could become saline.

Since completion of the 2019 studies, the geochemical classification of waste rock materials has been reassessed and the proposed WRD design has been updated (SRK, 2020). These changes triggered a requirement to refine the WRD source terms and update the seepage assessment.

This report provides an update to the earlier geochemical modelling and includes updated seepage quality predictions for cases tailored to reflect current material classifications and WRD design concepts.

2 Project Description

The North Star Magnetite Project includes expansion of the existing North Star (NTS) pit and development of the Eastern Limb North, Central and South pits. Waste rock is to be placed in a single WRD and process tailings will be placed in a tailings storage facility (TSF). A temporary low-grade ore stockpile (LGOS) will also be established. The mine infrastructure will include a crushing and screening hub, magnetic separation processing plant, roads and other associated facilities. Figure 2-1 shows the layout of the mine area.

The NTS pit is expected to be the deepest pit and the currently proposed pit shell will intersect PAF rock. Since mining will take place below the groundwater table, at cessation of operations lakes are expected to form within the pits. IBO has undertaken hydrogeological modelling of the long-term post-closure conditions near the pits. The modelling results indicate that the lakes will represent permanent groundwater sinks in the local hydrogeological environment.

Surface water features of interest are shown in Figure 2-2. There are several permanent pools in and around the mine area. One of these pools, Site 12 Pool, is located just east and downstream of the WRD.

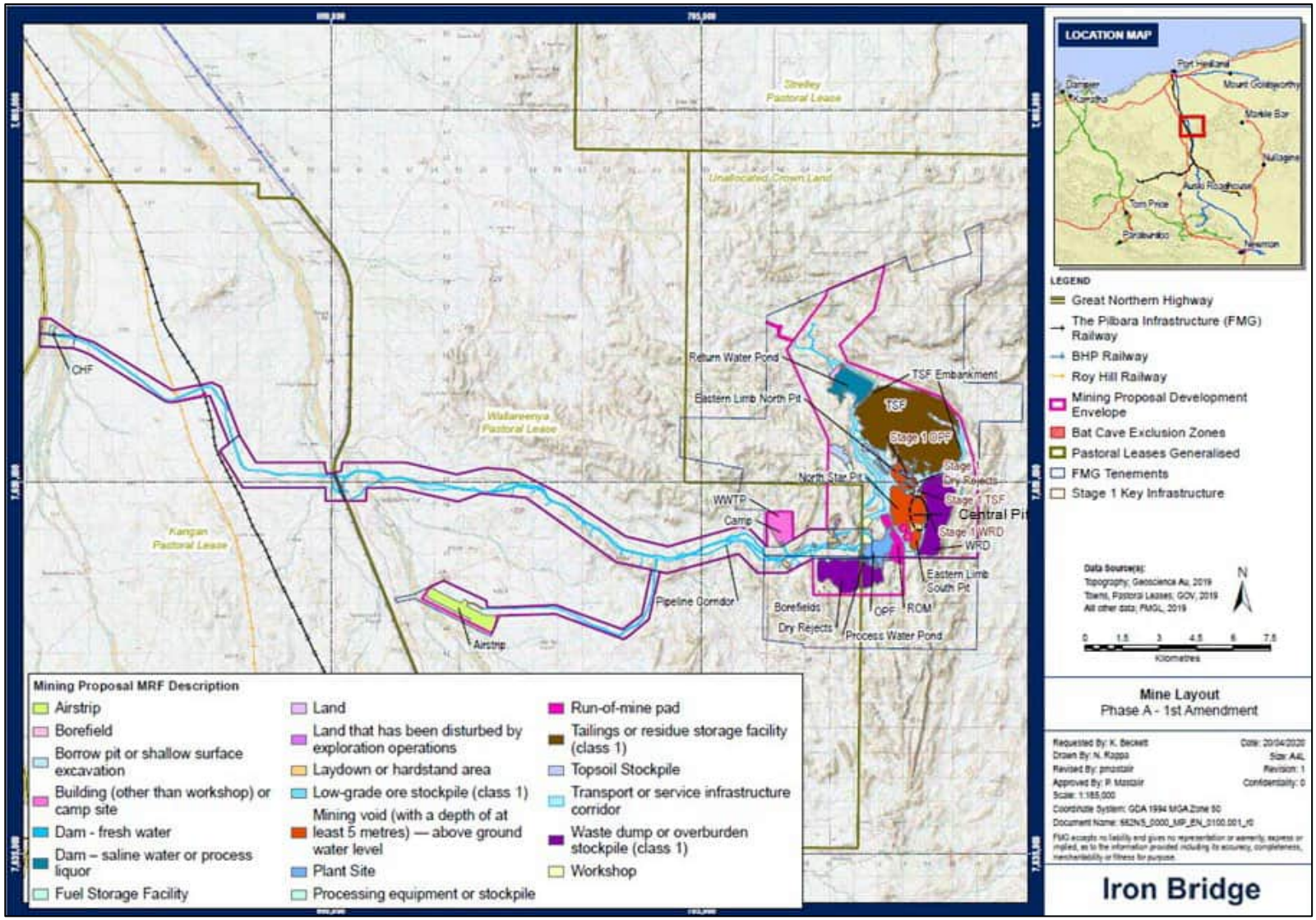


Figure 2-1: Mine layout

Source: IBO

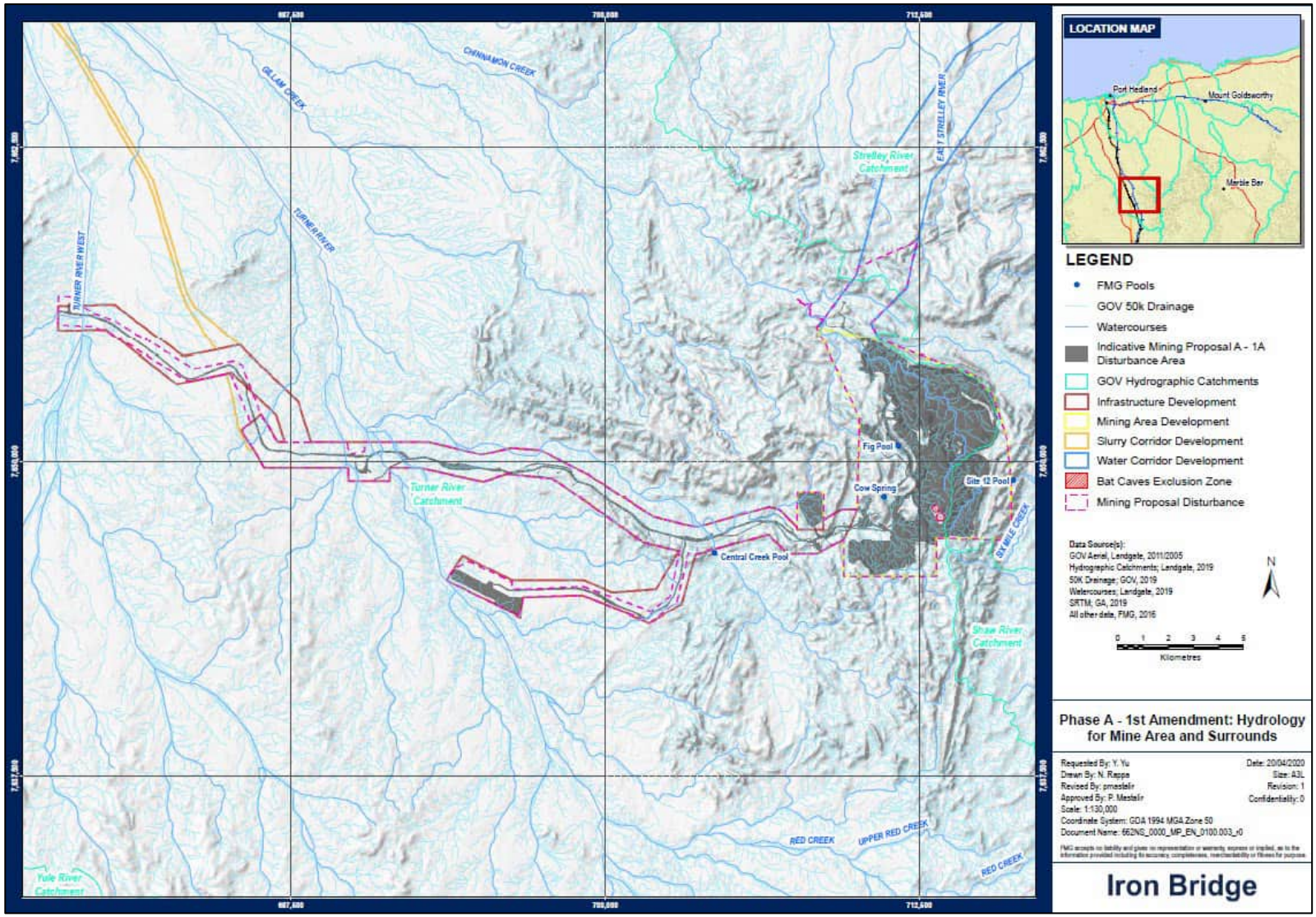


Figure 2-2: Iron Bridge infrastructure, mine site hydrology, and locations of water pools of interest

Source: IBO

3 Waste Rock Composition and Scheduling

3.1 AMD classification

The status of subsurface material characterisation programs is documented in SRK (2020). AMIRA- and MEND-based approaches for AMD classification were evaluated and both found to result in similar outcomes when used to identify PAF-classed material. The MEND approach could be implemented more readily based on available analytical data and was recommended as the basis for AMD classification. Classification is therefore based on the Neutralising Potential Ratio (NPR)[1] estimated from sulfur and calcium content (as analytical surrogates for acid and neutralising potential, respectively), in combination with a sulfur cut-off of 0.2, which was found to be effective in differentiating PAF and NAF material.

For the purposes of waste management, the AMD classification is simplified to three material categories, as follows:

- PAF: Waste with a sulfur content above the threshold (0.2% S) and an NPR less than 3. This category will include waste representing a risk of AMD (NPR <1) and material of uncertain (UC) acid potential (1 <NPR <3).
- NAF_S: Waste with a sulfur content above the threshold (0.2% S) but with an acid neutralising capacity exceeding the maximum potential acid (MPA) by a factor of three, i.e., an NPR greater than 3. While posing a low risk of AMD, such material may pose a risk of neutral (saline) mine drainage (NMD).
- NAF: All low-sulfur waste, i.e. sulfur content is less than the threshold value of 0.2% S. This waste category is considered to pose a low risk of AMD or NMD.

3.2 Material balance and scheduling

The provisional material balance derived from the block model and based on the classification approach is presented in Table 3-1 for the mining period 2021 to 2035.

Table 3-1: Provisional material balance

Material class	Waste rock	
	Volume (bcm)	Proportion
NAF	126,291,292	74%
NAF_S	10,319,225	6%
PAF	34,673,925	20%
Total	**171,284,441**	

Source: LOMMP_IB_2021Q1_v1.01_AMD_SCE01.xlsx.

Based on the outcomes of the block model, most of the waste rock to be produced is classed as NAF. Figure 3-1 shows scheduled annual production volumes and indicates that during the period 2026 to 2031, significant proportions of the waste rock will comprise PAF-classed material. Notably, each year the volume of NAF will exceed the volume of PAF material, except for 2028. Figure 3-2 shows the estimated average sulfur content for mined waste rock, by year and AMD classification.

[1] Ratio of acid neutralising capacity (ANC) to maximum potential acid (MPA), i.e. ANC/MPA.

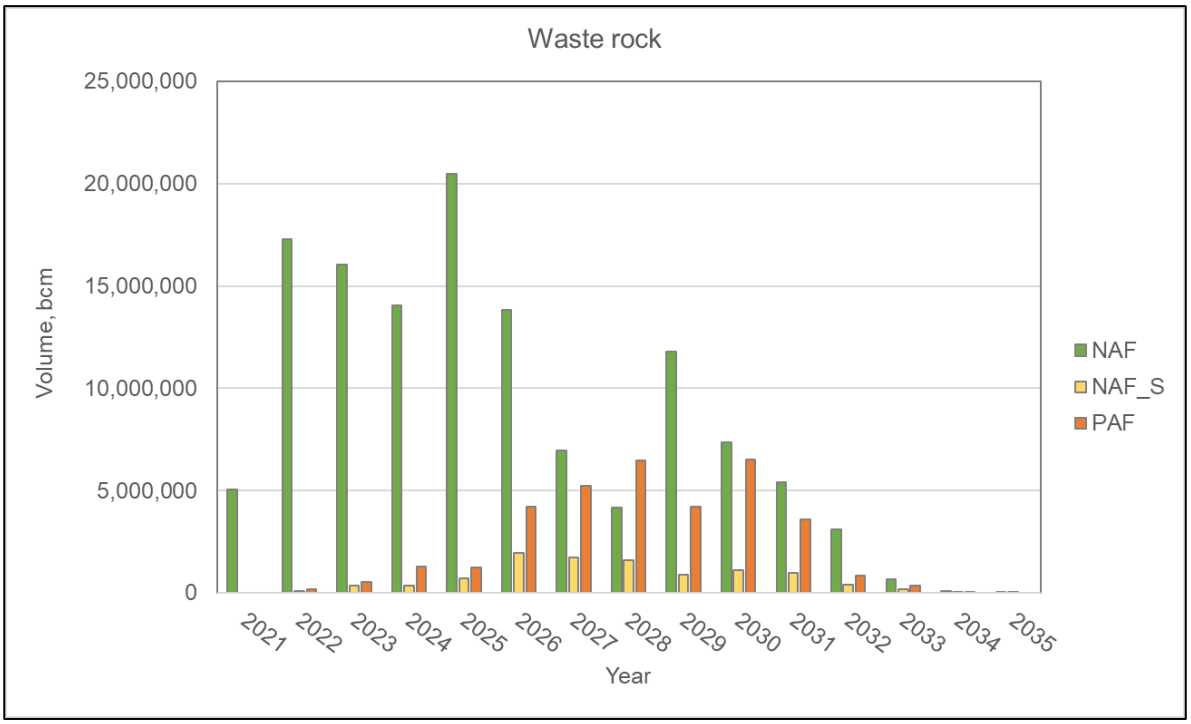


Figure 3-1: Schedule of waste mass produced during mining, differentiated by AMD class

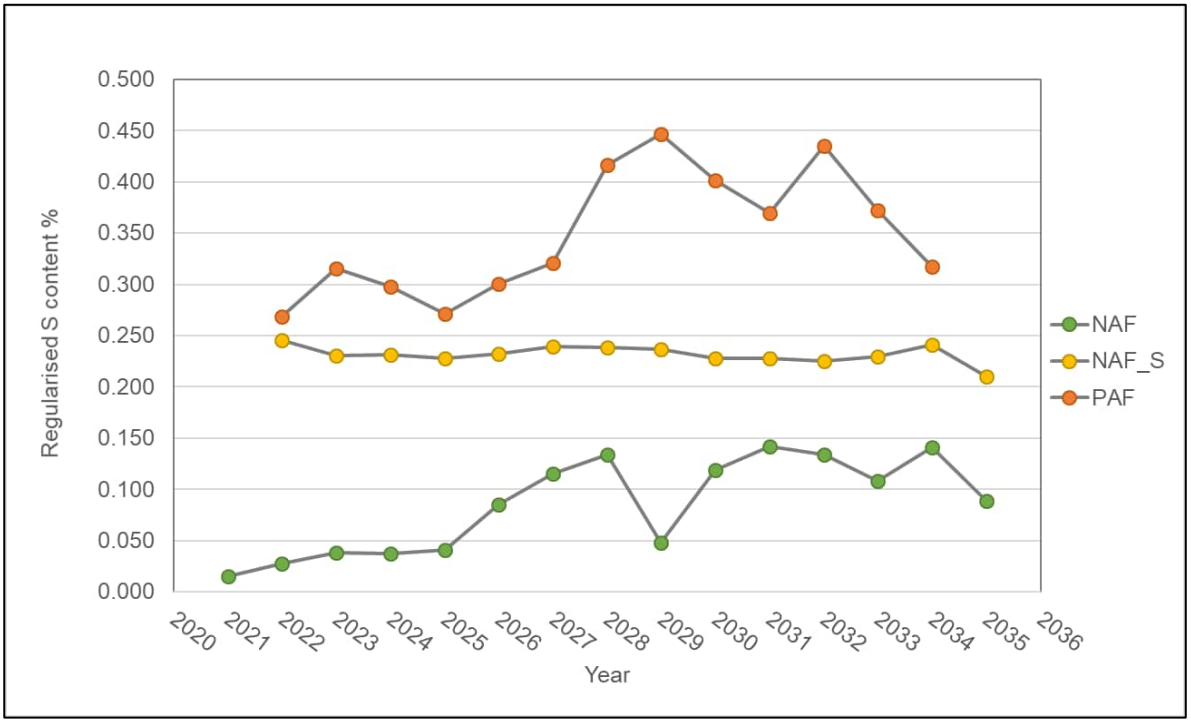


Figure 3-2: Estimated total sulfur content of waste mass produced during mining

4 Waste Rock Dump Design

While predominantly NAF waste rock will be mined, IBO recognises that the proportion of PAF-classed material could represent a risk of AMD if not managed appropriately. Similarly, the small proportion of NAF_S material could represent a risk of NMD and may require appropriate management as well.

Conceptual WRD designs are being developed by IBO to mitigate the risk of AMD and NMD. The proposed design is illustrated in Figure 4-1 and includes the following key features:

- Internal co-mingled PAF/NAF_S/NAF material – placement of potentially reactive PAF and NAF_S material alongside NAF within co-mingled cells referred to as 'PAF' cells. The 'PAF' cells will be deposited in 10 m lifts and stacked up to a maximum of six 'PAF' lifts (60 m height) within the WRD footprint.
- A basal layer comprising NAF, and possibly NAF_S, material. The target minimum thickness of the basal layer is 10 m.
- An outer shell (top surface and side slopes) – minimum 10 m thick – comprising NAF only.

The revised WRD design as shown in Figure 4-1 increases the distance between reactive material and the oxygen source (air at the WRD surface) with the aim of reducing oxygen ingress and thereby oxidation rates. The outer NAF layer will also reduce the risk of WRD run-off contacting reactive materials. Further, any acidic seepage that may eventuate within the 'PAF' cells has potential to be neutralised as it percolates through the basal NAF layer, reducing the risk of acidic WRD seepage. The basal layer will also prevent any underflow passing beneath the WRD from contacting PAF material in the overlying lifts.

The current mine schedule (Figure 3-1) indicates that large masses of NAF waste will be mined before PAF and NAF_S wastes are encountered. This would enable placement of NAF waste to form the basal layer, prior to placement of co-mingled materials within the 'PAF' cells. During the later stages of mining (after 2028), NAF waste rock volumes would generally exceed PAF material volumes. This should allow scheduling of PAF and NAF_S wastes to report to the internal co-mingled area of the WRD and placement of the NAF cover layer.

Based on the maximum internal PAF cell height (60 m) and 10 m encapsulation layers, the maximum WRD height is expected to be up to 80 m. Fewer 'PAF' cells would be deposited towards the edges of the WRD. As shown in Figure 4-2, IBO expects the 'PAF' cells to be concentrated toward the northern side of the WRD. The WRD footprint area is estimated at approximately 270 ha, of which 180 ha may contain PAF cells.

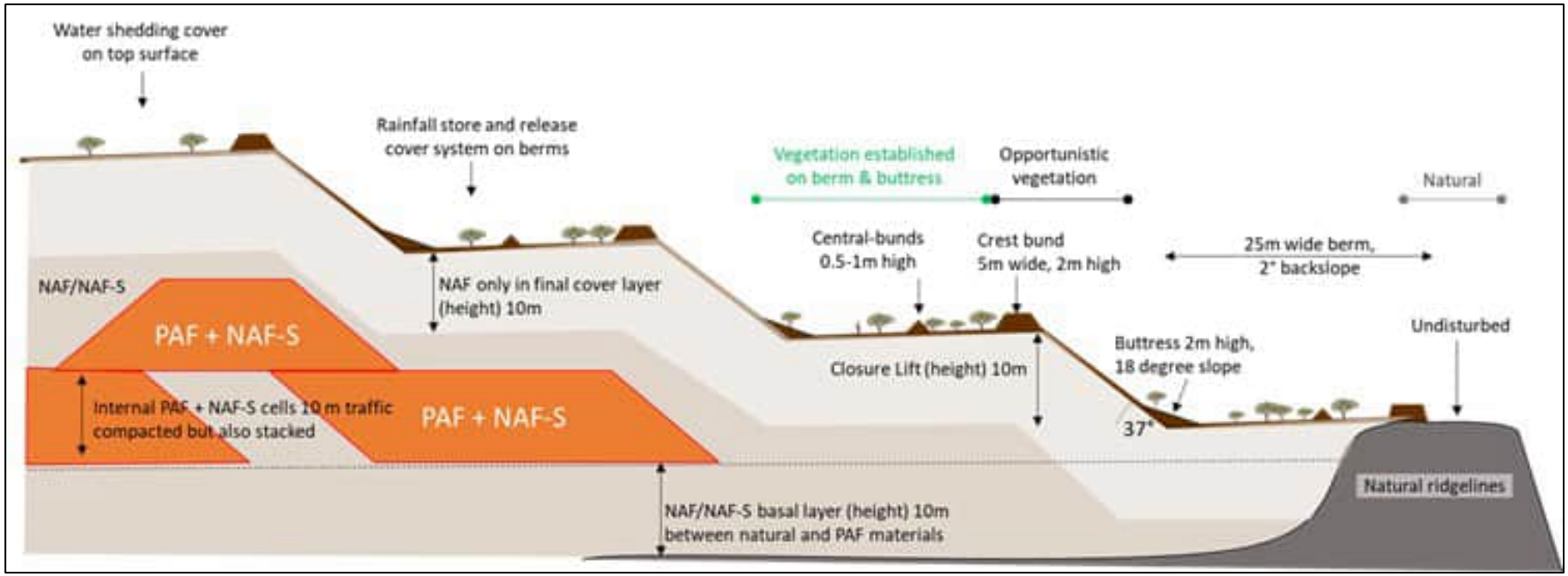


Figure 4-1: Schematic representation of stacked 'PAF' cells in the WRD

Source: IBO

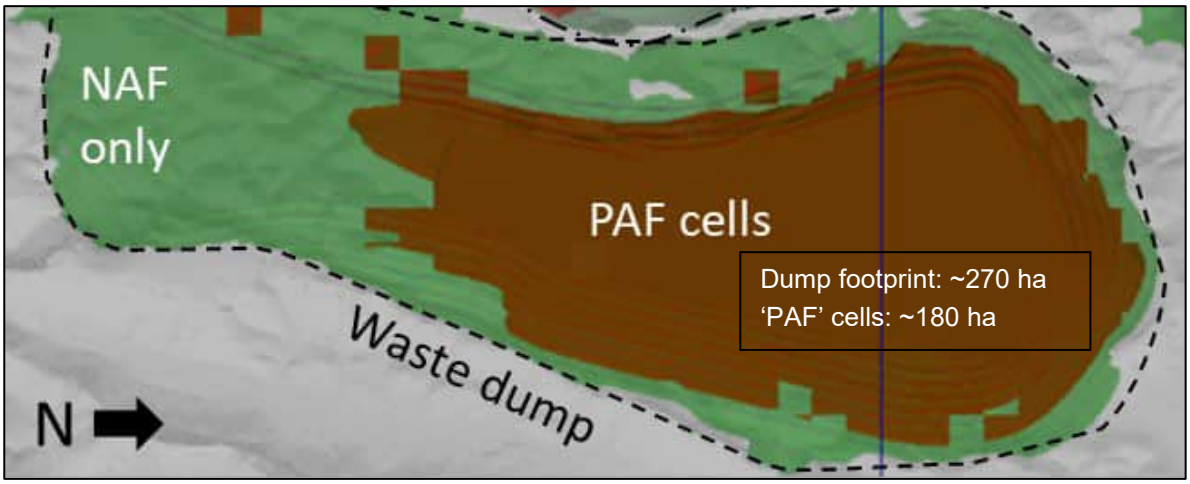


Figure 4-2: Schematic showing distribution of PAF cells within the WRD footprint

Source: IBO

5 Modelling Approach and Assumptions

5.1 General

While lateral seepage paths may occur where compacted horizons are encountered within the WRD (e.g. trafficked lift surfaces), most water infiltrating through the top surface of the WRD is expected to percolate downwards.

Seepage flows will be controlled primarily by the rate at which water infiltrates the top surface. Given the dry climate of the project area, it is expected that percolation rates will be slow and there will be a long lag time while the WRD 'wets up' (i.e. the moisture content increases to field capacity before seepage is released).

Seepage at the base of the WRD is expected to be dominated by slow percolation through water-retentive, fine-grained materials. Daily influences are not expected to have a strong effect on basal percolation rates. However, periodic flushing may occur during storm events, through preferential flow paths defined by more permeable, coarse-grained material where these are contiguous through the WRD.

Solute loadings are expected to be greater in the case of slowly percolating flows – due to the combination of finer grain size and greater reactivity within contacting material, and the longer water residence times (when compared to preferential flow paths) – than in rapid preferential flows. Modelling of seepage quality has therefore focused on accumulation of solutes in this more slowly percolating component of seepage. This is shown schematically in Figure 5-1.

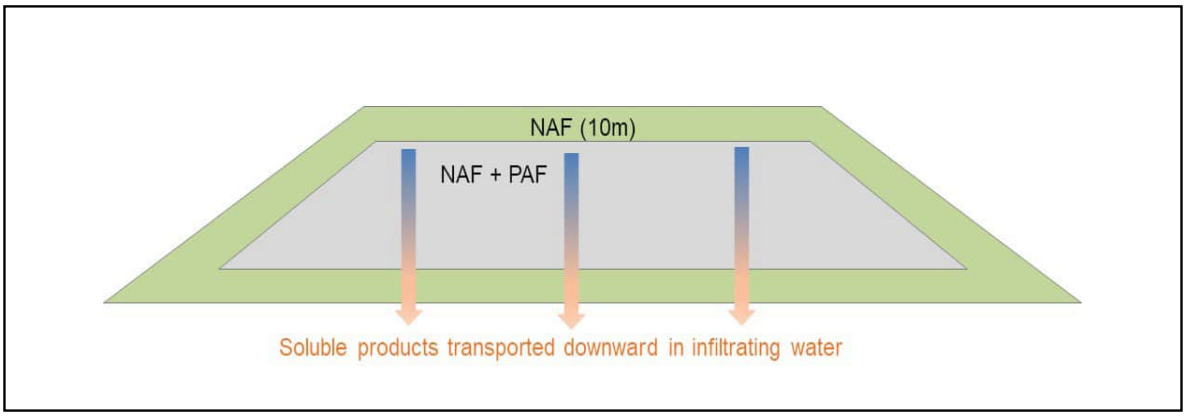


Figure 5-1: Schematic representation of solutes accumulating in WRD seepage

5.2 Solute production and release

Solute production rates have been quantified using results from laboratory-scale kinetic (column) tests. Key test results are summarised in Table 5-1. The kinetic test program is documented more fully in SRK (2020).

The results provide an indication of solute release rates as a function of a material attribute, such as sulfur content or AMD classification. Figure 5-2 shows average sulfate release rate plotted as a function of sample sulfur content. This and other correlations have been used to gain insight to controls on solute release from the materials. Conceptually, most solutes were considered to result from sulfide oxidation, or from reactions in response to sulfide oxidation as a result of subsequent neutralisation; solute production rates were therefore related directly to sulfate production.

Table 5-1: Kinetic test results – average solute release rates

Parameter	Unit	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
		Chert	Shale	Cherty BIF	Mineralised shale	Mineralised shale/ tailings blend	Tailings	Cherty BIF
Sample characteristics								
% S, estimated[1]	%	0.44	1	0.56	3.3	1.2	0.17	0.81
ANC, estimated[1]	kgH_2SO_4/t	5.5	23	10	1.3	8.6	20	2.6
NAPP (AP – ANC)	kgH_2SO_4/t	7.8	7.4	6.5	98	28	-10	22
NPR (ANC/AP)	-	0.41	0.76	0.61	0.013	0.23	3.9	0.1
Class	-	PAF	PAF	PAF	PAF	PAF	NAF	PAF
Kinetic test outcomes								
Week test stabilises[2]		10	14	5	10	22	14	5
Average leachate pH[3]	pH unit	8.3	7.7	8.1	2.4	7.4	8.4	7.8
SO_4	mg/kg/week	0.56	7.2	2.1	220	6.1	0.23	1.1
Cl	mg/kg/week	0.036	0.082	0.091	0.042	0.27	0.029	0.03
Ca	mg/kg/week	0.064	0.48	0.42	1.1	0.93	0.025	0.11
Mg	mg/kg/week	0.04	1.9	1.3	8.8	0.75	0.035	0.37
Na	mg/kg/week	3.2	0.072	0.038	0.042	0.97	2.4	1.2
K	mg/kg/week	0.34	0.074	0.044	0.032	0.26	0.3	0.15
Al	mg/kg/week	0.017	0.00085	0.00083	12	0.0031	0.004	0.0063
As	mg/kg/week	0.00026	0.000031	0.00003	0.00096	0.000068	0.000096	0.000043
Be	mg/kg/week	0.00062	0.00058	0.00066	0.0014	0.00062	0.00064	0.00056
Ba	mg/kg/week	0.0053	0.0048	0.007	0.0021	0.0038	0.0052	0.0057
Cd	mg/kg/week	0.0000027	0.0000031	0.000003	0.00086	0.0000024	0.0000022	0.000003
Cr	mg/kg/week	0.000069	0.000031	0.00003	0.16	0.000032	0.000024	0.000033
Co	mg/kg/week	0.000036	0.000031	0.00003	0.16	0.000024	0.000024	0.00004
Cu	mg/kg/week	0.00011	0.000031	0.00003	0.049	0.00005	0.000078	0.000055
Pb	mg/kg/week	0.000065	0.001	0.000088	0.1	0.0014	0.000068	0.0001
Mn	mg/kg/week	0.00021	0.011	0.00074	2	0.0045	0.00039	0.00062
Ni	mg/kg/week	0.000033	0.000034	0.000038	0.85	0.000042	0.000022	0.00013
V	mg/kg/week	0.00047	0.00031	0.0003	0.0031	0.00024	0.00022	0.0003
Zn	mg/kg/week	0.0014	0.0023	0.00077	0.24	0.0023	0.00057	0.001
Fe	mg/kg/week	0.019	0.0015	0.0016	54	0.0032	0.0048	0.016
Hg	mg/kg/week	0.0000027	0.0000031	0.000003	0.0000032	0.0000024	0.0000022	0.000003
Se	mg/kg/week	0.00003	0.00002	0.000035	0.00047	0.000056	0.000014	0.000041

Notes:

[1] No baseline characterisation was completed on the composite samples tested in the columns. While the compositions of individual samples are available, the masses used to prepare the composites had not been reported. Assumptions were made in order to estimate the composition of the mixed composites tested.

[2] Denotes the week after which trends in the leachate chemistry were judged to be stable.

[3] Average pH at stable conditions calculated from the average H^+ concentrations. Colour coding indicates acidic (orange) or neutral (green) pH conditions.

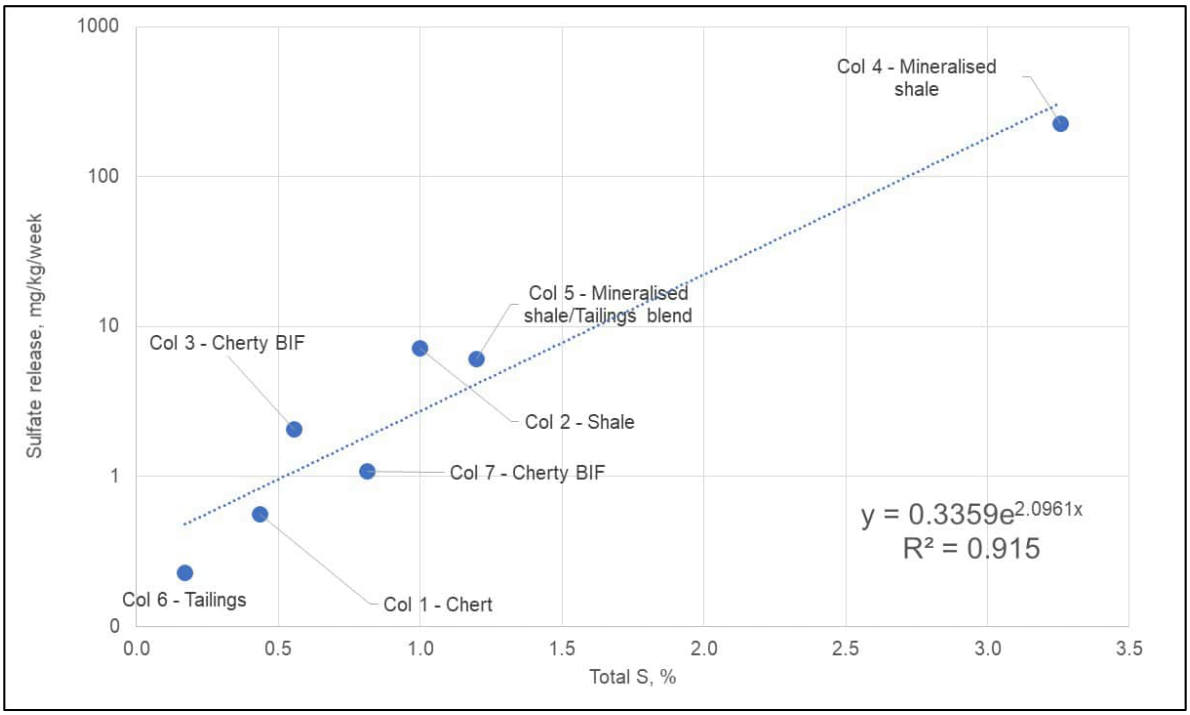


Figure 5-2: Average SO_4 production rate plotted as a function of (estimated) sample sulfur content

Table 5-2: Material types represented in the model

Material	Average initial S content (%)	SO_4 production rate (laboratory) (mg/kg/week)[1]	Description/comments
PAF	0.45	0.9	Sulfur content based on maximum average S% of PAF waste in any year from the mine schedule (considered a conservative approach)
NAF_S	0.23	0.5	Based on average S% of NAF_S waste for all years from the mine schedule
NAF	0.06	0.4	Based on average S% of NAF waste for all years from the mine schedule

Note:
[1] SO_4 production based on laboratory-derived sulfate release as a function of initial S% (Figure 5-2).

For each AMD category, the assumed sulfur content and sulfate production rate are presented in Table 5-2. Release rates for other solutes were calculated from the sulfate release as follows:

- PAF and NAF_S – using mass ratios relative to sulfate release as calculated from column test #4 PAF – Hanging Wall. This was the only test that generated acidic leachates; the mass ratios are therefore considered indicative of the full range of solutes that might be released as sulfides react.
- NAF – using positive correlations between element and sulfate release from pH neutral columns, where those correlations existed.

Release of sodium and potassium were calculated independently to reflect the long-term production of these solutes, which was not directly relatable to sulfur content or sulfate production rates as indicated by the kinetic testing. A laboratory-scale sodium production rate of 0.001 mg/kg/week was estimated for PAF material, and a rate of 1 mg/kg/week was calculated for NAF_S and NAF material. Potassium release was calculated using mass ratios relative to sodium release, and the material category as guided by the relevant column test data. These solutes were considered to be sourced

from a silicate mineral phase present in sufficient quantity to continue releasing these elements (and silicon) at a constant rate within the timeframe being considered.

The laboratory-derived solute production rates require scaling or extrapolation for application to the field-scale WRD. No quantitative site-specific data are available upon which to base scaling factors; ranges of values were therefore assessed based largely on professional judgement and discussion with IBO. Adopting scaling factors is acknowledged to be a simplification and does not account for spatial or temporal variability in solute production within the full-scale facility. However, the approach is considered appropriate for the illustrative calculations being undertaken as part of the current study. The specific factors and corresponding values are summarised in Table 5-3.

Table 5-3: Scaling factors and assumptions

Description	PAF	NAF_S	NAF	Comment
Surface area correction	0.15–0.3			Field-scale material is coarser grained than material tested at laboratory scale
Fraction solute flushed by rainfall/ infiltration	0.2–0.4			Represent incomplete flushing at field scale (e.g. preferential flows)
Temperature adjustment	1–5	1–2	1	Sulfide oxidation is exothermic and there is the potential for heating in reactive PAF materials; at the low sulfide content and the proposed WRD design the likelihood of sustaining high oxidation rates that could lead to elevated temperatures is considered to be low
Assumed proportion oxygenated	0.1–1	0.5–1	0.5–1	In reactive PAF materials, oxygen may be consumed rapidly and gas supply rates may be insufficient to maintain oxygenated conditions throughout the entire waste volume

5.3 Macroscopic WRD properties

The proposed shape of the WRD footprint is shown in Figure 4-2. The WRD is located over a valley and, due to the underlying topography, the height of the WRD will be variable.

For the purposes of modelling, the macroscopic properties of the WRD materials are assumed to be homogenous; values for some key characteristics were agreed upon with IBO as follows:

- porosity – 0.25 (guided by geotechnical studies)
- bulk density – 2,300 kg/m^3. This value was calculated by combining the porosity with the average of estimates of in situ density for Oxide, Kangaroo Caves and Pincunah Fresh rock (3,100 kg/m^3, 2,800 kg/m^{3}and 3,300 kg/m^3, respectively)
- field capacity water-filled porosity (after ‘wetting up’) – 0.05–0.15 (corresponds to 2–7% w/w water content).

Rates of water recharge to the WRD interior are dependent on the water balance in the near-surface layer of waste rock contained in the WRD. Studies undertaken by IBO have indicated that recharge could range between 0% and 11% of mean annual rainfall. These studies were based on modelling the behaviour of weathered ‘oxide’ material. The final WRD surface may comprise materials sourced from greater depth in the stratigraphy with physical properties that differ from the weathered oxide (i.e. coarser grained and more competent). Infiltration through coarser and more competent material may be higher; therefore, the current study assessed a recharge range of up to 20% of mean annual rainfall.

The water residence time within the WRD is a function of the dump height, recharge rate and water-filled porosity. Calculated residence times are illustrated in Figure 5-3, and range from decades at low water-filled porosity and high infiltration rates, to many centuries at high water-filled porosity and low infiltration rates, for a given WRD height.

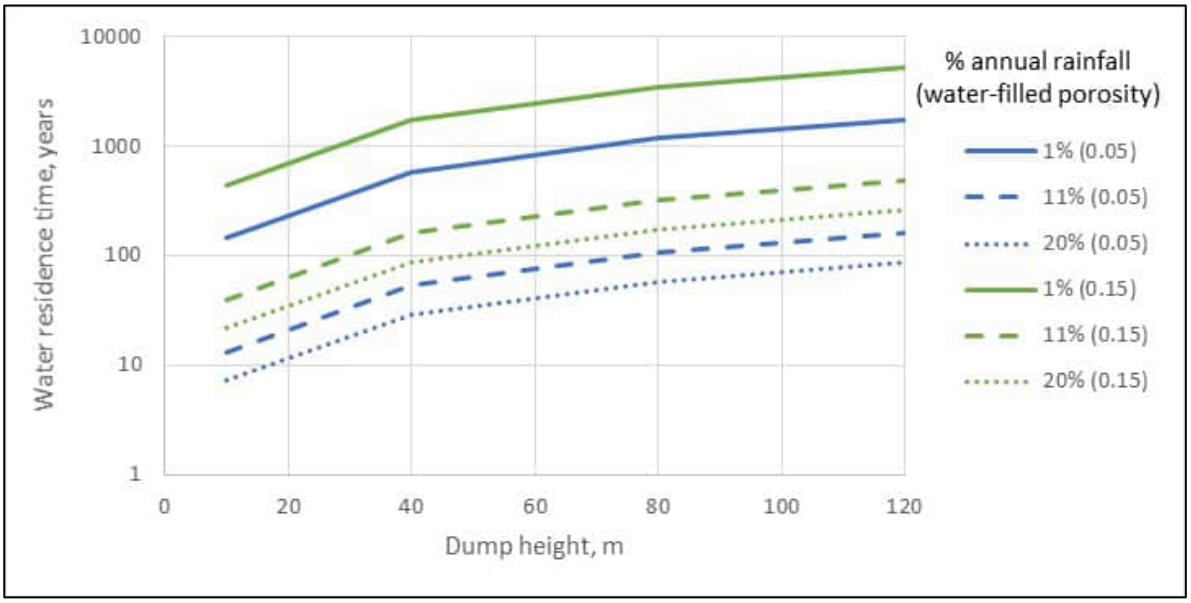


Figure 5-3: Water residence time in the WRD, as a function of recharge (as a percentage of mean annual rainfall) and height

Note: Figure based on mean annual rainfall (342 mm/year).

6 Predicted Seepage Quality

6.1 Assessment cases

As described in the previous section, the conceptual WRD design incorporates internal 'PAF' cells (containing co-mingled PAF, NAF_S and NAF material) that will be encapsulated within NAF basal and cover layers. The PAF cell area of the WRD will encompass approximately 180 ha (in plan, located in the northern part of the WRD footprint) and the remaining area of the WRD (approximately 90 ha) will contain only NAF materials. Therefore, to simplify the assessment of seepage quality, the WRD seepage water quality was estimated independently for the PAF cell area (approximately 180 ha) and the NAF-only area.

The highest risk of elevated solute release, and therefore the worst water quality, is expected to occur for seepage from the PAF cell area. Therefore, three cases were assessed for the PAF cell area to address the possible variability and quantity of the PAF-type materials. The three cases represent aa a base case bookended by a 'worst case' (i.e. NAF_S material classifies as PAF) and a 'best case' (i.e. NAF_S classifies as NAF material).

The case assumptions are summarised in Table 6-1 and reflect the assumption that the scheduled PAF and NAF_S waste volume would be placed entirely within the defined 'PAF' cell footprint area (with the remaining 'PAF' cell volume occupied by NAF).

Table 6-1: Cases assessed

Case	Proportion of material class (%)			Description
	PAF	NAF_S	NAF	
PAF cell area (co-mingled materials), 180 ha Three cases, to reflect potential variability in proportion of PAF at different locations				
1. Base Case	25	8	67	Co-mingled internal cell (60 m) based on average proportions from mine schedule; basal (10 m) and cover (10 m) layer 100% NAF
2. Best case (lower bound)	25	-	75	As for base case but NAF_S is not reactive
3. Worst case (upper bound)	33	-	67	As for base case but NAF_S is PAF
NAF-only area, 90 ha				
Base case	-	-	100	Comprises NAF only

For each case, a series of sensitivity calculations were performed to examine the influence of scaling factors and macroscopic WRD properties on the predicted outcomes. The variables assessed and values adopted are summarised in Table 6-2 and Table 6-3.

Most calculations were based on an area-weighted WRD height of 80 m, which, for the 'PAF' cell cases incorporate 60 m co-mingled material ('PAF' cells) and 20 m NAF (combined basal layer and cover thickness).

Two further variants are included in the assessment:

- a thinner 20 m layer of comingled material, spread out through the entire WRD footprint (270 ha)
- as above, but for a taller WRD (105 m), which would correspond to the maximum design capacity of the WRD (to accommodate 284 Mm^3 of waste rock).

Table 6-2: Sensitivity calculations – scaling factors

Description	Material category	Scaling factor					Comment
Option #		1	2	3	4	5	
Surface area correction	All	0.15	0.3	0.15	0.15	0.15	
Fraction solute flushed by infiltrating water	All	0.2	0.2	0.4	0.2	0.2	
Temperature adjustment	PAF NAF_S NAF	1 1 1	1 1 1	1 1 1	5 2 1	1 1 1	For most cases, any heat generated by reaction is expected to dissipate either via conduction through adjacent unreactive material or removal by flows of fluid. However, for selectively placed PAF material, elevated temperatures may develop.
Assumed proportion oxygenated	PAF NAF_S NAF	0.3 0.5 0.6	0.3 0.5 0.6	0.3 0.5 0.6	0.3 0.5 0.6	1 1 1	For diffusively supplied oxygen, consumption is expected to exceed supply within reactive material, restricting the volume reacting at any one time. Should convective supply of oxygen occur, greater volumes would be oxygenated.

Note: Grey highlight denotes the series of factors considered to be the 'base case'. Red text indicates the factor varied.

Table 6-3: Sensitivity calculations – macroscopic WRD properties

Description	Value for macroscopic attribute					
WRD height, m	80	80	105	80	80	80
Height 'PAF' cell	60	20	20	60	60	60
Footprint (NAF only/'PAF' cell) ha	90/180	0/270	0/270	90/180	90/180	90/180
Proportion of material types in vertical column through the 'PAF' cells						
PAF	25%	17%	13%	25%	25%	25%
NAF_S	8%	5%	4%	8%	8%	8%
NAF	67%	78%	83%	67%	67%	67%
Water infiltration and WRD water content						
Recharge, proportion of annual rainfall (%)	11	11	11	1	20	11
Water-filled porosity (water content, % w/w)	0.1 (4%)	0.1 (4%)	0.1 (4%)	0.05 (2%)	0.15 (7%)	0.15 (7%)

Note: Grey highlight denotes the series of factors considered to be the 'base case'. Red text indicates the factor varied.

6.2 Calculation basis

Most calculations focused on estimation of the mass of solute produced within a one-dimensional column (area 1 m^2; height varied according to the case in question) of waste rock. Solute production time was assigned equal to the time for one WRD pore volume (PV) exchange, i.e. to equate to the water residence time.

Solute production was considered to cease if the sulfur source had been depleted within the time period concerned. The release of sodium and potassium were exceptions. These solutes (and silicon) are considered to be sourced from an abundant silicate mineral phase and would continue to be released at a constant rate within the timeframe being considered.

The resultant solute mass released was dissolved in the relevant pore water flux to generate total solute concentrations in the seepage. Using the modelling code PHREEQC (Parkhurst et al., 2013), the calculated solute concentrations were adjusted to account for potential mineral and gas interactions and yield a corresponding dissolved solute concentration estimate. It should be noted that some cases resulted in very high solute concentrations, outside the confidence limits of the thermodynamic data; in these cases uncertainty exists as to the model outcomes.

For all calculations, the following interactions were considered:

- Equilibration with CO_2 in pore gas. Within the WRD, it is considered likely that CO_2 pore gas concentrations will be in excess of those expected in air (0.03 vol%) due to: (i) reaction of carbonate minerals with percolate to neutralise acid generated, and (ii) slow transport of CO_2 out of the system by diffusion. Pore gas CO_2 concentrations would vary within the WRD, spatially and temporally in response to gas generation and transport within the WRD, and exchange with the atmosphere at the dump surfaces. For simplicity, an elevated concentration of 0.3 vol % CO_2 (saturation index -2.5) was assumed for calculations examining the potential influence of carbonate-based neutralisation potential. For all other calculations, a lower CO_2 content of 0.1 vol% was assumed (saturation index -3).
- Precipitation of secondary minerals such as:
  - oxides and hydroxides – gibbsite, ferrihydrite, MnOOH, amorphous silica
  - sulfates – gypsum, barite
  - hydroxysulfates – jarosite, jurbanite, alunite
  - carbonates – calcite, dolomite, malachite.

Geochemical modelling also examined equilibration with acid-neutralising mineral phases. Two options were considered:

- Carbonate-based neutralisation adopting dolomite as the mineral phase. While dolomite has not been identified within the North Star materials, it was selected to reproduce release of both calcium and magnesium in response to acid generation (as has been observed in kinetic testing).
- Silicate-based neutralisation. Uncertainty exists as to the identity of the mineral contributing to the neutralisation capacity; possible candidates are:
  - stilpnomelane: $(K,Na,Ca)_{0\text{-}1.4}(Fe,Mg,Al,Mn)_{5.9\text{-}8.2}[Si_8O_{20}](OH)_4(O,OH,H_2O)_{3.6\text{-}8.5}$
  - stilbite: $(Ca,Na_2,K_2)[Al_2Si_7O_{18}].7H_2O$.

Thermodynamic data for stilpnomelane were not available. A sodium- and calcium-rich stilbite was present in the database. Several potential neutralising phases were examined: calcium-sodium-stilbite, analcime and phlogopite ($KAlMg_3Si_3O_{10}(OH)_2$), as a possible analogue for a magnesium-rich stilpnomelane, and kaolinite. Aluminium released by aluminosilicates during acid neutralisation reactions can be reprecipitated as aluminium hydroxide and/or -hydroxysulfate. Only combined reaction stoichiometries that result in a net consumption of protons, after accounting for precipitation of aluminium-bearing products, would result in net neutralisation. In the current work, calcium-sodium-stilbite and phlogopite dissolution has been shown to influence pH, while the other mineral phases did not. Therefore, for the current study, phlogopite was selected because its reaction with acid resulted in magnesium release and reproduced trends observed in kinetic testing

The final equilibrated chemistry (on completion of one PV exchange) was considered to be indicative of the seepage water quality from the given area of the WRD. Because the calculation method was relatively straightforward, multiple calculations were possible, allowing examination of alternative

inputs and model assumptions and providing insights as to how these inputs and assumptions would affect seepage outcomes.

For a subset of calculations, long-term concentration profiles in seepage were generated to illustrate how solute release might evolve in the future as multiple pore volumes are displaced from the WRD. These calculations are summarised in Section 6.5.

In all cases, important additional model premises were as follows:

- Solute production continues at a constant rate until the source mass has been consumed. It is likely that generation rates would decrease with time due to processes such as armouring, or reduction in reaction surface area as the source is depleted.
- Lag periods while the WRD 'wets up' have not been factored into the calculations. Lag would delay the onset of seepage and could also result in higher concentrations of percolate at the onset of seepage.
- Over time, the entire WRD height would contribute to solute loading (i.e. no volumes of rock were permanently excluded from contact with percolating seepage).

6.3 Calculated solute concentrations in seepage

For cases where neutralisation occurs within the WRD, calculated solute concentrations in seepage are presented in Table 6-4 (using base case scaling factors and WRD macroscopic properties). The table shows the calculated concentrations in the seepage from the 'PAF' cell and the NAF-only areas after approximately one pore volume displacement (or about 200 years after WRD construction). As discussed in Section 6.5, concentrations may evolve to higher values beyond the first pore volume. However, due to the uncertainty of such long-term predictions, the concentrations predicted for the first pore volume are considered reasonable for short- and medium-term assessment of seepage quality.

The percolate from the WRD as a whole would be a combination of these flows, mixed in a ratio relative to the basal flux from each area. The seepage is near-neutral whether carbonate or silicate-based neutralisation is represented. The seepage in all cases is moderately saline; the predicted total dissolved solids (TDS) content ranges between 2,800 mg/L and 3,100 mg/L.

For the assumed conditions, the major ion composition of the seepage is similar in all cases. However, seepage from the 'PAF' cell footprint is predicted to contain detectable concentrations of a wider range of trace metals and metalloids. It should be noted that concentrations of some metals and metalloids may be overestimated since the calculations may not include all possible solubility controls. Further, other possible attenuation mechanisms such as sorption have not been assessed. The waste rock contains high quantities of iron and aluminium oxyhydroxides and clays – mineral groups known to contribute strongly to adsorptive capacity. At near-neutral pH, many metals and metalloids would be expected to sorb onto such minerals and would reduce dissolved concentrations in seepage.

Table 6-5 presents the calculated solute concentrations in seepage where no neutralisation capacity is present in the WRD. This is considered an extremely unlikely circumstance. For the 'PAF' cells, acidic seepage could be a possibility; under these circumstances the pH would be around 3 and concentrations of some metals would be elevated.

Table 6-4: Calculated solute concentrations in seepage– complete neutralisation within WRD

		Carbonate-based neutralisation				Silicate-based neutralisation			
Scaling factors		**Scaling factors – Option #1 (Table 6-2)**							
WRD properties		**WRD height: 80 m; 11% annual recharge; water-filled porosity: 0.1**							
WRD footprint location		**'PAF' cell**			**NAF only**	**'PAF' cell**			**NAF only**
Case		**1. Base case**	**2. Best case**	**3. Worst case**	**Base case**	**1. Base case**	**2. Best case**	**3. Worst case**	**Base case**
Proportion of material category	PAF	0.25	0.25	0.33	0	0.25	0.25	0.33	0
	NAF_S	0.08	0	0	0	0.08	0	0	0
	NAF	0.67	0.75	0.67	1	0.67	0.75	0.67	1
pH	pH unit	7.4	7.4	7.4	7.5	7.3	7.4	7.3	7.7
Alkalinity	$mgCaCO_3/L$	86	88	87	97	21	24	21	52
Acidity calc.	$mgCaCO_3/L$	0.052	0.05	0.051	0.041	0.1	0.067	0.098	0.023
SO_4	mg/L	1500	1500	1500	1600	1600	1500	1600	1400
Cl	mg/L	0.12	0.092	0.12		0.12	0.092	0.12	
Ca	mg/L	280	270	280	220	170	190	170	240
Mg	mg/L	140	130	130	110	180	140	180	37
Na	mg/L	990	1000	990	1000	980	990	980	1000
K	mg/L	54	58	55	76	150	120	150	68
Al	mg/L	0.0000036	0.0000037	0.0000036	0.000004	0.0000045	0.0000042	0.0000045	0.0000037
As	mg/L	0.0028	0.0021	0.0028		0.0028	0.0021	0.0028	
Be	mg/L	0.0041	0.0031	0.004		0.0041	0.0031	0.004	
Ba	mg/L	0.0061	0.0046	0.006		0.0061	0.0046	0.006	
Cd	mg/L	0.0025	0.0019	0.0025		0.0025	0.0019	0.0025	
Cr	mg/L	0.46	0.35	0.46		0.46	0.35	0.46	
Co	mg/L	0.46	0.35	0.46		0.46	0.35	0.46	
Cu	mg/L	0.045	0.045	0.045		0.029	0.024	0.029	
Pb	mg/L	0.44	0.44	0.44	0.33	0.52	0.47	0.52	0.33
Mn	mg/L	0.017	0.016	0.017	0.012	0.042	0.025	0.041	0.0024
Ni	mg/L	1.3	1.2	1.3		2.5	1.9	2.5	
V	mg/L	0.0091	0.0068	0.009		0.0091	0.0068	0.009	
Zn	mg/L	3.2	3.3	3.2	3.8	3.2	3.3	3.2	3.8
Fe	mg/L	0.0077	0.0077	0.0077	0.0075	0.0084	0.008	0.0084	0.0069
Hg	mg/L	0.0000094	0.000007	0.0000093		0.0000094	0.000007	0.0000093	
Se	mg/L	0.0014	0.001	0.0014		0.0014	0.001	0.0014	
TDS	mg/L	3000	3000	3000	3100	3100	3000	3100	2800
Ion balance	%	43	42	43	36	42	43	42	39
Solubility controls	Neutralising mineral[1]	Dolomite ($CaMg(CO_3)_2$)				Phlogopite ($KAlMg_3Si_3O1_0(OH)_2$) – as an analogue for Mg-rich stilpnomelane			
	Other minerals	$Fe(OH)_3$, MnOOH, calcite, $PbCO_3$, Ca,Na-stilbite, pentasalt ($Ca_5K_2(SO_4)_6$:H_2O, tenorite (CuO), amorphous silica (SiO_2)				$Fe(OH)_3$, MnOOH, calcite, Ca,Na-stilbite, pentasalt ($Ca_5K_2(SO_4)_6$:H2O, tenorite (CuO), amorphous silica (SiO_2)			

Notes: Blank cells in the table indicate instances where the solute was not represented in the source. Redox conditions were assumed to be relatively oxidising, and pe was fixed at +10 (~Eh = +590 mV). The calculations were performed assuming that the system is open to exchange with CO_2 in the pore gas atmosphere: 0.3 vol% (carbonate-based) or 0.1 vol% (silicate-based) – see main text for further discussion. The calculated solutions show poor ion balance – positive imbalances probably relate to overestimation of sodium production within the NAF material – further work is required to better constrain the sodium source term.

[1] The selected neutralising mineral was assumed present along percolate pathways in quantities sufficient to provide effective neutralisation of seepage.

Table 6-5: Calculated seepage chemistry –no neutralisation (considered unlikely)

		Predicted seepage concentrations			
Scaling factors		**Scaling factors – Option #1 (Table 6-2)**			
WRD properties		**WRD height: 80 m; 11% annual recharge; water-filled porosity: 0.1**			
WRD footprint location		**'PAF' cell**			**NAF only**
Case		**1. Base case**	**2. Best case**	**3. Worst case**	**Base case**
Proportion of material category	PAF	0.25	0.25	0.33	0
	NAF_S	0.08	0	0	0
	NAF	0.67	0.75	0.67	1
pH	pH unit	2.7	2.8	2.7	7.7
Alkalinity	mg$CaCO_3$/L	-	-	-	46
Acidity calc.	mg$CaCO_3$/L	320	220	310	0.025
SO_4	mg/L	1600	1500	1600	1300
Cl	mg/L	0.12	0.092	0.12	
Ca	mg/L	270	280	270	290
Mg	mg/L	26	19	26	
Na	mg/L	1000	1000	1000	1000
K	mg/L	56	52	57	43
Al	mg/L	34	26	34	0.0000034
As	mg/L	0.0028	0.0021	0.0028	
Be	mg/L	0.0041	0.0031	0.004	
Ba	mg/L	0.0061	0.0046	0.006	
Cd	mg/L	0.0025	0.0019	0.0025	
Cr	mg/L	0.46	0.35	0.46	
Co	mg/L	0.46	0.35	0.46	
Cu	mg/L	0.14	0.11	0.14	
Pb	mg/L	0.52	0.47	0.52	0.33
Mn	mg/L	7.6	6.2	7.5	0.0033
Ni	mg/L	2.5	1.9	2.5	
V	mg/L	0.0091	0.0068	0.009	
Zn	mg/L	3.2	3.3	3.2	3.8
Fe	mg/L	41	26	40	0.007
Hg	mg/L	0.0000094	0.000007	0.0000093	
Se	mg/L	0.0014	0.001	0.0014	
TDS	mg/L	2800	2800	2800	2700
Ion balance	%	43	43	43	40
Solubility controls		All cases: amorphous silica (SiO_2), pentasalt ($Ca_5K_2(SO_4)_6:H_2O$) 'PAF' cell cases 1–3: K-jarosite NAF-only case 4: $Fe(OH)_3$, MnOOH, calcite, Ca,Na-stilbite			

Notes: Blank cells in the table indicate instances where the solute was not represented in the source. Redox conditions were assumed to be relatively oxidising, and pe was fixed at +10 (~Eh = +590 mV). The calculations were performed assuming that the system is open to exchange with CO_2 in the pore gas atmosphere: 0.1vol% – see main text for further discussion. The calculated solutions show poor ion balance – positive imbalances probably relate to overestimation of sodium production – further work is required to better constrain the sodium source term.

6.4 Sensitivity calculations

Selected outcomes from sensitivity calculations are presented in Figure 6-1. The following comments can be made:

- Low infiltration rates (low percentage recharge) result in long water residence times. Consequently, greater accumulation of dissolved reaction products occurs during transit through the WRD and higher solute concentrations are expected in basal seepage.
- Higher oxidation rates result in somewhat greater solute production – as calculated using the scaling factor for Options #4 and #5 (elevated temperatures and greater proportions of oxygenated WRD, respectively).
- All other factors being equal, calculated outcomes for low and high water-filled porosity are equivalent.

Mineral equilibria and solubility controls mask the model sensitivity for some parameters – for example, seepage pH is controlled by neutralisation capacity (assumed present in excess in the calculations shown in Figure 6-1) and is relatively constant irrespective of the scaling factors or macroscopic WRD properties.

On the other hand, zinc, which was not subject to any solubility controls for most of the calculations presented,[2] demonstrates that scaling factors and WRD properties may introduce ranges in model outcomes that extend to an order of magnitude or more. Many solutes are subject to solubility controls and outcomes are therefore a function of pH and other system parameters such as redox, solution salinity, ratios of constituent elements within the solute mix and carbon dioxide concentrations.

Some of the sensitivity outcomes showed that seepage quality may be better or worse than that calculated in the base case estimates. For some cases, very poor seepage quality is calculated – for example, the case with low infiltration rates. However, at the lower infiltration rates, the flow is much smaller and net loadings to the downstream environment would remain similar. Potential implications of WRD seepage are assessed in Section 7.

[2] Smithsonite ($ZnCO_3$) is calculated to precipitate for the low infiltration case.

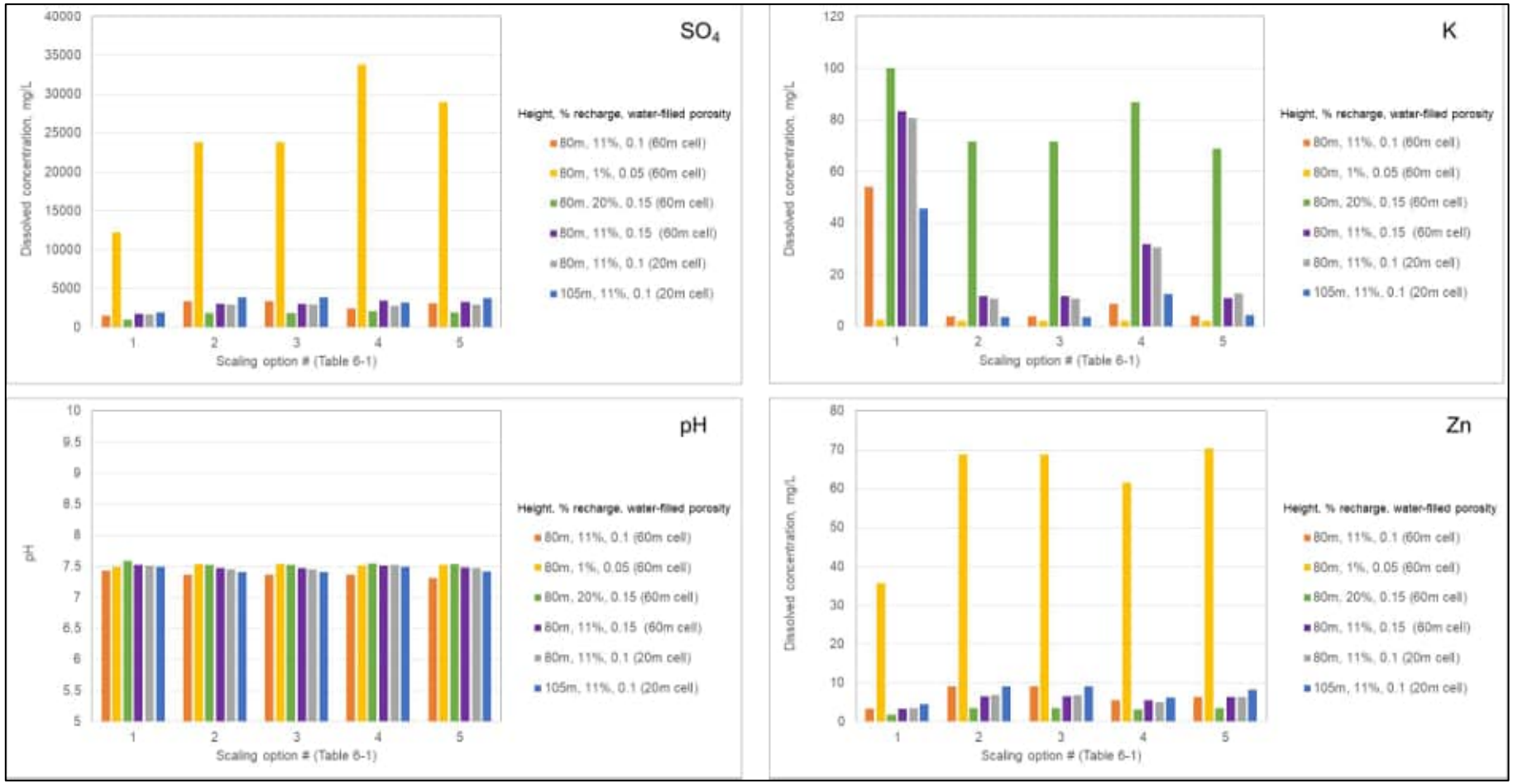


Figure 6-1: Sulfate, potassium, pH, and zinc in seepage, as a function of scaling factors and macroscopic WRD properties (base case 'PAF' cell seepage)

Note: For the calculations represented, carbonate-based neutralisation within the WRD was assumed.

6.5 Temporal evolution of solute concentrations

The simulations of temporal changes in solute concentrations adopted the same solute production terms as defined in the earlier calculations. However, these calculations accounted for:

- solute mass leaving the system (in outflowing seepage)
- representation of the accumulation of reaction products over time where solute generation rates exceed solute release in seepage, i.e. representing an additional source of solute release beyond the first pore volume exchange.

For base case scaling assumptions and macroscopic WRD properties, Figure 6-2 compares sulfate concentration profiles for seepage from the 'PAF' cell area for the base case. Profiles with and without the influence of sulfate solubility controls are shown.

Due to the additional influence of stored reaction product, dissolved sulfate concentrations in seepage increase after the first pore volume exchange. The dissolved sulfate concentration is predicted to peak at a maximum of about 5,600 mg/L (should no solubility limit apply) after about 1,000 years. The predicted peak concentration is lower at approximately 4,400 mg/L if solubility controls are considered.

The concentration profiles exhibit inflexion points corresponding to the times that the sulfide sources are depleted within the WRD. Depletion times (to complete oxidation) are calculated to be around 1,000 years for NAF material, 3,300 years for NAF_S and 6,600 years for PAF material. Note that the timeframe to leach sulfate reaction products from the WRD extend beyond the depletion of the sulfide sources due to the effects of preferential flow paths and incomplete flushing.

These simulations should be considered illustrative. Considerable uncertainty is inherent in modelling over such long timeframes. The calculations do, however, provide insight to the role of stored reaction products in controlling solute concentrations in the longer term. Further, it should be acknowledged that some of the outcomes are linked to the underlying assumption that sufficient neutralising capacity is present in the WRD to maintain near-neutral conditions over the entire simulated timeframe.

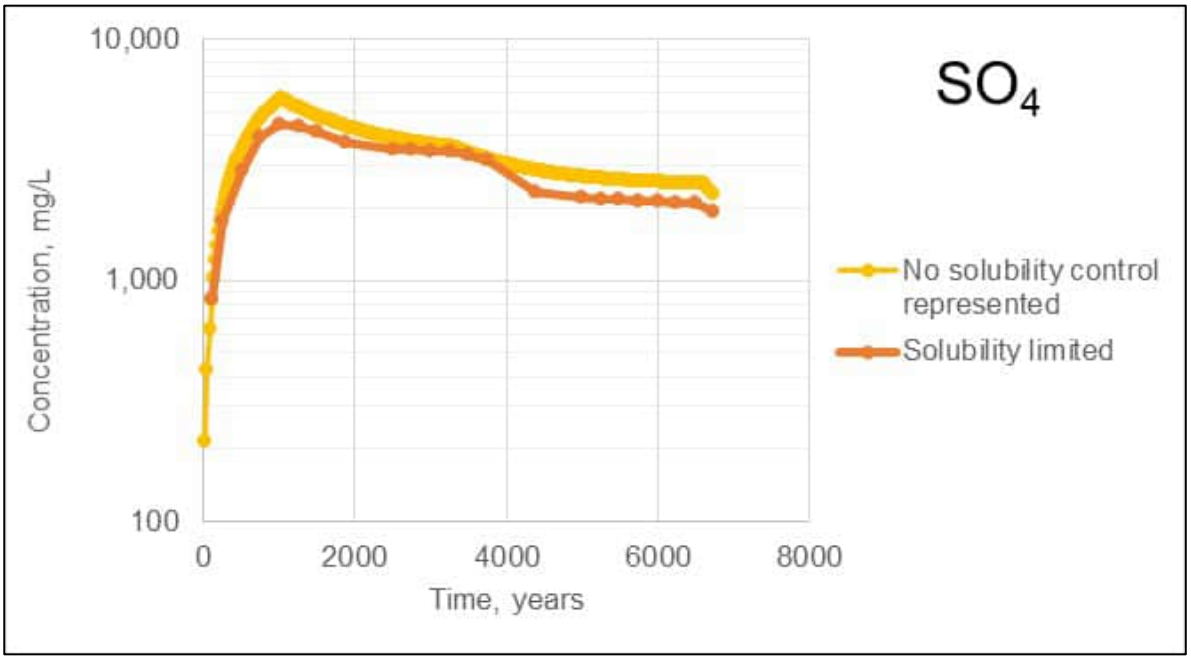


Figure 6-2: Profiles of dissolved sulfate in seepage as a function of time (PAF cell – base case assessment)

Note: Base case scaling assumptions and macroscopic WRD properties are represented.

7 Likelihood of Impacts: Screening Assessment

As part of the current scope, a high-level assessment was conducted to estimate the likelihood of downstream impacts. Detailed downstream impact assessments are being conducted by IBO as part of ongoing studies.

Table 7-1 compares the calculated base case solute concentrations and the IBO trigger values for groundwater and surface water. A number of parameters are expected to exceed the trigger values.

Impacted seepage from the WRD will encounter, and mix with, surface or groundwater along flow paths away from the source. The assessment performed herein is based on calculating the ratio of solute concentration in seepage to that in baseline groundwater or surface water. Where ratios are large, the likelihood of downstream impacts is greater.

Figure 7-1 presents the calculated ratios in the case of basal seepage from the 'PAF' cell footprint and from the NAF-only area. The baseline reference concentrations represent average concentrations in groundwater and surface water obtained from the IBO water quality monitoring datasets. There are some parameters where concentrations are 100 times higher in seepage than in baseline groundwater or surface water. In such cases, dilution factors greater than 1,000 would be required to lower concentrations in impacted seepage to those in line with baseline values.

The significance of such dilution factors should be considered in the context of the relative fluxes of WRD-impacted seepage and downstream flows. The footprint of the combined dump ('PAF' cell and NAF-only areas) is around 270 ha; WRD recharge from 1% to 20% represents an approximate seepage flux of between 9 ML/year and 185 ML/year, in total. A proportion of the seepage from the base of the WRD will report to groundwater and the balance as toe seepage to surface water. The impacts on the respective receptors would depend on the actual net flux to each.

IBO continues to perform surface water and groundwater modelling to inform estimates of the ranges of surface and groundwater fluxes that may apply. These results should provide the basis for assessing the available dilution and the net impacts that may result from the WRD seepage.

Table 7-1: Comparison of predicted base case solute concentrations with IBO trigger values

		Carbonate-based neutralisation		Silicate-based neutralisation		Averages from IBO WQ monitoring datasets		IBO interim trigger values	
Scaling factors		**Scaling factors – Option #1 (Table 6-2)**							
WRD properties		**WRD height: 8 0m; 11% annual recharge; water-filled porosity: 0.1**							
WRD footprint location		**'PAF' cell**	**NAF only**	**'PAF' cell**	**NAF only**	**Groundwater**	**Surface water**	**Groundwater**	**Surface water**
pH	pH unit	7.4	7.5	7.3	7.7	7.8	8.3	8.3	9
Alkalinity	mgCaCO3/L	86	97	21	52	420	428	580	600
Acidity calc.	mgCaCO3/L	0.052	0.041	0.1	0.023				
SO_4	mg/L	1500	1600	1600	1400	119	55	250	100
Cl	mg/L	0.12		0.12		221	128	500	200
Ca	mg/L	280	220	170	240	44	31	70	60
Mg	mg/L	140	110	180	37	104	110	180	160
Na	mg/L	990	1000	980	1000	136	68	300	100
K	mg/L	54	76	150	68	5	2	12	4
Al	mg/L	0.0000036	0.000004	0.0000045	0.0000037	0.01	0.07	0.03	0.2
As	mg/L	0.0028		0.0028		0.01	0.002	0.02	0.01
Be	mg/L	0.0041		0.0041		0.001	0.001	0.001	0.001
Ba	mg/L	0.0061		0.0061		0.03	0.02	0.08	0.05
Cd	mg/L	0.0025		0.0025		0.0001	0.0001	0.003	0.003
Cr	mg/L	0.46		0.46		0.001	0.001	0.05	0.04
Co	mg/L	0.46		0.46		0.003	0.001	0.007	0.0014
Cu	mg/L	0.045		0.029		0.006	0.001	0.023	0.020
Pb	mg/L	0.44	0.33	0.52	0.33	0.001	0.001	0.15	0.15
Mn	mg/L	0.017	0.012	0.042	0.0024	0.1	0.03	1.2	1.2
Ni	mg/L	1.3		2.5		0.01	0.002	0.18	0.16
V	mg/L	0.0091		0.0091		0.04	0.01	0.08	0.02
Zn	mg/L	3.2	3.8	3.2	3.8	0.1	0.03	0.13	0.12
Fe	mg/L	0.0077	0.0075	0.0084	0.0069	0.1	0.13	0.3	0.3
Hg	mg/L	0.0000094		0.0000094		0.0001	0.0001	0.0001	0.0001
Se	mg/L	0.0014		0.0014		0.01	0.01	0.01	0.01
TDS	mg/L	3000	3100	3100	2800	897	676	1450	900

Note: Blue shaded values exceed only surface water trigger values; grey shaded values exceed both surface and groundwater trigger values.

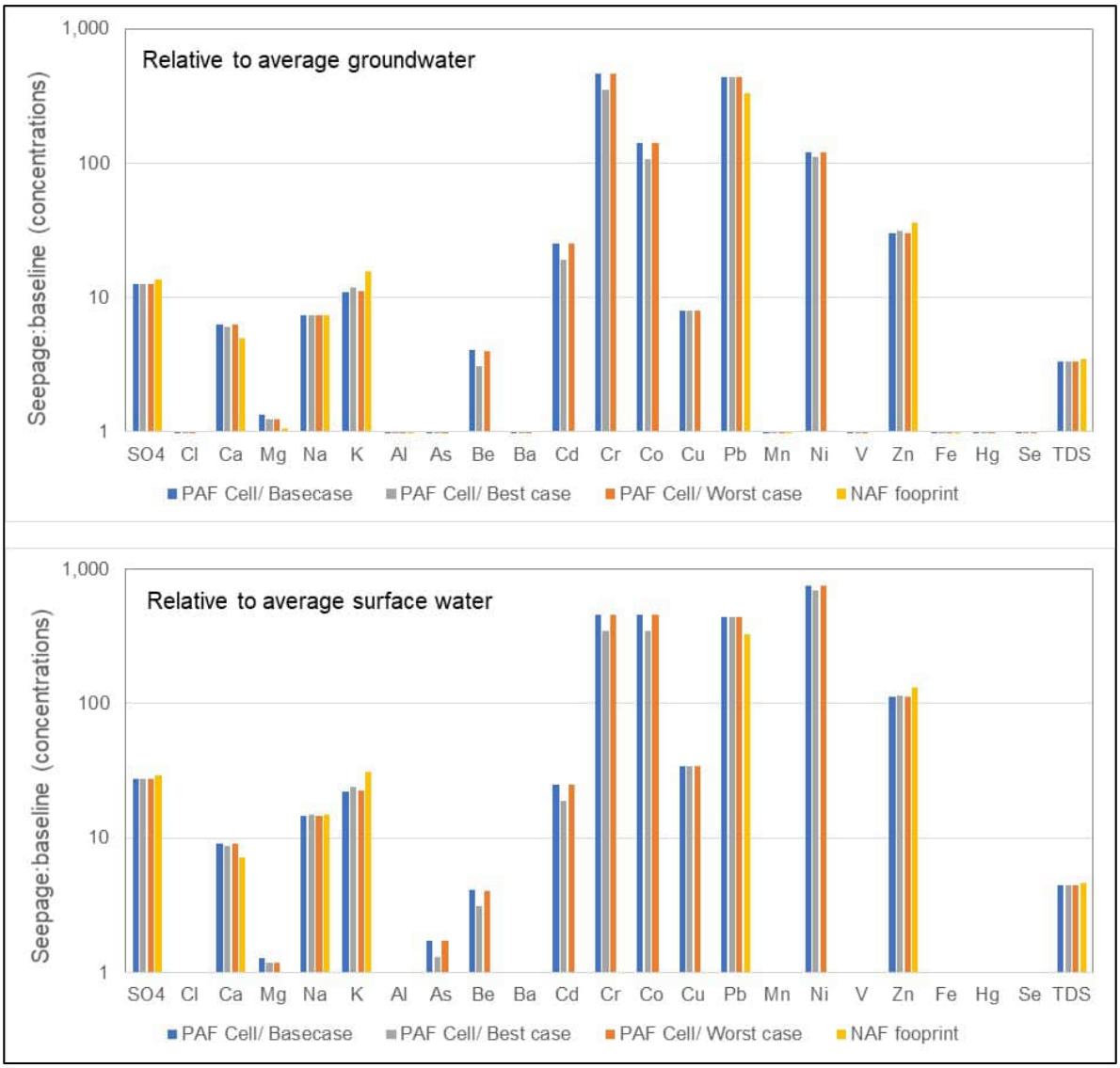


Figure 7-1: Ratio of seepage concentration to average concentration observed in water quality monitoring datasets

Note: Base case scaling assumptions and macroscopic WRD properties are represented.

8 Conclusions

A model of solute production has been developed to estimate solute concentrations in seepage from the 'PAF' cells (containing co-mingled PAF, NAF_S and NAF waste rock), and from the remainder of the WRD, containing NAF waste rock only. Using this model, solute concentrations in seepage have been estimated. Based on the modelling results, the following conclusions were reached:

- Acidic conditions are considered unlikely, on the basis that the sufficient carbonate- and/or silicate-based neutralisation potential would be encountered along seepage flow paths within the WRD.
- Seepage has the potential to become moderately saline, with elevated dissolved concentrations of sodium, calcium, magnesium, and sulfate. Dissolved concentrations of some metals and metalloids were calculated to reach concentrations in excess of IBO's interim trigger limits (while accounting for potential mineral solubility controls).
- For a few parameters, estimated seepage concentrations were more than 100 times higher than the average concentration in baseline groundwater or surface water (e.g. chromium, cobalt, lead, and nickel). In such cases, dilution within the downstream environment would be required to lower dissolved concentrations to acceptable values.

9 Recommendations

The conceptual models developed herein provide a preliminary assessment of the WRD seepage quality that may result in the short and longer term, based on available laboratory data and assumed constraints such as infiltration and material placement. In particular, oxidation and solute release rates from available kinetic data are limited, and the full range of waste rock materials may not be represented in the datasets. By necessity, the modelling has also adopted a number of simplifying assumptions and does not consider the full range of conditions and interactions that could occur. It is therefore recommended that the following activities be conducted to improve modelling accuracy and facilitate refinement of the model:

- Supplemental kinetic testing should be completed to represent the range of sulfur and acid neutralising capacity (ANC) contents that might occur within the materials that will be placed in the WRD, and to enable derivation of kinetic parameters for oxidation and alkalinity release specific to these materials. This should include closer examination of the role of reactive silicate minerals in the acid neutralisation reactions (i.e. silicon release rates should be measured). The tests should be operated for time periods sufficiently long (possibly many years) to allow for the potentially long lag times (to acidification) that may apply. The analyte list should be extended to include silicon, antimony, and lithium.
- Neutralising mineral capacity should be characterised. Modified acid-base characteristics curve (ABCC) testing, with full analysis of the final titrated solutions, should support the identification of minerals contributing to acid neutralisation.
- Alternative modelling approaches (e.g. SULFIDOX) should be applied to account for the relationships between oxygen supply and oxygen consumption within the WRD, which will vary spatially and temporally as sources within the heap are depleted. Such approaches could allow a more rigorous assessment of solute production within the WRD, particularly within the PAF cells, but also within the NAF-only material, which may also contain sulfide mineral sources, albeit at low concentrations.

Compiled by



Claire Linklater

Principal Geochemist

Peer reviewed by



John Chapman

Corporate Consultant

SRK Report Client Distribution Record

Project Number: FMG084

Report Title: North Star Magnetite Project – Waste Rock Dump Seepage Update

Date Issued: 15 December 2020

Name/Title	Company
Kirsty Beckett	Iron Bridge Operations

Rev No.	Date	Revised By	Revision Details
0	29/10/2020	Claire Linklater	Draft Report
1	15/12/2020	Claire Linklater	Report

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Appendix 12: ‘Plug’ Geotechnical Stability Assessment

Memo

Toe seepage evaluation of Iron Bridge waste rock dump plug

OUR REF	IB-1000-GE-GE-00001 Rev 1	**DATE**	3/06/2022
TO	Sophie Monaco, Vladmir Rios vera	**CC**	Justin Dixon; John Chow, Mudit Tandon, Verne Pere, Ying Yu, Sean Mcgunnigle, Kirsty Becket, Massoud Bayati, Ruby Herman
FROM	Daniel Dwumfour		

1. SUMMARY

An assessment was undertaken to understand seepage potential through the planned plug to be placed upstream of Site 12 pool at Iron Bridge. The plug is designed to prevent sediment discharge and manage surface water run-off impacting Site 12 pool and is planned to be constructed from oxide material (Oxides) for the lea01_0000_001_r02 design. The assessment used a numerical seepage model to assess water movement through the plug based on runoff from a 1% annual exceedance probability (AEP) rainfall event.

It is considered that potential movement of water through the plug is vertical from rainfall or ponding and that horizontal flow leading to seepage at the downstream plug face/toe will only occur when there is constant source of water leading to a steady state condition within the plug. Seepage modelling targeted the ability for a 1% AEP event to saturate the plug by placing a ponded body of water behind the plug, representative of the collected run-off, and assessing how the wetting front progressed over a 60 day period. Conservative material properties and hydrogeological conditions were adopted for the analyses.

The model indicates that water preferentially percolates vertically within the plug and that minor horizontal saturation occurs adjacent to the ponded water and progressing saturated zone.

Seepage will not occur at the toe of the waste rock plug from the water ponded upstream of the plug during a 1% Annual Exceedance Probability rainfall event. Insufficient head and volume of pond exist to generate the saturation required to drive enough horizontal flow to reach the toe of the plug. Ponding is also ephemeral with the bulk of water typically lost through evaporation processes.

The Oxides are a well sorted material, in that they have a range of grain sizes, and are a suitable plug material.

The width of the plug and upstream location of the pond is effective for preventing toe seepage.

2. PLUG CONSTRUCTION MATERIAL

The plug is designed to be constructed using oxide material (Oxides) from site. Oxides are a mixture of silty, sand, gravels and cobbles. Figure 1 and 2 shows typical Oxides from Iron Bridge.



Figure 1: Oxides from the Pincunah unit (NS-03000-RP-EN-0001 Rev 1)



Figure 2: Oxides from Stage 1 starter dump with fluorescent tennis balls for scale.

3. SEEPAGE ANALYSIS

3.1 Model construction

The seepage package in Roscience Slide2 software was used to undertake an unsaturated transient seepage analysis within the plug. Section A as shown in Figure 3 was selected for the model, cross section shown in figure 4.

Adopted hydraulic conditions were conservative and include:

- Ponded water level behind the plug based on runoff during 1% AEP rainfall event which was model to dissipate conservatively over 2 months.
- Oxide permeability of 1.0 e^{-4} is mid-range for weathered oxide and adopted from SRK,2019 NS-0000-RP-GE-0002
    - This is at least an order of magnitude higher than the 3.33 e^{-6} m/s indicated in NS-03000-RP-EN-0001 Rev 1 based on infiltration and permeability test on the oxide
- Lower bound saturated volumetric moisture content adopted

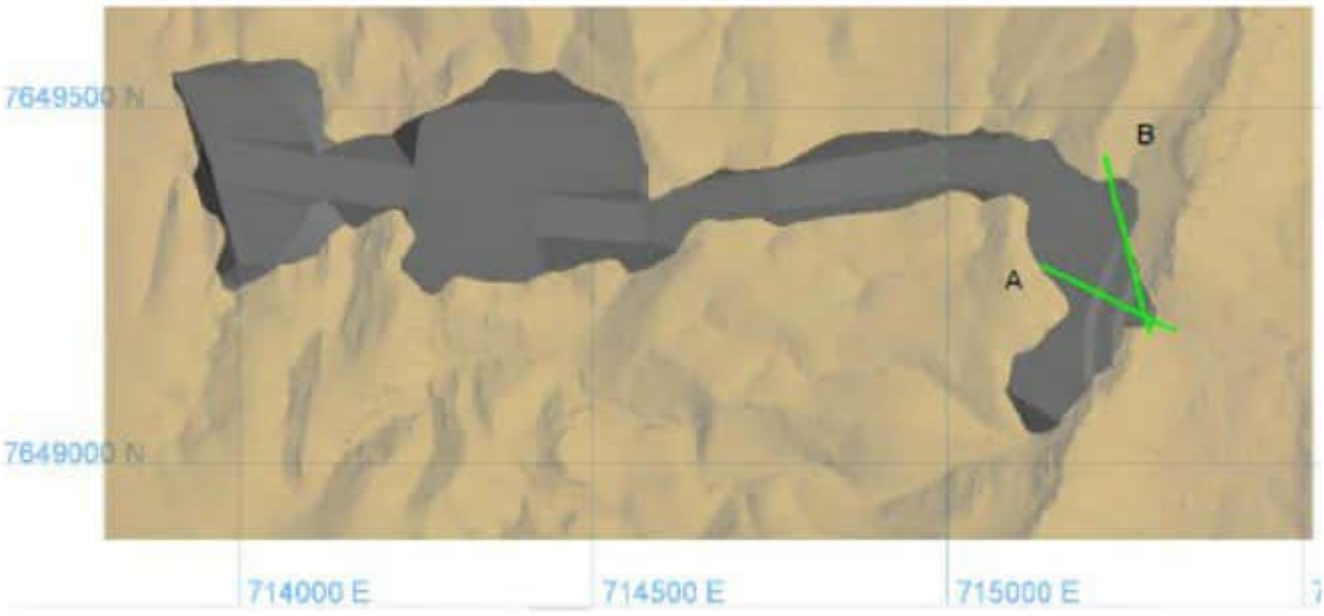


Figure 3: Plan of the WRD plug showing sections

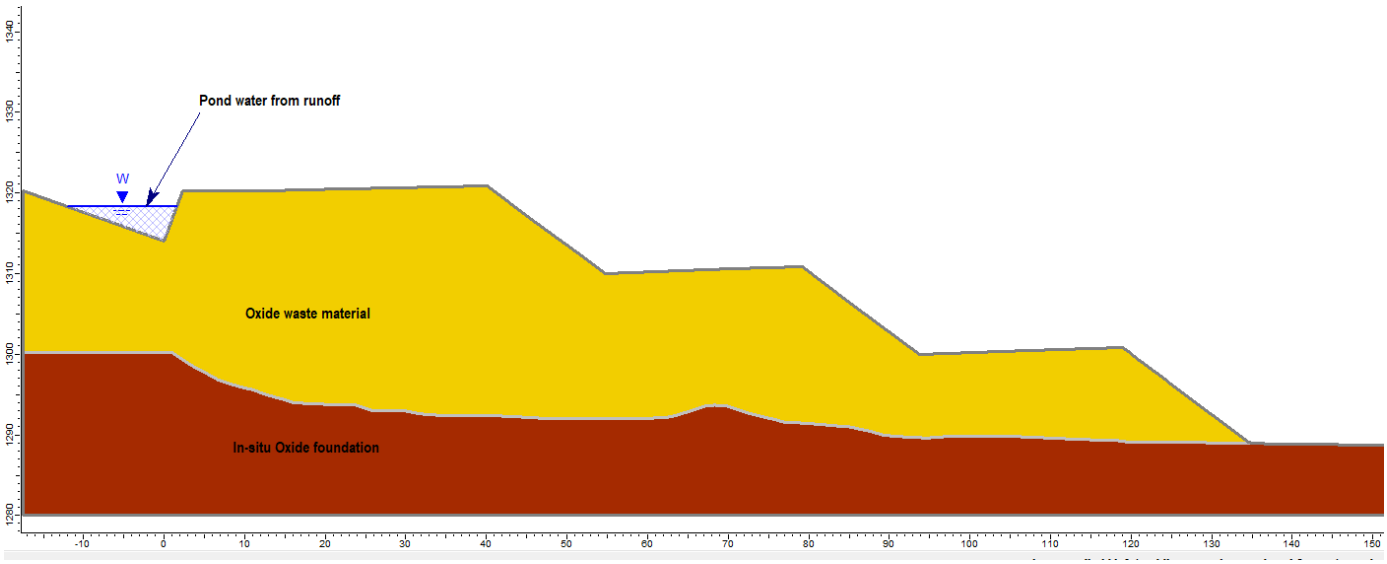


Figure 4: Cross section through the seepage model

Table 1: Permeability and saturated moisture content values

Material	Permeability (m/s)	Saturated volumetric moisture content (VMC)	Residual moisture content
Oxide waste	1.0 e^{-4}	0.25	0.05
Oxide foundation	1.0 e^{-4}	0.25	0.02

3.2 Modelling results

The results from the seepage analyses are presented in Figure 5 to Figure 7 showing results for a 6-day, 30 day and 60 day conditions. A wetting front is seen as a change in volumetric water content migrating down through the plug. The residual water content (0.05 for the plug and 0.02 for the foundation) remains unchanged for the bulk of the model except for the zone below and adjacent to the pond.

Most of the infiltration is in a vertical direction with limited horizontal flow observed directly adjacent to the pond. No discharge occurs at the toe of the waste plug which is seen as no change in moisture content from the initial residual moisture condition.

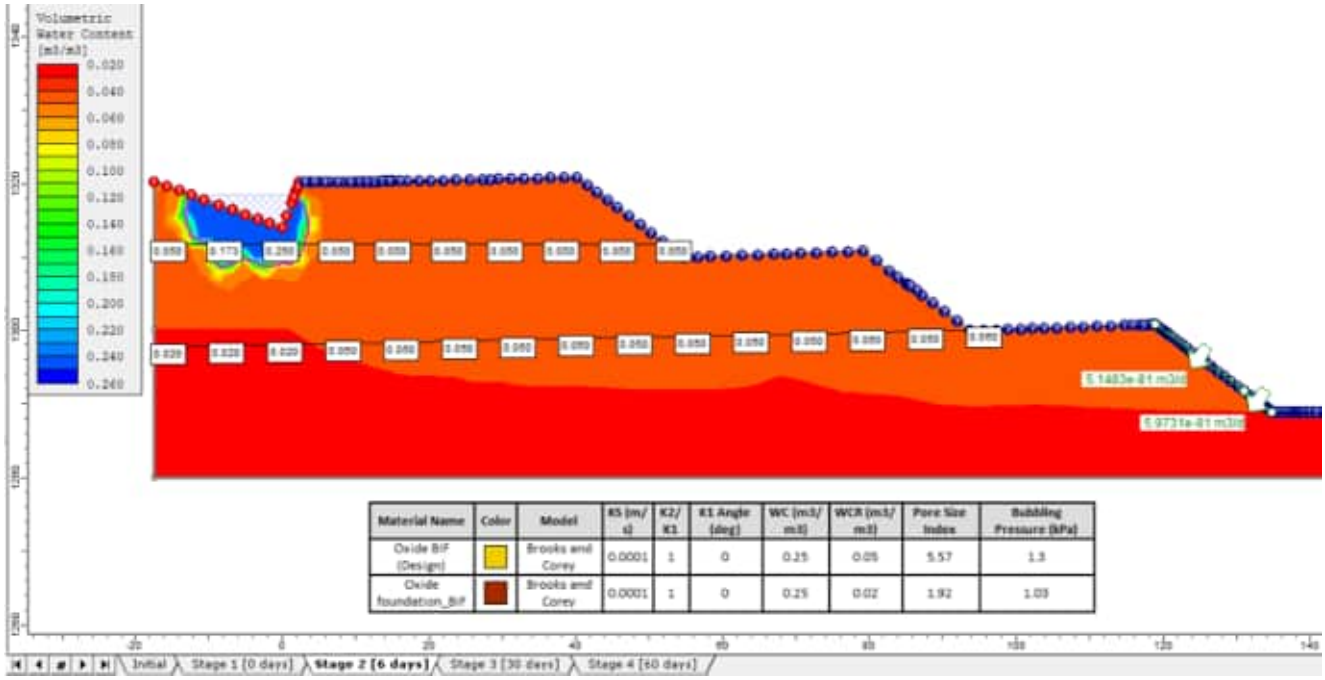


Figure 5: Day 6 base case seepage assessment results for Section A.

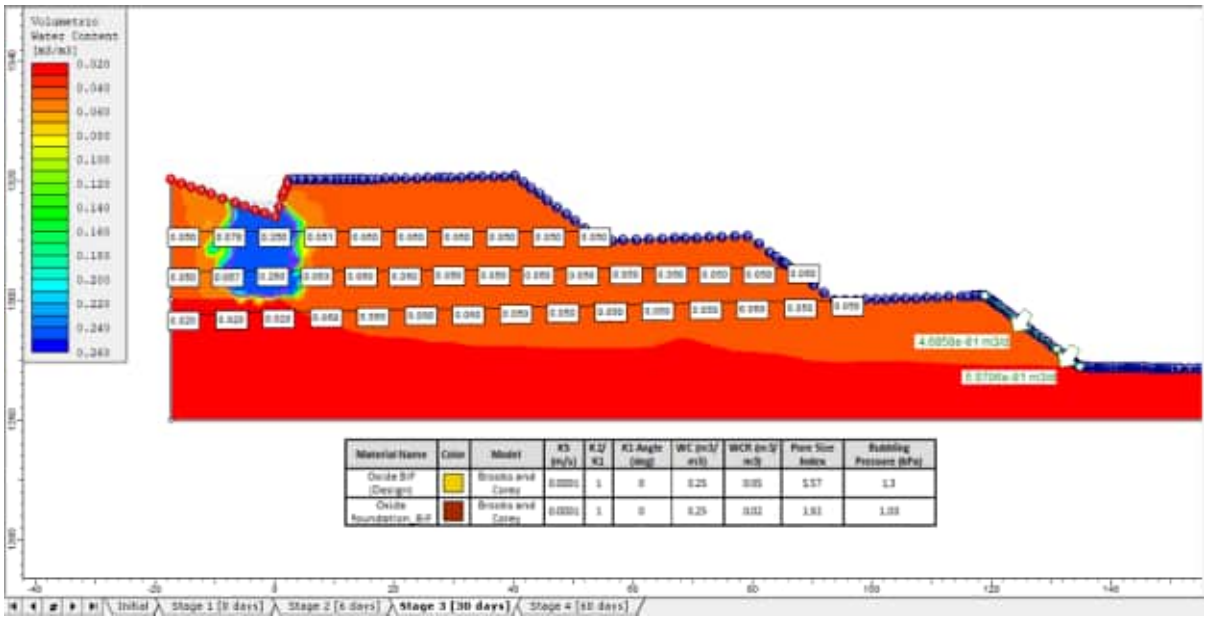


Figure 6: Day 30 base case seepage assessment results for Section A.

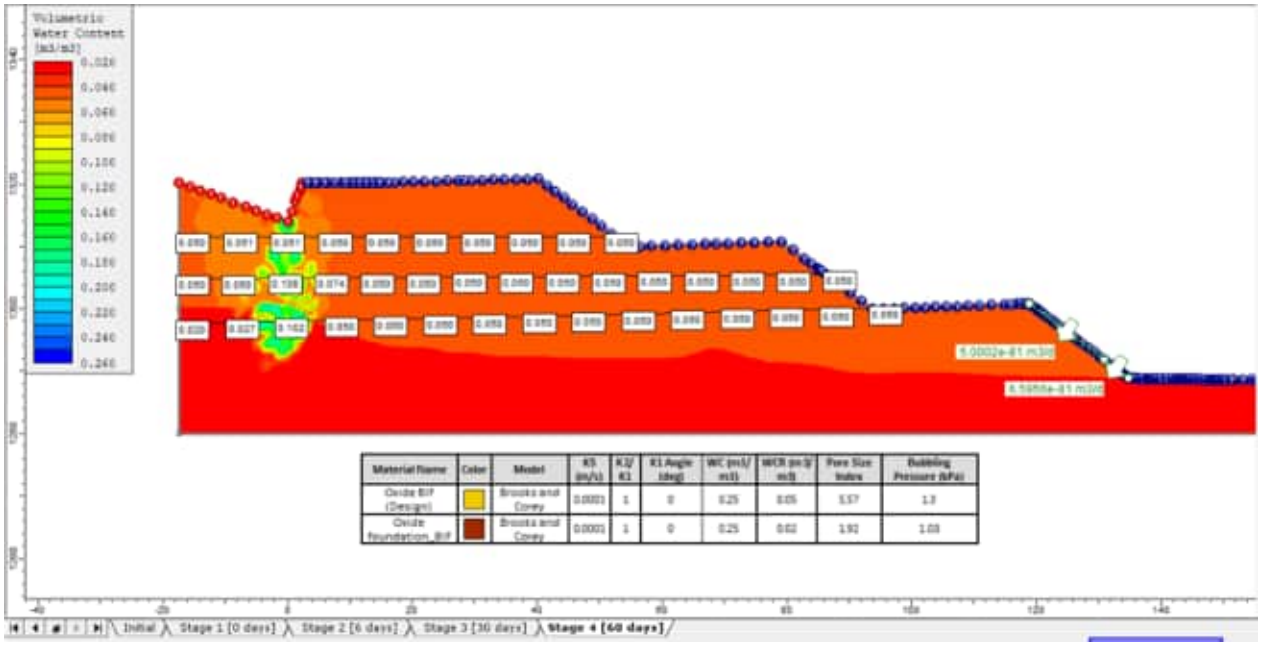


Figure 7: Day 60 base case seepage assessment results for Section A.

3.3 Discussion

The models show the infiltration of the ponded water progressing vertically through the plug as a dissipating zone of saturation; seen in the day 60 results as the material is not as its saturated volumetric content of 0.25. A constant recharge source would be required to maintain a saturated zone.

The initial ponded water level was based on the run-off from a 1% AEP being captured in the pond and this is considered to be a reasonable scale event to test the effectiveness of the plug.

4. CONCLUSIONS

The seepage assessment using the volumetric moisture content at saturation indicates the transient ponding as a result of a 1% AEP rainfall event will infiltrate/percolate through the plug but will not lead to seepage at the toe of the plug.

Appendix 13: Memo: Iron Bridge – Waste Rock Dump Water Management

Memo

Iron Bridge – Waste Rock Dump Water Management

OUR REF	Insert Doc#_Rev# here	**DATE**	7/07/2022
TO	Vladimir Rios Vera	**CC**	Sophie Gaunt, Sean Mcgunnigle, Michael King, Ruby Hermawan
FROM	Jordin Barclay, John Chow		

This memo provides a summary of water management methods that will be used to mitigate potential impacts of seepage from the North Star Waste Rock Dump (WRD) to Site 12 Pool.

The principles regarding seepage mitigation are to:

1. Prevent runoff of surface water and seepage from the WRD footprint into Site 12 Pool. The mitigation method includes installation of a plug in a natural gap along the ridgeline at the eastern extent of the WRD.
2. Intercept surface water and/or groundwater that could potentially bypass the plug. This will be achieved by removing excess surface water at the upstream side of the plug and installation of abstraction bores along the alignment of the plug.
3. Reduce water infiltration into the waste landform where there is PAF material through shaping and collection of surface water.
4. Implement a low risk trial to assessment and confirm that the water management is effective. The initial area of placement will be in an area where there is minimal risk to Site 12 Pool and an assessment can be made to confirm the effectiveness of the water management during operations.

Seepage Management - Plug

The WRD footprint is almost entirely within (greater than 99%) the Site 12 Pool hydrological catchment (Figure 1). The majority of surface water runoff from the proposed WRD footprint reports to a plug that will be constructed between two ridges. The plug is situated downstream of the WRD and upstream of Site 12 Pool (Figure 1). The plug is proposed to be constructed with predominately oxidised material. Construction will commence with an interim plug at the start of WRD development followed by construction of the final plug will continue concurrently with WRD construction during the dry season. The plug is designed to manage the following two aspects for minimising the impact to Site 12 Pool:

- Prevent sediment discharging from the WRD to Site 12 pool
- Prevent surface water runoff from the WRD to Site 12 pool

Figure 2 below shows 1% (1 in 100) AEP flood extent and accumulative ponding water after initial construction of the plug and prior to WRD construction. The simulated 1% AEP flood extent illustrates where water may pond during operations.

As the WRD is being constructed, excess water that accumulates at the upstream extent of the plug will be pumped away for use or discharge in line with the disposal of pit water. Excess surface water and seepage collection at the upstream extent of the plug will occur until the WRD overlaps with the plug and collection of excess surface water is no longer possible.

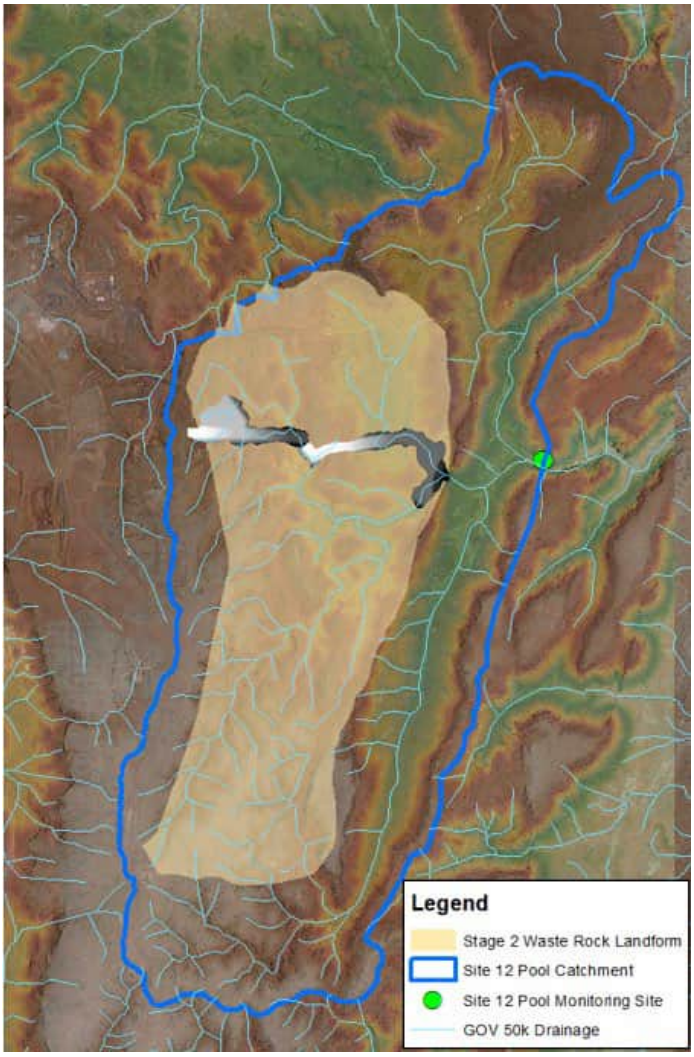


Figure 1: Site 12 Pool Hydrological Catchment

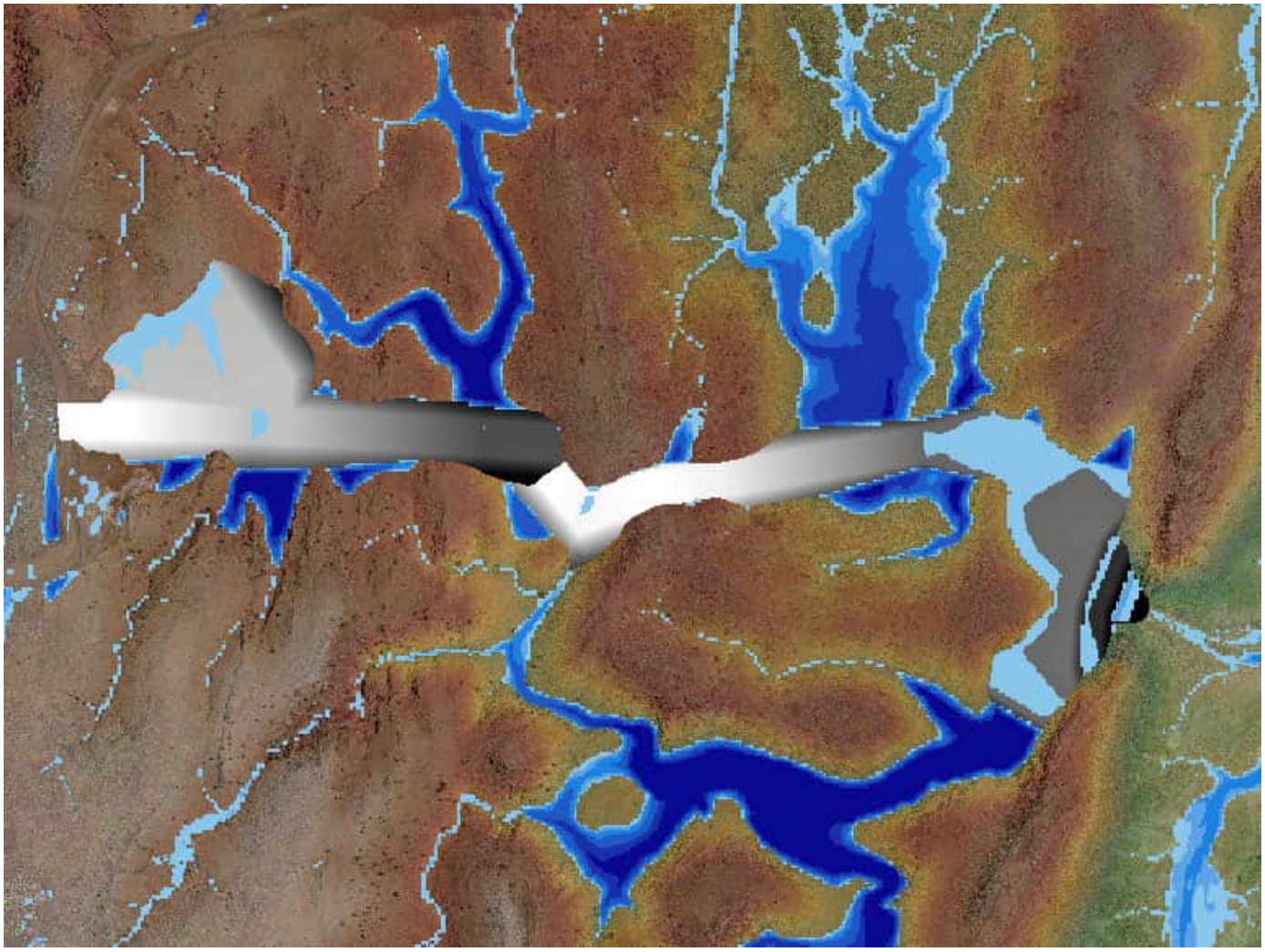


Figure 2: 1% AEP Flood Extent After Plug Installation

Seepage Management – Interception Bores

Once the plug reaches a stable height, a seepage monitoring point will be installed near the centre point of the pre-plug valley bottom. The monitoring bore will be used to monitor changes in water quality and water level to assess the potential for seepage to bypass the plug. Furthermore, at least one seepage interception bore(s) will be installed along the alignment of the plug (Figure 3).

Operation of the interception bores will be initiated prior to ceasing collection of excess surface water from the upstream extent of the plug. Should water be present it will be abstracted from the interception bores and used for site water purposes.

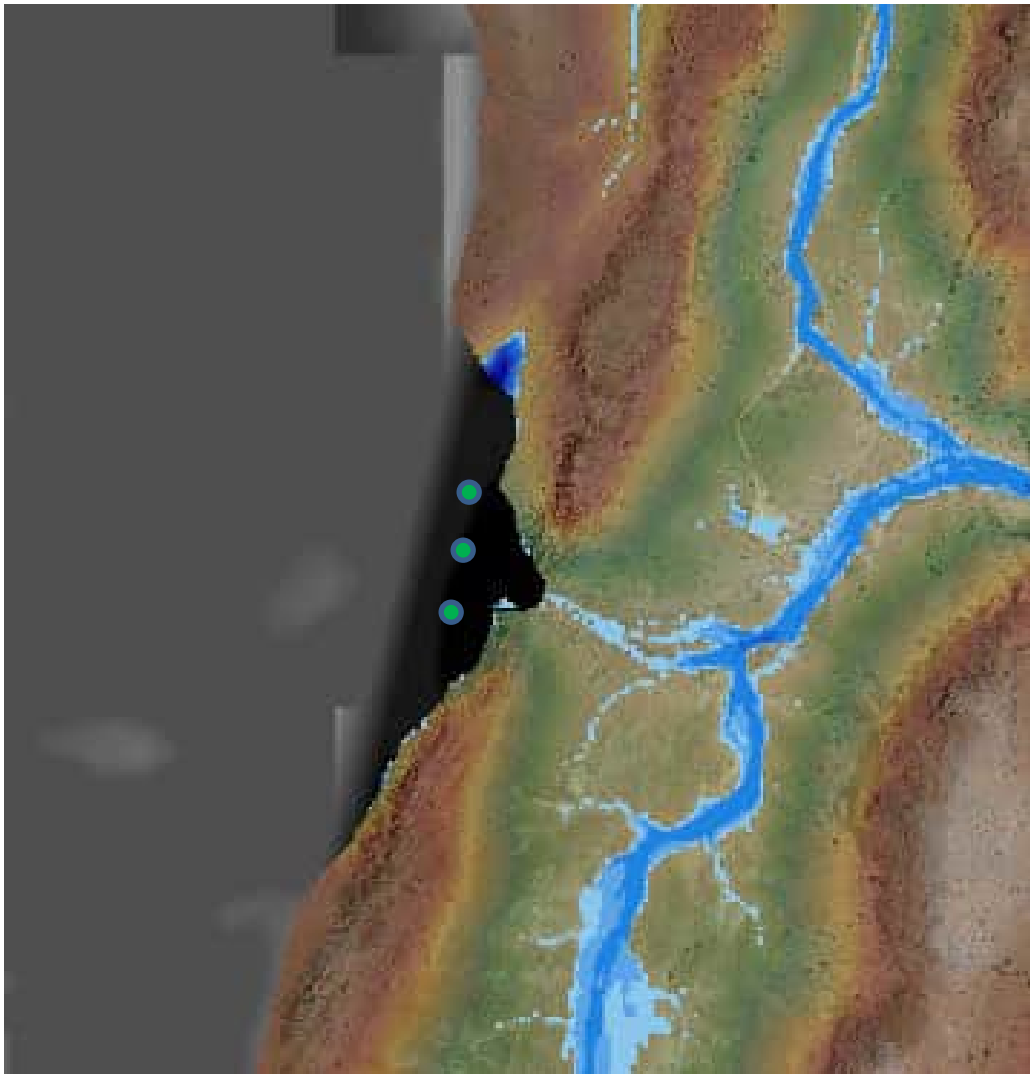
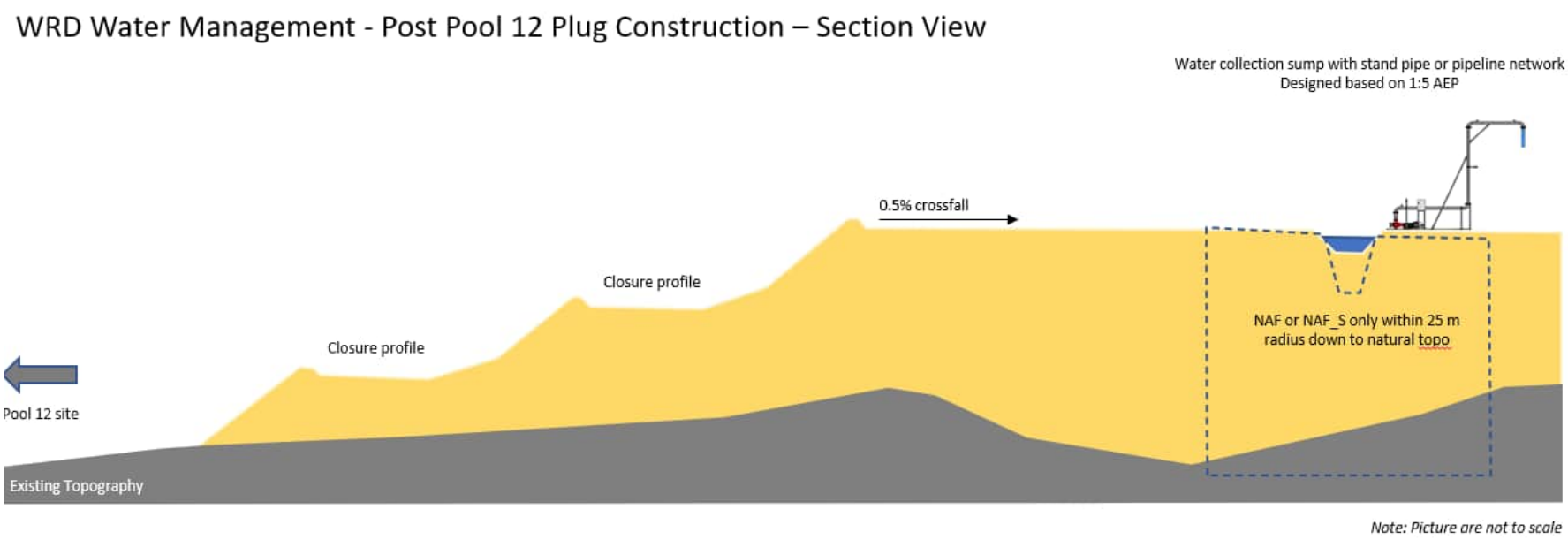


Figure 3: 1% Plug location and Conceptual locations for Abstraction and Monitoring Bores (green dots)

Runoff Management – Shaping and Collection

The operating methodology of the waste dump will have surface water diverted away from the Pool 12 catchment and collected. This is conceptually shown in Figure 4. The progressive surface of the waste dump will have a 0.5% cross fall, so water will naturally flow away from the waste dump edge that is along the Site 12 Pool catchment. This cross fall will be achieved using high precision machine guidance. If a 0.5% crossfall is shown to be insufficient to avoid water pooling, this will be increased until effective. The required crossfall is dependent on how the material compacts when placed and trafficked which is yet to be established. The catchments will have a 25 m exclusion distance from any PAF material down to the natural topography. Figure 5 shows the concept in plan view.

Once collected, where practical, the water will be pumped away for use or discharge in line with the disposal of pit water. The water catchment and pumping will be suitable for a 20% (1 in 5 year) rainfall event.



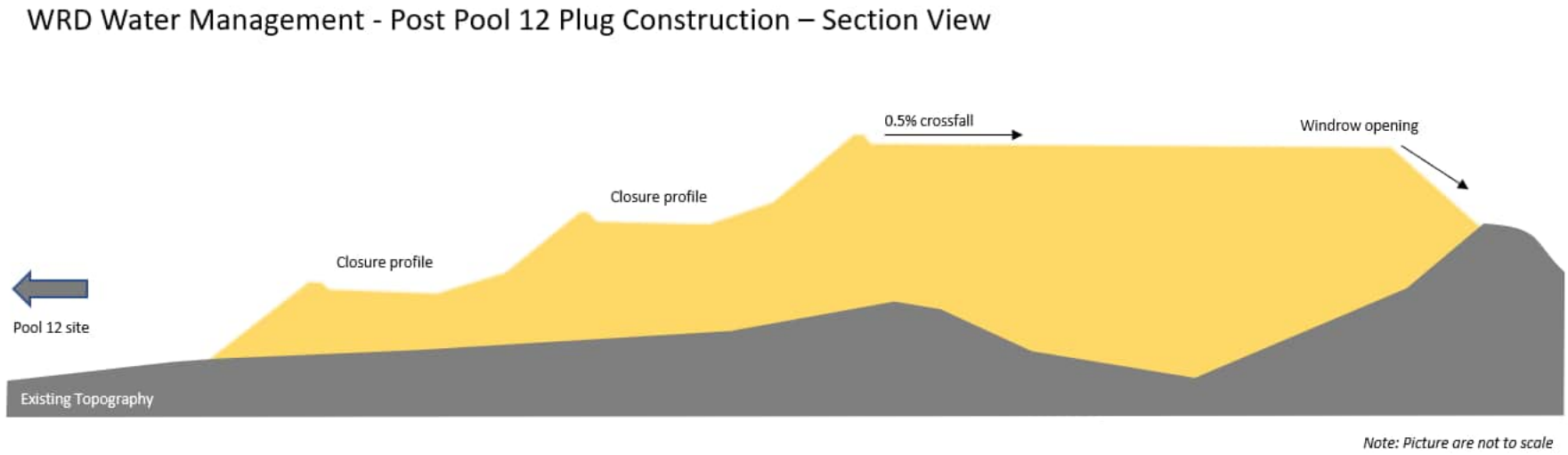


Figure 4: Waste Rock Dump - Operating Method for Surface Water Management

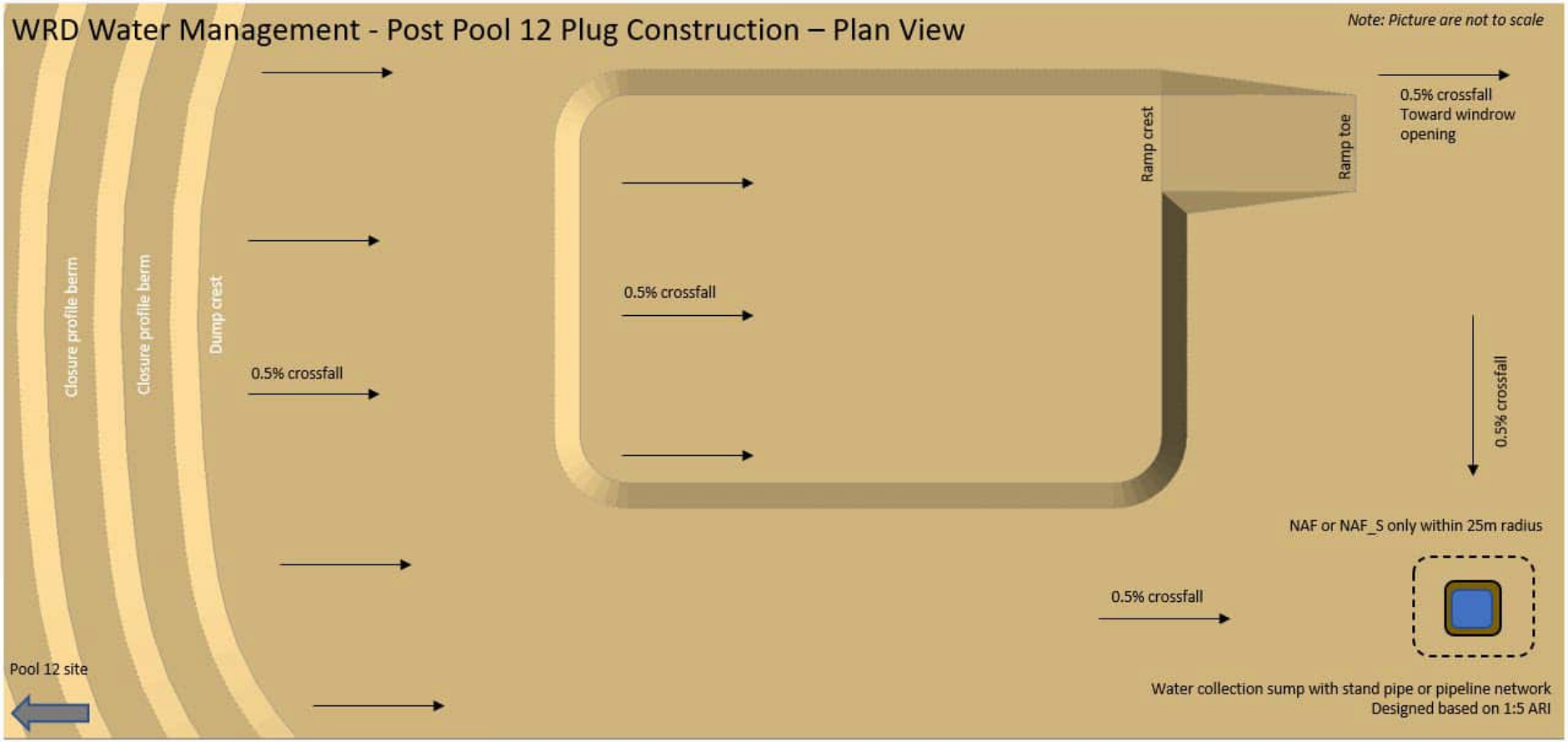


Figure 5: Waste Rock Dump - Operating Method Plan View

Initial Placement - Low Risk Assessment & Confirmation

The initial placement of material will be in the north-west section of the waste rock dump as shown in Figure 6 which is around 900 m from the plug. This provides a low-risk opportunity to make an assessment and confirm that the water management is effective. This initial area of placement will be in an area where there is minimal risk to Site 12 Pool as it is significantly further upstream (1.1 km). The initial causeway will act as a plug in a similar way to the final Site 12 Pool Plug and the 1% AEP water pooling can be seen in Figure 6. This interim plug waste rock disposal area and is planned to be built by the start of the 2023 wet season (November 2022) so the assessment will cover a period of expected precipitation.

The next placement location for waste rock will continue to be on the north and west sides of the waste rock dump. This will effectively continue the trial of the water management into 2023 and 2024 before waste is placed against the final Site 12 Pool Plug.

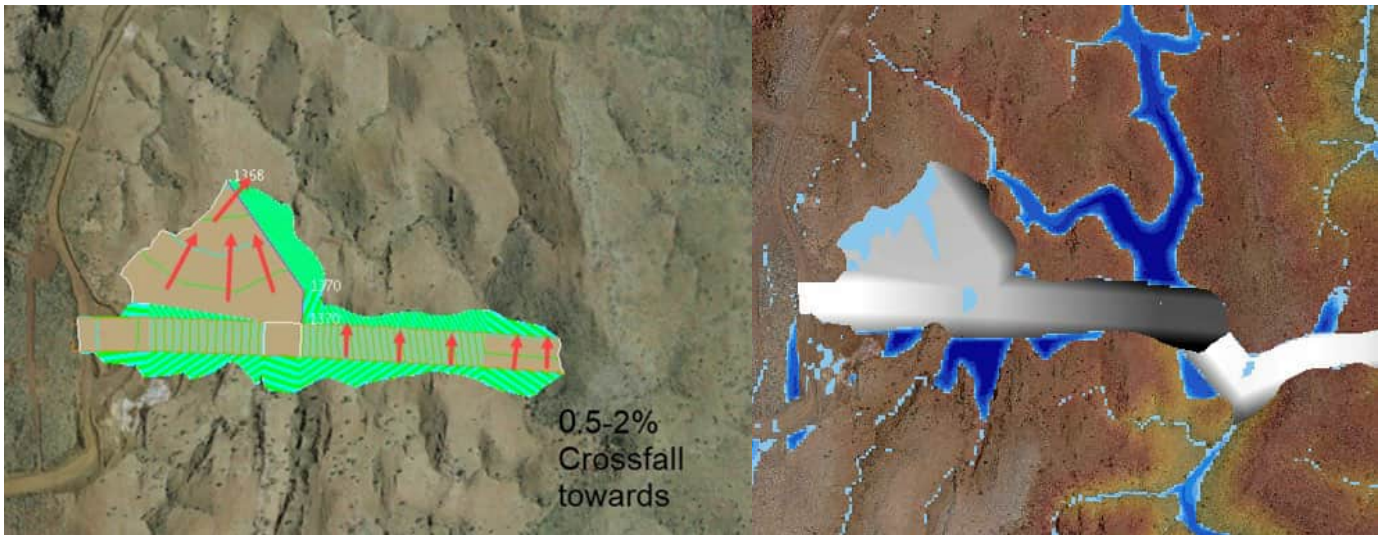


Figure 6: Waste Rock Dump North West Initial Placement Area

Monitoring

This initial placement area acting as a trial will be monitored using water height markers in the ponded areas and a program of visual inspections to monitor for water flow through the interim plug. Water run-off will be monitored and regular drone photogrammetry carried out to assess sedimentation, erosion and calculate catchment area. One or more rainfall gauges will be installed to allow accurate calculations.

The assessment will deliver confirmation of the amount of water runoff from the waste landform surface using the operating strategy. Any pumps that are installed will have a flow meter installed to measure water removal.

Waste Placement Limitation

Waste placement will be initially limited to areas of low risk to Site 12 Pool until there is satisfaction that the water management systems are effective at addressing the risk. This limitation on placement boundary is shown in Figure 7 in a pink hashed line. Apart from the access to the Site 12 Pool Plug, all placement areas are more than 500 m from the Plug which will minimise risk. This area is sufficient to allow two (2) wet seasons to pass in order to verify the effectiveness of the controls to protect the Site 12 Pool.

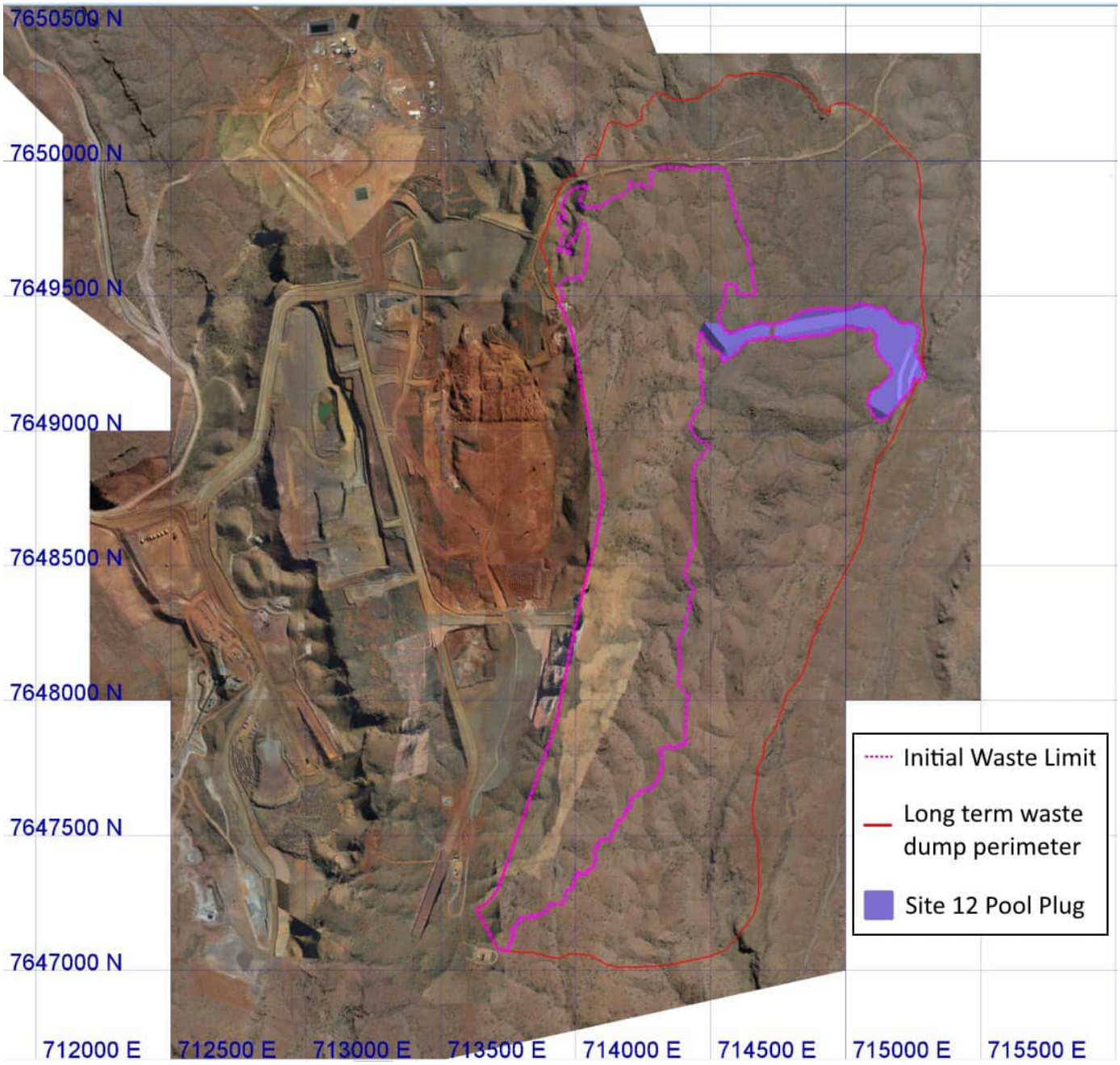


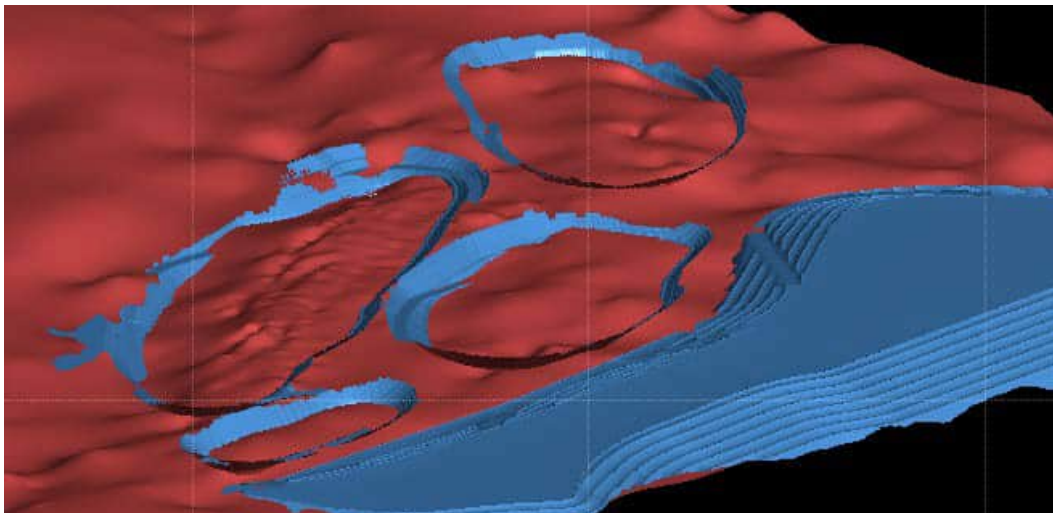
Figure 7: Waste Rock Dump Limited Placement Area

Appendix 10: Geotechnical Characterisation of Waste Rock Materials

Iron Bridge Project – Geotechnical Characterisation of Waste Rock Materials

Report Prepared for

IB Operations Pty Ltd



Report Prepared by

SRK Consulting (Australasia) Pty Ltd

FMG062

April 2019

Iron Bridge Project – Geotechnical Characterisation of Waste Rock Materials

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April 2018

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Executive Summary

The Iron Bridge magnetite project currently consists of three main deposits – North Star, Eastern Limb, and Glacier Valley. SRK Consulting (Australasia) Pty Ltd (SRK) was requested by Fortescue Metals Group (FMG) to perform a geotechnical assessment for a single large waste rock dump (WRD) expected to be approximately 100 m in height at closure.

The study is to be done in two stages:

- Stage 1: Geotechnical characterisation of waste materials
- Stage 2: Stability assessments of WRD for the final closure landform and operations lifts.

This report presents the details of Stage 1 (geotechnical characterisation of waste rock materials). SRK will issue a memorandum summarising the outcomes of the WRD stability assessments at a later stage.

Available data

The data provided for this assessment was largely collected from blasted materials of Iron Bridge Stage 1 starter pit. In addition, information relating to the access road cut and data collected as part of Iron Bridge pit designs were also provided for use as required.

Geotechnical characterisation and outcomes

Geotechnical characterisation of the Iron Bridge WRD was carried out for the development of shear strength models to be adopted in stability assessments for closure and operational conditions. Precise determination of shear strength of waste rock is considered difficult due to several factors such as spatial variations and limitations in obtaining representative data, material placement methods and associated segregation, particle crushing under loading and time-dependent consolidation. In a practical approach, the empirical strength method using the Barton-Kjaernsli criterion (Barton & Kjaernsli, 1981; Barton, 2008), based on site-specific data as available, has been adopted to develop non-linear shear strength parameters of various waste rock materials. The shear strength in this method is a function of normal stress, equivalent roughness, size-dependant equivalent strength and residual friction angle of rock particles. The design and lower bound envelopes developed are presented in Figure ES-1 and Figure ES-2, respectively. The lower bound strength envelopes were developed for assessments to understand the impact of uncertainties on the data.

Oxide Kangaroo Cave Shale (KCS) presents significantly lower shear strength (lower than the envelope for friction angle 30°), followed by Fresh KCS and Oxide banded iron formation (BIF) – close to the minimum Indraratna envelope. The shear strength envelopes of all Fresh BIF units show relatively stronger materials falling midway between the minimum Indraratna and maximum Leps empirical reference envelopes. ‘Eastern Limb S- Fresh BIF’ presents the weakest strength envelope of all the Fresh BIF units.

Figure ES-2 shows the lower bound strength envelopes of Oxide and Fresh KCS fall below the referenced minimum Indraratna envelope; however, Fresh BIF envelopes remain between the minimum Indraratna and maximum Leps empirical reference envelopes, with relative drop in strength.

The characterisation of the materials is expected to facilitate effective closure design assessments using representative and conservative (lower bound) material strength parameters.

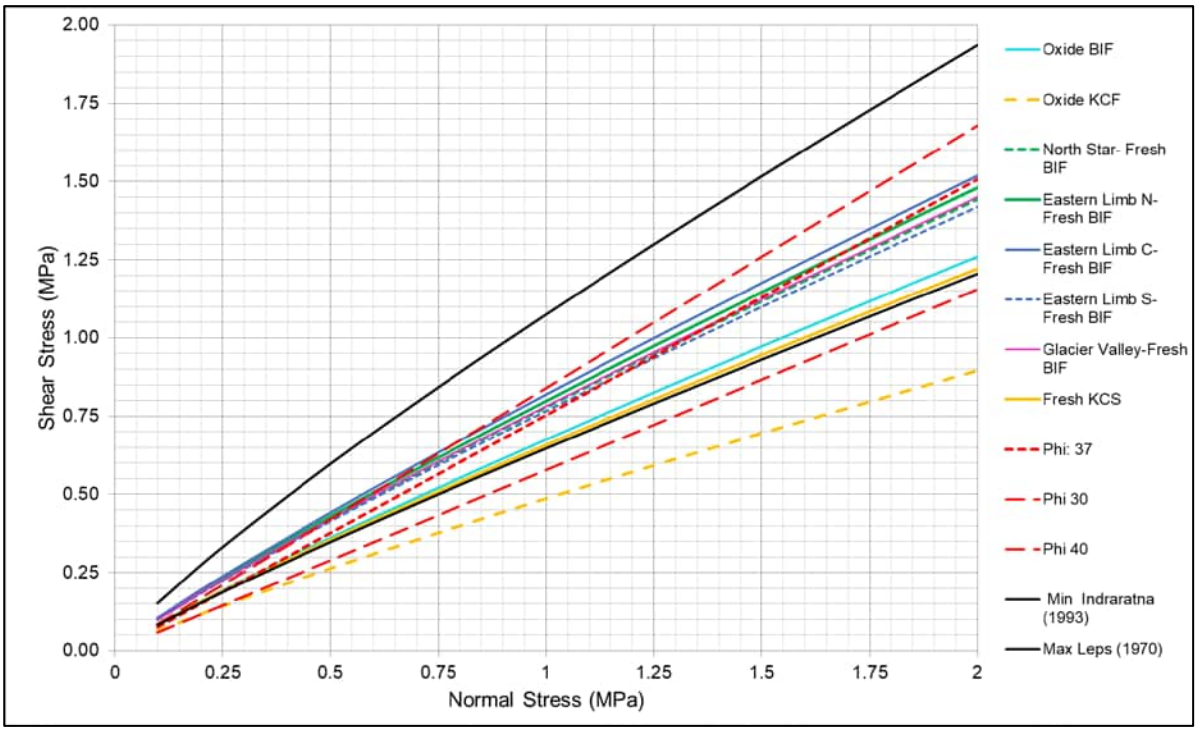


Figure ES-1: Design non-linear shear envelopes

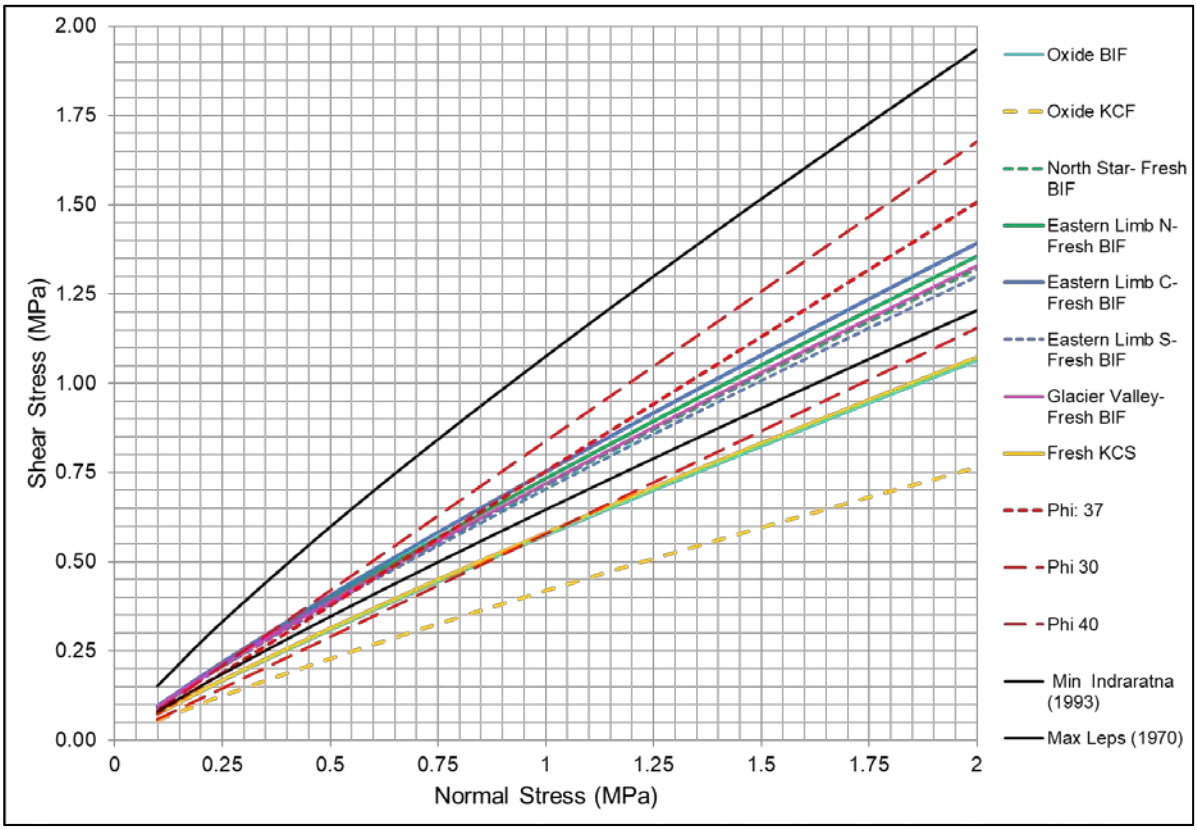


Figure ES-2: Lower bound non-linear shear envelopes

Recommendations

Several assumptions (e.g. porosity and dump density) were made in characterising the waste rock, and in some cases, there was limited data available for assessment (e.g. residual friction angle). It is therefore recommended that the design parameters of the various waste rock materials be reviewed

and updated during operations. Additional site-specific tests (e.g. dump density and roughness assessments) and laboratory testing (e.g. sawcut shear and specific density tests) are recommended in order to expand the dataset and thus increase data confidence levels. The performance of waste materials on the actual WRD during operations will be used for verification of the study outcomes.

Typical reduction in the angle of friction, with the increase of confining pressure can be attributed to material crushing. As waste rock particles tend to break due to increased confinement, large-scale testing on blasted samples will generally allow better representation of the likely field performance. The height of the Iron Bridge WRD is approximately 100 m, and associated confining pressures are not expected to be significantly high. Therefore, sensitivity analyses as part of the evaluation of the stability of the WRDs will generally help in determining the actual benefit and necessity of large-scale testing and sampling for the shear strength study.

SRK recommends that any significantly weak waste materials, for example, KCS material, be dumped away from the WRD slope structure to prevent instability issues arising.

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Disclaimer

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

List of Abbreviations

Abbreviation	Meaning
BIF	banded iron formation
DST	direct shear test
D_{10}	particle size at 10% passing
D_{50}	particle size at 50% passing
DI	durability index
FES	field estimated strength
IB	Iron Bridge
k	permeability
KCS	Kangaroo Cave Shale
LB	lower bound
PSD	particle size distribution
R	equivalent roughness
S	equivalent strength
SD	slake durability
UCS	unconfined compressive strength
WRD	waste rock dump
ϕ_r	residual friction angle

1 Introduction and Scope of the Report

1.1 Background of the project

On 4 February 2019, SRK Consulting (Australasia) Pty Ltd (SRK) was requested by Justin Dixon of Fortescue Metals Group (FMG) to provide a proposal for the geotechnical assessments of a waste rock dump (WRD) for the Iron Bridge Project located approximately 120 km south of Port Hedland in Western Australia (Figure 1-1). The Iron Bridge Project is of a vast resource of magnetite consisting currently of three main deposits – North Star, Eastern Limb and Glacier Valley. The required geotechnical assessment focuses on a single large WRD, the height of which is expected to be approximately 100 m at closure. The location of the WRD in relation to the Iron Bridge pits is shown in Figure 1-2.

SRK was requested to conduct the study in two stages:

- Stage 1: Geotechnical characterisation of waste rock materials
- Stage 2: Stability assessments of the WRD for the final closure landform and operational lifts.

This report presents details of the geotechnical characterisation of waste rock materials. SRK will issue a memorandum summarising the outcomes of WRD stability assessments at a later stage.



Figure 1-1: Location of the Iron Bridge Project in the Pilbara region

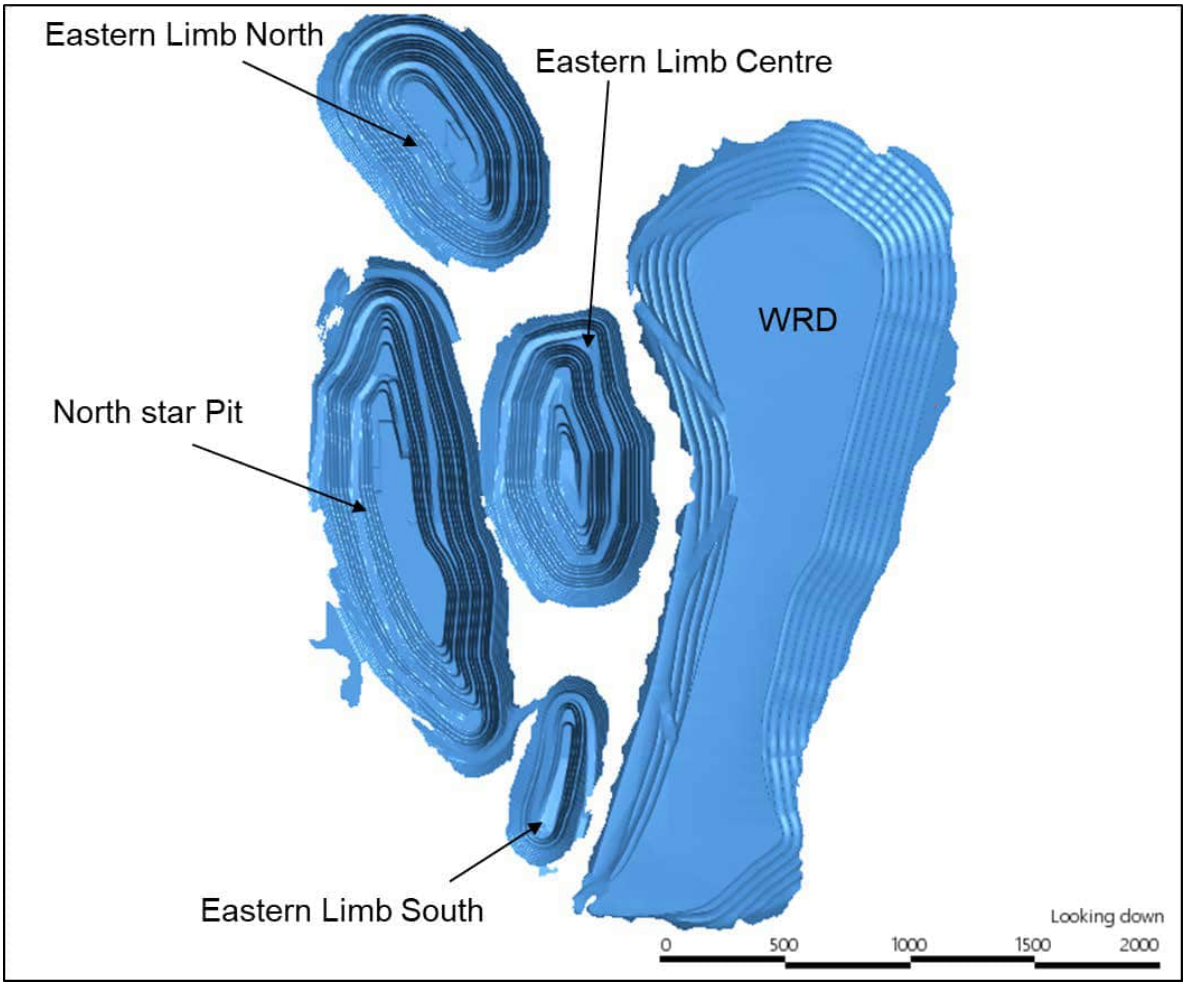


Figure 1-2: Locations of waste rock dump in relation to the Iron Bridge pits

1.2 Scope of work

The scope of work requested by FMG for this project is summarised as follows:

1 Characterisations of various waste rock materials, and the development of non-linear shear strength envelopes

2 Stability analyses for determining appropriate maximum tipping heights for various waste rock materials for operational purposes

3 Seepage/ infiltration analyses to develop pore pressures for input to stability analyses for closure designs

4 Stability analyses of closure dump designs

5 Provision of recommendations and reporting.

Material characterisation for the WRD foundation was excluded from the scope at this stage; however, a one-day site visit to observe the foundation conditions and to provide recommendations is part of the scope.

1.3 Available information

Most of the particle size distribution (PSD) data provided for this assessment was collected from blasted materials of Iron Bridge Stage 1 starter pit. In addition, information relating to the access road cut and data collected as part of Iron Bridge pit designs were also provided for use as required.

FMG provided the following:

- Waste rock PSD database, and blasting study target PSDs
- Sawcut shear test results
- Laboratory UCS (unconfined compressive strength) data collected as part of the pit design study
- Draft waste rock assessment parameters in MS Excel format
- Iron Bridge Geotechnical Feasibility study report for pit design by AMC (2019).

1.4 Statement of SRK independence

Neither SRK nor any of the authors of this Report have any material present or contingent interest in the outcome of this Report, nor do they have any pecuniary or other interest that could be reasonably regarded as being capable of affecting their independence or that of SRK.

SRK has no prior association with FMG concerning the mineral assets or no beneficial interest in the outcome of the technical assessment being capable of affecting its independence.

SRK's fee for completing this Report is based on its normal professional hourly rates plus reimbursement of incidental expenses. The payment of that professional fee is not contingent upon the outcome of the Report.

2 Mine Site Geology

The deposit host geology is a steeply dipping banded iron formation (BIF) containing magnetite that has been deformed and metamorphosed. The weathering profile is typically 40–60 m in depth, forming an oxidised caprock that extends throughout the Iron Bridge Project area, across all three underlying rock formations – the Kangaroo Caves, Pincunah and Corboy Formations. Figure 2-1 illustrates the geological settings of North Star and Eastern Limb deposits as an example. The host BIF is the Pincunah Member of the Gore Creek Group, with the Kangaroo Caves Formation (Sulphur Springs Group) and Corboy Formation (Gore Creek Group) forming the western and eastern mineralisation bounds respectively (Simpson, 2017).

The Kangaroo Caves consists of massive to pillow-brecciated andesitic volcanic rocks, with variable amounts of cherts and shales increasing towards the top of sequence (Simpson, 2017), which is conformably overlain by the Pincunah Member. The KCS is a fine-grained, highly foliated steeply west-dipping unit which will form the upper slope of the North Star hanging wall. The road cuttings indicate that it consists of occasional BIF and cherty bands. The Pincunah Member is dominated by cherty silicate BIF with minor (locally dominant) siltstone and trace sandstone.

The Iron Bridge deposits are located over a north–south strike length of approximately 12 km. Although the deposits have identical host stratigraphy, dislocated by several faults, each deposit has been variably deformed and altered, resulting in unique differences in material (Simpson, 2017).

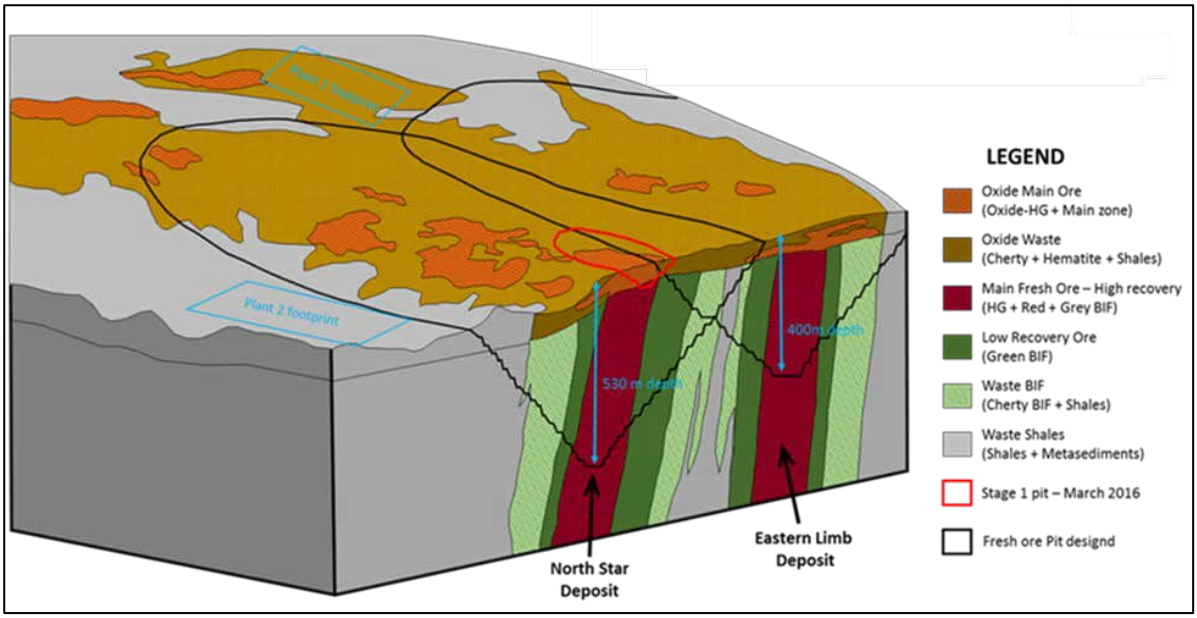


Figure 2-1: Geological settings of the North Star and Eastern Limb deposits

Source: FMG

3 Geotechnical Characterisation of Waste Rock

Characterising waste rock materials is one of the most important aspects of the WRD geotechnical assessment. Several factors, as outlined in the subsequent sections, were considered for the material characterisation. Information available from the Stage 1 starter pit, access road cut, and Iron Bridge pit design study was used for the characterisation and for defining non-linear shear strength envelopes. The following waste rock materials that will be generated from the Iron Bridge deposits are included in this characterisation:

- Oxide BIF
- Oxide KCS
- North Star – Fresh BIF
- Eastern Limb N – Fresh BIF
- Eastern Limb C – Fresh BIF
- Eastern Limb S – Fresh BIF
- Glacier Valley – Fresh BIF
- Fresh KCS.

Waste materials that have significantly lower strength than the major units and are easily recognisable will generally be expected to be placed away from the structural zone of final WRD profile.

3.1 Particle size distribution

PSDs of waste rocks were produced using standard sieve analyses and Split-Net imaging techniques. The PSD samples, sample source and analysis methods used are listed in Table 3-1; most of the samples were collected from the starter pit. A limited number of PSDs are available for Oxide KCS and Fresh BIF (two PSDs each), and no PSD has been developed for Fresh KCS due to unavailability of samples at this stage. The raw PSD data are included in Appendix A.

Table 3-1: Details of PSD samples and analysis method

Rock unit	PSD method	Sample name	Sample source
Oxide BIF	Sieve	NSWR0001 (AECOM) NSWR0002 (AECOM) NSWR0003 (AECOM) NSWR0004 (AECOM)	Starter pit
	Split-Net	Photo 15 Sample 1 Photo 16 Sample 2 Photo 17 Sample 3 Photo 18 Sample 4 Photo 19 Sample 5	Starter pit
Oxide KCS	Split-Net	Photo 20 Sample A Photo 21 Sample B	Access road cut
Fresh BIF	Split-Net	BIF Stockpile A BIF Stockpile B	Starter pit

Figure 3-1 presents PSD curves for Oxide BIF, Oxide KCS and Fresh BIF, along with the PSDs for minimum and mean blasting study targets (the purple dashed line in the figure) and the measured mean PSDs (the red dashed lines in the figure). FMG indicated that the drill and blast design will target fragmentation between the mean and minimum blasting study PSDs, or finer. In discussion with

FMG, the lower bound PSD for this characterisation was selected as the minimum of the mean measured PSD and minimum blasting study PSD.

PSDs of a waste material will be naturally variable due to spatial variation in the material properties and drill and blast practices. In addition, various methods for determining PSDs and sampling sources will have limitations in terms of estimating the fines and coarse contents, and hence professional judgements were applied in choosing expected PSD range and design D_{50} (particle size at 50% passing) values. To understand the influence of variability, SRK adopted a design and sensitivity scenario in the assessment. The selected ranges of PSDs and D_{50} values are presented in Table 3-2. Due to insufficient data within various Fresh BIF materials, the identified PSD ranges are applied for all Fresh BIFs.

Table 3-2: Expected PSD range of waste rock

Rock unit	PSD range		D_{50} range
	Lower	Upper	
Oxide BIF	Measured mean PSD	Mean blasting study PSD	25–170 mm
Oxide KCS	Measured mean PSD	Mean blasting study PSD	25–170 mm
Fresh BIF	Minimum blasting study PSD	Mean blasting study PSD	60–170 mm

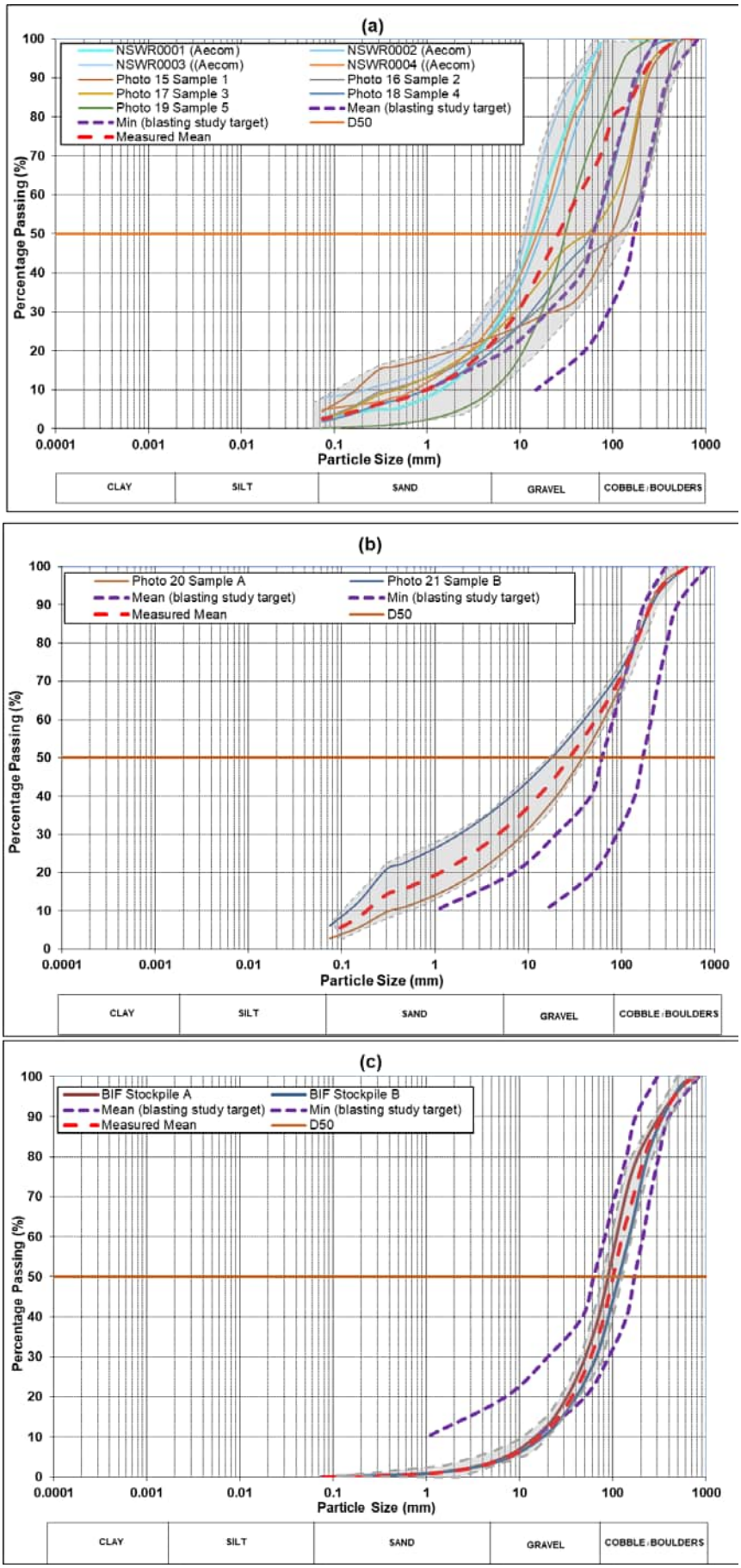


Figure 3-1: PSD curves for a) Oxide BIF; b) Oxide KCS and c) Fresh BIF

3.2 Unconfined compressive strength

The intact strength for each rock type has been defined primarily on laboratory UCS test results from extensive investigation programs that form the Geotechnical Feasibility Study (AMC, 2019). Due to the absence of testing data for Oxide KCS materials, the intact strength was assigned based on field estimated strength (FES) from the core logging program associated with the Geotechnical Feasibility Study update. Statistical parameters developed mainly from laboratory UCS data are presented in Table 3-3 and depicted in Figure 3-2. These statistical parameters excluded the tests failed along weak planes.

Table 3-3: Statistical summary for laboratory UCS

Rock unit	UCS (MPa)					
	Mean	Median	10th percentile	25th percentile	75th percentile	SD*
Oxide BIF	36	35	16	22	43	20
Oxide KCS**	11	-	-		-	9
North Star - Fresh BIF	194	190	103	143	237	70
Eastern Limb N – Fresh BIF	244	253	151	204	294	69
Eastern Limb C – Fresh BIF	306	310	205	252	360	74
Eastern Limb S – Fresh BIF	167	174	96	134	205	51
Glacier Valley – Fresh BIF	204	190	119	168	246	64
Fresh KCS	151	159	81	111	189	54

*standard deviation; ** based on FES data.

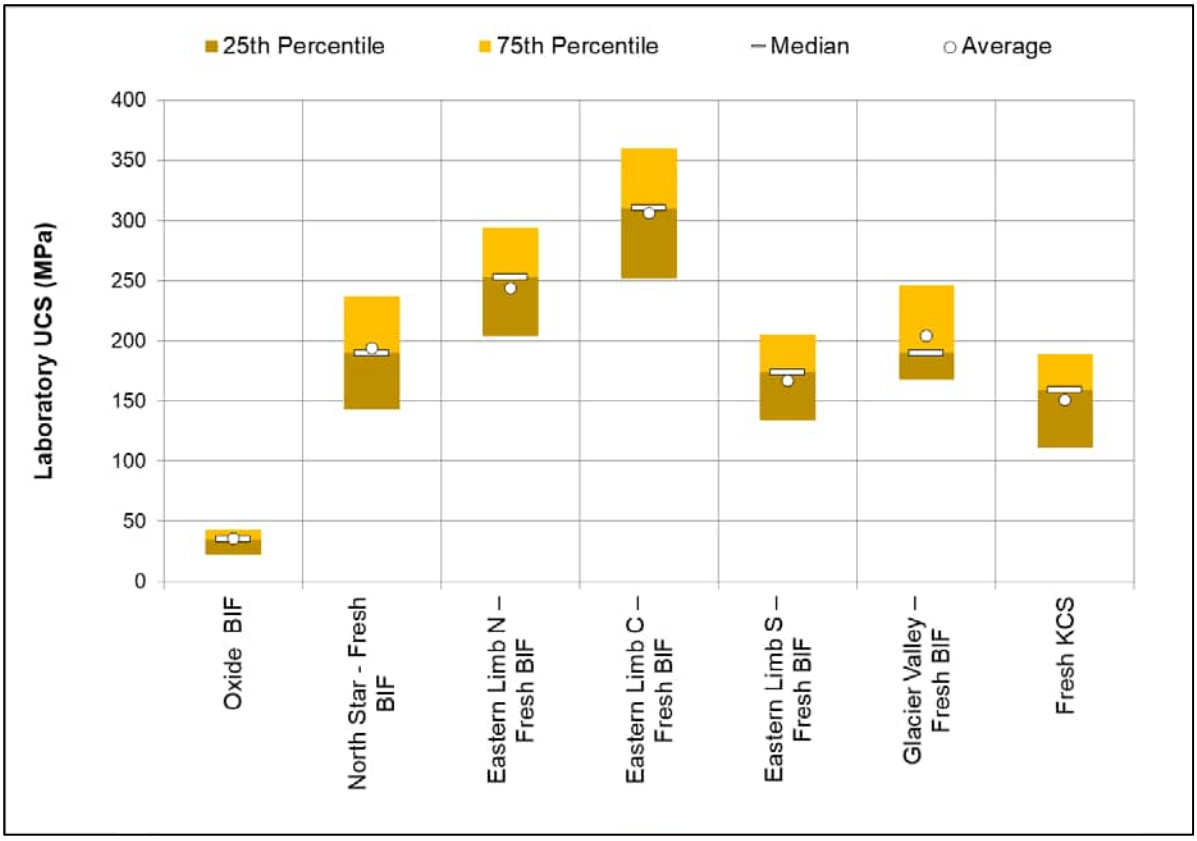


Figure 3-2: Box and whisker plots of laboratory UCS

3.3 Residual friction angle

The residual friction angle (ϕ_r) was evaluated using the results of direct shear testing conducted on sawcut samples. The number of sawcut test results available is limited and statistical parameters for ϕ_r were therefore not developed. The impact of ϕ_r on the shear strength of waste materials will be significant. Sawcut test results plotted in terms of normal and shear stress, along with envelopes of interpreted residual friction angles are shown in Figure 3-3 to Figure 3-5 for Oxide BIF, Fresh BIF and Fresh KCS, respectively. The interpreted ϕ_r values are summarised in Table 3-4. A lower bound assessment for Fresh BIF was not possible due to inadequate data. Therefore, within various Fresh BIF materials, the interpreted ϕ_r value is applied for all Fresh BIFs.

Table 3-4: Summary of residual friction angles

Rock Unit	Residual friction angle (°)	
	Design	Lower bound
Oxide BIF	28	26
Fresh BIF	26	-
Fresh KCS	23	22

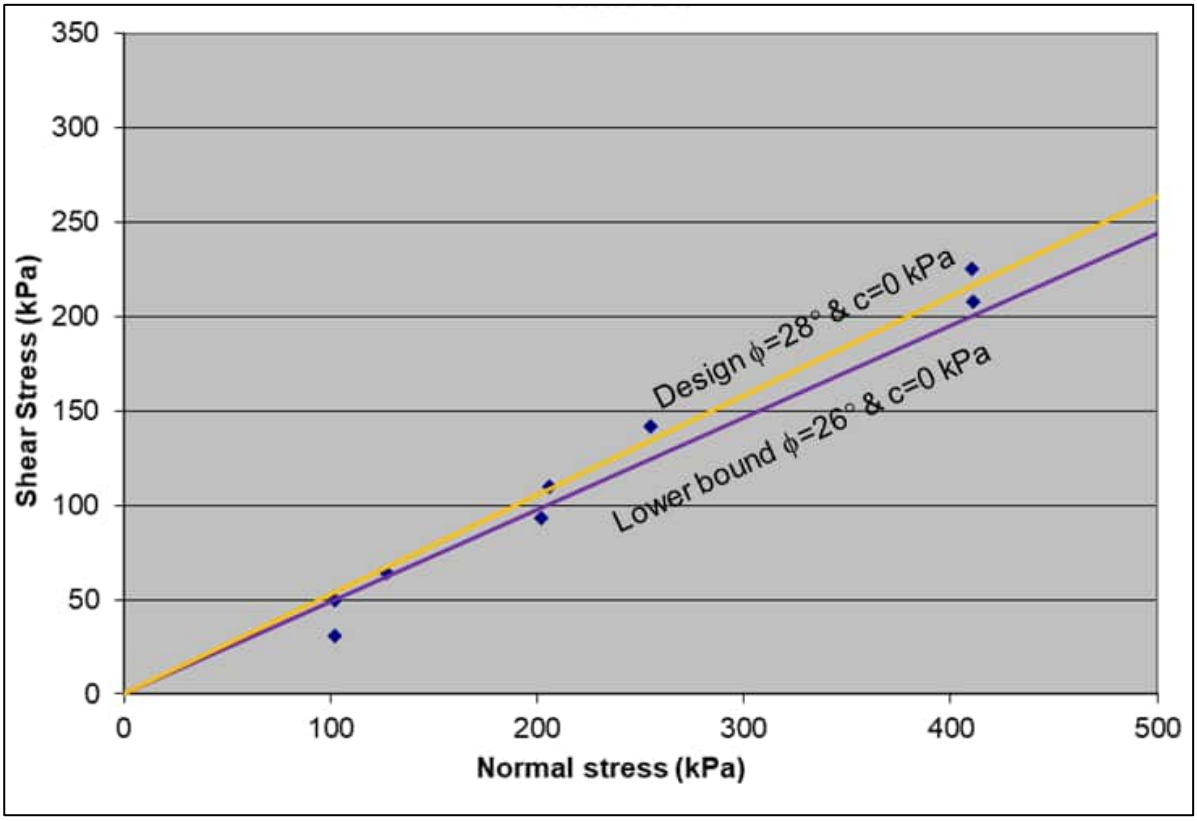


Figure 3-3: Sawcut test results for Oxide BIF - Residual

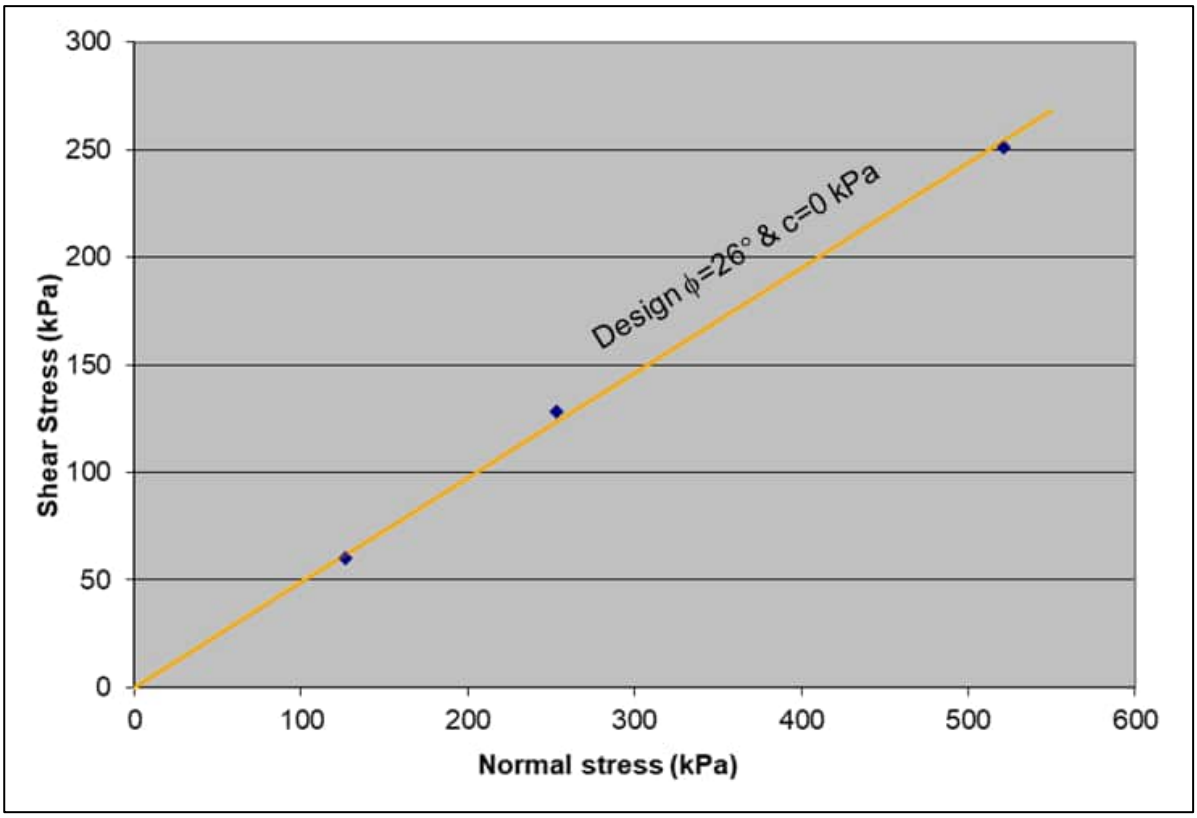


Figure 3-4: Sawcut test results for Fresh BIF - Residual

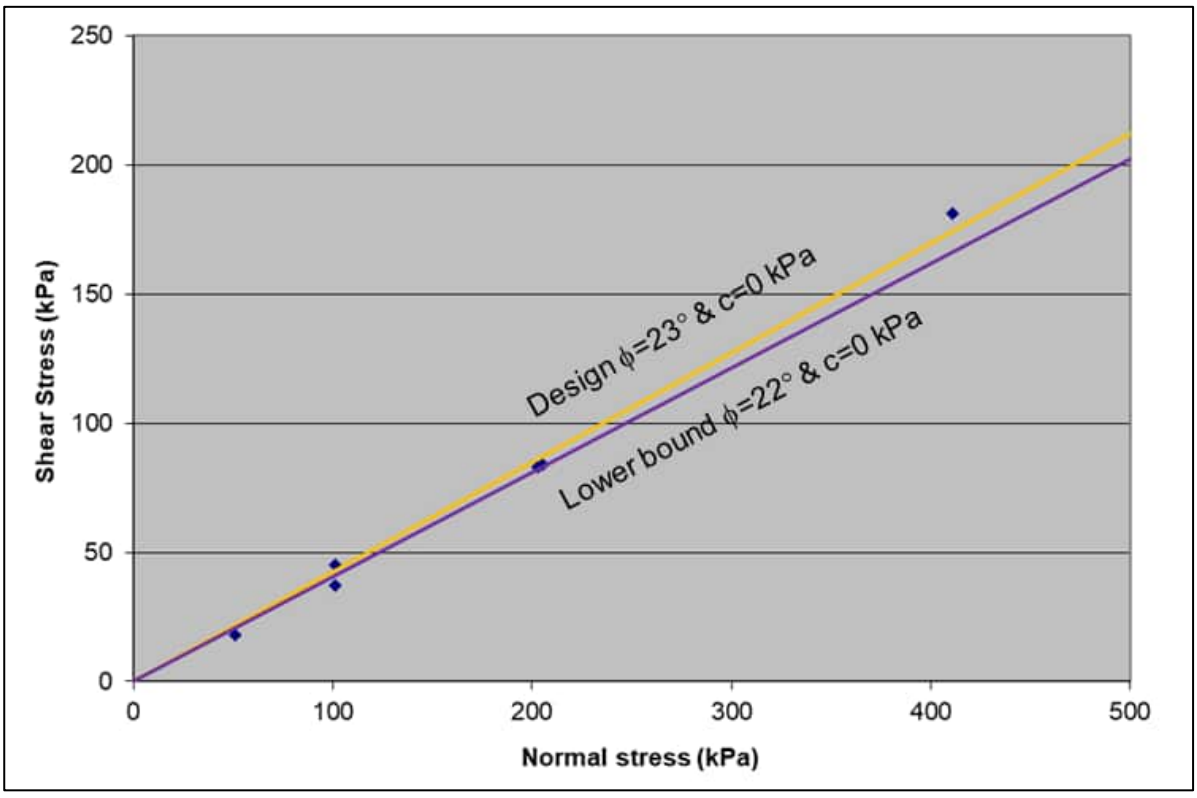


Figure 3-5: Sawcut test results for Fresh KCS - Residual

3.4 Permeability

Permeability of waste rock materials will generally be influenced by many factors such as PSD, proportion of fines, porosity (degree of densification or consolidation) and fluid viscosity. Permeability values considering the finer and coarser limits of the PSDs were assessed for saturated conditions using empirical methods.

The following empirical methods were considered in the assessments:

- Kozeny-Carman: In this method, the full range of PSD data is used along with porosity and fluid viscosity. For any waste material, dump porosity will have a significant impact on permeability. Therefore, this method is considered comprehensive.
- Hazen: For this method, only the D_{10} value from the PSD is used, and this method is applicable when the uniformity coefficient ($Cu=D_{60}/D_{10}$) is less than 5.
- Beyer: For this method also, only the D_{10} value from the PSD is used, and this method is applicable when Cu is between 1 and 20.
- Sherard: For this method, only D_{15} value from PSD is used.

The Kozeny-Carman method was the principal method applied for the interpretations, with the other methods used for comparison purposes. Finer and coarser limit PSDs were chosen as the lower and upper limit PSDs presented in Table 3-2 in Section 3.1. The input parameters and applicable methods for considered waste rock units are shown in Table 3-5.

Table 3-5: Input parameters and applicable method

Rock unit	Cu		D_{10} (mm)		D_{15} (mm)		Applicable methods	
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Oxide BIF	>20	14	0.8	15	2.4	32.5	Kozeny-Carman and Sherard	Kozeny-Carman, Beyer and Sherard
Oxide KCS			0.2		0.6			
Fresh BIF			1		4			

Estimated permeability values from applicable methods are presented in Figure 3-6 for various waste rock materials of lower (fine) and upper (coarse) PSD limits. An example calculation sheet with relevant parameters and equations is included in Appendix B. A summary of lower and upper bound order of magnitude permeability values (values for a porosity of 25% in the Kozeny-Carman method) is presented in Table 3-6. It is noted that the permeability for the finer end of measured PSDs for Oxide materials will provide a permeability approximately one order of magnitude lower than the permeability of the lower bounds presented in Table 3-6 (i.e. 1×10^{-3} for Oxide BIF and 1×10^{-4} for Oxide KCS).

Higher permeabilities of waste rock materials may be better for slope stability performance due to expected faster drainage, but in terms of surface water and infiltration, greater recharge could occur, resulting in larger-volume seepages and erosion developing after rainfall event, which could cause instability.

Table 3-6: Summary of estimated order of magnitude permeabilities

Rock unit	Permeability (m/s)	
	Lower	Upper
Oxide BIF	~1×10^{-2}	1–4
Oxide KCS	~1×10^{-3}	
Fresh BIF	~2×10^{-2}	

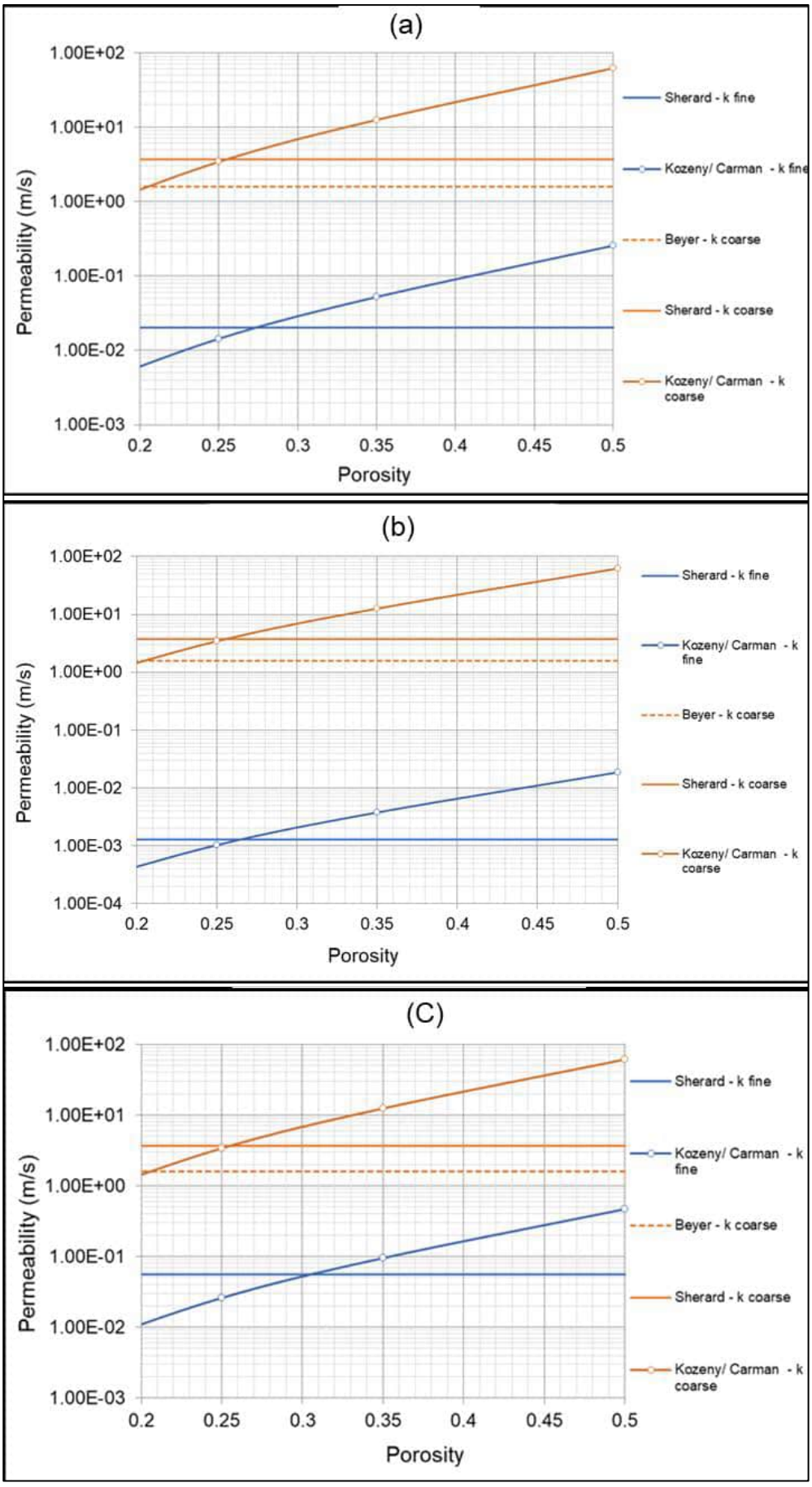


Figure 3-6: Interpreted permeability values a) Oxide BIF; b) Oxide KCS; c Fresh BIF

3.5 Durability

Slake durability laboratory tests have been undertaken on rock samples to evaluate resistance to deterioration under weathering conditions. The slake durability index (DI) obtained from the tests provides a quantitative measure of durability. Test results were plotted (Figure 3-7) against slake durability index classification (Franklin & Chandra, 1972) to understand the degree of durability. Based on this assessment, Oxide and Pincunah Fresh BIF are indicated to have very high to extremely high durability, whereas KCS has high to very high durability.

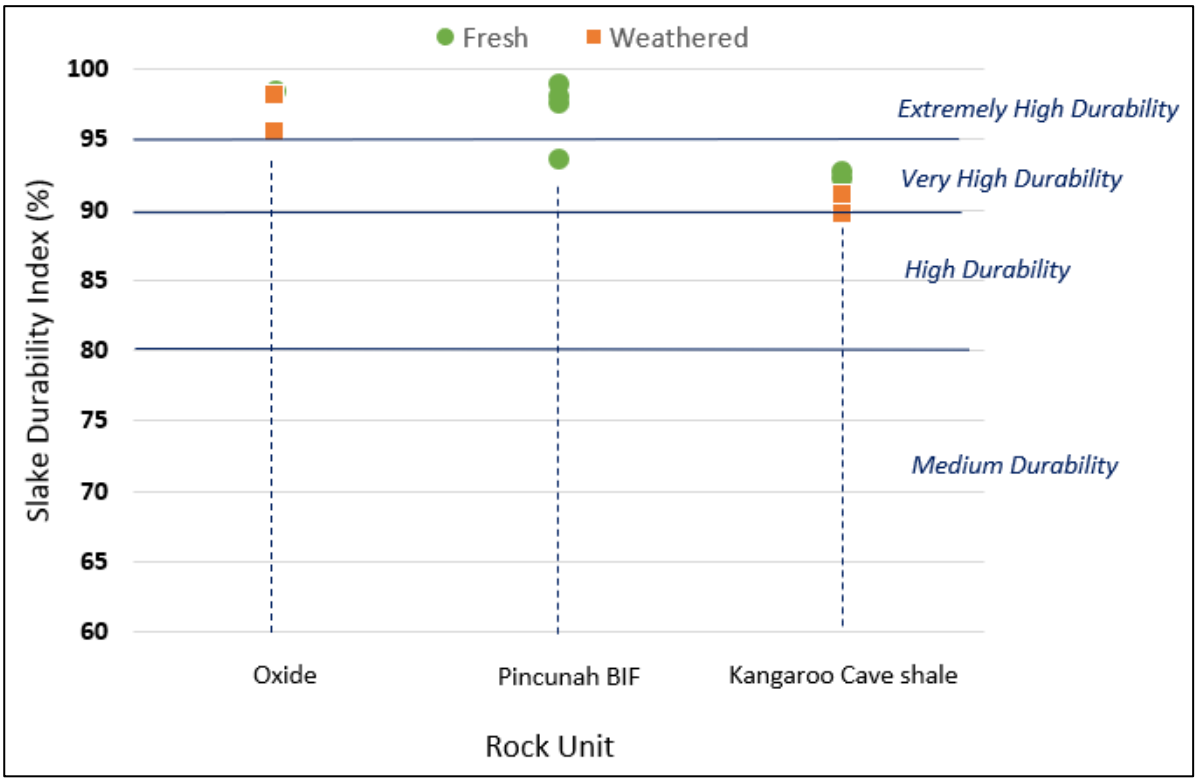


Figure 3-7: Slake durability index results

3.6 Liquefaction potential

The Iron Bridge site is not situated in a seismically active area, and the potential for large earthquakes and liquefaction-induced instability to occur is minimal. Materials susceptible to liquefaction should also be loose and nearly fully saturated which will also rarely be expected to occur in this WRD. However, available PSD data was used to assess the liquefaction potential of waste rock materials for any worst-case scenarios. Figure 3-8 presents the gradation curves of waste materials considered in this study in comparison with liquefaction susceptibility limits presented in CSIRO (2017). Figure 3-8 shows that most parts of the grading curves are beyond the limits, which indicates that liquefaction susceptibility is insignificant.

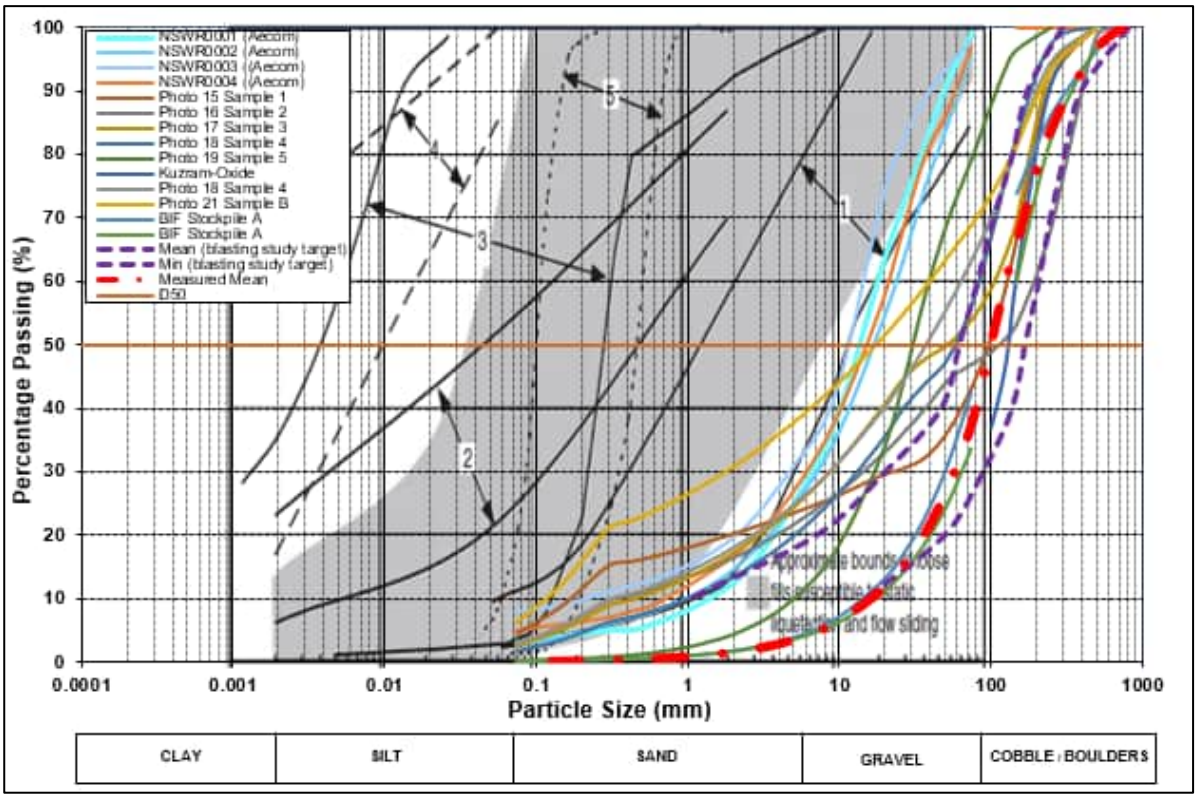


Figure 3-8: Range of gradation of soils which exhibited flow slide behaviours

Source: Modified after CSIRO, 2017

3.7 Dump density

Dump densities are generally estimated by site tests (e.g. water or sand replacement methods) on existing WRDs. As there is no such data available, approximate dump densities were estimated using available in situ bulk densities reported by AMC (2019) and an assumed porosity (25%). Moisture contents of the materials at in situ and 'as dumped' conditions were assumed to be similar. The approximate dump density values estimated for various materials are presented in Table 3-7.

Table 3-7: Dump densities

Unit	In situ bulk density (kN/m^3)	Porosity	Dump density (kN/m^3)
Oxide BIF	31	0.25	23
Oxide KCS	31	0.25	23
North Star – Fresh BIF	33	0.25	25
Eastern Limb N – Fresh BIF	32	0.25	24
Eastern Limb C – Fresh BIF	34	0.25	26
Eastern Limb S – Fresh BIF	32	0.25	24
Glacier Valley – Fresh BIF	34	0.25	26
Fresh KCS	28	0.25	21

3.8 Non-linear shear strength

Precise determination of shear strength of waste rock is considered difficult due to several factors, such as spatial variations and limitations in obtaining representative data, material placement methods and associated segregation, particle crushing under loading, and time-dependent consolidation.

As there is no practical method to derive shear strength of an in situ sample, the empirical strength method using the Barton-Kjaernsli criterion (Barton & Kjaernsli, 1981; Barton, 2008), based on site specific data as available, has been adopted. The criterion is defined by the following relationship and parameters:

$$\tau = \sigma_n \tan(R \log \frac{S}{\sigma_n} + Phi_r)$$

where:

σ_n = effective normal stress

R = equivalent roughness, which is a function of the particle roundness and the porosity (n) of the dumped waste

S = size-dependent equivalent strength of the blasted particles, based on the UCS and the typical waste rock particle size at 50% passing (D_{50})

Phi_r = residual friction angle on the sawn surface of the rock.

3.8.1 Parameters for non-linear shear strength envelopes

The parameters selected for the development of non-linear strength envelopes are summarised in Table 3-8. The approach for determining the parameters is discussed in the following sections.

Table 3-8: Selected parameters for assessment of non-linear shear strength

Rock unit	Dump density (kN/m^3)	Waste porosity (%)	Equivalent roughness, R	Design UCS (MPa)		D_{50} (mm)		Equivalent strength, S (MPa)		Residual friction, ϕ_r (°)	
				Design	Sensitivity	Design	LB (upper)	Design	LB	Design	LB
Oxide BIF	23	25	6	36	18	65	170	10.1	4.3	28	26
Oxide KCS	23	25	6	11	6	65	170	3.1	1.3	23*	22*
North Star – Fresh BIF	25	25	6.5	194	97	100	170	50.4	23.2	26	26**
Eastern Limb N – Fresh BIF	24	25	6.5	244	122	100	170	63.4	29.2	26	26**
Eastern Limb C – Fresh BIF	26	25	6.5	306	153	100	170	79.6	36.8	26	26**
Eastern Limb S – Fresh BIF	24	25	6.5	167	83	100	170	43.4	20.0	26	26**
Glacier Valley – Fresh BIF	26	25	6.5	204	102	100	170	52.9	24.4	26	26**
Fresh KCS	21	25	6.5	151	76	100++	170++	39.4	18.2	23	22

* Values obtained for Fresh KCS are adopted as there is no data.

** Design values are adopted for the lower bound due to inadequate data.

++ Values used for Fresh BIF were applied as there is no data.

3.8.2 Porosity and dump density

An appropriate assessment of dump density and porosity is difficult due to many factors such as spatial variations, material segregations, material consolidation (due to increased loading); these parameters can therefore only be assessed by practical methods. The porosity of the waste rock will generally be based on the 'as dumped' density and the density of the rock particles evaluated in the laboratory. There is no site-specific data available for assessing these parameters appropriately. Therefore, a porosity value of 25% was assumed based on past WRD design studies for other FMG sites (SRK, 2014; SRK, 2018) and the approximate dump densities for various waste rock types were estimated as described in Section 3.7. The selected parameters are provided in Table 3-8. These parameters will need to be verified and improved during operations by reconciliation of weight and volume at the site-specific WRD.

3.8.3 Equivalent roughness

Equivalent roughness (R) is a function of particle roundness and surface roughness of waste rock and the 'as dumped' porosity. Particle angularity will generally be influenced by rock strength and brittleness, blasting and excavation processes, and weathering. Previous studies reported that the Oxide materials have particles that are predominately medium to coarse and subangular to rounded (AECOM, 2015). SRK's observation during the site visit for assessing foundation conditions suggests that blasted Fresh BIF particles are largely angular, and the particle surface roughness of Oxide and Fresh BIF are in general planar smooth. Based on the experience with similar materials, Fresh KCS particles were assumed to be more angular with a general surface roughness in the planar smooth category.

Considering these parameters and a waste porosity of 25%, the empirical scheme developed by Barton (2008) provided likely R value of 6 for Oxides, and 6.5 for Fresh KCS and BIF, as shown in Figure 3-9.

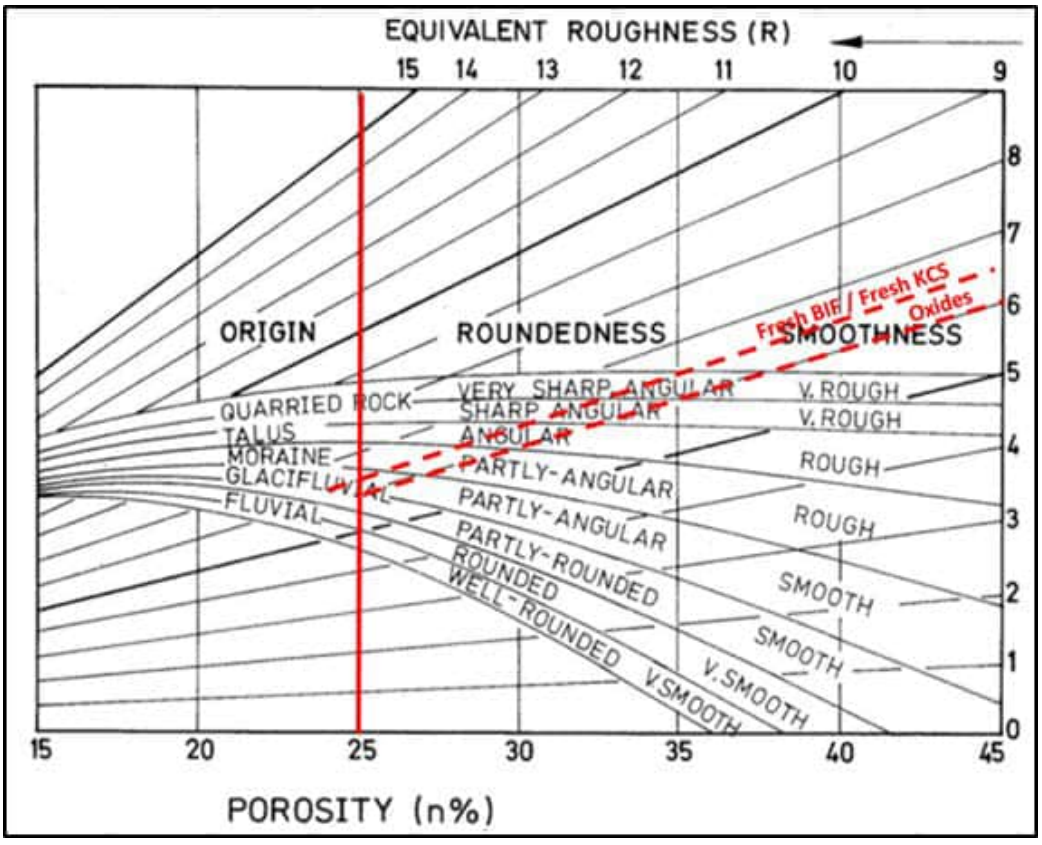


Figure 3-9: Empirical method to assess equivalent roughness parameters

3.8.4 Equivalent strength

The size-dependent parameter equivalent strength (S) of the blasted particles is determined based on rock surface strength and typical waste rock particle size at 50% passing (D_{50}). Interpretation of expected D_{50} ranges for various waste materials is described in Section 3.1. For rock surface strength, mean laboratory UCS values as presented in Table 3-3 in Section 3.1 were adopted for design, and half the mean value was conservatively adopted for sensitivity assessment in each case to account for long-term closure conditions.

The equivalent strength was then assessed based on the strength assessment scheme proposed by Barton & Kjaernsli, 1981 (Figure 3-10). Figure 3-10 shows a D_{50} of 100 mm will yield an S value of 0.26 times the UCS of the material. The selected design and lower bound D_{50} and UCS values, along with corresponding interpreted S values, are presented in Table 3-8.

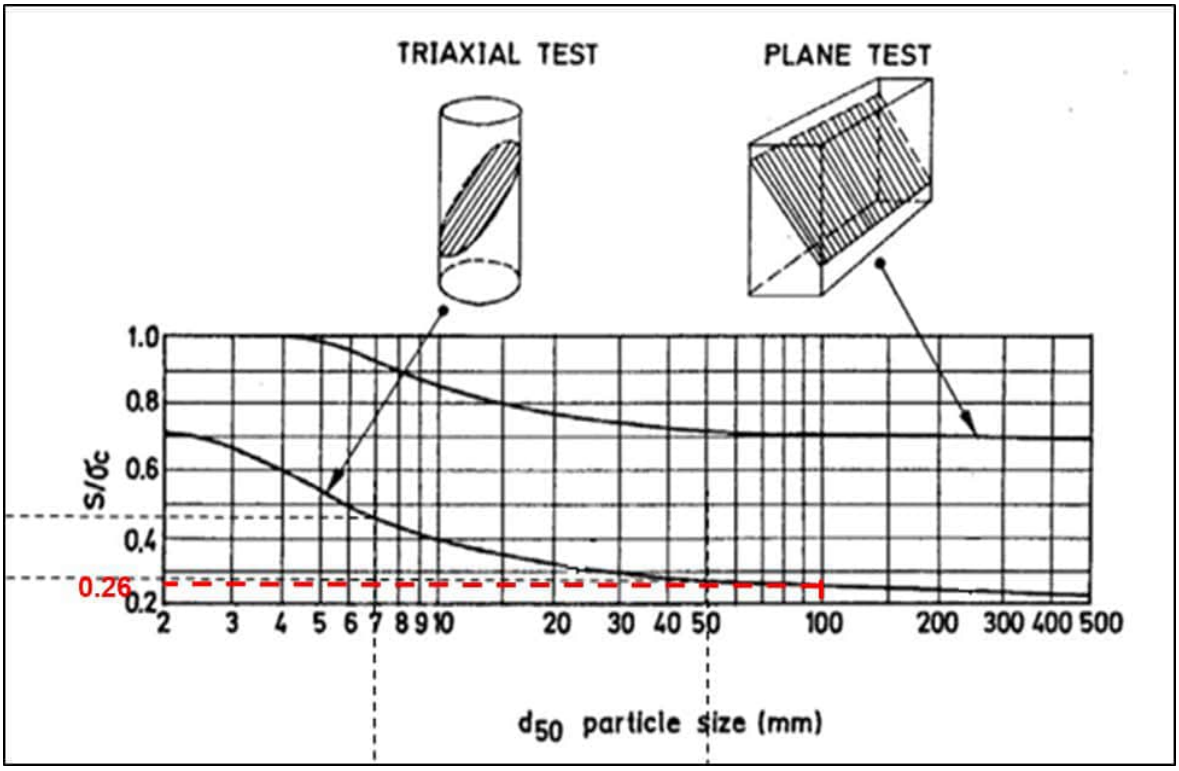


Figure 3-10: Empirical method to assess equivalent strength parameter

3.8.5 Residual friction angle

The residual friction angle (ϕ_r) was evaluated using the results of direct shear tests conducted on sawcut samples as described in Section 3.3. The adopted design and lower bound ϕ_r values are presented in Table 3-8.

3.9 Non-linear strength envelopes

Shear strength envelopes were developed for various representative waste rock materials considering the parameters listed in Table 3-8. Design and lower bound shear strength envelopes are presented in Figure 3-11 and Figure 3-12, respectively, and the shear strength parameters obtained for the power curves are summarised in Table 3-9. Lower bound shear strength envelopes were developed using lower bound ϕ_r and S values with the design R values. For comparison purposes, linear strength envelopes of 30°, 37° and 40° friction angles, the lower limit envelope for rockfill material proposed by Indraratna (1993), and the envelope for high strength rock fill defined by Leps (1970), are included for reference in Figure 3-11 and Figure 3-12.

In this evaluation, Oxide KCS presents significantly lower shear strength (lower than the envelope for 30° friction angle), followed by Fresh KCS and Oxide BIF. The shear strength envelopes of all the Fresh BIF units show relatively stronger trend, and out of all the fresh BIF units, 'Eastern Limb S- Fresh BIF' presents the weakest trend of strength envelope.

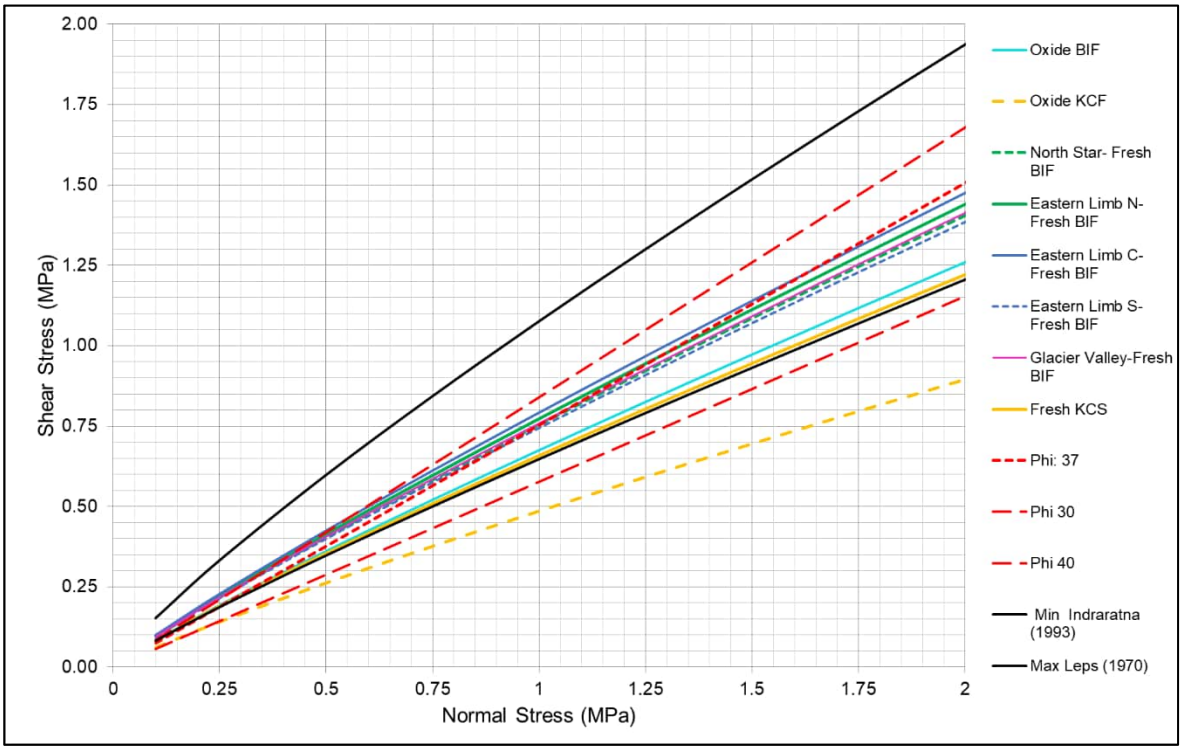


Figure 3-11: Design non-linear shear envelopes

As shown in Figure 3-11, the design strength envelopes for Oxide BIF and Fresh KCS are similar or very close to the minimum Indraratna envelope, whereas Fresh BIF envelopes are located approximately in the middle of the minimum Indraratna and maximum Leps reference envelopes. Figure 3-12 shows that the lower bound strength envelopes of Oxides and Fresh KCS fall below the minimum Indraratna envelope; however, Fresh BIF envelopes remain between the minimum Indraratna and maximum Leps envelopes, with relative drop in strength.

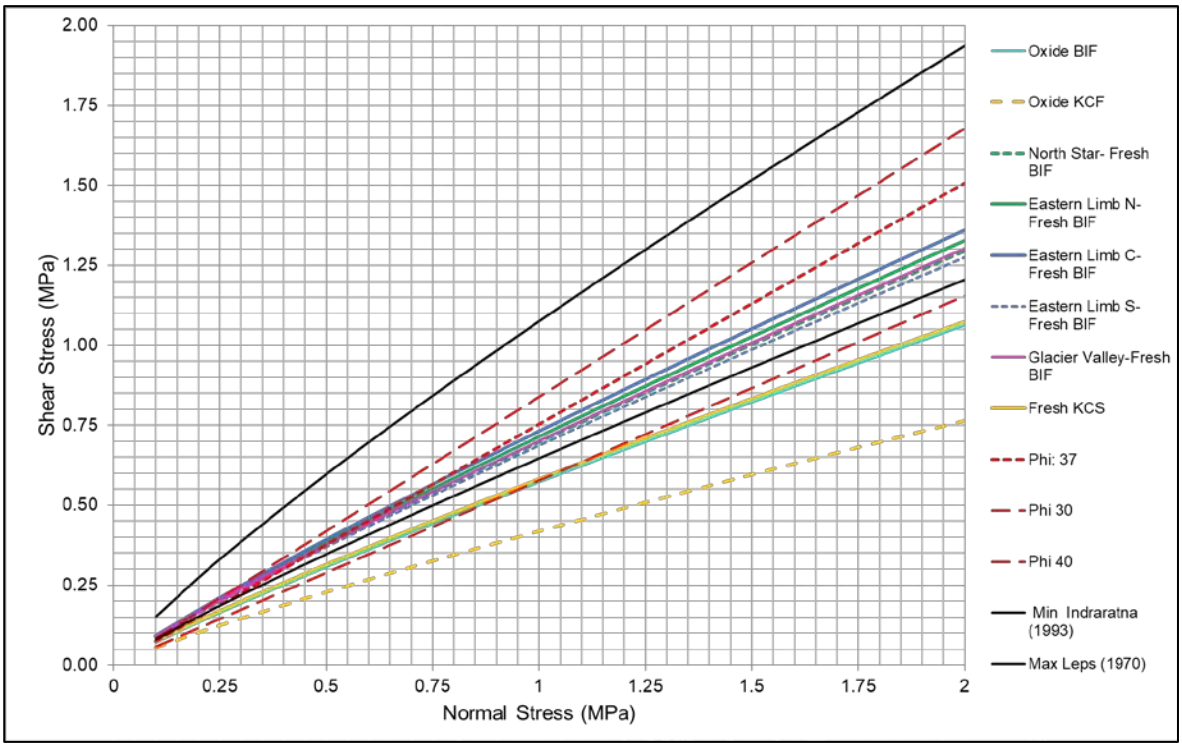


Figure 3-12: Lower bound non-linear shear envelopes

Table 3-9: Summary of shear strength parameters

Rock unit	Non-linear shear strength relationship (Power curve) $\tau = A(\sigma n)^b$ (τ and σn in MPa)			
	Design envelope		Lower bound envelope	
	A	b	A	b
Oxide BIF	0.674	0.904	0.572	0.898
Oxide KCF	0.485	0.889	0.417	0.879
North Star - Fresh BIF	0.755	0.899	0.696	0.897
Eastern Limb N - Fresh BIF	0.773	0.899	0.713	0.898
Eastern Limb C - Fresh BIF	0.791	0.900	0.730	0.898
Eastern Limb S -Fresh BIF	0.743	0.899	0.685	0.896
Glacier Valley - Fresh BIF	0.758	0.899	0.700	0.897
Fresh KCS	0.658	0.895	0.580	0.890

4 Conclusion and Recommendations

4.1 Conclusion

Geotechnical characterisation of the Iron Bridge rock dump was carried out for the development of shear strength models to be adopted in stability assessments at closure and operational conditions. Precise determination of shear strength of waste rock is considered difficult due to several factors such as spatial variations and limitations in obtaining representative data, material placement methods and associated segregation, particle crushing under loading and time-dependent consolidation. Using a practical approach, the empirical strength method using the Barton-Kjaernsli criterion (Barton & Kjaernsli, 1981; Barton, 2008), based on site-specific data as available, has been adopted to develop non-linear shear strength parameters of various waste rock materials. Design and lower bound shear strength envelopes were developed for the WRD assessments. The lower bound strength is expected to provide some understanding of the impact of uncertainties on the data.

Oxide KCS presents significantly lower shear strength (lower than the envelope for friction angle 30°), followed by Fresh KCS and Oxide BIF (close to the referenced minimum Indraratna envelope). The shear strength envelopes of all the Fresh BIF units are relatively stronger, falling midway between the minimum Indraratna and maximum Leps empirical reference envelopes. 'Eastern Limb S- Fresh BIF' presents the weakest strength envelope of all Fresh BIF units.

The characterisation of waste rock materials is expected to facilitate effective closure design assessments using representative and conservative (lower bound) material strength parameters.

4.2 Recommendations

Several assumptions (e.g. porosity and dump density) were made in characterising the waste rock, and in some cases, there was limited data available for assessment (e.g. residual friction angle). It is therefore recommended that the design parameters of the various waste rock materials be reviewed and updated during operations. Additional site-specific tests (e.g. dump density and roughness assessments) and laboratory testing (e.g. sawcut shear and specific density tests) are recommended to expand the dataset and thereby increase data confidence levels. Performance of waste materials on the actual WRD during operations will be used for verification of the study outcomes.

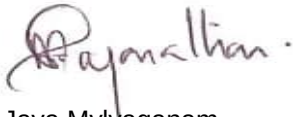
Typical reduction in the friction angle with increased confining pressure can be attributed to material crushing. As waste rock particles tend to break due to increased confinement, large-scale testing on blasted samples will generally allow better representation of the likely field performance. The height of the Iron Bridge WRD is approximately 100 m, and associated confining pressures are not expected to be significantly high. Therefore, sensitivity analyses as part of the evaluation of the stability of the WRDs will in general help in determining the actual benefit and necessity of large-scale testing and sampling for the shear strength study.

It is recommended that any significantly weak waste materials (e.g. KCS) be dumped away from the WRD slope structure to prevent instability issues arising.

Project Number: FMG062

Report Title: Iron Bridge Project – Geotechnical Characterisation of Waste Rock Materials

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Principal Consultant

Peer Reviewed by



Ian de Bruyn

Principal Consultant

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Appendices

Appendix A: PSD data

	Percentage passing													
	Oxide BIF	Oxide BIF	Oxide BIF	Oxide BIF	Oxide BIF	Oxide BIF	Oxide BIF	Oxide BIF	Oxide BIF	Oxide BIF	Oxide KCS	Oxide KCS	Fresh BIF	Fresh BIF
AS Sieve (mm)	NSWR0001 (Aecom)	NSWR0002 (Aecom)	NSWR0003 ((Aecom)	NSWR0004 ((Aecom)	Oxide Bulk (Landloch)	Photo 15 Sample 1	Photo 16 Sample 2	Photo 17 Sample 3	Photo 18 Sample 4	Photo 19 Sample 5	Photo 20 Sample A	Photo 21 Sample B	BIF Stockpile A	BIF Stockpile B
750							100						100	100
500	100	100	100	100		100	98.48	100	100		100	100	96.29	96.79
250	100	100	100	100		91.11	67.87	93.18	97.27	100	94.45	93.12	86	82.08
150	100	100	100	100		66.68	53.2	69.73	82.62	96.52	81.35	81.51	73.8	60.05
125						58.45	50.78	63.8	75.57	93.31	75.72	77.64		
100						50.66	48.66	58.49	66.28	87.39	69.5	73.35		
75	99	96	98	97		43.09	46.81	53.76	55.95	79.03	63.13	68.76	42.38	33.55
53	92	85	94	87		36.44	44.32	50.05	47.91	69.76	56.14	63.92	31.22	25.03
37.5	82	75	89	80		32.35	39.88	47.76	43.95	58.02	49.78	59.16	22.85	18.69
26.5	72	63	82	68		30.52	35.86	44.5	39.83	43.6	44.1	54.72	16.7	13.94
19	62	53	72	56		29.41	32.38	39.7	34.67	32.34	39.26	50.77	12.36	10.53
9.5	38	35	42	38		26.08	26.15	30.78	25.99	17.45	30.79	43.42	6.61	5.85
4.75	24	24	30	26		23.32	21.11	23.67	19.36	9.4	24.12	37.13	3.53	3.25
2.36	14	16	21	18		20.75	17.02	18.14	14.38	5.03	18.87	31.74	1.87	1.79
1.18	9	11	16	13		18.53	13.8	13.99	10.73	2.71	14.85	27.26	1	1
0.6	6	8	13	9		16.67	11.34	10.94	8.13	1.48	11.85	23.66	0.54	0.56
0.425	5	7	12	8		15.85	10.31	9.7	7.1	1.09	10.63	22.11	0.4	0.42
0.3	5	6	11	7		15.14	9.46	8.69	6.27	0.81	9.62	20.79	0.29	0.32
0.15	4	4	9	6		8.92	5.47	4.97	3.56	0.42	5.53	12.16	0.15	0.17
0.075	3	3	8	5		4.46	2.74	2.49	1.78	0.21	2.76	6.08	0.07	0.08
Non-Standard (mm)														
100					100									
50					87.7									
25					75.8									
5					44.3									
2					30.4									
0.2					10.9									
0.02					3.5									
0.002					1.2									

Appendix B: Sample permeability calculation sheet

Permeability assessment methods

Kozeny/ Carman

$$k = \frac{\gamma_w}{\eta}\frac{d_w^2}{C_i}\frac{n^3}{(1-n)^2}$$

ΔP	d_{small}	d_{large}	d_{mean}	$\Delta P/d_{mean}$
0.1	0.001	0.8	0.4	0.250
0.1	0.8	4	2.40	0.042
0.1	4	10	7.0	0.014
0.1	10	16	13.0	0.008
0.1	16	25	20.5	0.005
0.1	25	40	32.5	0.003
0.1	40	70	55.0	0.002
0.1	70	100	85.0	0.001
0.1	100	200	150.0	0.001
0.1	200	500	350.0	0.000
			Σ	0.325 mm^{-1}

γw =		10	KN/m3
η =	Viscosity	1.02E-06	KN.s/m2
n =	Porosity	0.25	
dw = $1/\Sigma(\Delta p/d_{mean})$ =		3.075	mm

C_1 =	180	k = 1.4E-02	m/s
C_1 =	210	k = 1.2E-02	m/s

k = 1.430 cm/s

Hazen

$k = 0.01\ d_{10}^2$ (Cu < 5) (d_{10} [mm], k [m/s])

D_{60} =	40	mm
D_{10} =	0.8	mm

Cu = D_{60}/D_{10}

Cu = 50.0

k = 6.4E-03 m/s : **0.640 cm/s**

Fact. C	1.1	1.0	0.9	0.8	0.7	0.6

C= **0.6**

k = 3.8E-03 m/s : **0.384 cm/s**

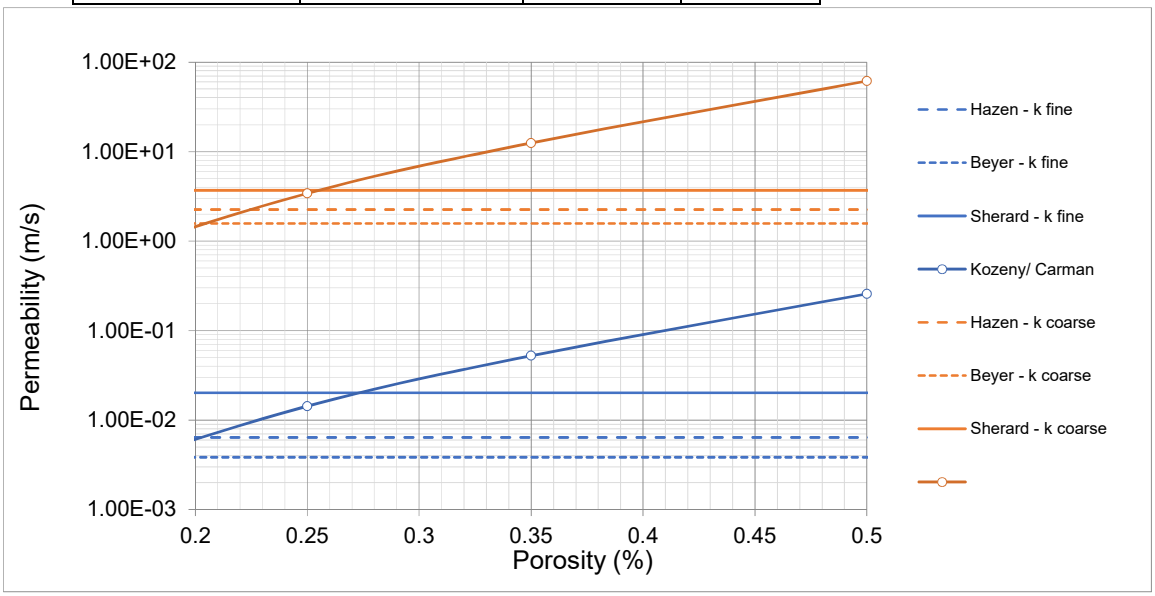
Sherard

$k = 0.35\ d_{15}^2$ (d_{15} [mm], k [cm/s])

D_{15} =	2.400	mm

k = 2.0E-02 m/s : **2.016 cm/s**

Porosity	Method	Permeability (m/s)	
		Fine	Carse
0.15	Kozeny/ Carman	2.41E-03	5.75E-01
0.25		1.43E-02	3.42E+00
0.35		5.23E-02	1.25E+01
0.5		2.57E-01	6.16E+01
Applicability			
(Cu < 5)	Hazen - k fine	6.40E-03	-
(1 < Cu < 20)	Beyer - k fine	3.84E-03	-
-	Sherard - k fine	2.02E-02	-
(Cu < 5)	Hazen - k coarse	-	2.25E+00
(1 < Cu < 20)	Beyer - k coarse	-	1.58E+00
-	Sherard - k coarse	-	3.70E+00
Cu		50	14



SRK Report Client Distribution Record

Project Number: FMG062

Report Title: Iron Bridge Project – Geotechnical Characterisation of Waste Rock Materials

Date Issued: 3 April 2019

Name/Title	Company
Justin Dixon	Fortescue Metals Group

Rev No.	Date	Revised By	Revision Details
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1	03/04/2019	Jaya Mylvaganam	Revised Final Report

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Appendix 11: Dry Rejects Stockpile Design with Addendum Memo

Appendix 11a: Iron Bridge Dry Rejects Stockpile Design

Iron Bridge Dry Rejects Stockpile Design

NOTE THE CLOSURE DESIGN PRESENTED IN THIS REPORT DOES NOT REPRESENT THE CURRENT CLOSURE STRATEGY, UNLESS OTHERWISE DIRECTED WITHIN THE MCP.

AN ADDENDUM MEMO HAS BEEN PROVIDED AT THE END OF THIS REPORT TO DISCUSS THE IMPLICATIONS OF USING 18 DEGREE SLOPES, AND OTHER FACTORS THAT HAVE CHANGED SINCE THIS REPORT WAS COMMISSIONED.

Report Prepared for

IB Operations Pty Ltd



Report Prepared by

SRK Consulting (Australasia) Pty Ltd

IBO057

May 2019

Iron Bridge Dry Rejects Stockpile Design

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Executive Summary

SRK Consulting (Australasia) Pty Ltd (SRK) was appointed by Iron Bridge Operations (IBO) to undertake the design of the dry rejects stockpile to support the Iron Bridge Magnetite Project Feasibility Study and Mining Proposal Application.

The stockpile is required to store the production of approximately 242 Mt of dry rejects over an estimated 20-year life of mine (LOM). The dry rejects is planned to be stacked using a telescopic radial stacker, with a final stockpile height of approximately 80 m and footprint of approximately 239 ha.

The stockpile has been designed to ensure it is geotechnically stable, non-contaminating and erosion resistant. The design has been completed in accordance with the 'Guidelines for Mine Waste Dump and Stockpile Design' (CSIRO, 2017). The stockpile has been designed using an inherent risk-based approach, identifying the key aspects that could pose challenges to the landform and focusing on developing solutions and mitigation measures accordingly.

Analyses included consideration of extreme events relating to rainfall and seismicity. CSIRO's waste dump and stockpile stability rating and hazard classification (WSRHC) system indicates that the instability hazard for this stockpile is between a Moderate Hazard and a Low Hazard.

The dry rejects are coarse grained and well graded, with approximately 86% of particles greater than 75 µm. They are geochemically benign and will be placed at a moisture content of approximately 3% (w/w). A comprehensive laboratory testing program was carried out to define the geotechnical characteristics of the dry rejects.

The stockpile, mainly founded on shallow to surficial rock, will be a stepped landform that uses large benches and bunds to control surface water and contain sediment. The toe position of each successive lift is stepped in an optimal bench design distance that will assist with forming the required overall landform slope at closure. Due to the natural topography, most of the runoff flows away from the landform, with the stockpile designed to hold the maximum design rainfall event.

The slope stability assessment results for all considered scenarios for both operations and closure indicate a Factor of Safety (FOS) well in exceedance of the acceptance criteria. An infiltration assessment was undertaken using a true climate boundary at the surface to reasonably replicate the expected field conditions. The stockpile will not experience fully saturated conditions (to any significant depth) under any conceivable scenario. Being unlikely to saturate, the stockpile is unlikely to liquefy under any conceivable operating conditions.

The conceptual closure design ensures the stockpile will be physically safe to humans and animals, geotechnically stable, non-contaminating, erosion resistant and can support native vegetation after ceasing of operations. The stockpile will be capped with a protective layer of oxide waste rock of at least 0.5 m thickness across the full stockpile surface and at least 2.0 m on the slope face to provide erosional stability and enable revegetation where possible. The closure landform will be stepped uniformly with lifts at angle of repose of 10 m height and 25 m bench widths. The stockpile has been designed to retain water from its closed catchment rainfall. The top surface and benches will be constructed to accommodate the maximum design rainfall event (PMF, 72 hours).

Performance monitoring should be carried out on an ongoing basis during operations, rehabilitation and the post-closure period to ensure that the design intent is met during the stockpile's development through to the end of its life cycle. Monitoring of key aspects used in the design, such as moisture development/ distribution within the stockpile and the achieved angle of repose, is important in terms of validating the design.

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Disclaimer

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

1 Introduction and Scope of Report

SRK Consulting (Australasia) Pty Ltd (SRK) was appointed by Iron Bridge Operations (IBO) to undertake the design of the dry rejects stockpile to support the Iron Bridge Magnetite Project Feasibility Study and Mining Proposal Application. The stockpile is required to store the production of approximately 242 Mt of dry rejects over an estimated 20-year life of mine (LOM).

The dry rejects material is planned to be stacked using a telescopic radial stacker, with a final stockpile height of approximately 80 m and footprint of approximately 239 ha. The stockpile has been designed to ensure it is geotechnically stable, non-contaminating and erosion-resistant. The design has been completed in accordance with the 'Guidelines for Mine Waste Dump and Stockpile Design' (CSIRO, 2017).

1.1 Project background

The owner and proponent of the project is IB Operations Pty Ltd (IBO), a joint venture between FMG Iron Bridge Ltd (FMG and Baosteel) and Formosa Steel. IBO's Stage 2 development aims to process and extract magnetite ore by upgrading existing infrastructure from the North Star Hematite Project (Stage 1), which has been in operational readiness since April 2016. Magnetite concentrate (in slurry form) produced from Stage 2 operations will be piped to FMG's port facilities at Port Hedland for drying before shipment.

1.2 Site description

The Iron Bridge Magnetite Project is located approximately 1,240 km northeast of Perth and 120 km south of Port Hedland via the Great Northern Highway in the Pilbara region of Western Australia (Figure 1-1). The local topography consists of a series of plateaus, hills, ridges and valleys with elevation in this area ranges between 270 m AHD and 400 m AHD[1]. Figure 1-2 shows the proposed location of the stockpile and plant which is located southwest from the existing TSF.

Inspection of the proposed stockpile footprint was completed by SRK on 22 November 2018. Two ridge formations were observed from the north to south; one ridge is along the western toe while another one passes through the centre of the proposed footprint. The near-surface ground conditions appeared to be rocky with little topsoil around the footprint area and limited vegetation (Figure 1-3). Some fine-grained materials were seen in the banks of streams; there was no water in these streams.

[1] ATC Williams,2015, North Star Stage 2 – Geotechnical Investigation – Plant Site and Airport - Report



Figure 1-1: Site location map

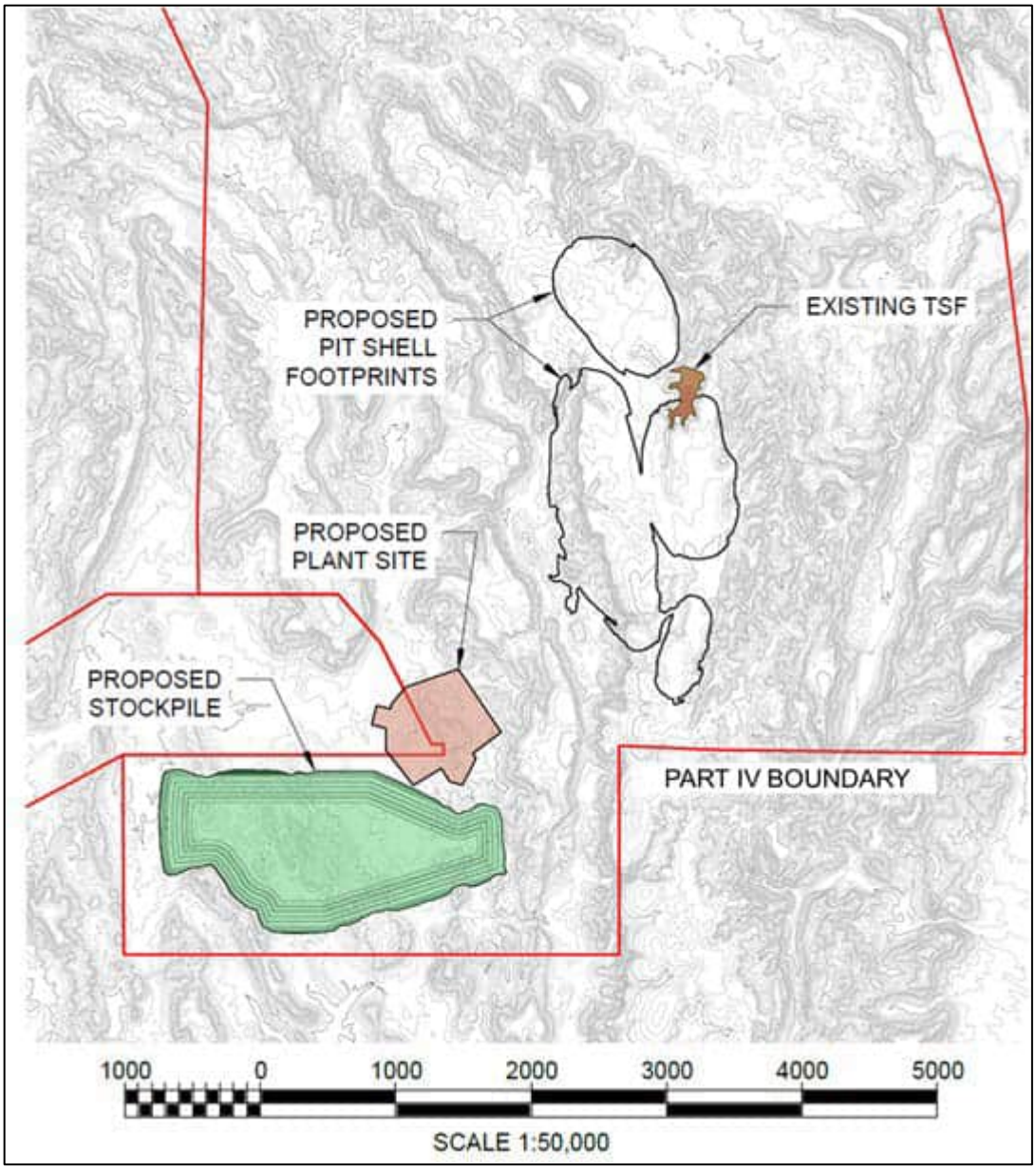


Figure 1-2: Conceptual infrastructure around the proposed stockpile location



Figure 1-3: Typical natural surface conditions of stockpile footprint

1.3 Climate

The climate at Iron Bridge in the Pilbara region is classified as semi-arid to arid with high temperatures and low irregular rainfall. Average annual rainfall typically has high inter-annual variability (both spatially and temporally) associated with irregular tropical cyclones. Temperatures are generally high during the summer months, with the maximum daily temperature exceeding 32°C. In the winter period, temperatures range between 19°C and 22°C during the day and between 7°C and 8°C during the night. The climate has two distinctive seasons; a hot summer from October to April and a mild winter from May to September.

In the absence of a weather station which provides comprehensive climate data at Iron Bridge, SRK has sourced data from the Scientific Information for Land Owners (SILO), which is a database of Australian climatic data. The datasets are constructed from observational data obtained from the Australian Bureau of Meteorology (BOM), sourcing data from nearby weather stations as appropriate. The key climate information applicable to the site is summarised in Table 1-1, which is based on SILO sourced from various weather stations including Redmont and Marble Bar.

Table 1-1: Average climate data based on SILO (-21.72° S,119.4° E)

Month	Mean monthly rainfall (mm)	Mean monthly pan evaporation (mm)	Average temperature (C°)	Mean daily exposure (MJ/m^2)	Relative humidity (%)
January	76.8	355.0	32.7	26.3	47.5
February	80.9	288.9	31.8	24.4	51.1
March	52.1	294.5	30.6	22.9	46.0
April	21.1	246.8	27.3	20.0	41.6
May	20.0	194.0	22.2	16.7	45.3
June	20.4	154.9	18.7	15.1	49.2
July	11.8	167.8	18.0	16.6	45.5
August	6.2	205.4	20.1	20.2	40.6
September	1.3	264.0	23.8	23.9	34.5
October	3.0	345.3	27.6	26.9	32.7
November	8.9	376.0	30.6	28.8	33.1
December	39.5	388.1	32.5	28.1	39.3
Total/ Average	**342**	**3,281**	**26**	**22**	**42**

The rainfall intensity-frequency-duration (IFD) relationships are shown in Table 1-2 and illustrated in Figure 1-4.

Table 1-2: Intensity-frequency-duration table

Duration (minutes)	1 year (mm)	2 years (mm)	5 years (mm)	10 years (mm)	20 years (mm)	50 years (mm)	100 years (mm)	500 years (mm)
60	28	33	47	57	67	81	91	122
120	35	41	59	72	85	103	118	158
180	39	46	67	83	99	121	140	188
360	47	56	86	108	131	164	190	255
720	57	69	110	141	175	222	259	347
1,440	69	85	139	180	225	287	335	456
2,880	83	102	166	215	267	335	388	512
4,320	90	111	179	229	282	348	399	523

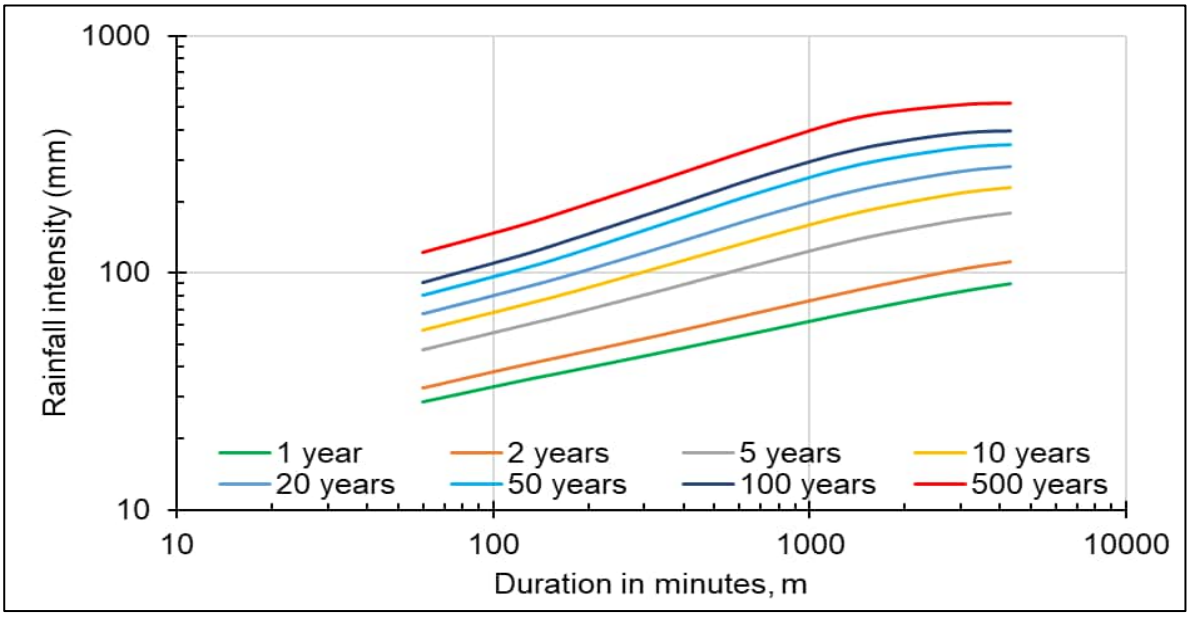


Figure 1-4: Design rainfall intensity chart

1.4 Geology

Based on the geotechnical desktop study by WorleyParsons in 2012, the proposed site is in the Pilbara Craton which is comprised of Archaean rocks including volcanic, sedimentary and mafic-ultramafic intrusive rocks of the Pilbara, Mount Bruce and De Grey Supergroups, as well as various granitic complexes. Metamorphism associated with the intrusion of plutonic granitic bodies has altered the surrounding rocks of the various supergroups, resulting in the formation of an extensive granite-greenstone terrain. Regolith profiles and Cainozoic accumulations of alluvium and colluvium are generally thin and sparsely distributed in the region, generally only attaining any significant thickness near major drainage systems.[2]

The geological units directly associated with the site include several members of the Pilbara Supergroup, including the Sulphur Springs Group, Gorge Creek Group and various other unassigned

[2] WorleyParsons,2012. North Start Magnetite Project Feasibility Study – Plant Site: Geotechnical Desk Study and Site Reconnaissance Report

units, the Yule Granitoid Complex, Soanesville Group and the superficial Cainozoic and Quaternary deposits. However, only Sulphur Springs Group's litho-stratigraphic units are within the surrounding area.

The 2,500–3,000 m thick Sulphur Springs Group has four main components – Pincunah Member (banded iron formation, or BIF), Kangaroo Caves Formation (basalt-andesite volcanic and associated volcaniclastics), Kunagunarrina Formation (high magnesium basalt and komatiitic basalt) and Leilira Formation (siliclastic sandstones)[3]. Figure 1-5 shows the stockpile's proposed location lies on rock units mainly from the Kangaroo Caves Formation, AScbi, and rock units from the Kunagunarrina Formation, ASkuk and ASkbm. The rocks units are explained as follow:

a. AScbi: Andesitic to basaltic lavas; pillowed and massive, with associated intrusive sills, metamorphosed

b. ASkbm: High magnesium basalt; massive and pillowed flows, metamorphosed

c. ASkuk: Komatiite and basaltic komatiite flows; commonly with spinifex texture, locally pillowed, metamorphosed.

The stockpile footprint area is composed of mainly basalt-andesite units which include volcanic flows, intrusive rocks and sedimentary rocks, such as volcanogenic sandstones and siltstones. Along the terrain, these rock units vary from areas of gently undulating relief where defect spacing is close and weathering is slightly more developed, to elevated strike ridges where the rock mass is of a blocky nature and slightly weathered rock is exposed at the surface[2].

The Sulphur Springs Group has been subjected to weathering under warm and wet conditions, resulting in the localised formation of laterite and duricrust during the Tertiary and Quaternary periods. The concurrent erosion has similarly resulted in the superficial accumulation of colluvial and alluvial deposits on the slopes.

The geology beneath the stockpile footprint is illustrated in SRK Drawing IBO057-0005.

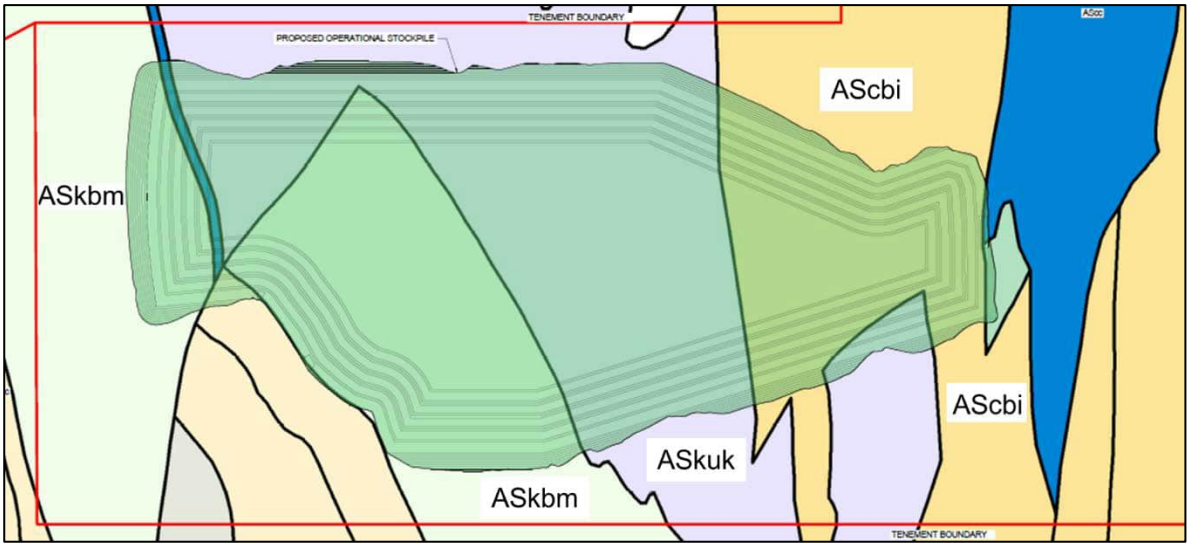


Figure 1-5: Principal solid geology/ rock units along the proposed site

[3] Golder Associates, 2015. Geochemical Characterisation Report and AMD Assessment, Iron Bridge North Star Project

1.5 Geochemistry

Geochemical assessment was undertaken by GHD in 2012[4] on the dry rejects for net acid generation (NAG), net acid producing potential (NAPP), total metals, ASLP (Australian Standard Leaching Procedure) leach test, NAG liquor, paste pH, ABCC (acid buffering characteristic curve) and XRD (X-ray diffraction). Based on the GHD assessment, the results had shown that the dry rejects are non-acid forming (NAF) and have acid neutralising capacity (ANC). Due to the presence of carbonate materials as confirmed in XRD analysis, the available ANC is approximately 30% of the total ANC as tested in ABCC tests.

The total metal analysis showed low concentration of all metals except manganese; the risk of acid and metalliferous drainage (AMD) is limited. ASLP leach testing revealed that these materials are relatively inert and unlikely to produce saline or acidic drainages when in contact with fresh water. Moderate alkalinity levels detected in leachate due to partially soluble carbonate minerals in the dry rejects. During the interaction with AMD leachate, the dry rejects produced a leachate with low concentrations of most metals and a moderate level of salinity.

Sodium levels in the leachate were higher compared to calcium and magnesium levels, possibly due to the sodic discharges from buffering reactions of dry rejects and AMD discharges. NAG liquor analysis indicated that after complete oxidation of these dry rejects, dry rejects will not release high levels of soluble metals and all metal concentrations are below the ANZECC (Australian and New Zealand Environment and Conservation Council) freshwater criteria.

1.6 Surface water and groundwater

Streams in the Pilbara region are ephemeral and flow for a short duration after rainfall events. However, major rainfall events from cyclones can cause major flows in several rivers during the wet season while remaining dry between August and November, with periodic short-duration flows[5]. Surface water runoff and drainage from the stockpile landform during high rainfall events will likely report to surface water drains – either natural or engineered drains. Most of the drainages from different sub-catchments would naturally flow towards the Turner River catchment area[3].

The regional hydrogeology is characterised by Archaean granite-greenstone which is generally overlain by thin alluvial sediments in the river valley. Depth to the groundwater below the surface in the granitic area is generally 5–10 m. Groundwater from exploration bores at the site varies between 36 m and 280 m, confirming the expectation that groundwater levels in the greenstone formations are deeper. Groundwater occurrences within the granitic and greenstone sequences occur primarily in fractured and weathered zones along fractures and joints. Greenstone aquifers may also be located within brittle (cherty) rocks and the water is fresh inland becoming brackish towards the coast[6]. The Pilbara region and in particular the granite-greenstone terrain is not considered a major regional groundwater resource.[5] Primary porosity in the overlying shallow unconfined Quaternary sediments is hydraulically connected to some secondary porosity in the weathered and fractured Archaean basement[7].

[4] GHD, 2012. Report for North Star Magnetite Project – Geochemical Assessment
[5] GHD, 2014. North Star Detailed Geochemistry Assessment Kinetic Column Leach Test
[6] Haig, T. 2009. The Pilbara Coast Water Study Hydrogeological Record Series. Document Reference:HG 34, Department of Water
[7] WorleyParsons, 2012. Preliminary Dewatering Assessment – Document Reference: Ref 301012-01426.

There is potential for perched aquifers to be present in the weathered zone due to compartmentalisation of groundwater in the sub-vertical bedding planes. Groundwater springs have been observed in the northeastern part of the site which may indicate the presence of a perched water table, or alternatively, an aquifer residing above the lower water table[7].

1.7 Geotechnical foundation soils

Based on the initial site reconnaissance and review of the available geotechnical data by SRK, the stockpile footprint is considered to mainly be on shallow to surficial rock, with some thin alluvial/ colluvial soils within the numerous narrow drainage paths, and some residual rocks at depths between 1.0 m and 1.5 m. ATC Williams[1] carried out site investigation on the plant site, which is located close to the proposed site of the stockpile and confirmed the observation during the site visit. In general, the types of materials encountered during the test pit excavations comprised less than 1 m thickness of superficial soils over extremely weathered rock, becoming highly weathered with increasing depth. A thin residual soil profile was encountered locally at the rock surface. Table 1-3 summarises the subsurface conditions of the plant site, while Figure 1-6 illustrates the geotechnical section of a plant located close to the stockpile footprint.

As construction of the stockpile progresses, any specific areas of concern that arise should be targeted (risk based) for confirmatory investigation programs if necessary

Table 1-3: Process plant borehole subsurface summary: depth to base of materials

ID	Surface Elevation (m AHD)	Main rock type	Alluvial cover (m bgl)	Residual soil (m bgl)	EW rock (m bgl)	HW to MW rock (m bgl)	SW to FR rock (m bgl)
BH01	284.9	Andesite	1.8	6.0	-	10.0	>15.4
BH02	286.3	Basalt	0.5	-	-	1.0	>9.0
BH04	287.1	Dolerite	1.8	1.9	2.9	6.3	>9.4
BH05	293.8	Andesite	0.3	-	1.2	3.3	>9.4
TP04	285.0	NA	1.2	1.7	4.5	>4.6	-
TP05	285.5	NA	0.8	1	3.3	>3.4	-
TP16	290.0	NA	0.6	1.2	2.9	>3	-

Source: ATC Williams,2015 [1].

Notes: EW = extremely weathered; HW = highly weathered; MW = moderately weathered.

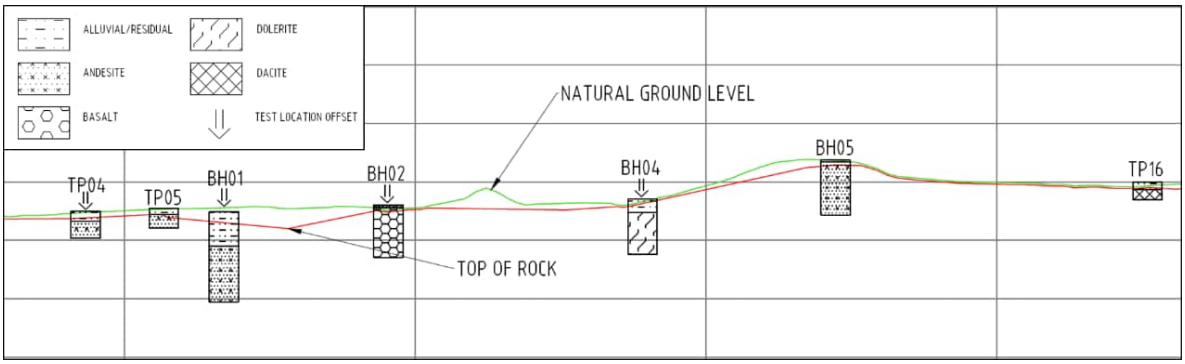


Figure 1-6: Plant geotechnical section based on site investigation by ATC Williams[1]

2 Design Criteria

2.1 Waste dump and stockpiles stability rating and hazard classification (WSRHC)

Figure 2-1 illustrates the waste dump and stockpile stability rating and hazard classification (WSRHC) system[10] used to identify the hazards and risk associated with the stockpile designs. The outcome of this assessment is presented in Table 2-1, which shows that the instability hazard is between Moderate Hazard and Low Hazard.

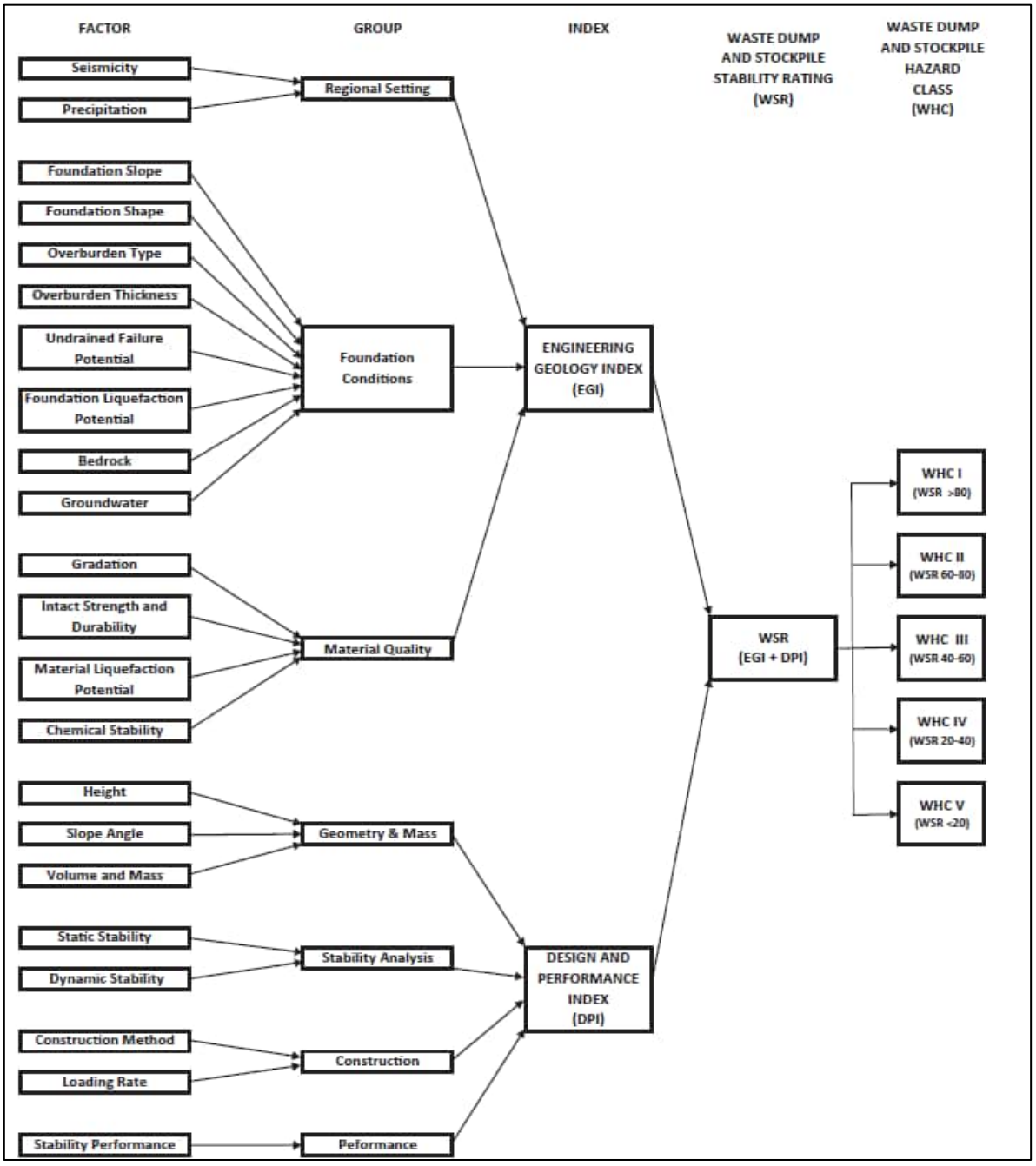


Figure 2-1: Structure of waste dump and stockpile stability rating and hazard classification (WSRHC) system

Source: CSIRO 2017.

Table 2-1: Iron Bridge stockpiles stability rating and hazard class

Index	Factor	Lower Bound	Upper Bound
Engineering Geology Index (EGI)	Regional settings	5	7.5
	Foundation conditions	5.5	12.5
	Material quality	6.5	10.0
Design and Performance Index (DPI)	Geometry and mass	6.5	7.5
	Stability analyses	6.0	8.5
	Construction	8.0	11.5
	Performance	7.5	15
Waste dump and stockpile rating (WSR)		45	72.5
Waste dump and stockpile hazard classification (WHC)		III	II
Instability hazard		Moderate Hazard	Low Hazard

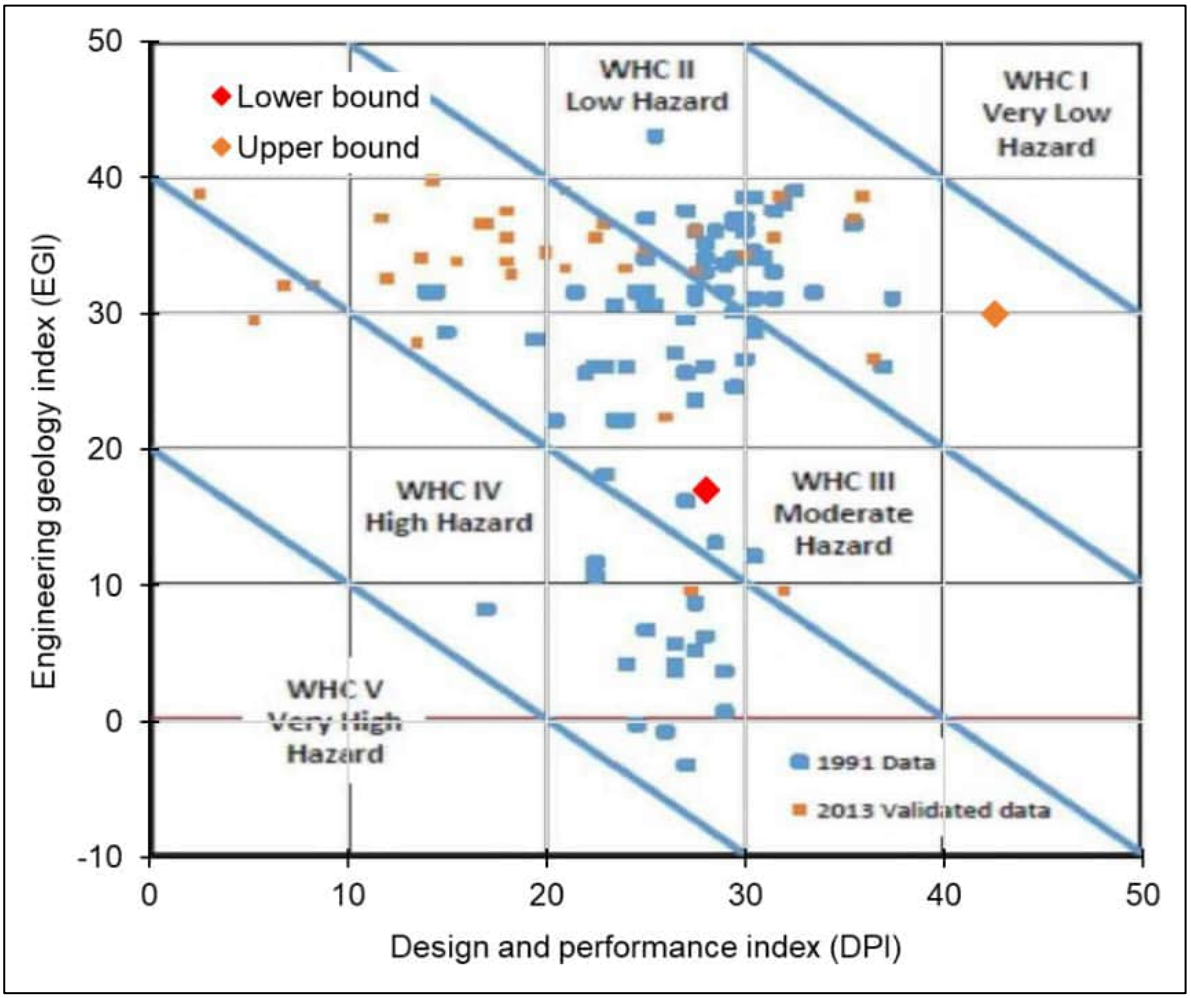


Figure 2-2: Comparison of upper and lower bound dry rejects stockpile datawith results of the 1991 and 2013 waste dump and stockpile hazard chart data

2.2 Design criteria summary

2.2.1 Design acceptance criteria

The key design acceptance criteria used in the design are summarised in Table 2-2. The design acceptance criteria for stability are summarised in Table 4-4.

Table 2-2: Design acceptance criteria summary

Criteria	Operations		Closure		Source/ comment
	Design base value	Design sensitivity value	Design base value	Design sensitivity value	
Design earthquake	OBE		MCE		IBO/ CSIRO (2017)
Design storm	AEP 100-year	AEP 500-year	AEP 500-year	PMP	IBO/ CSIRO (2017)

Notes: OBE = operating basis earthquake; AEP = annual exceedance probability; MCE = maximum credible earthquake.

2.2.2 Design parameters summary

The key parameters used in the design are summarised in Table 2-3.

Table 2-3: Design parameters summary

Parameter	Value	Source/ comment
OBE, AEP 475-year	0.06 g	IBO (Tetra Tech, Solomon – Seismic Peak Ground Accelerations for Design, 2012)
MCE	0.34 g	IBO (Tetra Tech, Solomon – Seismic Peak Ground Accelerations for Design, 2012)
AEP 100-year, 72-hour	399 mm	IBO
AEP 500-year, 72-hour	523 mm	IBO
PMP, 72-hour	2,210 mm	IBO
LOM	20 years	IBO
Ore production rate	20 Mtpa	IBO
Dry rejects production rate	12.1 Mtpa	IBO
Dry rejects stored dry density	1.95 t/m^3	SRK derivation from laboratory testing
Dry rejects placed moisture content	3% (w/w)	IBO
Angle of repose	37 degrees	IBO confirmed by SRK from site observation and LiDAR data

3 Material Characterisation

Figure 3-1 shows the particle size distribution (PSD) of the dry rejects provided by IBO and used for the laboratory testing. The dry rejects are coarse-grained and well-graded, with approximately 86% of particles greater than 75 µm. The material is of low plasticity and can be classified as SM: Sand-silt mixture.

The dry rejects will be placed at a moisture content of approximately 3% (w/w), with the only moisture due to that applied along the conveyor route.

A laboratory testing program was carried out to define the geotechnical characteristics of the dry rejects. IBO delivered approximately 100 kg of dry rejects to E-Precision Laboratory Pty Ltd (EPL) to carry out the geotechnical testing. The key geotechnical parameters estimated for the design of the stockpile are presented in Table 3-1.

Full details of the material characterisation and laboratory test certificates are provided in Appendix B.

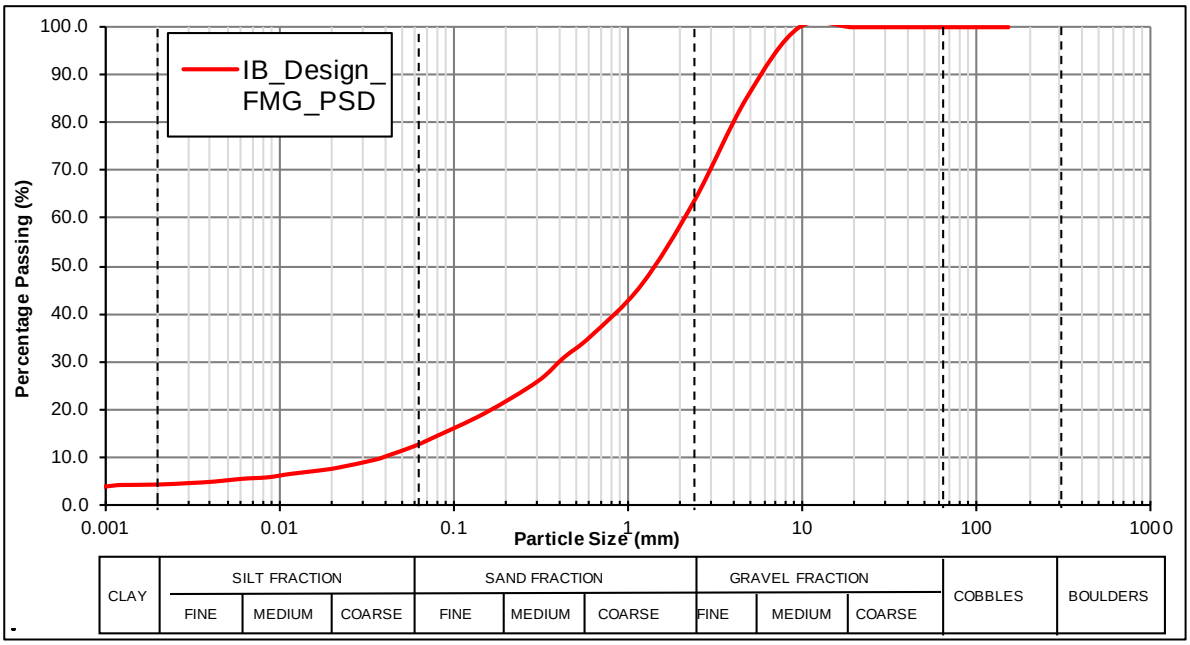


Figure 3-1: Particle size distribution of coarse rejects samples

Note: Grading cut-offs are based on AS 1726:2017.

Table 3-1: Key design dry rejects characterisation data based on laboratory testing

Properties	Sub-properties	Design Values	Units	Comments
PSD	% Clay	5	%	Based on Australian Standards
	% Silt	9	%	
	% Sand	50	%	
	% Gravel	36	%	
Atterberg limits	Liquid limit, w_L	16.2	%	Fines fraction is low plasticity
	Plasticity index, I_p	8.5		
Density	Minimum dry density, $\rho_{dry,min}$	1.86	t/m^3	
	Maximum dry density $\rho_{dry,max}$	2.13	t/m^3	
Permeability	Value at min density, $k_{\rho,min}$	2.4×10^{-6}	m/s	Using results from falling head test
	Value at max density, $k_{\rho,max}$	8.3×10^{-7}	m/s	
Unsaturated flow	Initial VWC	0.28	-	SWCC based on minimum dry density of dry rejects subjected to drying mechanism
	Residual VWC	0.01	-	
	Saturated permeability	2.5×10^{-6}	m/s	
CBR	Soaked	10 – 18	%	Range due to specified sample densities
	Unsoaked	11 – 30	%	
Consolidation	Compression index, C_C	0.16	-	Average interpreted value
	Coefficient of consolidation, c_v	0.3	m^2/yr	Average interpreted value
	Compressibility	8.0×10^{-5}	m^2/kN	Average value
Strength	Effective friction angle, φ_{peak}	44	°	Interpreted value
	Cohesion, c	0	kPa	No cohesion for uncemented materials
Elastic stiffness	Effective stress,σ'_v = 50 kPa	60	MPa	The elastic stiffness was estimated from the stress-strain curves of the drained triaxial tests at five different confining stresses. The elastic stiffness was measured at 0.1% strain which is within the elastic region of the material.
	Effective stress,σ'_v = 100 kPa	132	MPa	
	Effective stress,σ'_v = 250 kPa	156	MPa	
	Effective stress,σ'_v = 500 kPa	288	MPa	
	Effective stress,σ'_v = 1000 kPa	849	MPa	

4 Stockpile Design

The engineering drawings illustrating the layout, development, water management and key details of the dry rejects stockpile are listed in Table 4-1 for reference.

Table 4-1: Engineering drawing list

Sheet Number	Sheet Title
IBO057-0000	DRY REJECTS STOCKPILE DESIGN PROJECT LOCATION & DRAWING LIST
IBO057-0005	DRY REJECTS STOCKPILE GEOLOGY LAYOUT
IBO057-0010	DRY REJECTS STOCKILE OPERATIONAL LAYOUT & SECTIONS
IBO057-0015	DRY REJECTS STOCKPILE OPERATIONAL WATER MANAGEMENT PLAN
IBO057-0020	DRY REJECTS STOCKPILE OPERATIONAL DETAILS
IBO057-0025	DRY REJECTS STOCKPILE PROGRESSIVE SURFACE DRAINAGE LAYOUT
IBO057-0030	DRY REJECTS STOCKILE CONCEPTUAL CLOSURE LAYOUT & SECTIONS
IBO057-0035	DRY REJECTS STOCKPILE CONCEPTUAL CLOSURE WATER MANAGEMENT PLAN
IBO057-0040	DRY REJECTS STOCKPILE CONCEPTUAL CLOSURE DETAILS

4.1 Layout and configuration

The primary objective of the stockpile design is to optimise the dry rejects storage capacity (minimising the disturbed footprint), while ensuring safe stacking operations. The dry rejects material is planned to be stacked using a telescopic radial stacker, with a maximum final stockpile height of approximately 86 m and footprint of approximately 239 ha.

The proposed operational layout and details of the stockpile are shown in SRK Drawings IBO057-0010 and IBO057-0020.

The following aspects have been considered in siting the stockpile:

- Positioning within tenement boundaries
- Avoiding interrupting significant drainage lines
- Blending the stockpile into the natural hill sides if possible
- Ensuring its location outside of any possible future pit cut-back or any other development
- Ensuring the toe of the stockpile is not close to mine pits.

The stockpile is split over two major sub-catchments of the Iron Bridge site, with approximately half of the topography flowing towards the main southern stream and the other half towards the major northern stream, as indicated in Figure 4-1. As the stockpile footprint is sited high in the catchments, most runoff flows away from the landform, with only two very small external catchments collecting inflowing runoff on the east and south east extents.

The stockpile will be a stepped landform that uses large berms and bunds to control surface water and contain sediment. The toe position of each successive lift is stepped in an optimal bench design distance that will assist with forming the required overall landform slope at closure.

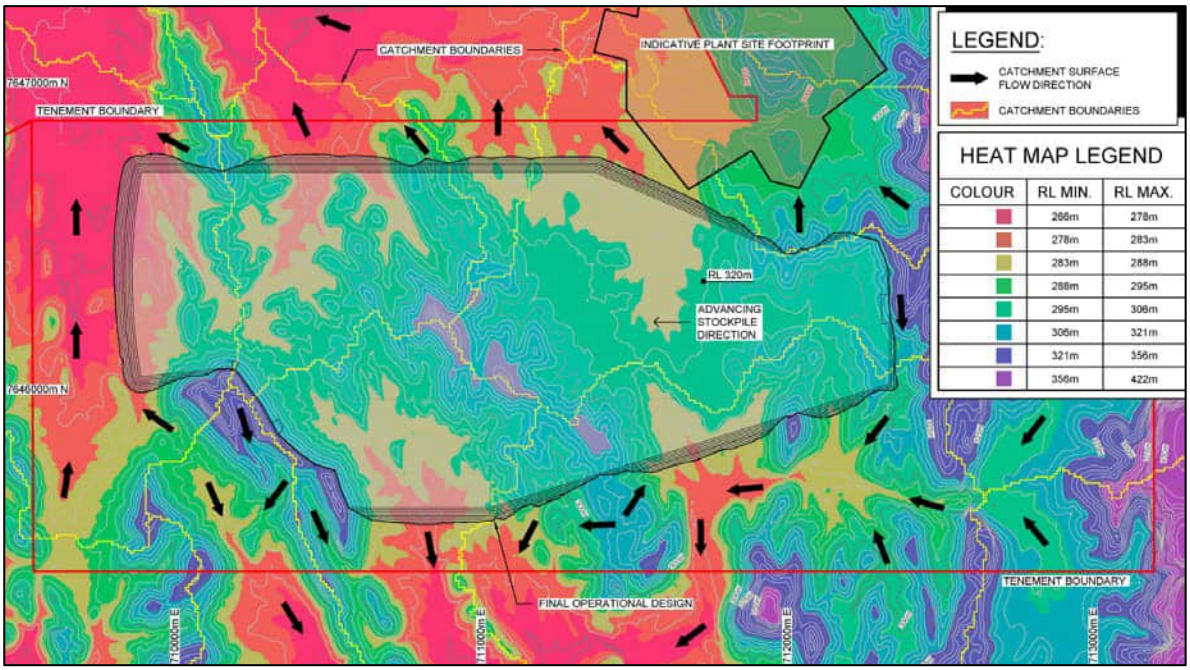


Figure 4-1: Sub-catchments beneath the stockpile footprint

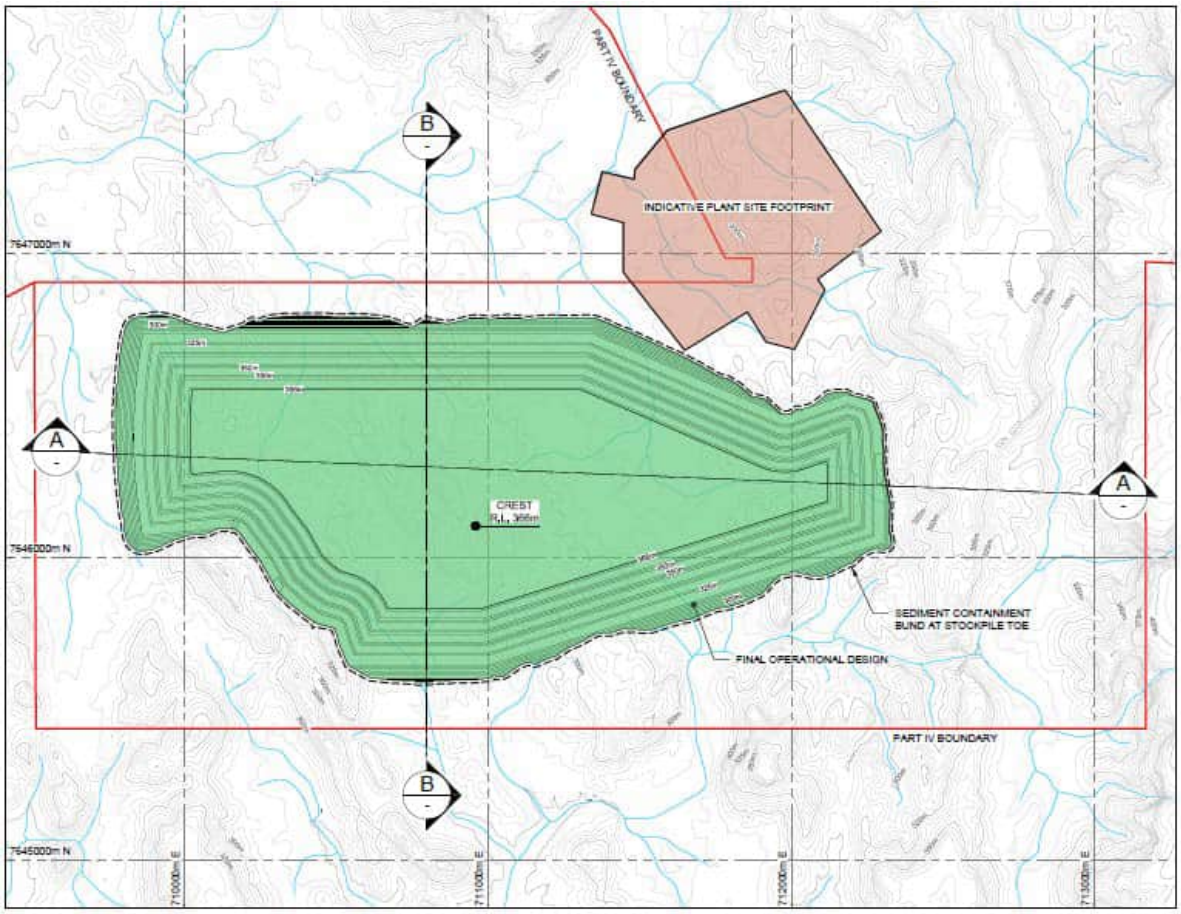


Figure 4-2: Operational stockpile layout

Source: SRK Drawing IBO057-0010

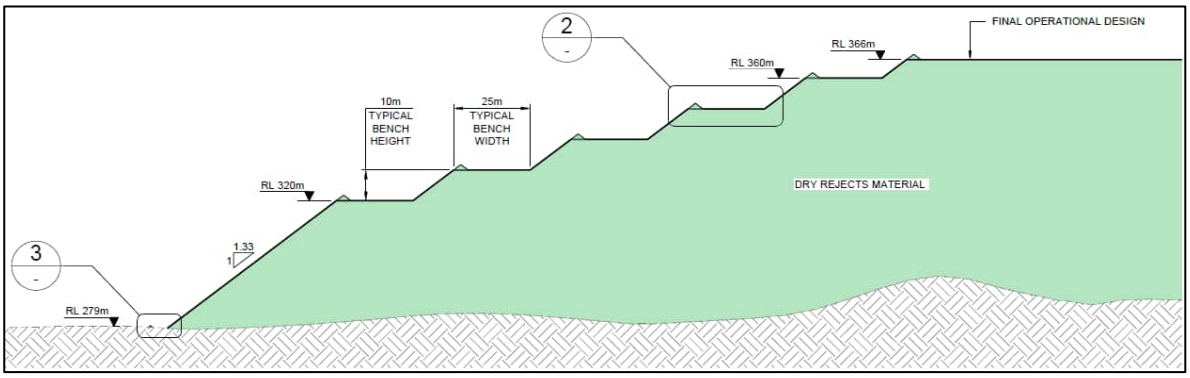


Figure 4-3: Operational stockpile section

Source: SRK Drawing IBO057-0020

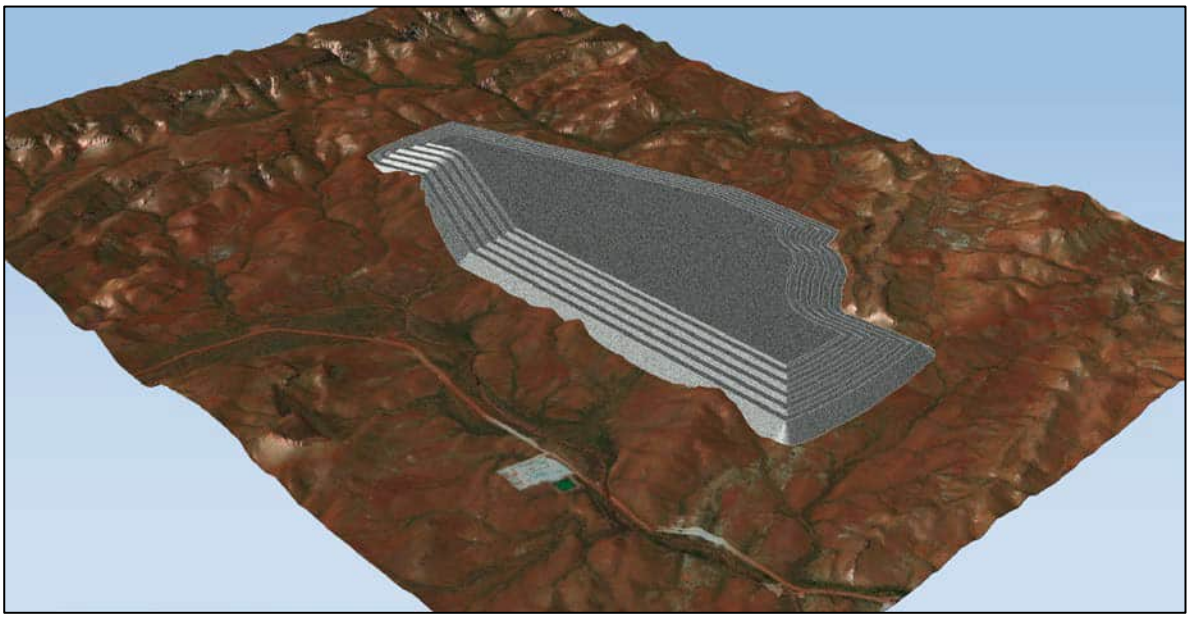


Figure 4-4: Isometric view of final operational stockpile, facing south

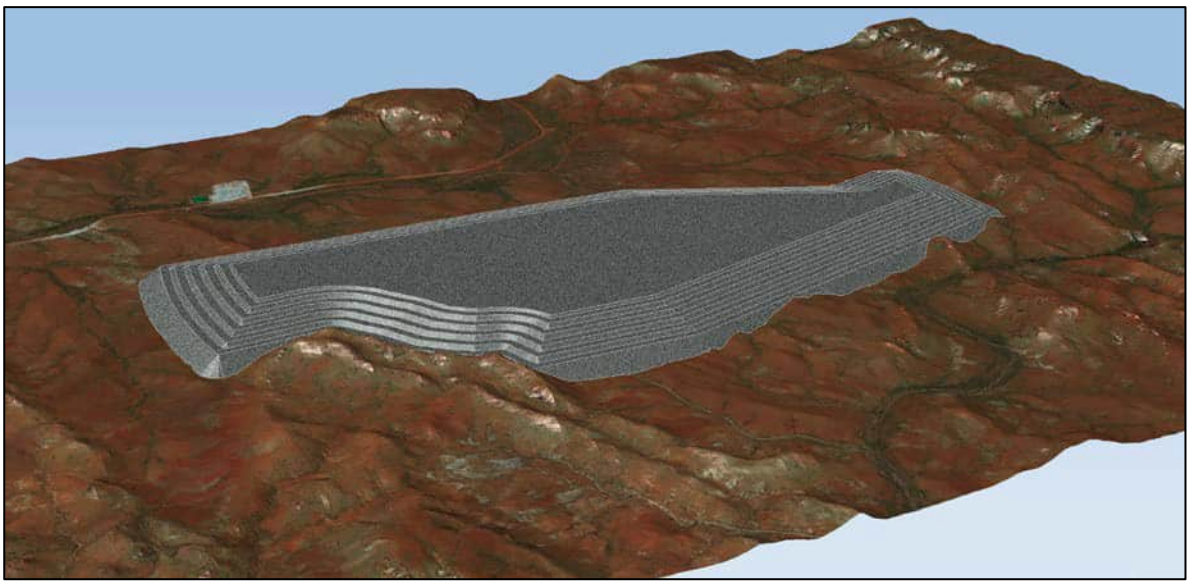


Figure 4-5: Isometric view of final operational stockpile, facing north

4.1.1 Stockpile development

It is envisaged that the stockpile will be constructed in layers, with the first lift built to cover the full footprint. The first lift has been designed significantly higher than the remaining lifts to facilitate a practical and efficient stacking process. The rugged and undulating topography across the stockpile footprint means that an initial typical 10 m high lift would be impractical. The stockpile's first lift, up to RL 320 m, will have an average stack height of 24 m and a maximum height of 44.5 m. This enables a solid platform to be constructed across the full footprint, enabling remaining lifts to be stacked without impediment.

There is the potential option to abut the stockpile into the eastern hillside to maximise the storage and limit the external catchment. This can be considered during operations depending on the efficiency of stacking in this steeper zone.

Table 4-2: Stockpile geometric design summary

Parameter	Operational	Closure
Maximum elevation (RL m)	366	368
Maximum height (m)	85.5	87.5
Average height (m)	54	49.5
Total footprint area (ha)	239	281
Top surface area (ha)	99	99
Toe perimeter length (m)	6,840	8,520
Volume (Mm^3)	121.2	131.6

Table 4-3: Operational stockpile individual lift geometric summary

Lift number	Maximum elevation (RL m)	Maximum lift height (m)	Footprint area (m^2)	Storage volume (m^3)	Time (years)
1	320	44.5 (24 m average)	2,254,869	54,633,480	8.8
2	330	10	1,803,867	18,444,237	3
3	340	10	1,576,702	16,153,525	2.6
4	350	10	1,360,470	13,972,101	2.3
5	360	10	1,155,834	11,904,695	1.9
6	366	6	989,266	6,053,566	1

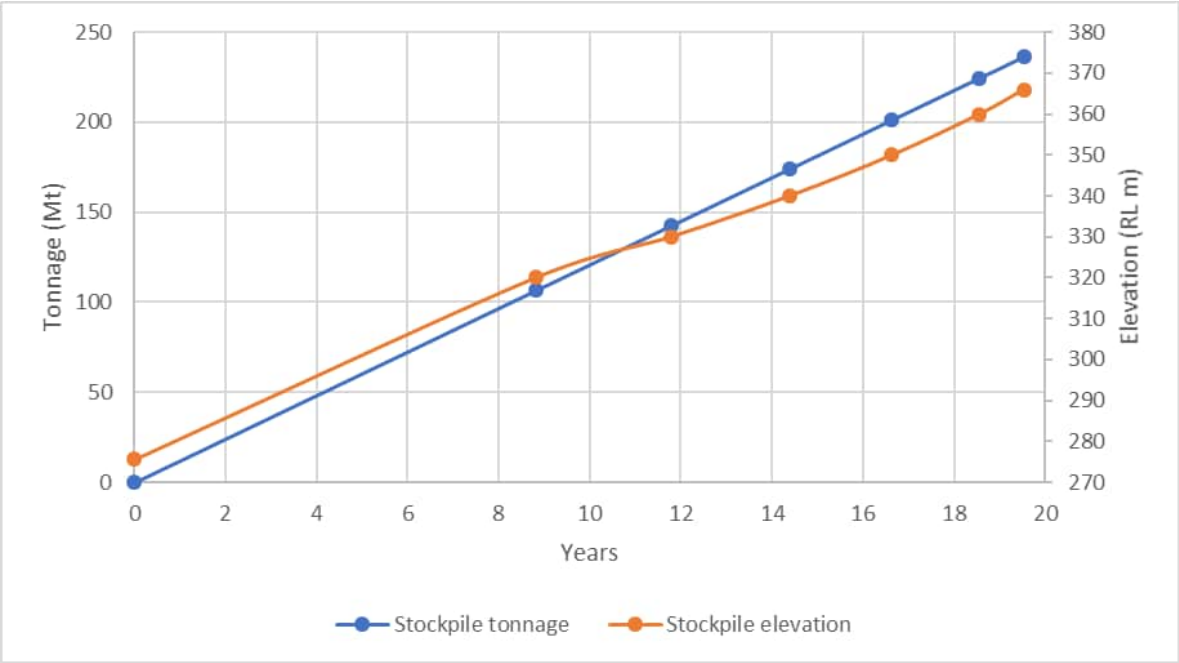


Figure 4-6: Stage curve of stockpile development, with the six lifts indicated corresponding to details in Table 4-3

4.1.2 Radial stacker operation

The dry rejects will be placed in the stockpile via a system of relocatable telescopic radial stackers. The stacking system is designed to handle the rejects, which is conveyed to the stockpile on the overland tripper conveyor. The material then moves down the string of portables toward the radial stacker for discharge to (stacking on) the stockpile.

The radial stackers (horizontal reach of 36.5 m to 42.6 m) will build progressive kidney-shaped mini rejects stacks with the same radius and maximum height of 10 m (flat with 6 m wide top). This is shown indicatively in Figure 4-7. The stacking sequence continues until the first lift of the stockpile is completely stacked. The stacking system is then repositioned on the second lift using access roads and ramps for the first cell of the second lift. The cycle continues for the entire stockpile stacking operation.

The California Bearing Ratio (CBR) test results (Table 3-1 and Appendix B) indicate that the stacker (driving on tracks) should be able to traffic across the rejects surface following rainfall.

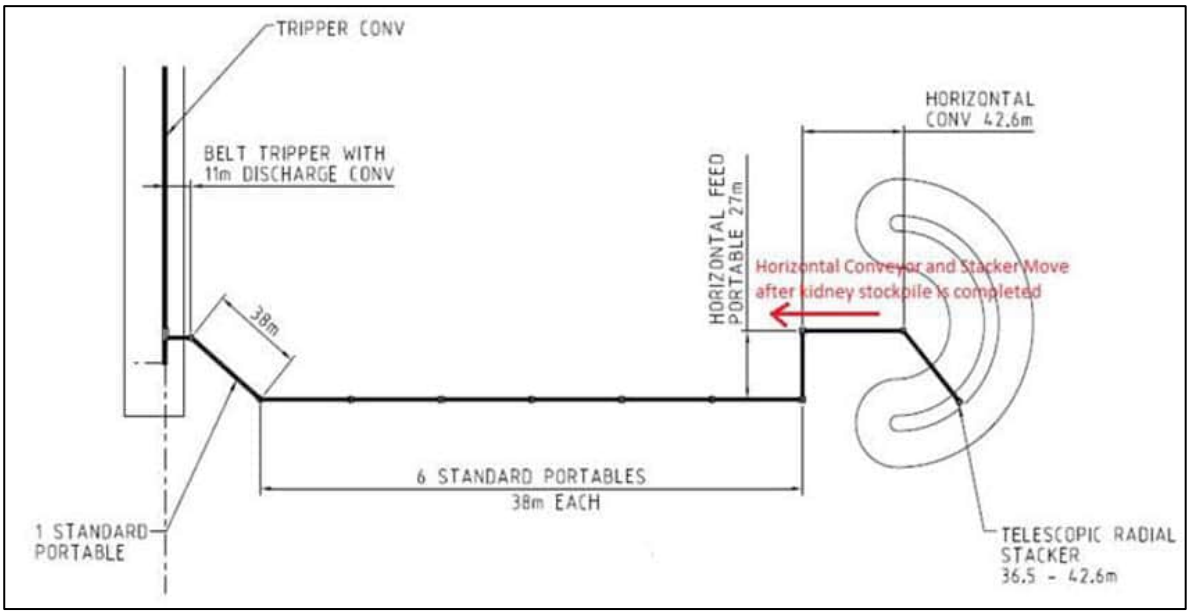


Figure 4-7: Typical arrangement of dry rejects system

4.2 Surface water management

As detailed in Section 4.1, most of the runoff flows away from the landform due to the natural topography. The stockpile has been designed to retain direct catchment rainfall. The top surface, benches and batters will be constructed in operations so that they hold the maximum expected design rainfall event (AEP of 100 years); however, due to the alignment with the closure configuration, the PMF, 72-hour event can be accommodated.

The proposed water management design of the operational stockpile is shown in SRK Drawings IBO057-0015 and IBO057-0020.

It is recommended that the top surface be progressively split into a paddock-type layout, with individual sections of approximately 300 m maximum width separated by 0.5 m high dumped bunds. Each of these paddocks will be graded towards the centre to control large storm events and manage runoff, reducing any potential impact on stacking operations. These bunds, made of the dry rejects, would then be progressively stacked over without disrupting operations. The extent and stringency of this should be determined following observation of initial large rainfall events and their potential impact, as this is for operational efficiency rather than overall stability or erosional considerations.

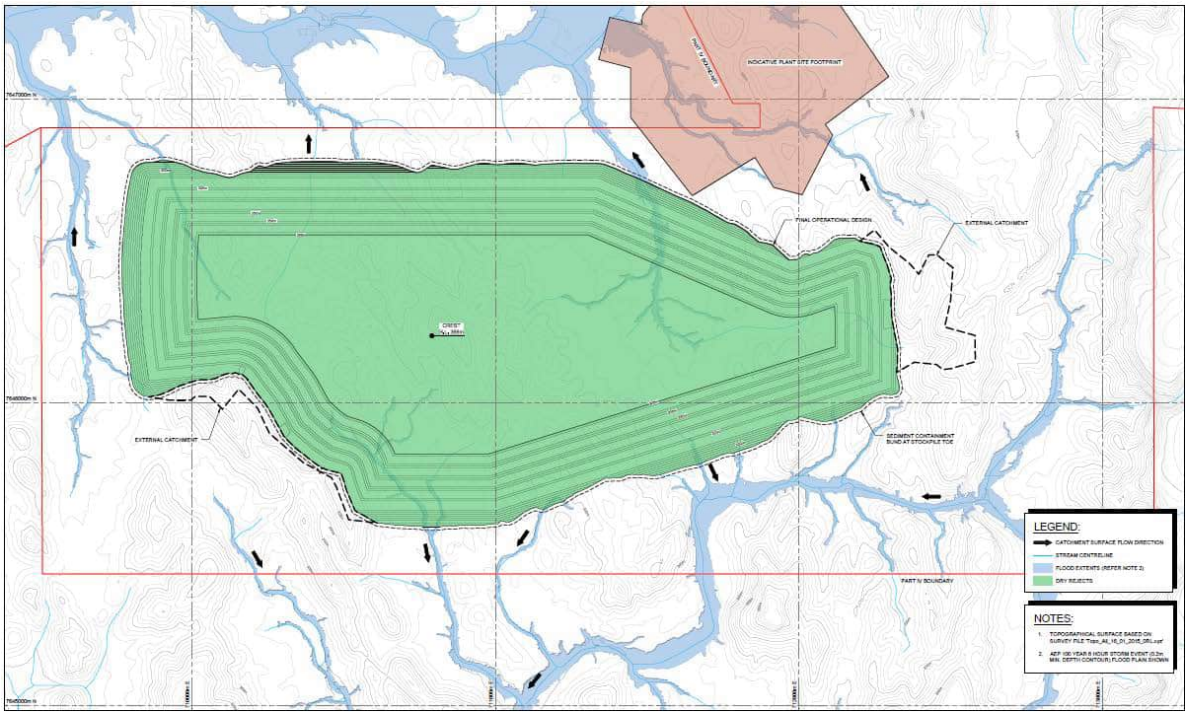


Figure 4-8: Operational stockpile water management layout

Source: SRK Drawing IBO057-0015

Following large storm events, some sediment may be eroded off the dry rejects batter slopes. This sediment will tend to settle out at the toe of the stockpile due to the sharp change in slope and thus velocity. A sediment containment bund constructed around the toe of the full stockpile perimeter will serve two functions – trapping sediment being eroded from the batter slope of the first lift and containment of most of the runoff coming from the slope. The bund (1 m high), constructed of erosion-resistant material such as the oxide waste rock, and offset distance from the toe (10 m) has been designed to contain the estimated total erosion (Landloch, 2018) over the period that the first lift is expected to be exposed for prior to progressive rehabilitation (Section 5.3). This bund would be progressively built as the stockpile footprint expands. After extreme storm events, it is recommended that the full perimeter of the stockpile is inspected to assess the level of erosion and any significant impacts to the slope that may have occurred, or whether cleaning of the sediment containment area is necessary.

This sediment containment bund will also act to divert the two small external catchment flows around the stockpile on the east and southeast extents during operations so that they do not affect the performance of the stockpile.

It is also recommended that erosion-resistant coarse rock (e.g. oxide waste rock) is placed at the toe of the stockpile at select locations where the material comprises thin alluvial/ colluvial soils, rather than exposed surficial rock, to protect the base of the stockpile from erosion during storm events. This would act as a transition between the steep batter face and the natural ground.

A channel constructed at the stockpile toe is not considered necessary due to the small reporting catchment and the shape of the topography, with runoff typically flowing away from the stockpile. Additionally, the rugged and rocky ground surface renders channel construction impractical.

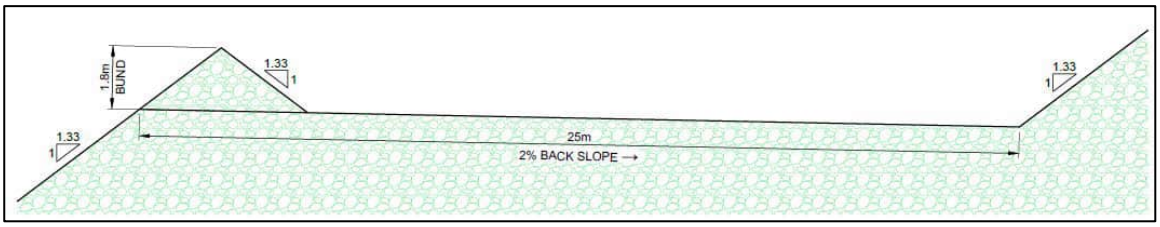


Figure 4-9: Operational stockpile typical bench detail

Source: SRK Drawing IBO057-0020

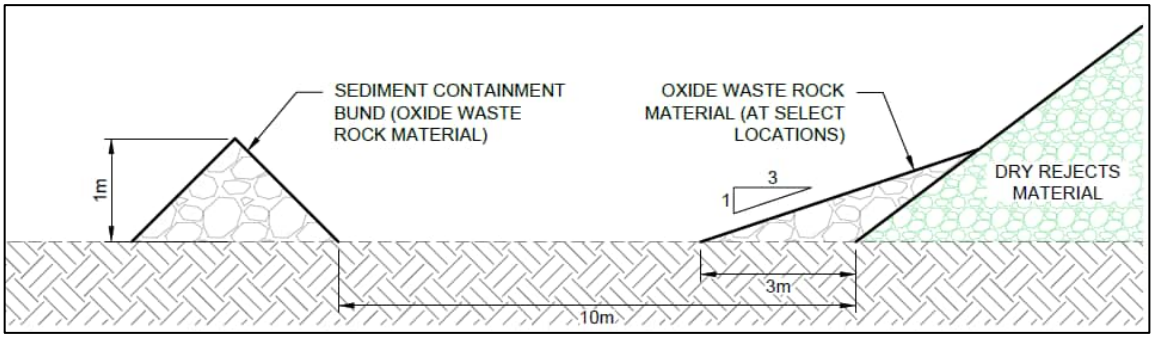


Figure 4-10: Sediment containment bund around stockpile perimeter toe

Source: SRK Drawing IBO057-0020

4.2.1 Interim operational management

The development of the stockpile and surface water impacts during the early stages has been assessed while the first lift and coverage of the full footprint is in process. SRK Drawing IBO057-0025 indicates that as the stockpile development progresses westwards from the plant, the surface water upgradient of the stacking face will generally continue to either flow away from the stockpile in the immediate sub-catchments ahead. There will be relatively short periods where small portions of the sub-catchment will flow into the stockpile face as the stacking crosses small drainage lines; however, the areas are very small and will not have an adverse effect on operations.

4.3 Infiltration assessment

An infiltration assessment using SEEP/W (GeoStudio, 2018) was undertaken using a true climate boundary at the surface to reasonably replicate the expected field conditions. This analysis was used to assess the response of the dry rejects and the degree of saturation of the stockpile due to various climate scenarios including extreme storm events. This is important to understand in relation to assessing the liquefaction potential and stability of the dry rejects material, as well as to determine the requirement for any sub-surface drainage measures. The degree of saturation of the dry rejects was monitored at selected depths in the model to assess the spatial distribution of moisture in the soil layers as well as any potential phreatic surface development within the stockpile. As noted in Table 2-3, the dry rejects material is expected to arrive at the stockpile with a moisture content of 3% (w/w).

Full details of the assessment, including figures and plots illustrating the results, are provided in Appendix C.

In summary, based on the outcomes of the infiltration assessment, the stockpile will not experience fully saturated conditions under any conceivable scenario, including the following:

a. Typical operating year (based on 2018 climate data)

b. Wettest climate year (based on SILO database)

c. Extreme storm event (based on AEP 100 year, 72-hour event)

d. Extreme storm event (based on AEP 500 year, 72-hour event).

The only scenario that led to any section of the stockpile becoming saturated was the AEP 500 year, 72-hour storm event. In this case, the upper 1 m material layer may reach a near-saturated condition. However, due to the transient and very limited depth of this saturation, the impact is considered negligible and would not create an adverse situation for the stockpile stability, even during a seismic event.

4.4 Water balance

As part of the seepage modelling, a near-surface water balance using the SEEP/W model outputs was assessed to identify potential infiltration and percolation under typical operating conditions, i.e. using average climate data from 2018. Figure 4-11 shows that most of the water from rainfall events in the wet season infiltrates the soil surface or evaporates into the atmosphere. Water from infiltration during the wet season is subsequently removed by evaporation instead of downward percolation that recharges the soil column. If water that percolates downward is not enough to recharge the soil column, the soil column will remain unsaturated. Substantial infiltration into the soil column and minimal runoff from the soil surface was observed following a large storm event (Day 150). The net percolation observed at the base of the column was 0.015 m^3 (per metre). This implies that a very minimal volume of water may be released from the stockpile to the adjacent groundwater or surface water under any condition.

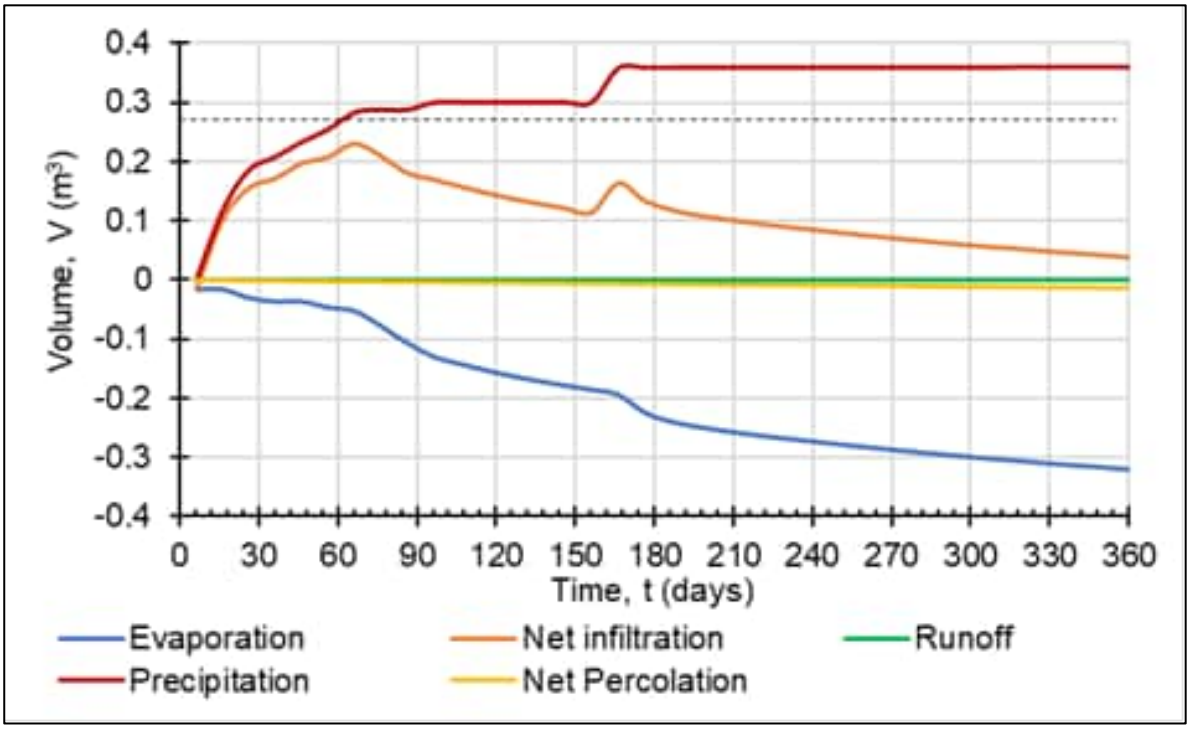


Figure 4-11: Near-surface water balance under normal operating conditions

4.5 Liquefaction assessment

The laboratory results obtained for the dry rejects have been used to assess the material's liquefaction potential. Two methods were used for this screening assessment – Hunter and Fell (2003)[8] and Japanese Criteria for Port and Harbour Facilities. These methods are solely based on PSD and are for screening purposes only. The design PSD of the dry rejects was plotted on the suggested plots of liquefaction susceptibility criteria as shown in Figure 4-12 and Figure 4-13. The assessment shows that the coarse rejects material is susceptible to liquefaction based on the PSD of the dry rejects.

Although the dry rejects are susceptible to liquefy based on its PSD, if the dry rejects remain unsaturated, the probability of liquefaction is minimal. Based on infiltration assessment done in Section 4.2, the stockpile is unlikely to saturate (to any significant depth) and therefore unlikely to liquefy under any conceivable operating conditions.

Only material in the upper 1 m (approximately) of the stockpile could have potential to saturate following an extreme storm (e.g. AEP 500 year, 72-hour) based on the infiltration assessment. However, it is not plausible to have an extreme storm event and an extreme earthquake event occurring at the same time, and it is therefore considered that the liquefaction potential of the stockpile is extremely low.

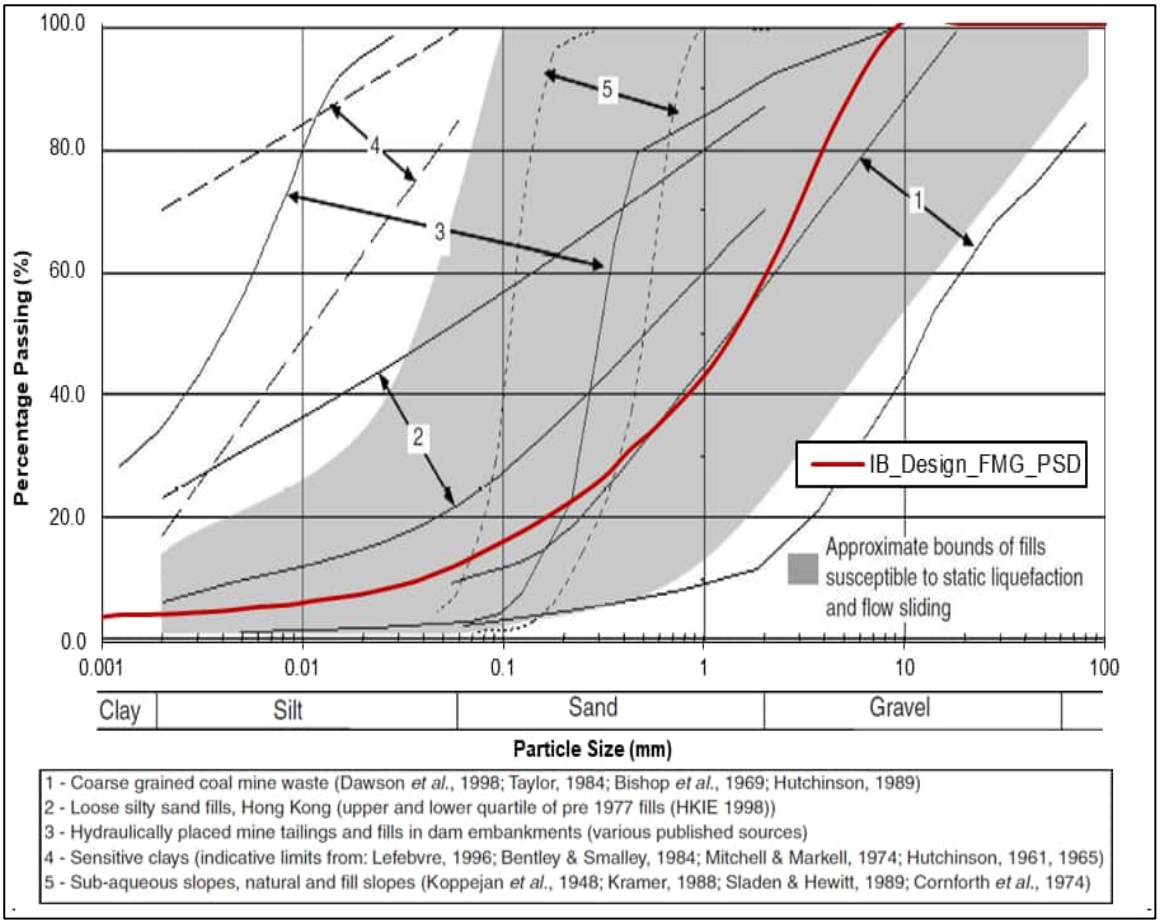


Figure 4-12: PSD of soils susceptible to flow liquefaction under static and earthquake loading

Source: Hunter and Fell, 2003.

[8] Hunter, G and Fell, R, 2003. Travel distance angle for" rapid" landslides in constructed and natural soil slopes, *Canadian Geotechnical Journal*, *40*(6), pp1123-1141.

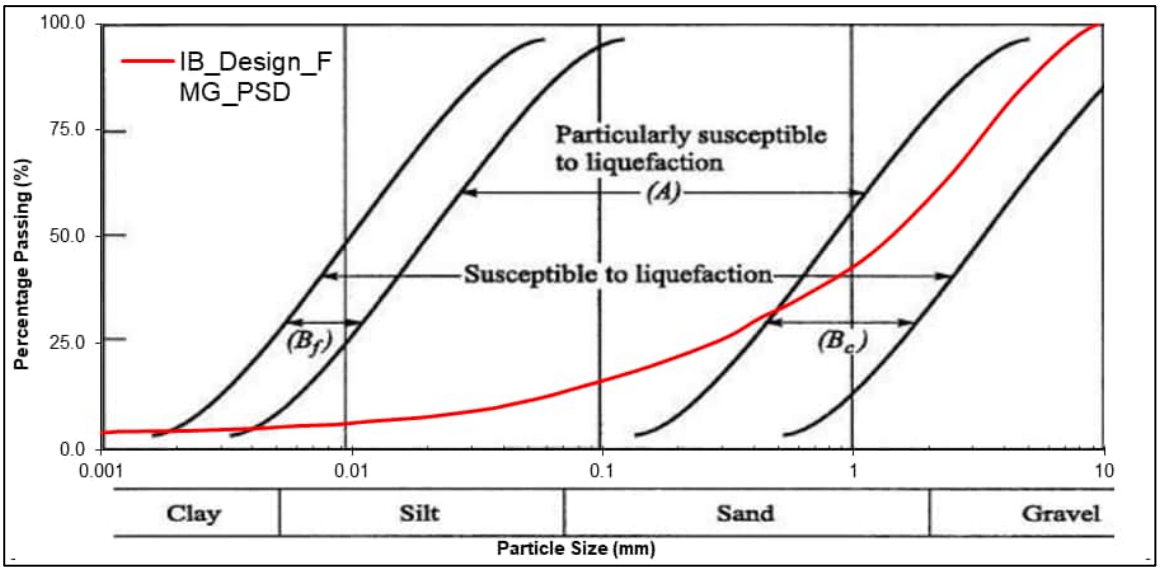


Figure 4-13: Japanese liquefaction susceptibility criteria for port and harbour facilities

Source: Iai et al., 1989[9].

4.6 Slope stability assessment

Slope stability assessment of the stockpile using the limit equilibrium method was performed using Slide V7.0 software (Rocscience, 2016). Non-circular slip surfaces were evaluated using the GLE/ Morgenstern-Price method to determine the critical factor of safety (FOS) in both static and seismic (pseudo-static) conditions.

Slope stability model outputs are provided in Appendix D for reference.

4.6.1 Acceptance criteria

Table 4-4 summarises the design acceptance criteria considered for various analysis scenarios based on CSIRO (2017) recommendations and discussions with IBO. The suggested acceptance criteria were based on the moderate consequence and moderate confidence level of the stockpile design using Table 8.5 in CSIRO (2017)[10]. The acceptance criteria were then applied to the slope stability assessment using the flowchart illustrated in Figure 4-14.

As detailed in Section 4.2, the stockpile is not expected to experience fully saturated conditions under any conceivable scenario due to the very low placement moisture content (3%), low rainfall and high evaporation rates of the site. Even under extreme storm conditions (e.g. AEP 500-year event), the potential for a phreatic surface to develop within the stockpile is negligible. Therefore, the stability models for operations (with the AEP 100-year design basis and 500-year sensitivity) have been modelled with no developed phreatic surface.

The influence of the PMP event has been considered as part of the closure stability analysis detailed in Section 5.5.

Based on the design case material properties and slope geometry detailed in Section 4.6.2, the minimum FOS of a single stockpile lift is approximately 1.3, therefore greater than the minimum FOS criteria of 1.1 typically adopted for controlling the required personnel exclusion zone. IBO will define

[9] Iai, S, Tsuchida, H and Koizumil, K, 1989. A liquefaction criterion based on field performances around seismograph stations. *Soils and Foundations*, *29*(2), pp 52-68.

the required exclusion zone for site personnel during operations based on stability acceptance criteria stipulated in the site Stockpile Management Plan.

Table 4-4: Stability acceptance criteria based on CSIRO (2017)[10]

Condition	Loading	Minimum FOS requirement
Operational profile (Short term)	Global/ multi-bench, static	1.3–1.4
	Stacker standoff check, static	1.3–1.5
	Global/ multi-bench, pseudo-static (OBE)	1.1
Closure profile (Long term)	Global, static	1.5
	Global, static, PMP pore pressure	1.1
	Global, pseudo-static (MCE)	>1.0

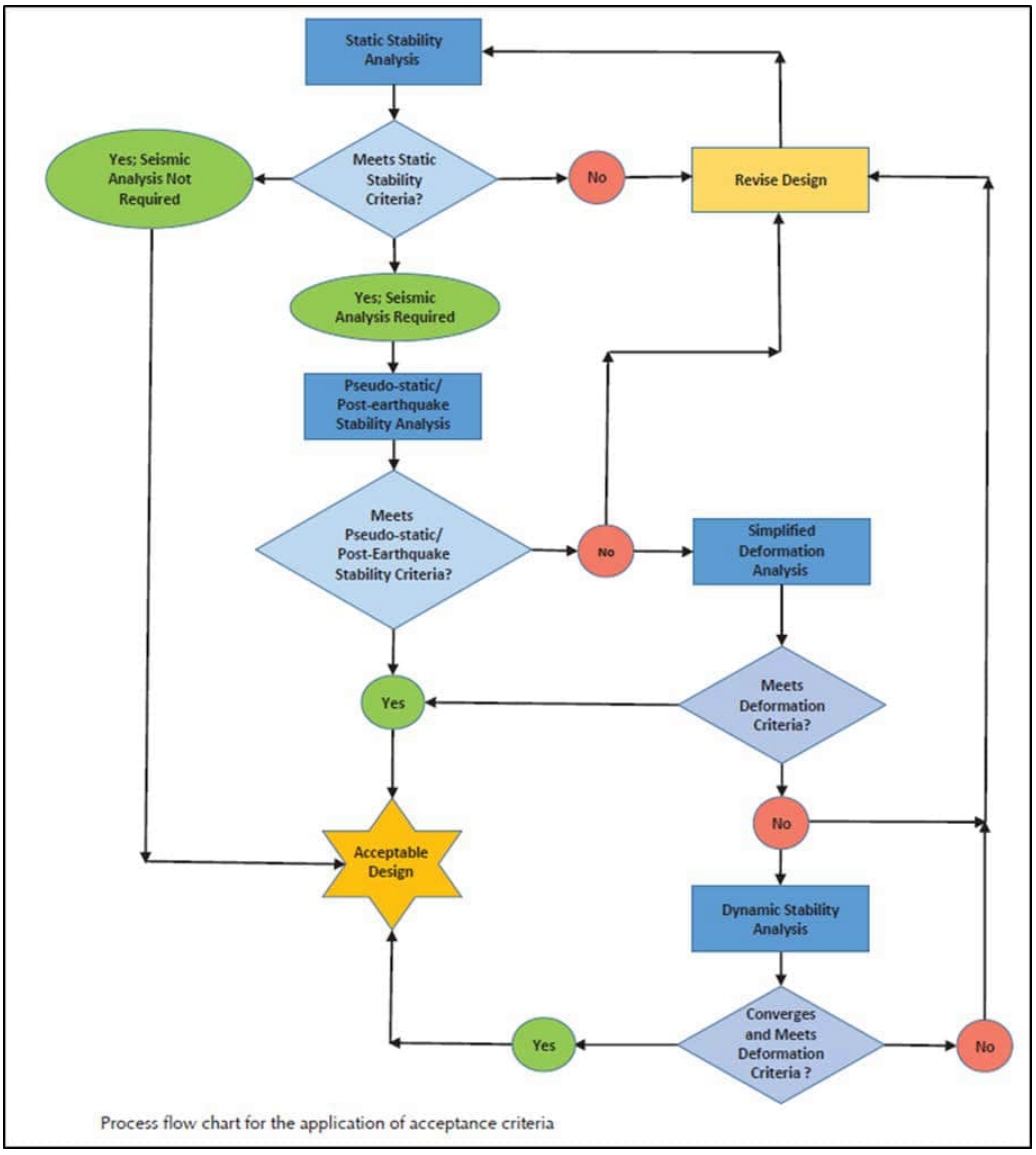


Figure 4-14: Process flow chart for the application of the acceptance criteria

[10] Hawley, M. and Cunning, J., 2017. *Guidelines for Mine Waste Dump and Stockpile Design*. CSIRO Publishing.

4.6.2 Stability analysis inputs

Material properties

The dry rejects material was modelled to have a Mohr-Coulomb strength with zero cohesion and a friction angle of 44° based on the laboratory data. The foundation was included for modelling purposes even though it is not expected to lead to any instability concerns due to the shallow surficial rock evident across the footprint (refer to Section 1.7). The foundation was modelled as a bed rock layer with generalised Hoek-Brown strength with an unconfined compressive strength (UCS) of 10 MPa, Geological Strength Index (GSI) of 35 and m*i* of 10. The properties of the foundation are based on the soil and rock design parameters reported for the plant site and airport[11].

Modelling scenarios

The slope stability assessment was undertaken in two stages. The first stage was used to define the following elements for a given lift height:

a. Minimum bench width

b. Minimum setback distance for radial stacker.

The second stage of analysis was to identify the minimum FOS for the initial lift height (maximum of 44.5 m) as well as the 10 m incremental lifts with a minimum bench width of 25 m.

Slope geometry

Given that the dry rejects will be stacked, the slopes of the stacked material will be formed at the angle of repose. SRK considered β of 37° based on IBO's advice (and observed by SRK) on site observations for the design case, with 44°, conservatively matching the friction angle obtained from the laboratory tests, considered as a sensitivity check. The stability models for Stage 1 and Stage 2 are illustrated in Figure 4-15 and Figure 4-16. The location with the highest stockpile height (at the western extent) was used for the analysis.

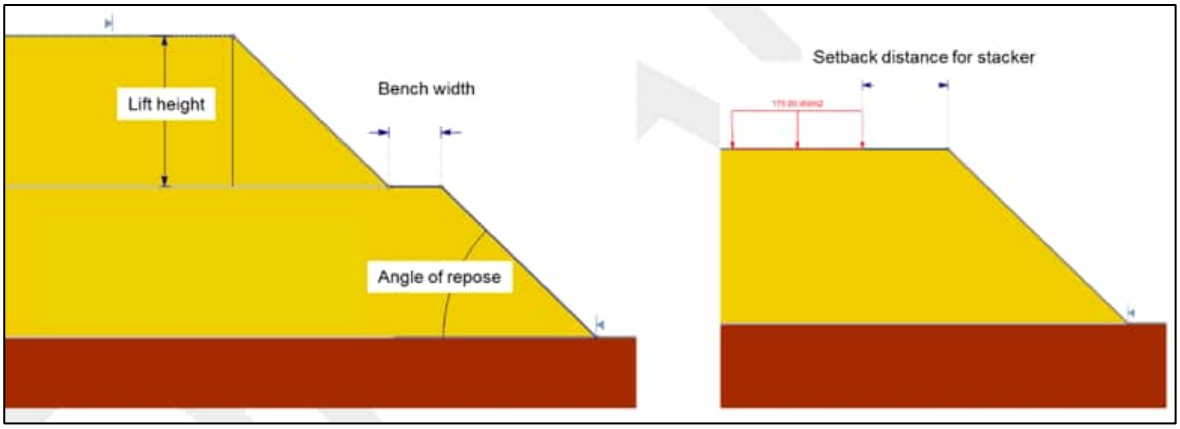


Figure 4-15: Slide model geometry for Stage 1

[11] ATC Williams, 2015. North Star Magnetite Stage 2 – Geotechnical Investigation Plant Site and Airport

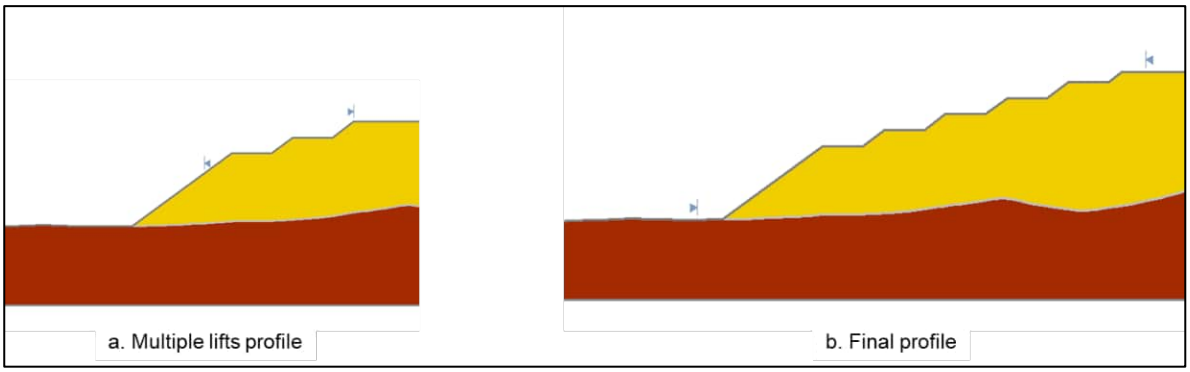


Figure 4-16: Slide model geometry for Stage 2

Load due to radial stacker

The presence of the overland tripper conveyor CV624 will exert approximately 175 kPa stress on the ground at the point closest to the exposed slope. Hence, the load due to the radial stacker was modelled as a distributed load of 175 kPa across 15 m.

Seismic coefficient

A peak ground acceleration (PGA) value of 0.06g associated with 1 in 475-year return period event was considered for operational basis earthquake (OBE) analyses and a PGA value of 0.34g was considered for a maximum credible earthquake (MCE) event for the long-term assessment (refer to Section 5.3.1). The horizontal seismic coefficient was estimated as k=0.5 × PGA/g (USACE, 1984[12]).

4.6.3 Assessment results for Stage 1

SRK adopted minimum FOS of 1.3 and 1.5 to obtain the minimum bench width for a given lift height and the minimum setback distance for the stacker, respectively.

Figure 4-17 shows the required distance for the bench width and the setback distance for the radial stacker from the crest of the stockpile using an angle of repose of 44° (sensitivity case).

For the design case of an angle of repose of 37°, there is no bench width requirement for stability purposes as the minimum FOS of 1.3 (excluding sloughing) is achieved based on the geometry of the stacked slope alone. It is recommended that the achieved angle of repose is verified during operations and the configuration optimised, accounting for stability, as required.

A comparison of the estimated minimum setback distances for the radial stacker using both design case and sensitivity case angles of repose – 37° and 44° – is shown in Figure 4-18. As expected, the required offset distance width using β=37° is lower than that required for β=44°. It is observed that an offset distance of at least approximately 3 m is required to accommodate the loading of the radial stacker for the design case.

[12] Hynes-Griffin, M E and Franklin, A G, 1984. *Rationalizing the seismic coefficient method* (No. WES/MP/GL-84-13). Army Engineer Waterways Experiment Station Vicksburg Ms Geotechnical Lab.

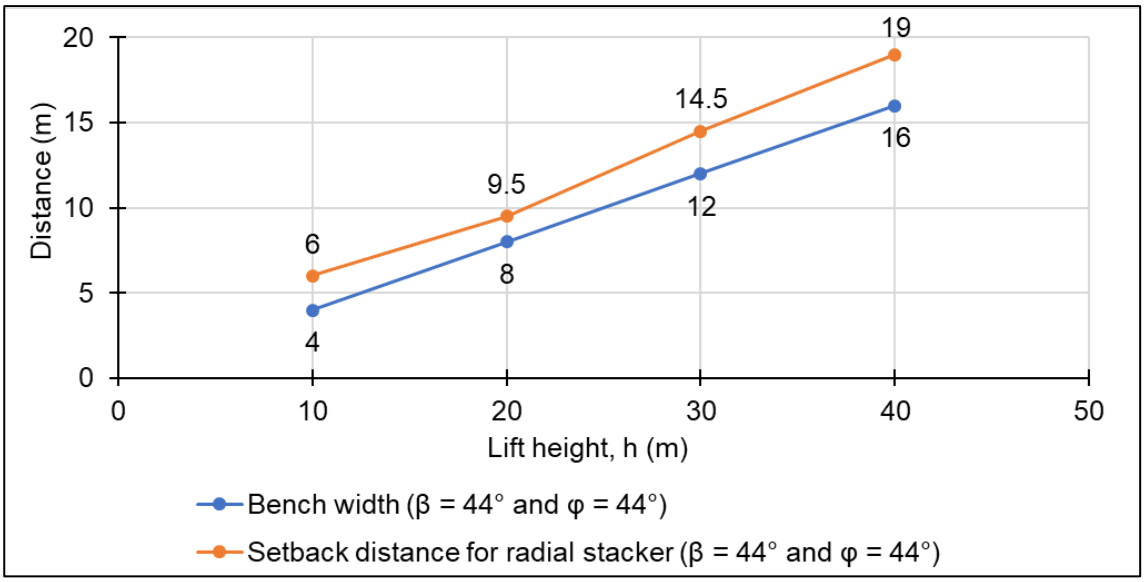


Figure 4-17: Minimum distance for bench width and radial stacker setback distance using β=44° and φ=44° (sensitivity case)

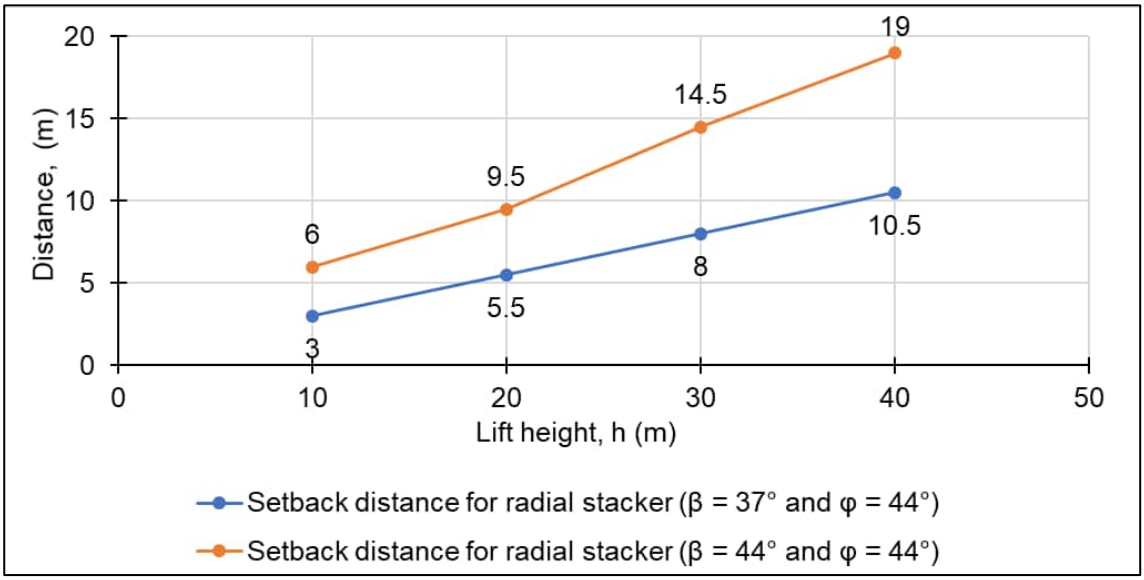


Figure 4-18: Comparison between radial stacker setback distances for varying angles of repose (design and sensitivity cases)

4.6.4 Assessment results for Stage 2

The slope stability assessment results for Stage 2 are presented in Table 4-5 for all considered scenarios (using the design case angle of repose). The reported values of FOS are well in exceedance of the acceptance criteria.

Table 4-5: Slope stability results for the operational phase (using the design case angle of repose)

Models	Period	Conditions	Required FOS	Achieved FOS
1	Operation	Static – interim operational, multiple lift failure	1.3	1.8
2	Operation	Static – final operational, global failure	1.3	2.7
3	Operation	Pseudo-static (OBE) – interim operational, multiple lift failure	1.1	2.1
4	Operation	Pseudo-static (OBE) – final operational, global failure	1.1	2.6

4.7 Settlement analysis

One-dimensional settlement of the stockpile was estimated based on the elastic settlement and primary settlement of the coarse-grained dry rejects material. The foundation is not expected to lead to any settlement concerns due to the shallow surficial rock evident across the footprint (refer to Section 1.7). Cumulative total settlement estimated for the stockpile (maximum height of approximately 80 m) is approximately 2 m, composed of 0.15 m elastic settlement and 1.85 m primary settlement as shown in Figure 4-19. Given that the stockpile will be developed in stages and the dry rejects are mainly granular, the settlement will occur almost immediately after placement due to equipment loading and self-weight. The cumulative settlement of 2.2 m is the sum of instantaneous settlements for every layer placed of dry rejects by the radial stacker. The magnitude of each instantaneous settlement is minimal and would not impact the operation or stability of the stockpile.

The long-term settlement of the stockpile has not been undertaken for this assessment; however, the magnitude of this settlement is expected to be relatively minor and does not impact the stability of the stockpile. Further details of the assessment are provided in Appendix E.

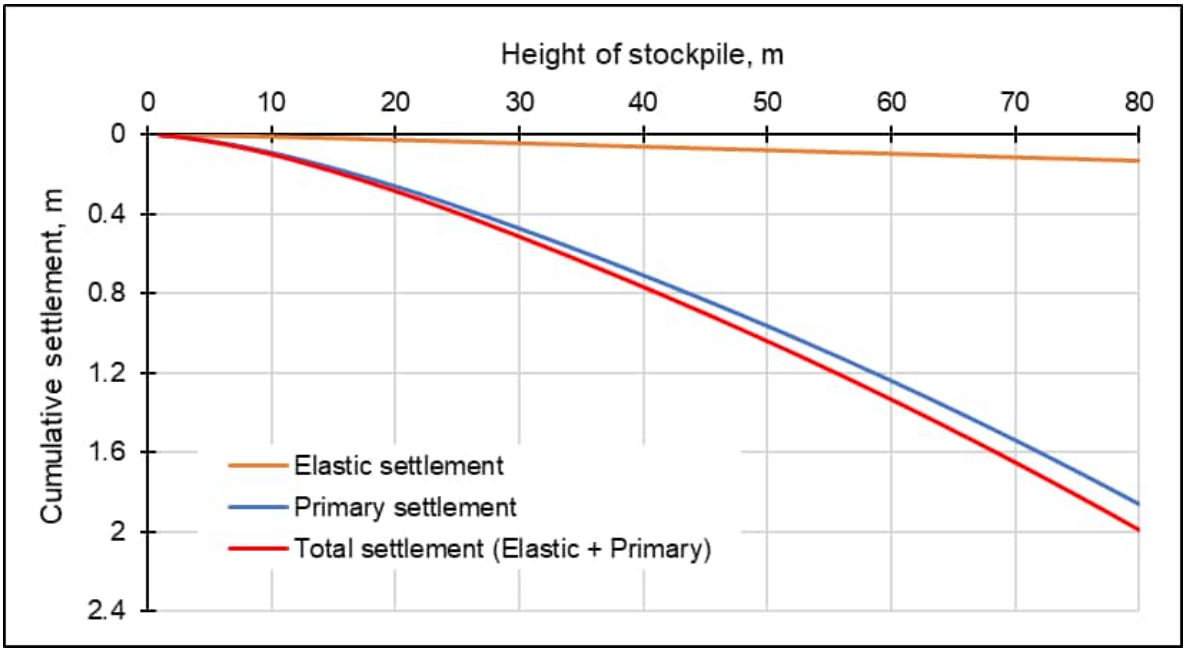


Figure 4-19: Elastic, primary and total settlement of stockpile

4.8 Runout estimate

Predicting potential runout of a stockpile failure is critical for risk assessment and developing a mitigation plan..

The potential distance that runout debris may travel should a hypothetical failure of the stockpile occur was undertaken using two empirical correlations by Hunter and Fell (2003) and Devoli et al. (2009). Table 4-6 shows the predicted runout distance and volumes based on the two different methods.

Table 4-6: Results from runout analysis

Empirical correlations	Runout distance (m)	Runout volume (m^3)
Hunter and Fell (2003)	214	Up to 10^7
Devoli et al. (2009)	226	Up to 3×10^4

Based on this, the potential runout distance of approximately 230 m can be estimated for a stockpile with a height of 80 m, with a maximum potential runout volume predicted of approximately 1×10^7 m^3. A 250 m offset distance from the stockpile footprint should be considered during the planning of the surrounding infrastructure to minimise the potential damages to infrastructure and equipment, and potential loss of life. While failure and runout could potentially occur anywhere around the stockpile perimeter, the locations where the runout would be of higher consequence are where the stockpile is near the maximum height, for example, at the western flank, central southern flank and central northern flank. Further details of the analysis are provided in Appendix F.

4.9 Monitoring and instrumentation

Performance monitoring should be carried out on an ongoing basis during operations, rehabilitation and the post closure period to ensure that the design intent is met during the stockpile's development through to the end of its life cycle. Monitoring of key aspects used in the design, such as moisture development/ distribution within the stockpile and the achieved angle of repose, is important in terms of validating the design.

The critical areas are likely to be those closer to the plant and where runoff is observed to pond around the stockpile toe following large storm events, such as intersections with natural ephemeral streams.

Inspection requirements for assessment of stability performance should be outlined in a Stockpile Management Plan. Operational safety and stability inspections and assessments are also conducted to ensure:

- the proposed stacking standoff distance is sufficient for the safe use of the operating equipment
- the total stack height is stable under all loading conditions that will occur during stockpile operation.

Design parameters will be reviewed, revised and updated during operations based on performance, or if further geotechnical investigations to support the project result in differences in the expected properties. It is recommended that the geotechnical characterisation of the rejects should be reviewed following any change in ore, process or produced PSD. In situ permeability testing of the dry rejects during the early stages of operation should be undertaken to verify the field permeability.

Table 4-7 lists the types of data measured and instruments to be used at the stockpile during operation. The elements to be monitored are based on those aspects of the stockpile operation that are considered critical to its overall stability and performance, including validating design assumptions. Given the extensive footprint of the stockpile, it is not feasible to monitor all of the slopes. Table 4-7 includes conceptual details on the proposed monitoring locations (e.g. number and depth etc.). These details should be optimised based on the confirmed stockpile development sequence, and then verified at regular intervals to ensure they are sited appropriately.

The measured data will allow for the following:

- Verification of design and analysis assumptions especially the degree of saturation of the stockpile
- Evaluation of behaviour during operation and closure while establishing and maintaining the stockpile performance record
- Provide advanced warning of potential instability to implement mitigative measures to reduce the impact of instability.

Table 4-7: Proposed conceptual stockpile monitoring

Instrumentation	Purpose	Location details	Minimum data review frequency
LiDAR surveys	To monitor angle of repose, erosion and overall development of landform during operation (and closure)	Survey of full stockpile extents	Quarterly
Soil moisture probes / sensors	To verify design assumption that stockpile will remain in an unsaturated condition with minimal pore water pressure development. The sensors will measure volumetric moisture content and distribution within the stockpile	Sensors placed at depths of approximately 2 m, 5 m and 10 m, at three separate locations across the stockpile (e.g. during the early stages of operation once the stockpile has been developed up to the RL 320 m platform)	Monthly and following large storm events

4.9.1 Monitoring program

General

Full monitoring requirements will be defined as a part of the Stockpile Management Plan. The general inspection requirements which may be refined as part of the development of the operating manual are listed under Daily, Monthly, Annual and Event-specific.

Daily

Daily inspections should include the following:

- Record of construction/ operational activities
- Record of stockpile level
- Observation and identification of dusting and adopted mitigation measures
- Consideration of dry rejects characteristics – any observable changes
- Inspection of stockpile batter slopes for evidence of erosion or seepage.

Monthly

Monthly inspections should include the following:

- Visual inspection of stockpile batter slopes and benches for evidence of cracking, erosion or seepage
- Measurement of soil moisture sensors installed within the stockpile.

Annually

Independent review by a professional with appropriate experience in the design, construction and operation of waste dumps/ stockpile, in accordance with the Stockpile Management Plan.

Event-specific

The following inspections should be undertaken following significant storm events or seismic activity:

- Inspection of stockpile batter slopes and benches for evidence of cracking or movement erosion or seepage
- Inspection of sediment containment bunds for erosion/ sediment accumulation
- Record of ponding extents (if any) on the stockpile surface.

5 Conceptual Closure

5.1 Objectives

A conceptual closure and rehabilitation strategy have been developed including the post-closure objectives outlined by the DMP (2015a) to create a safe, stable, non-polluting landform, as well as the below minimum objectives by CSIRO (2017):

- Protect public health and safety
- Prevent or reduce environmental degradation
- Allow for productive future land use (either its original use or an acceptable alternative).

The closure design ensures the stockpile will be physically safe to humans and animals, geotechnically stable, non-contaminating, erosion-resistant and can support native vegetation after ceasing of operations. The proposed conceptual closure arrangement is presented on SRK Drawings IBO057-0025, IBO057-0035 and IBO057-0040 (Appendix A). Conceptual closure design considerations are summarised in the following sections.

5.2 Erosion

Erodibility and sediment properties of oxide waste rock was assessed by Landloch (2018)[13] through laboratory-based methods and numerical modelling. Based on the outcomes of the studies, the following measures were suggested to minimise erosion during closure:

a. Adopting a batter height of 10 m and a uniform slope with a gradient of 37°
b. Installing crest bunding to control extreme rainfall events
c. Dividing the top surface into drainage paddocks to control storm runoff.

It is expected that with the implementation of the proposed measures, the stockpile landform will achieve long-term erosional stability. The degree of erosion will be well within acceptable rates based on the findings of the *Acceptable erosion rates for mine waste landform rehabilitation modelling in the Pilbara, Western Australia* (Landloch, 2018) and will not affect the integrity of the cover.

5.3 Landform and capping

The recommended closure design strategy is a stepped landform that utilises large berms and bunds to control surface water and contain sediments. The dry rejects stockpile will be capped with a protective layer of oxide waste rock of at least 0.5 m thickness across the full surface and 2 m on the slope face to provide erosional stability and enable revegetation where possible. The closure landform will be stepped uniformly with lifts at angle of repose of 10 m height and 25 m bench widths. The batter slope lengths have been minimised to help reduce water velocity and therefore reduce erosion potential (Section 5.2). This concept is illustrated in Figure 5-1 and Figure 5-4.

The intent is to progressively cap the landform to reduce the period of exposure of the higher face of the first lift. Stacking of the full first lift will take in the order of 8.7 years, following which IBO will begin to place the capping layer against the first lift around the full footprint.

The proposed closure layout and details of the stockpile are shown in SRK Drawings IBO057-0030 and IBO057-0040.

[13] Landloch, 2018. Assessment of the growth media and erosion potential of selected wastes and soils

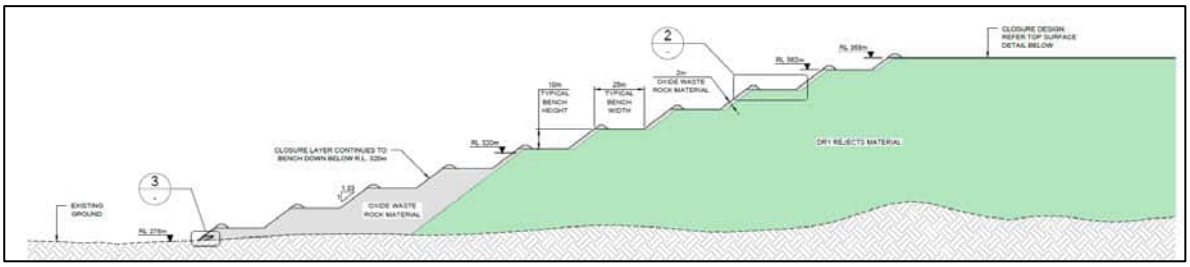


Figure 5-1: Closure stockpile conceptual section

Source: SRK Drawing IBO057-0040

Table 5-1: Stockpile geometric design summary

Parameter	Operational	Closure
Maximum elevation (RL m)	366	368
Maximum height (m)	85.5	87.5
Average height (m)	54	49.5
Total footprint area (ha)	239	281
Top surface area (ha)	99	99
Toe perimeter length (m)	6,840	8,520
Volume (Mm^3)	121.2	131.6

5.3.1 Capping material

For this design, oxide waste rock has been adopted as it is the more conservative selection in terms of stability.

The oxide waste rock is non-saline, pH balanced, fertile and has a low tendency of clay dispersion to reduce the risk of erosion. It is expected that oxide waste from Pincunah BIF material, having a wider band of PSDs as shown in Figure 5-2, will be suitable for use as a capping layer. The PSD of this material is relatively compatible with the dry rejects and will reduce potential for wash-out of the rejects.

The fresh rock to be used for rock armouring is expected to have grading like that shown in Figure 5-3, which is based on fragmentation analysis.

Fresh rock could also potentially be used for a portion of the closure capping, with an outer covering of oxide waste rock, particularly in the wider zone below the first lift (RL 320 m). Testing and further investigation should be undertaken during operations to confirm the compatibility of the rejects with the coarser fresh rock.

Further assessment of available quantities will also influence the specific material placement strategies.

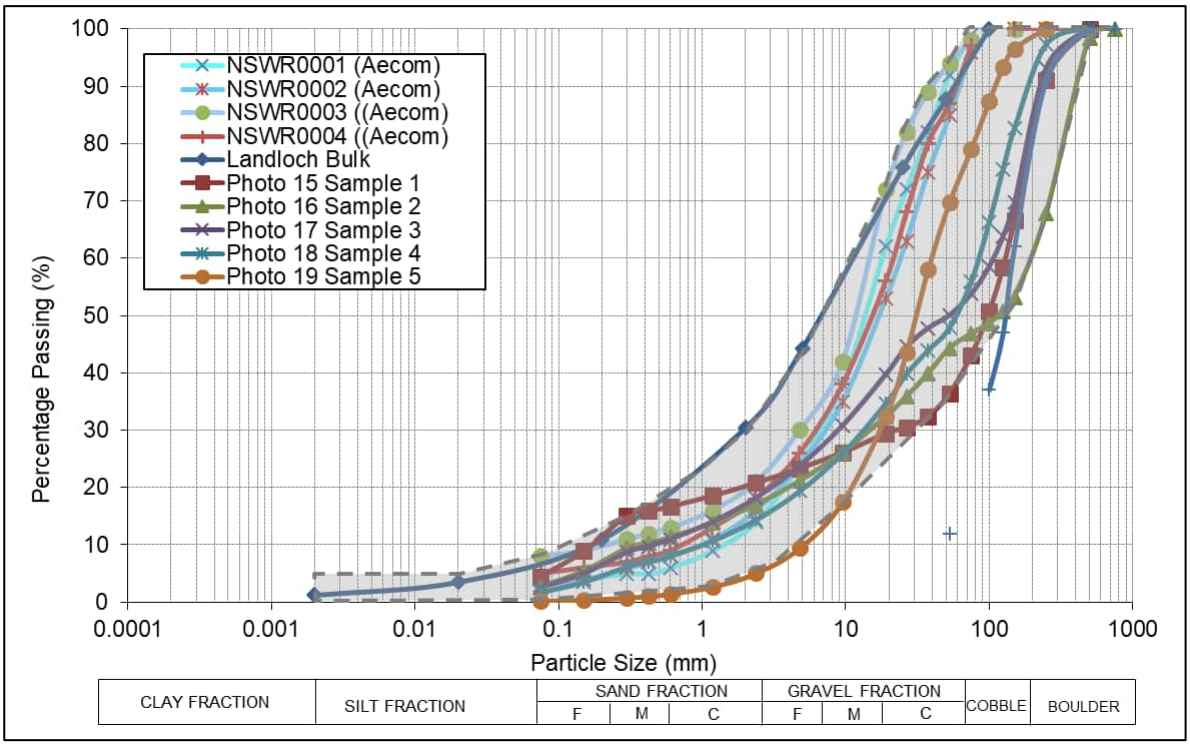


Figure 5-2: Particle size distribution of oxide waste rock materials

Source: IBO, 2019.

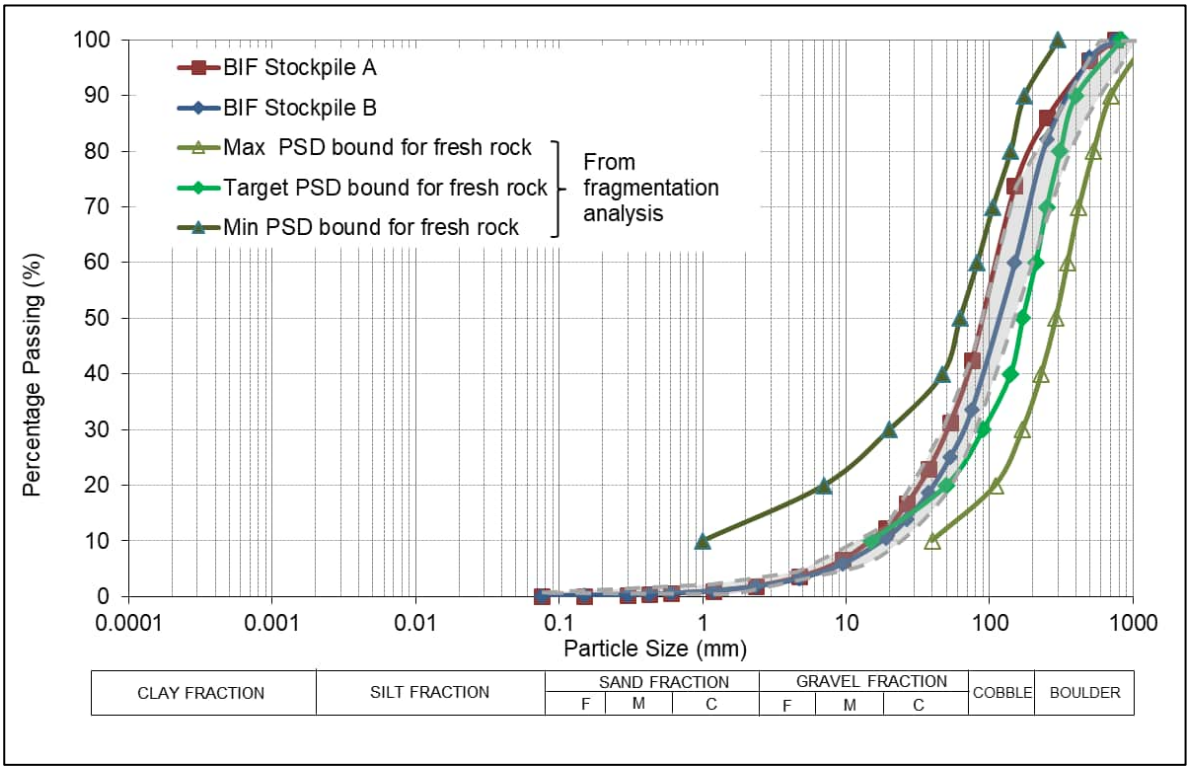


Figure 5-3: Particle size distribution of fresh rock

Source: IBO,2019.

5.4 Surface water management

The stockpile has been designed to retain water from closed catchment rainfall. The top surface and benches and batters will be constructed to accommodate the maximum expected design rainfall event (PMF, 72-hour).

The proposed closure water management design of the stockpile is shown in SRK Drawings IBO057-0035 and IBO057-0040.

The top surface is proposed to be split into a paddock-type layout to reduce the potential for widespread concentrated sheet flows to erode the surface, with individual sections of approximately 300 m maximum width separated by 1 m high bunds. Each of these paddocks will be graded towards the centre to control large storm events and limit the impact to the internal containment bunds, promoting a combination of evaporation and infiltration to remove excess storm water. These paddocks have been sized so that the maximum flow path is limited to approximately 200 m in any direction and a corresponding maximum velocity of 0.5 m/s, which correlates to limiting the erosion potential of the rejects to only the finer end of the PSD (approximately D15 or less, equivalent to a particle size of <2mm) under an extreme storm event (greater than an AEP of 2,000 years).

Bunds of 2 m high with a 2 m wide top will be placed around the perimeter of the top surface and on all external benches for containment to limit the potential of runoff flowing down the batter slopes.

As detailed in Section 4.1, as the stockpile footprint is sited high on the catchment, most runoff flows away from the landform, with only two very small external catchments collecting inflowing runoff on the east and southeast extents. These zones will be armoured with erosion and scour-resistant fresh rock to protect the base of the stockpile. The flood extents for the PMF of the natural streams has been assessed and any outer slope zones where this flood could impact the landform will also be armoured with fresh rock. The fresh rock armour will have a nominal thickness between 2 m and 5 m and a minimum height of 2 m, as shown indicatively in Figure 5-5.

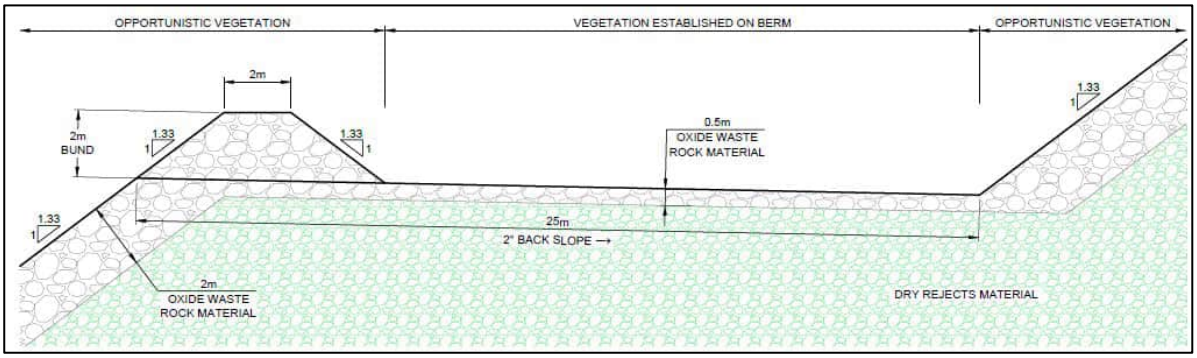


Figure 5-4: Closure stockpile conceptual bench detail

Source: SRK Drawing IBO057-0040

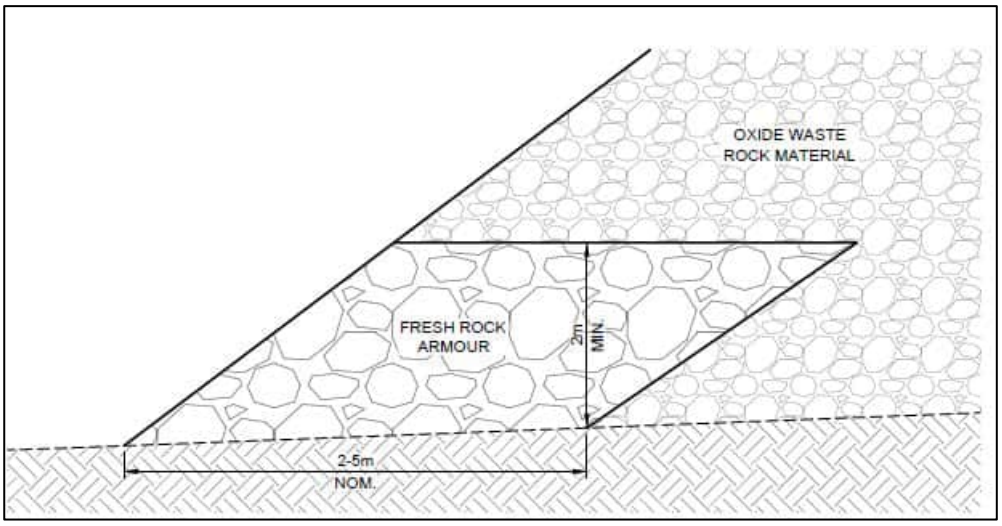


Figure 5-5: Fresh rock armouring protection within PMF flood extents

Source: SRK Drawing IBO057-0040

5.5 Slope stability

The slope stability assessment for closure was undertaken using the same methodology, acceptance criteria and material properties detailed in Section 4.6. The slope stability model outputs are provided in Appendix D for reference.

For closure, a layer of oxide waste material is added. The oxide waste was modelled with the design non-linear strength parameters of Oxide BIF based on SRK (2019)[14]. Specific material parameters for the fresh rock armouring of the profile at closure to control material erosion have been omitted from the analysis as their influence on overall slope stability is deemed negligible.

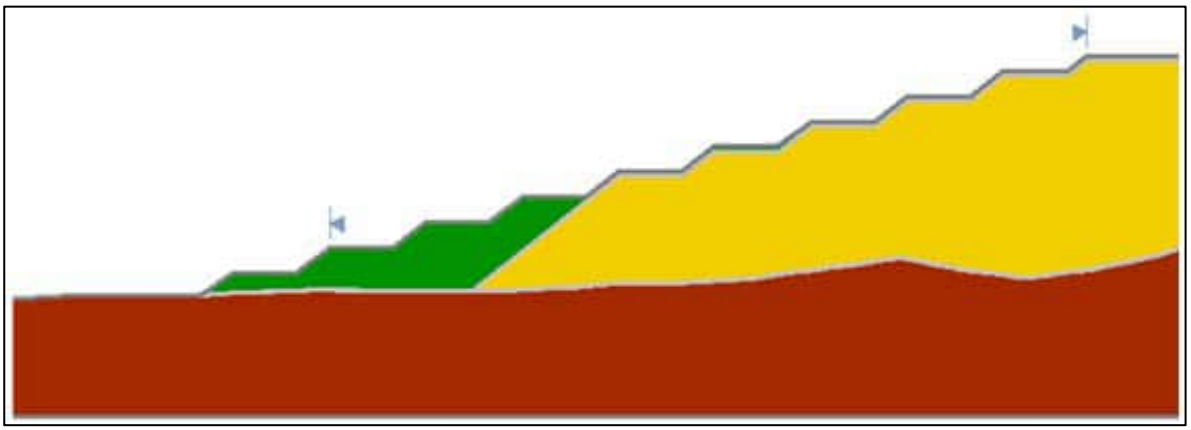


Figure 5-6: Slide model geometry for the closure stability assessment

As detailed in Section 4.2, the stockpile is not expected to experience fully saturated conditions under the AEP 500-year design basis event. As the potential for a phreatic surface to develop within the stockpile is negligible, the design case stability model for closure have been modelled with no developed phreatic surface.

However, the influence of the PMP 72-hour event has been considered for the sensitivity case.

The analyses were conducted using Slide under unsaturated/ saturated transient conditions to produce pore pressures (PP) within the stockpile due to storm event infiltration based on ponding on the stockpile benches.

The hydraulic parameters adopted for this analysis are presented in Table 5-2. Hydraulic properties for the oxide waste rock and foundation were adopted from SRK's report[14], while hydraulic properties of the dry rejects were estimated using laboratory data, i.e. SWCCs.

Table 5-2: Waste rock hydraulic parameters adopted

Material	Volumetric saturated moisture content	K (saturated) (m/s)	Volumetric residual water content
Oxide BIF	0.25	1×10^{-5}	0.05
Dry rejects	0.28	2.5×10^{-6}	0.01
Foundation	0.2	1×10^{-6}	0.02

A conservative infiltration rate of 0.38 m/day (16 mm/h) into the bench was simulated for eight days representing a constant rate of infiltration into the stockpile. The infiltration rate was limited by the permeability of the dry rejects. The 8-day infiltration duration was estimated based on the storm event period plus an additional five days for ponds perched on the benches to drain through infiltration.

The slope stability assessment results for closure are presented in Table 5-3 for all scenarios considered. The reported values of FOS are well in exceedance of the acceptance criteria.

The minimum standoff distance to achieve a FOS criteria of 1.5 to delineate the required personnel exclusion zone is approximately 3 m (Model 9 below), which would be within the external bund. IBO will confirm this required exclusion zone for personnel during closure based on stability acceptance criteria within the site Stockpile Management Plan.

Table 5-3: Slope stability results for the closure phase

Models	Period	Conditions	Required FOS	Achieved FOS
5	Closure	Static – closure, global failure	1.5	3.5
6	Closure	Pseudo-static (MCE) – closure, global failure	1.0	2.0
7	Closure	Static (PMP pore pressure) – closure, global failure	1.1	3.0
8	Closure	Static – closure, localised failure through oxide waste	1.5	2.3
9	Closure	Static – closure, localised failure to estimate minimum standoff distance	1.5	1.5

5.6 Geochemical stability

The oxide waste rock is non-saline and pH balanced (Section 5.3.1). The long-term geochemical stability of the dry rejects under weathering conditions was assessed by GHD[5] through kinetic column leach experiments. Based on GHD's interpretation, the dry rejects were identified as acid consuming (AC) material with a low risk of acidic and metalliferous or saline leachates forming. Hence, the stockpile does not pose long-term geochemical risks to the environment.

5.7 Revegetation

The intention of the revegetation is to provide further erosion protection, withstand terrestrial fauna and to assist with blending into the natural landscape. The stockpile will be rehabilitated with native vegetation across its surface except in areas designed as being at the angle of repose or covered by fresh rock armour. The requirement for the addition of topsoil to support revegetation will be determined as part of revegetation trials. The dry rejects are non-saline alkaline materials with an

[14] SRK, 2019. FMG062_MEMO_Iron Bridge WRD Stability Assessment

average pH of 8.8 compared to the in-situ soil which has an average pH of 6.8. The high pH of the dry rejects may impact the potential growth of some plants. Hence, oxide wastes will be used as capping materials as recommended by Landloch (2018) to create a root zone with lower pH. The current ecosystem in the surrounding area indicates the probable vegetation density that could be achieved in the longer term. The development of revegetation programs for rehabilitation need to be planned well in advance of closure to ensure successful revegetation on the stockpile. The revegetation program may include using trial pots to evaluate seed mixes, seeding methods and seedbed preparation as well as preparation of seed banks to propagate plants for needed for closure.

5.8 Monitoring

The stockpile will continue to require long-term monitoring, inspection and maintenance to ensure the stockpile is confidently trending towards, or has achieved, the closure landscape function.

Post-closure inspections focus on ensuring the design is stable and there are no signs of significant erosion or settlement. Evidence of channel flow or sheet erosion, or failure of berms or bunds, are indications that the design is not performing as per the design intent. Defects should be remediated once observed to avoid major uncontrollable erosion or slope failure occurring.

The post-closure monitoring and inspection carried out periodic may include:

- Water quality – ensuring chemical constituents that are released from the stockpile to downstream surface water should not endanger public, wildlife or environmental health and safety
- Stability of stockpile – ensuring the surface does not erode significantly under natural events (such as storms or earthquakes) or other disruptive forces, for example, the use of all-terrain vehicles after closure
- Erosion – ensuring erosion is minimal and the capping layer has sufficient thickness throughout the whole surface area of the stockpile
- Revegetation – demonstrating that rehabilitation outcomes are consistent with the revegetation program.

6 Schedule of Quantities

The estimated schedule of quantities for operations and closure are summarised in Table 6-1. The internal bunds across the top surface placed during operations have been excluded as it is expected the placement and construction of these will be an operational decision, as detailed in Section 4.2.

Table 6-1: Schedule of quantities for operations and closure

Operations	
Bench external bunds, dry rejects, dumped	145,000 m^3
Sediment containment bund	7,000 m^3
Benches grading and shaping to indicated backslope	843,000 m^3
Closure	
Capping layer, oxide waste rock	7,520,000 m^3
Fresh rock armouring	31,000 m^3
Bench external bunds, oxide waste rock	393,000 m^3
Top surface external bund, oxide waste rock	49,000 m^3
Top surface internal paddock bunds, oxide waste rock	11,000 m^3
Top surface grading and shaping to indicated slopes	990,000 m^2
Benches grading and shaping to indicated backslope	1,091,000 m^2

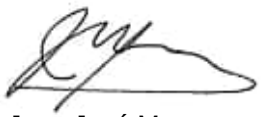
Compiled by



Nick Thompson

Senior Consultant

Peer Reviewed by



Juan José Moreno

Principal Consultant

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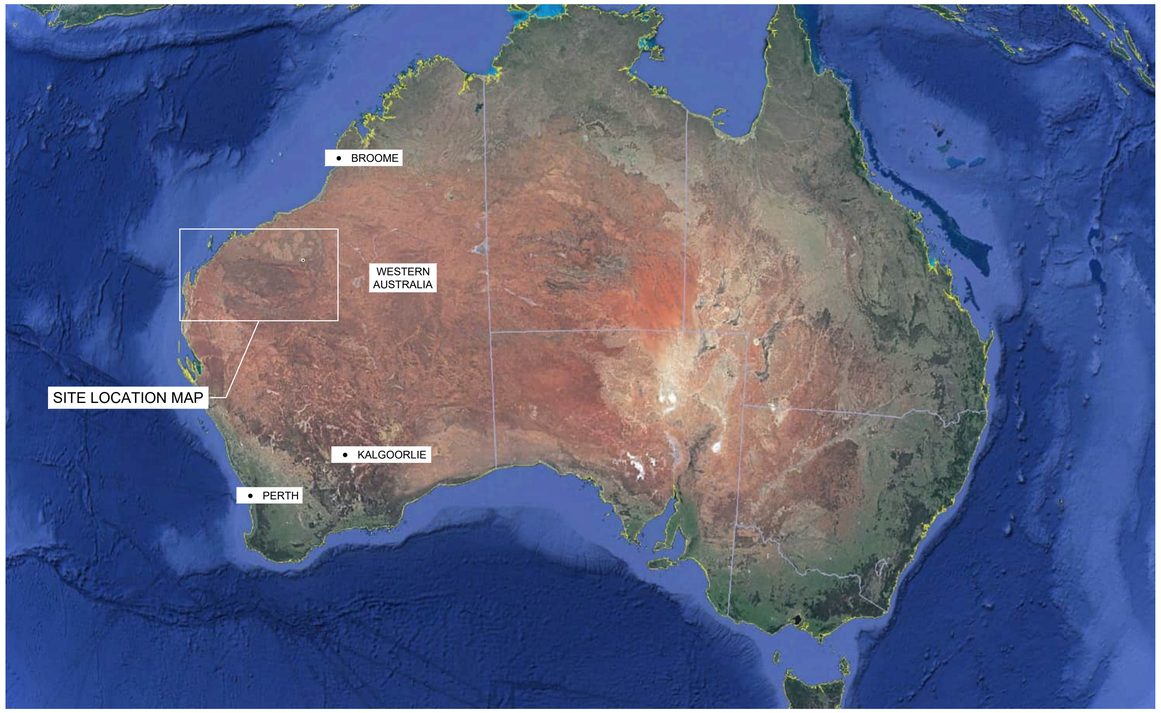
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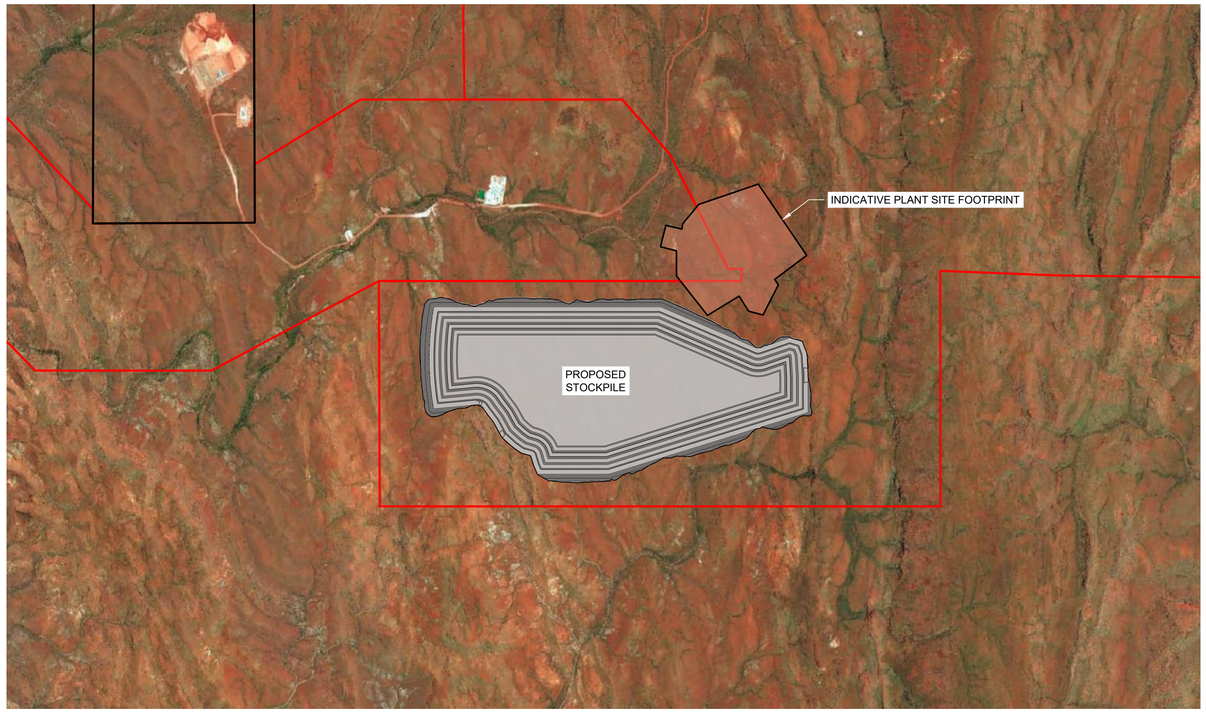
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Appendices

Appendix A: Drawings



COUNTRY LOCATION MAP
SCALE 1:15,000,000



PROJECT LOCATION MAP
SCALE 1:20,000



SITE LOCATION MAP
SCALE 1:2,000,000

DRAWING LIST

Sheet Number	Sheet Title
IBO057-0000	DRY REJECTS STOCKPILE DESIGN PROJECT LOCATION & DRAWING LIST
IBO057-0005	DRY REJECTS STOCKPILE GEOLOGY LAYOUT
IBO057-0010	DRY REJECTS STOCKPILE OPERATIONAL LAYOUT & SECTIONS
IBO057-0015	DRY REJECTS STOCKPILE OPERATIONAL WATER MANAGEMENT PLAN
IBO057-0020	DRY REJECTS STOCKPILE OPERATIONAL DETAILS
IBO057-0025	DRY REJECTS STOCKPILE PROGRESSIVE SURFACE DRAINAGE LAYOUTS
IBO057-0030	DRY REJECTS STOCKPILE CONCEPTUAL CLOSURE LAYOUT & SECTIONS
IBO057-0035	DRY REJECTS STOCKPILE CONCEPTUAL CLOSURE WATER MANAGEMENT PLAN
IBO057-0040	DRY REJECTS STOCKPILE CONCEPTUAL CLOSURE DETAILS

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srk consulting
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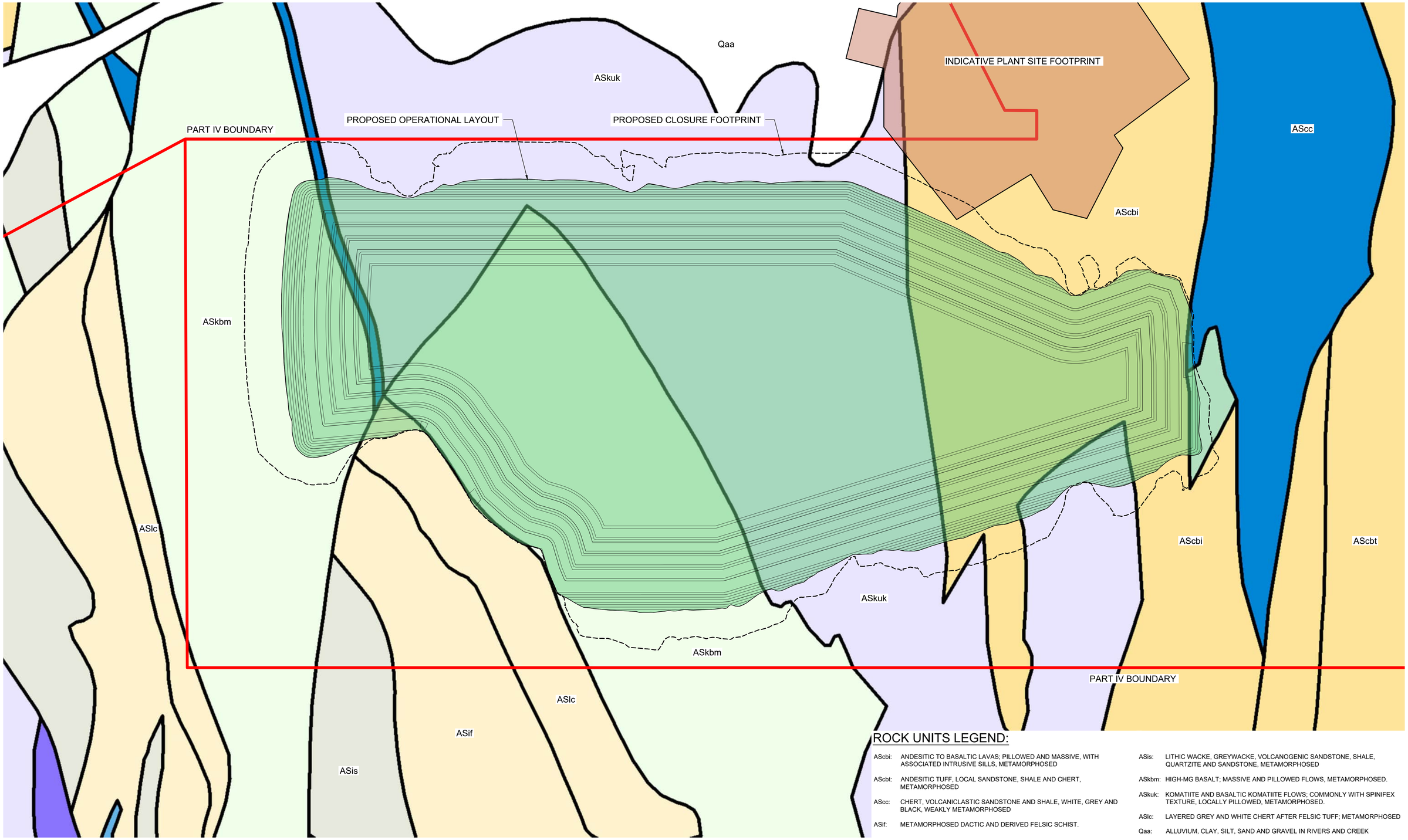
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DRY REJECTS STOCKPILE DESIGN
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ROCK UNITS LEGEND:

AScbi: ANDESITIC TO BASALTIC LAVAS; PILLOWED AND MASSIVE, WITH ASSOCIATED INTRUSIVE SILLS, METAMORPHOSED

AScbt: ANDESITIC TUFF, LOCAL SANDSTONE, SHALE AND CHERT, METAMORPHOSED

AScc: CHERT, VOLCANICLASTIC SANDSTONE AND SHALE, WHITE, GREY AND BLACK, WEAKLY METAMORPHOSED

ASif: METAMORPHOSED DACTIC AND DERIVED FELSIC SCHIST.

ASis: LITHIC WACKE, GREYWACKE, VOLCANOGENIC SANDSTONE, SHALE, QUARTZITE AND SANDSTONE, METAMORPHOSED

ASkbm: HIGH-MG BASALT; MASSIVE AND PILLOWED FLOWS, METAMORPHOSED.

ASkuk: KOMATIITE AND BASALTIC KOMATIITE FLOWS; COMMONLY WITH SPINIFEX TEXTURE, LOCALLY PILLOWED, METAMORPHOSED.

ASlc: LAYERED GREY AND WHITE CHERT AFTER FELSIC TUFF; METAMORPHOSED

Qaa: ALLUVIUM, CLAY, SILT, SAND AND GRAVEL IN RIVERS AND CREEK

GEOLOGY LAYOUT

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SCALE 1:5,000

CLIENT REVIEW

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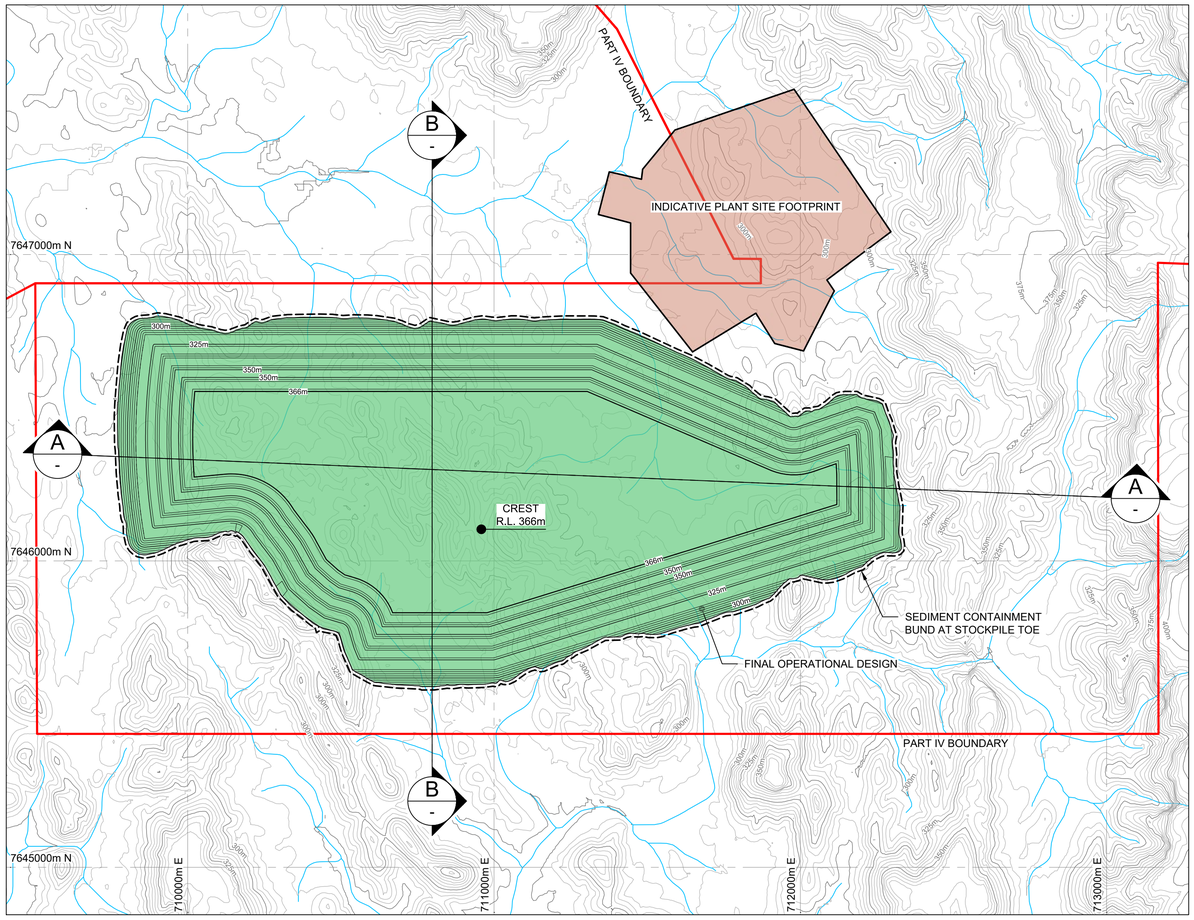
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DRY REJECTS STOCKPILE GEOLOGY LAYOUT

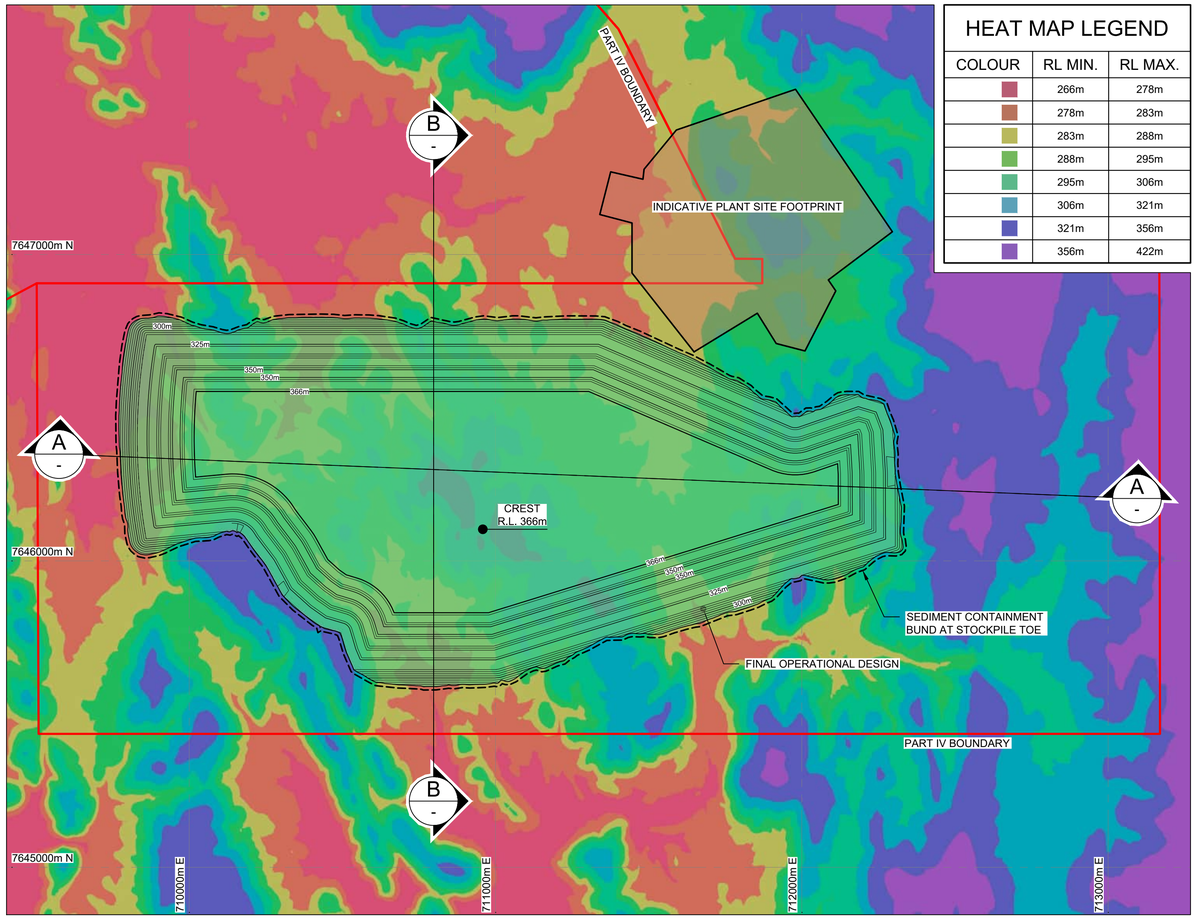
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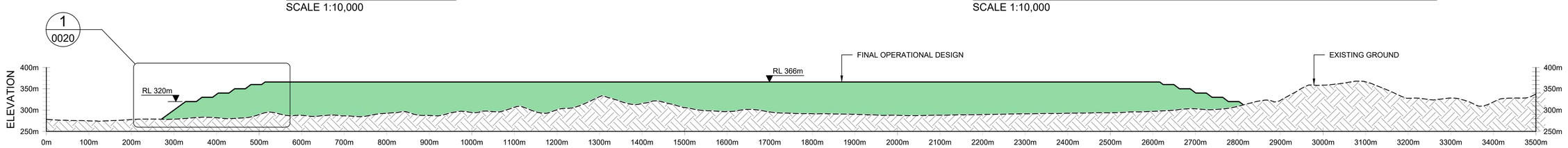
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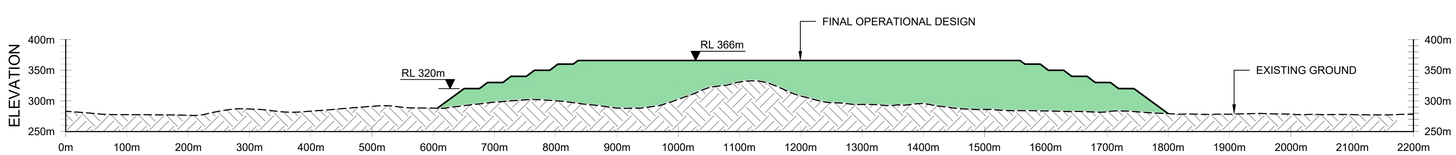
OPERATIONAL LAYOUT
SCALE 1:10,000



OPERATIONAL LAYOUT WITH ELEVATION HEAT MAP UNDERLAY
SCALE 1:10,000



SECTION A
SCALE: 1:5000



SECTION B
SCALE: 1:5000

LEGEND:
- STREAM CENTRELINE
- DRY REJECTS

NOTE:
TOPOGRAPHICAL SURFACE BASED ON SURVEY FILE 'Topo_All_16_01_2015_0RL.xyz'

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SCALE 1:5,000

CONTOUR INTERVALS U.N.O.
EXISTING TOPOGRAPHY: 5m & 25m
DESIGN TOPOGRAPHY: 5m & 25m

COORDINATE SYSTEM
HORIZONTAL DATUM: MGA50
VERTICAL DATUM: GDA94

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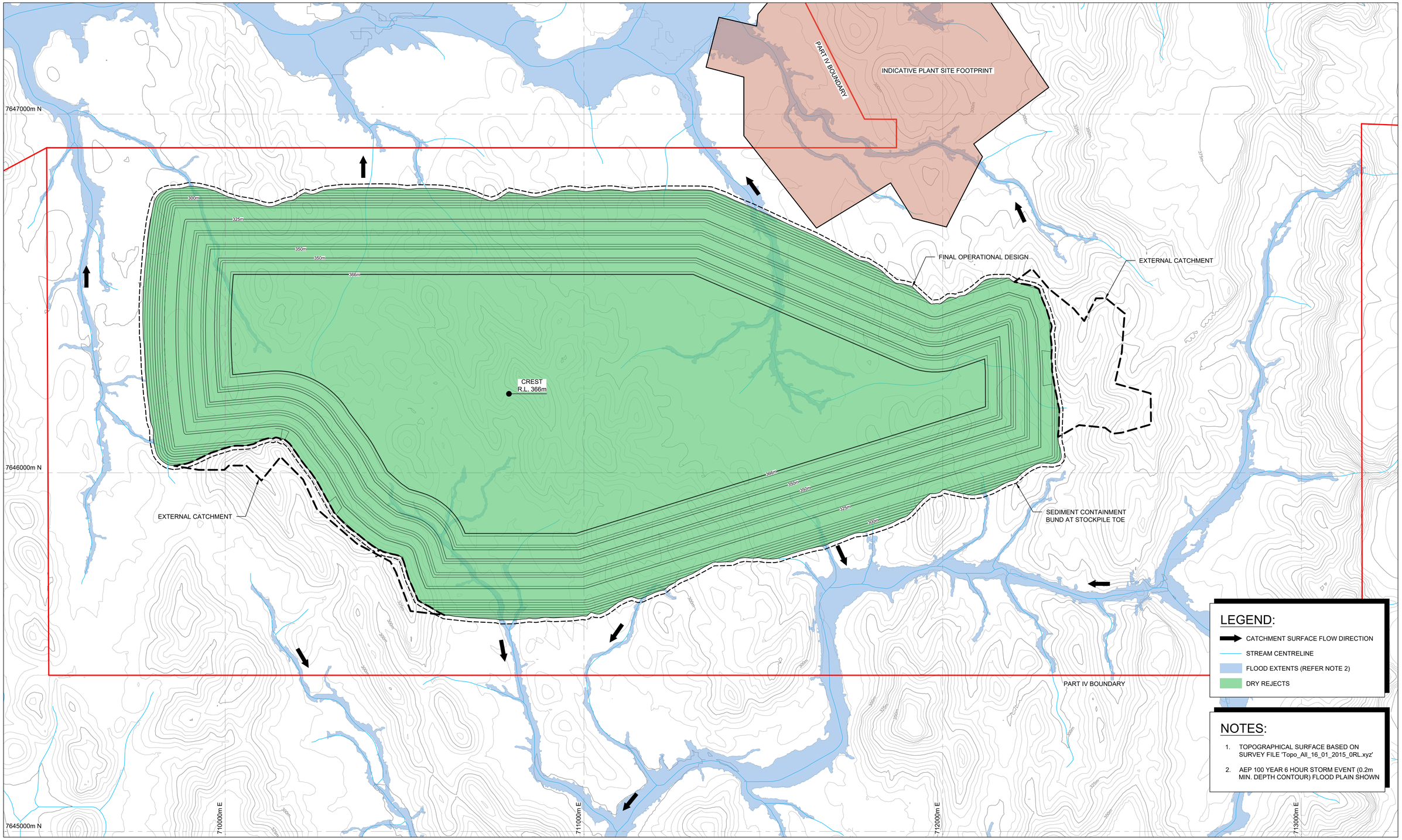
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DRY REJECTS STOCKPILE OPERATIONAL LAYOUT & SECTIONS

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LEGEND:

- CATCHMENT SURFACE FLOW DIRECTION
- STREAM CENTRELINE
- FLOOD EXTENTS (REFER NOTE 2)
- DRY REJECTS

NOTES:

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2. AEP 100 YEAR 6 HOUR STORM EVENT (0.2m MIN. DEPTH CONTOUR) FLOOD PLAIN SHOWN

OPERATIONAL WATER MANAGEMENT PLAN

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SCALE 1:5,000

CONTOUR INTERVALS U.N.O.
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DESIGN TOPOGRAPHY: 5m & 25m

COORDINATE SYSTEM
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VERTICAL DATUM: GDA94

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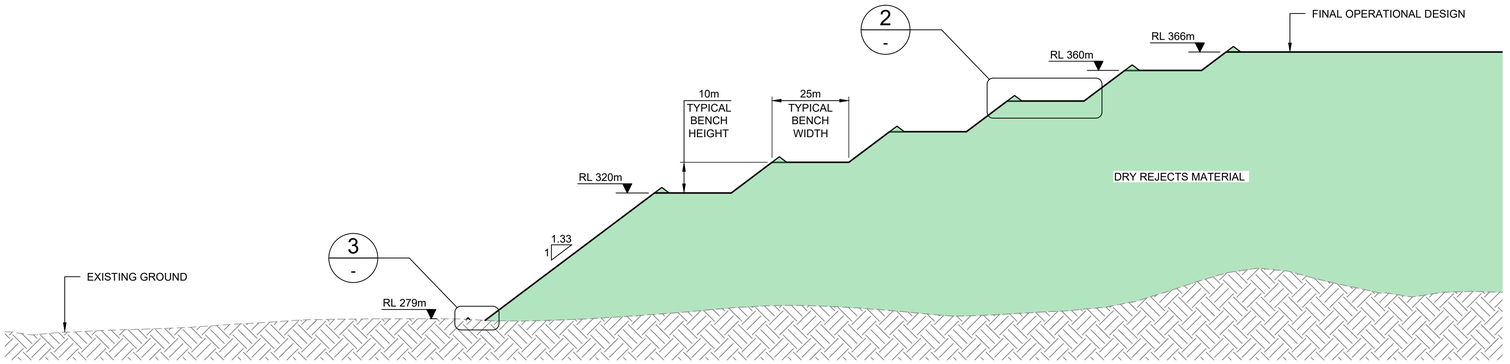
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DRY REJECTS STOCKPILE
OPERATIONAL WATER MANAGEMENT PLAN

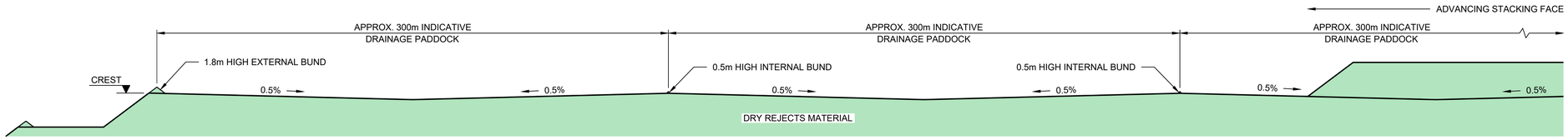
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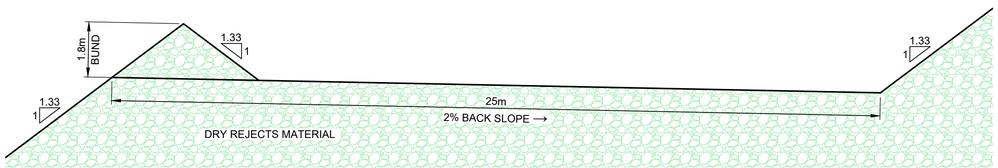
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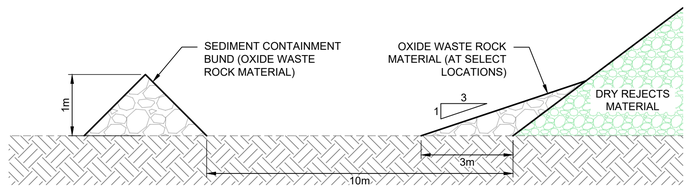
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OPERATIONAL TOP SURFACE DETAIL
N.T.S.



2 - OPERATIONAL BENCH DETAIL
SCALE 1:100



3 - OPERATIONAL SEDIMENT CONTAINMENT BUND DETAIL
N.T.S.

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SCALE 1:100

CLIENT REVIEW
PLOTTED: Friday, 26 April 2019 11:06:12 AM

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		A	15.04.19	ISSUED FOR CLIENT REVIEW	TREV	MORE	THOM	THOM			

IRON BRIDGE

srk consulting

NORTH

PROJECT NUMBER
FMG057

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VENDOR/DESIGNER DRG No.
IBO057-0020

REV:

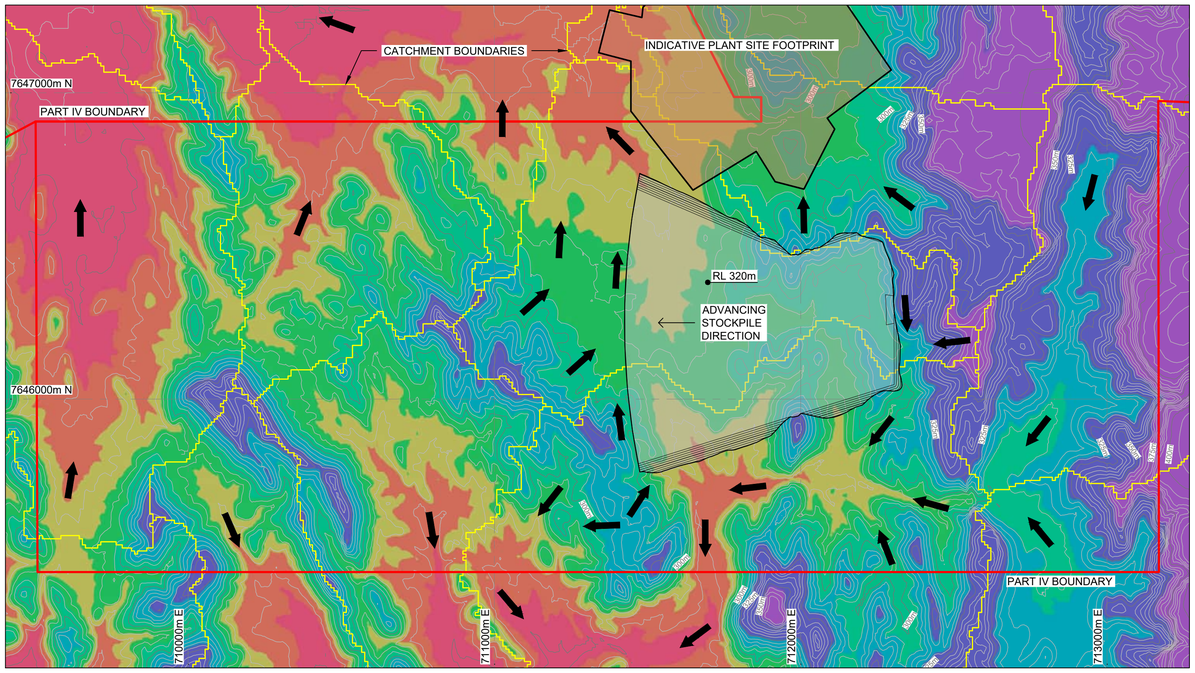
Fortescue Metals Group Ltd

DRY REJECTS STOCKPILE OPERATIONAL DETAILS

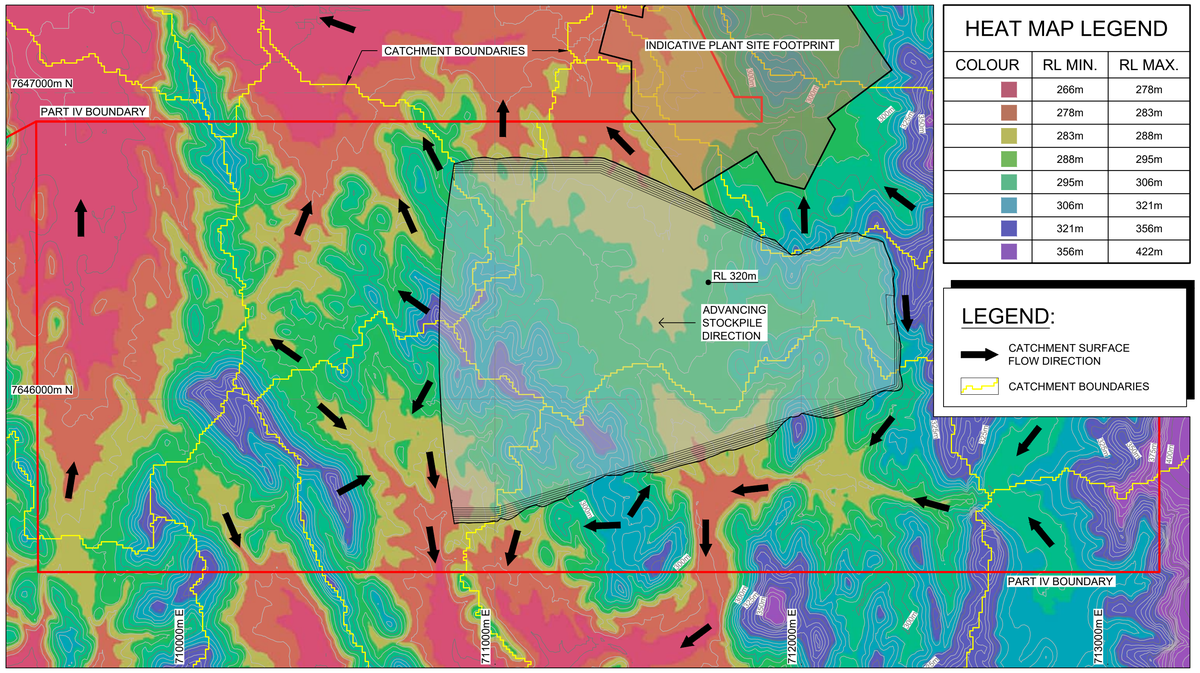
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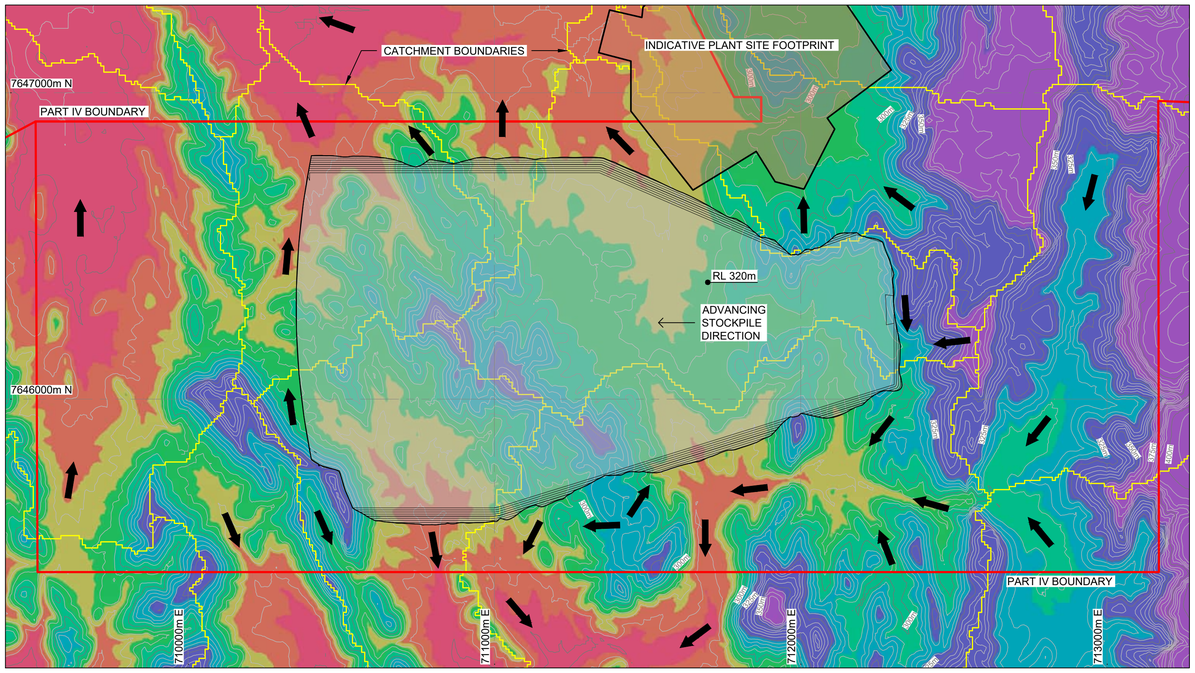
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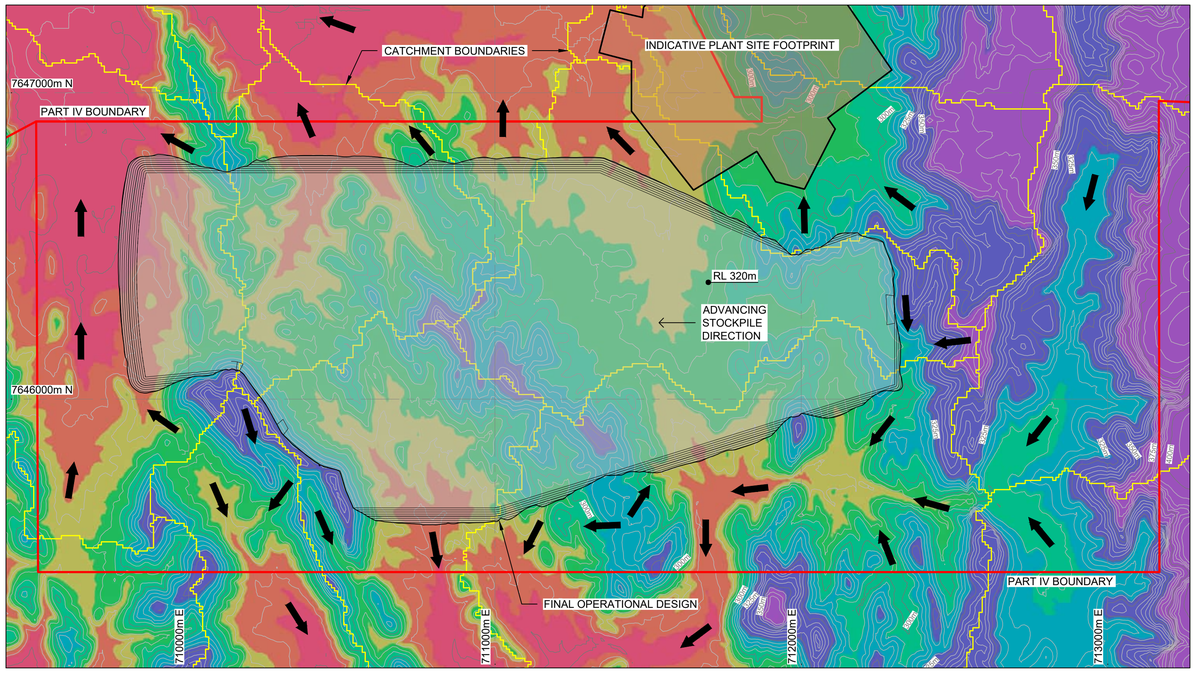
PROGRESSIVE SURFACE DRAINAGE LAYOUT (APPROX. YEAR 2)
SCALE 1:10,000



PROGRESSIVE SURFACE DRAINAGE LAYOUT (APPROX. YEAR 4)
SCALE 1:10,000



PROGRESSIVE SURFACE DRAINAGE LAYOUT (APPROX. YEAR 6)
SCALE 1:10,000



PROGRESSIVE SURFACE DRAINAGE LAYOUT (APPROX. YEAR 9)
SCALE 1:10,000

HEAT MAP LEGEND

COLOUR	RL MIN.	RL MAX.
	266m	278m
	278m	283m
	283m	288m
	288m	295m
	295m	306m
	306m	321m
	321m	356m
	356m	422m

LEGEND:

- CATCHMENT SURFACE FLOW DIRECTION
- CATCHMENT BOUNDARIES

200 0 200 400 600 800 1000
SCALE 1:10,000

INDICATIVE ONLY

CONTOUR INTERVALS U.N.O.
EXISTING TOPOGRAPHY: 5m & 25m
DESIGN TOPOGRAPHY: 5m & 25m

COORDINATE SYSTEM
HORIZONTAL DATUM: MGA50
VERTICAL DATUM: GDA94

CLIENT REVIEW
PLOTTED: Friday, 26 April 2019 11:06:29 AM

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		A	15.04.19	ISSUED FOR CLIENT REVIEW	TREV	MORE	THOM	THOM			

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REV:

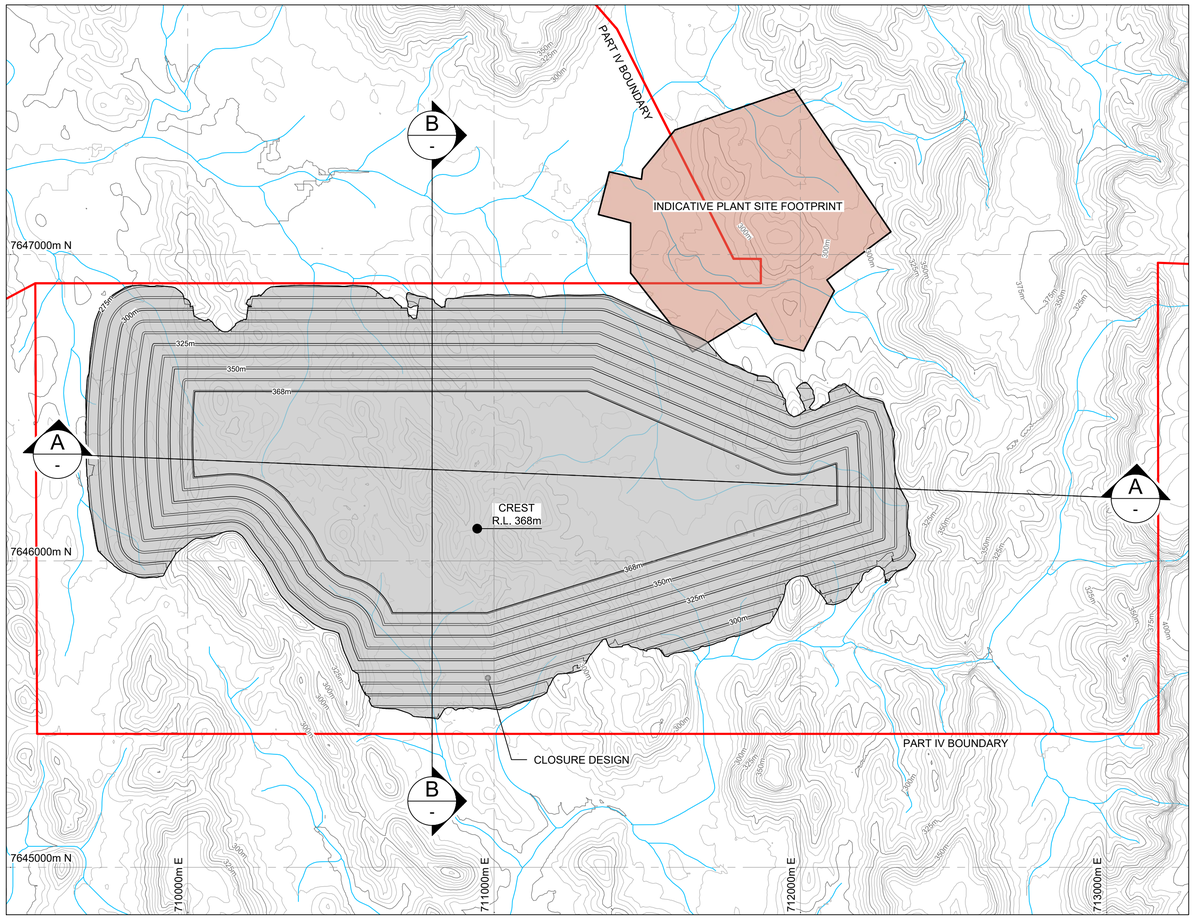
Fortescue Metals Group Ltd

PROJECT NUMBER: FMG057

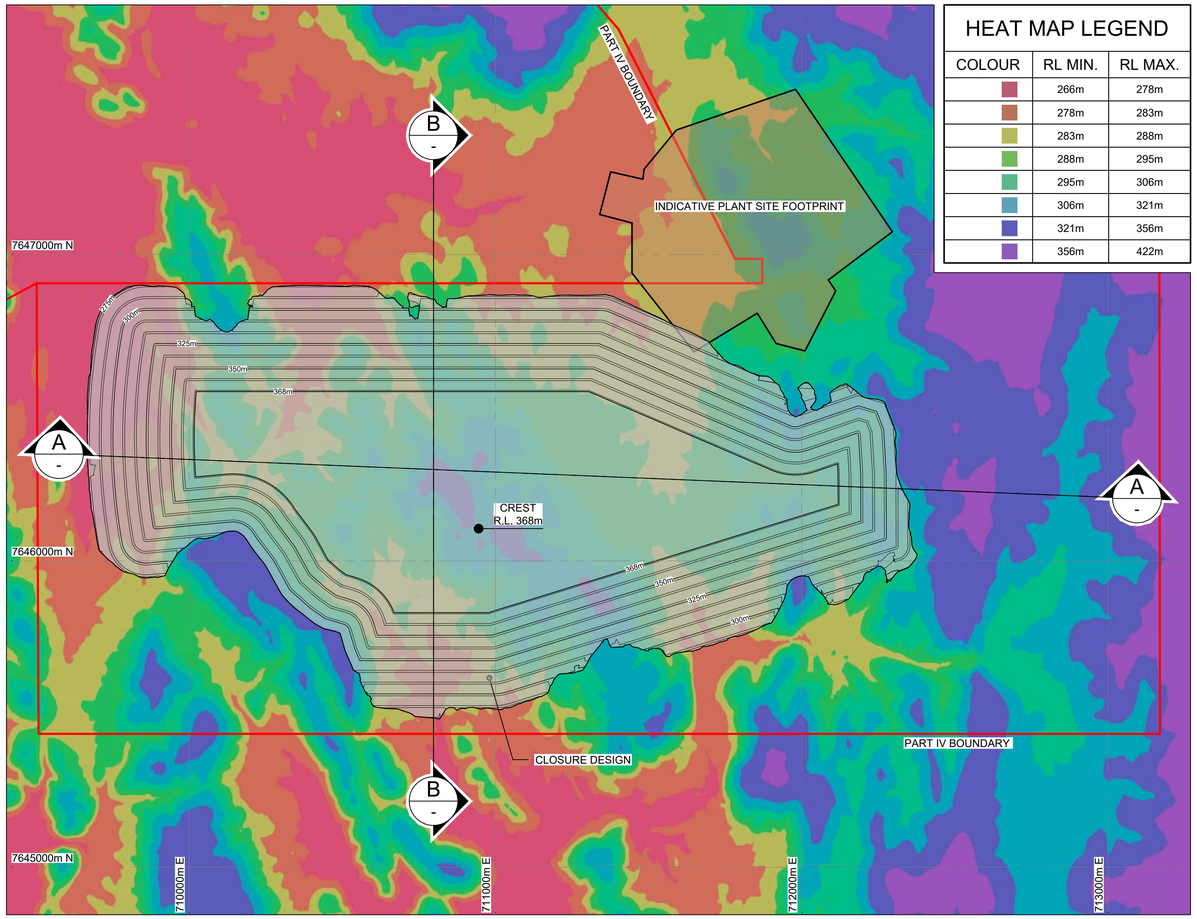
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PROGRESSIVE SURFACE DRAINAGE LAYOUTS

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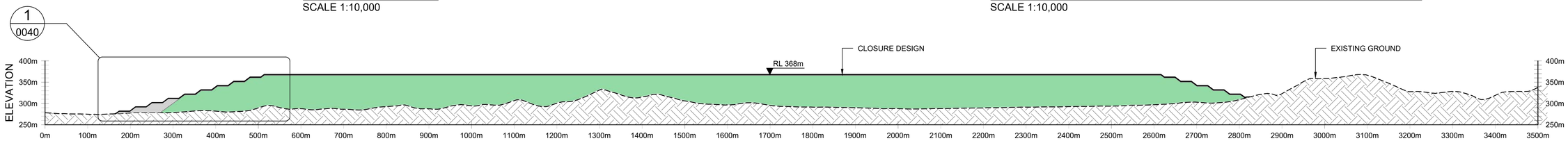


CLOSURE LAYOUT
SCALE 1:10,000

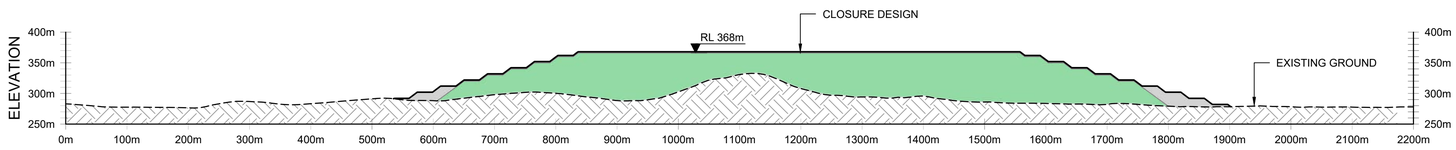


CLOSURE LAYOUT WITH ELEVATION HEAT MAP UNDERLAY
SCALE 1:10,000

HEAT MAP LEGEND		
COLOUR	RL MIN.	RL MAX.
	266m	278m
	278m	283m
	283m	288m
	288m	295m
	295m	306m
	306m	321m
	321m	356m
	356m	422m



SECTION A
SCALE: 1:5000



SECTION B
SCALE: 1:5000

LEGEND:
- STREAM CENTRELINE
- DRY REJECTS
- OXIDE WASTE ROCK

NOTE:
TOPOGRAPHICAL SURFACE BASED ON SURVEY FILE 'Topo_All_16_01_2015_0RL.xyz'

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SCALE 1:5,000 (100 0 100 200 300 400 500)

CONTOUR INTERVALS U.N.O.
EXISTING TOPOGRAPHY: 5m & 25m
DESIGN TOPOGRAPHY: 5m & 25m

COORDINATE SYSTEM
HORIZONTAL DATUM: MGA50
VERTICAL DATUM: GDA94

CLIENT REVIEW
PLOTTED: Friday, 26 April 2019 11:06:43 AM

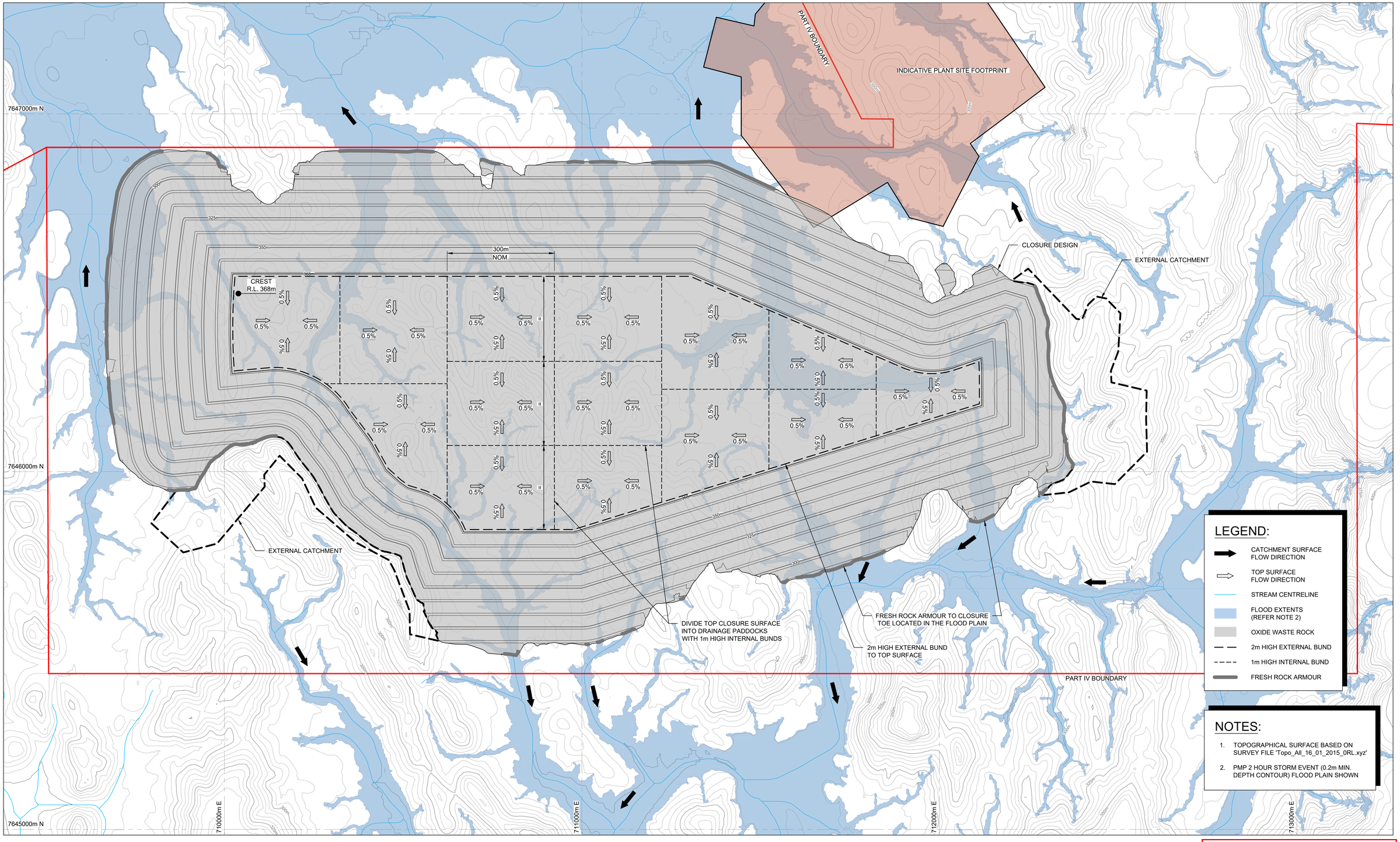
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		A	15.04.19	ISSUED FOR CLIENT REVIEW	TREV	MORE	THOM	THOM			

IRON BRIDGE
srk consulting
NORTH

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VENDOR/DESIGNER DRG No.: IBO057-0030
REV:
PROJECT NUMBER: FMG057
Fortescue Metals Group Ltd
DRY REJECTS STOCKPILE CONCEPTUAL CLOSURE LAYOUT & SECTIONS
A1
SCALE
DRG No.: 0030
REV: B

FILE: P:\FMG057 - IRON BRIDGE STOCKPILE DETAILED DESIGN\04_WORKING_FILES_IDRAFTING\00 - DRAWINGS\01 - SHEETS\FMG057-0030.DWG
PLOTTED: Friday, 26 April 2019 11:06:43 AM



CLOSURE WATER MANAGEMENT PLAN

SCALE 1:5,000

100 0 100 200 300 400 500
SCALE 1:5,000

CONTOUR INTERVALS U.N.O.
EXISTING TOPOGRAPHY: 5m & 25m
DESIGN TOPOGRAPHY: 5m & 25m

COORDINATE SYSTEM
HORIZONTAL DATUM: MGA50
VERTICAL DATUM: GDA94

CLIENT REVIEW
PLOTTED: Friday, 26 April 2019 11:07:09 AM

VENDOR/DESIGNER DRG No.: IBO057-0035
REV:

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		A	15.04.19	ISSUED FOR CLIENT REVIEW	TREV	MORE	THOM	THOM			

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PROJECT NUMBER: FMG057

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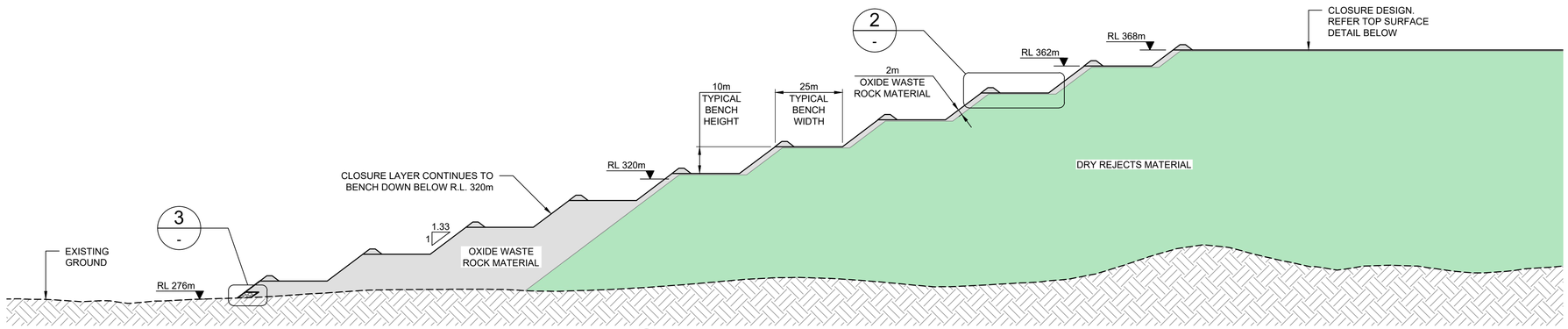
Fortescue Metals Group Ltd

DRY REJECTS STOCKPILE
CONCEPTUAL CLOSURE WATER MANAGEMENT PLAN

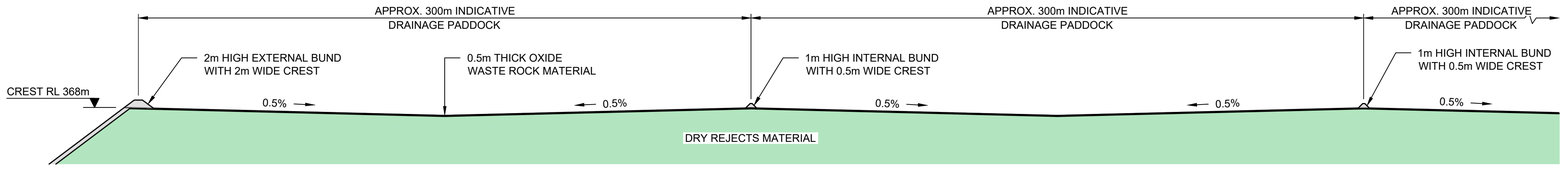
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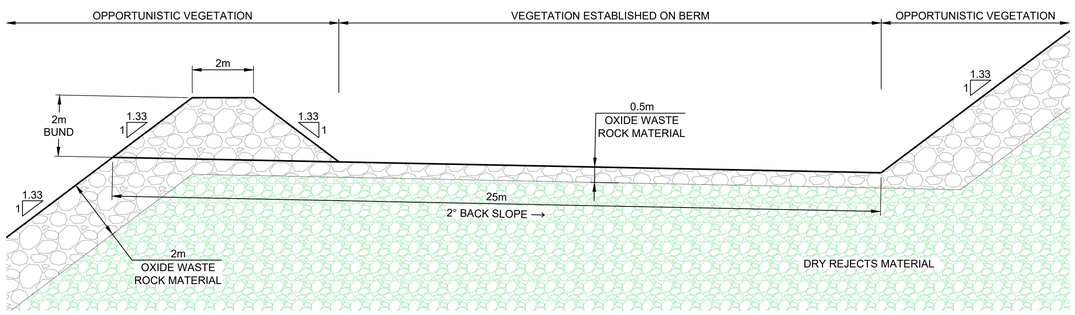
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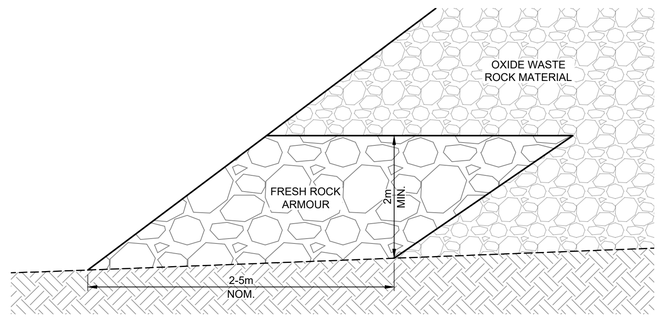
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SCALE 1:1,000



CLOSURE TOP SURFACE DETAIL
N.T.S.



2 / - CLOSURE BENCH DETAIL
SCALE 1:100



3 / - CLOSURE TOE ROCK ARMOUR DETAIL
SCALE 1:50

20 0 20 40 60 80 100
SCALE 1:1,000

2 0 2 4 6 8 10
SCALE 1:100

1 0 1 2 3 4 5
SCALE 1:50

CLIENT REVIEW
PLOTTED: Wed□esday, 8 May 2019 10:00:14 AM

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		A	15.04.19	ISSUED FOR CLIENT REVIEW	TREV	MORE	THOM	THOM			

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VENDOR/DESIGNER DRG No.: IBO057-0040
REV:

PROJECT NUMBER: FMG057

Fortescue Metals Group Ltd

DRY REJECTS STOCKPILE CONCEPTUAL CLOSURE DETAILS

A1 | SCALE | DRG No.: 0040 | REV.: C

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PLOTTED: Wed□esday, 8 May 2019 10:00:14 AM

Appendix B: Material characterisation

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Project Memo

Client:	Fortescue Metals Group	**Date:**	22 January 2019
Attention:	Daniel Dwumfour	**From:**	Nick Thompson/ Andrew Lim
Project No:	FMG057	**Revision No:**	1
Project Name:	Iron Bridge Stockpile Detailed Design		
Subject:	Coarse Rejects Material Characterisation		

1 Introduction

SRK Consulting (Australasia) Pty Ltd (SRK) was appointed by Fortescue Metals Group (FMG) to undertake a detailed design of a coarse rejects stockpile to support the Iron Bridge Magnetite Project Feasibility Study and Mining Proposal Application.

As part of the design, a laboratory testing program was carried out to define the geotechnical characteristics of the material.

This memorandum has been developed to provide the following:

- Summary of the laboratory testing program
- Interpretation of the laboratory testing results
- Summary of design parameters to be adopted.

Appendix A contains the laboratory reports by E-Precision Laboratory who carried out the testing.

2 Laboratory testing program

FMG delivered approximately 100 kg of dry coarse rejects to E-Precision Lab (EPL) for the geotechnical testing.

The laboratory tests undertaken by EPL included:

- Particle size distribution (PSD) with hydrometer (1 test)
- Atterberg limits (1)
- Minimum-maximum relative density (1)
- Standard Proctor compaction (2)
- California bearing ratio (CBR) tests (4)
- Falling Head permeability (2)
- Constant Head permeability (1, with 3 confining pressures)
- One dimensional consolidation using oedometer (1)
- Multi-stage direct shear (1, with 3 confining pressures)
- Single-stage consolidated undrained (CU) triaxial (5)
- Single-stage consolidated drained (CD) triaxial (5).

3 Interpretation of laboratory resting results

3.1 Particle size distribution (PSD) with hydrometer

EPL constructed a design PSD specified by FMG (Figure 3-1). This sample grading was used for all tests undertaken.

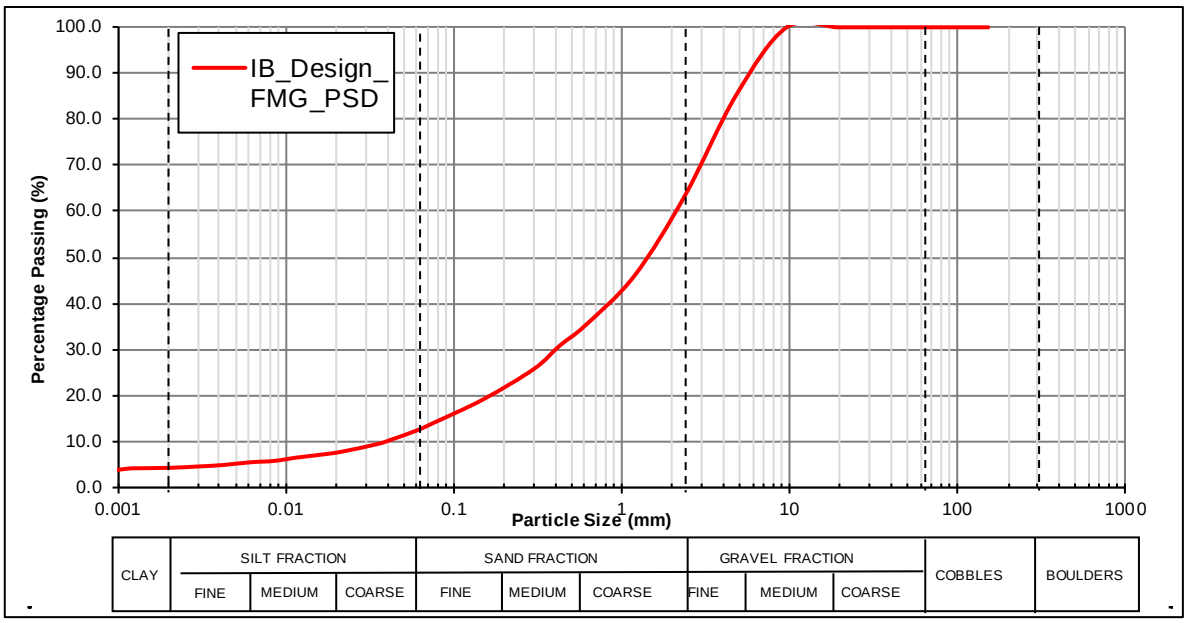


Figure 3-1: Particle size distribution of coarse rejects samples

Note: Grading cut-offs are based on AS 1726:2017.

The sample is coarse-grained with approximately 86% of material greater than 75 µm. The coarse fraction is split between 42.5% GRAVEL (>2.36 mm) and 57.5% SAND (<2.36 mm). The total fines content is approximately 14% with 9% silt and 5% CLAY. The fines content is >12% and the sample can be classified as SM: Sand-silt mixtures. The coarse rejects are well graded as the materials have coefficient of uniformity, Cu, >4 (Cu=58.4) and coefficient of curvature, Cc, within 1 and 3 (Cc=2).

3.2 Soil plasticity using Atterberg limits

One Atterberg limit test was completed on the sample. The result is classified using the Casagrande plasticity chart (Figure 3-2). The datum is located on the border line with CL-ML as well as located close to the border line of U-line such that the U-line is an upper bound for most natural soils. It behaves as CL material with low plasticity and may represent the unusual behaviour of fines content.

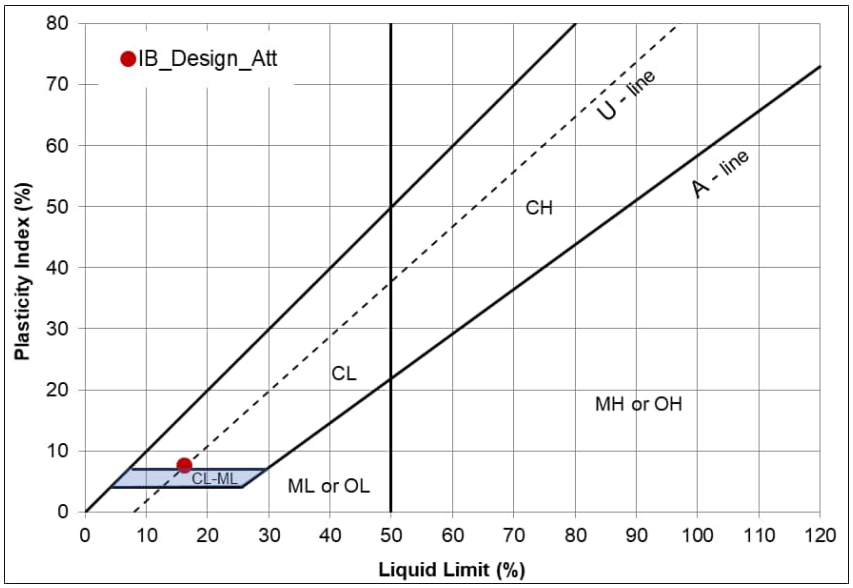


Figure 3-2: Casagrande plasticity chart

3.3 Relative density test and Proctor compaction tests

One maximum and minimum test and two Standard Proctor compaction tests were performed on the coarse rejects samples. The results are shown in Table 3-1.

Table 3-1: Relative density and moisture density relationship results

Tests	Soil parameters	Values
Relative density	Max dry density (t/m^3)	2.13
	Min dry density (t/m^3)	1.86
Standard Proctor	Max dry density (t/m^3)	2.13 (average)
	Optimum moisture content (%)	9

3.4 California Bearing Ratio tests

Four samples were prepared for California bearing ratio (CBR) tests in two conditions (soaked and unsoaked) at two different dry densities, 1.94 t/m^3 and 2.02 t/m^3, respectively. These specified densities corresponded to relative densities of 35% (loose state) and 60% (medium dense state), respectively. The results are shown in Table 3-2.

Table 3-2: Results of CBR tests

Test ID	Dry density (t/m^3)	CBR value (%)	Conditions
SCBR_1.94	1.94	10	Soaked
SCBR_2.02	2.02	18	
UCBR_1.94	1.94	11	Unsoaked
UCBR_2.02	2.02	30	

The CBR test is used to evaluate mechanical strength of the surface; the harder the surface, the higher the rating. However, it still provides useful additional information for material like the coarse rejects.

It is observed that samples with higher dry density have higher CBR values compared to samples with lower dry density. Additionally, unsoaked samples have higher CBR values compared to soaked samples for a given dry density. This is to be expected.

These values indicate that the stacker (driving on tracks) should be able to traffic across the rejects surface following rainfall.

3.5 Constant head triaxial and falling head permeability tests

Two samples were remoulded (minimum and maximum dry density) for the falling head, and one sample remoulded to the minimum dry density for the constant head; both tests at 3.0% moisture content. For the constant head, the sample was confined to three different pressures of 250 kPa, 1,000 kPa and 2,000 kPa, respectively, in a triaxial device.

Figure 3-3 shows the permeability results for various conditions from both testing methods. The permeability from falling head tests obtained were of 2.4×10^{-6} m/s for the sample at minimum dry density and 8.3×10^{-7} m/s for sample at maximum dry density. The permeability from constant head tests, were 4.6×10^{-8} m/s for 250 kPa confining pressure, 2.0×10^{-8} m/s for 1,000 kPa confining pressure and 8.1×10^{-9} m/s for 2,000 kPa confining pressure.

Based on the properties of the material (such as PSD and Atterberg limits), SRK considers the falling head test results are more representative of what will be encountered in the field.

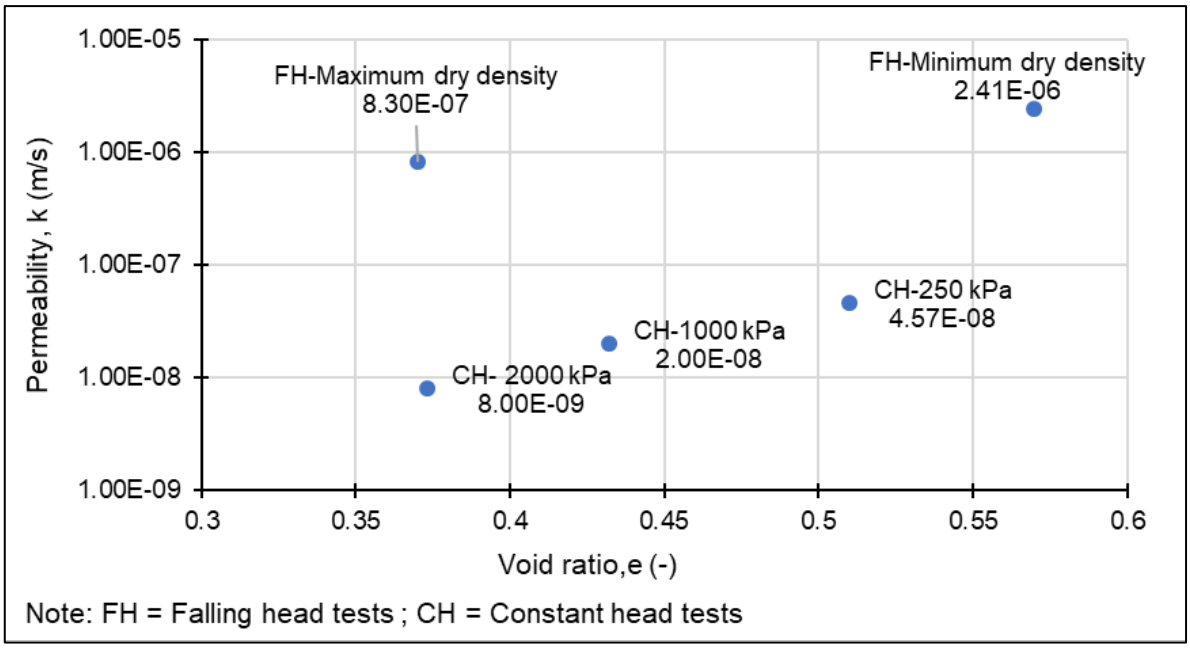


Figure 3-3: Permeabilities from constant head and falling head tests

3.6 Consolidation properties from one-dimensional consolidation

One sample was prepared at a minimum density with 3% moisture content and consolidated up to eight stages (Figure 3-4). Plots with the coefficient of consolidation and compressibility with effective vertical stress are presented in Figure 3-5. These indicate that the material is of low compressibility, as the void ratio reduces from 0.54 (equivalent to the minimum dry density) to 0.37 (almost at the maximum dry density), suggesting there will be limited settlement of the material in the stockpile.

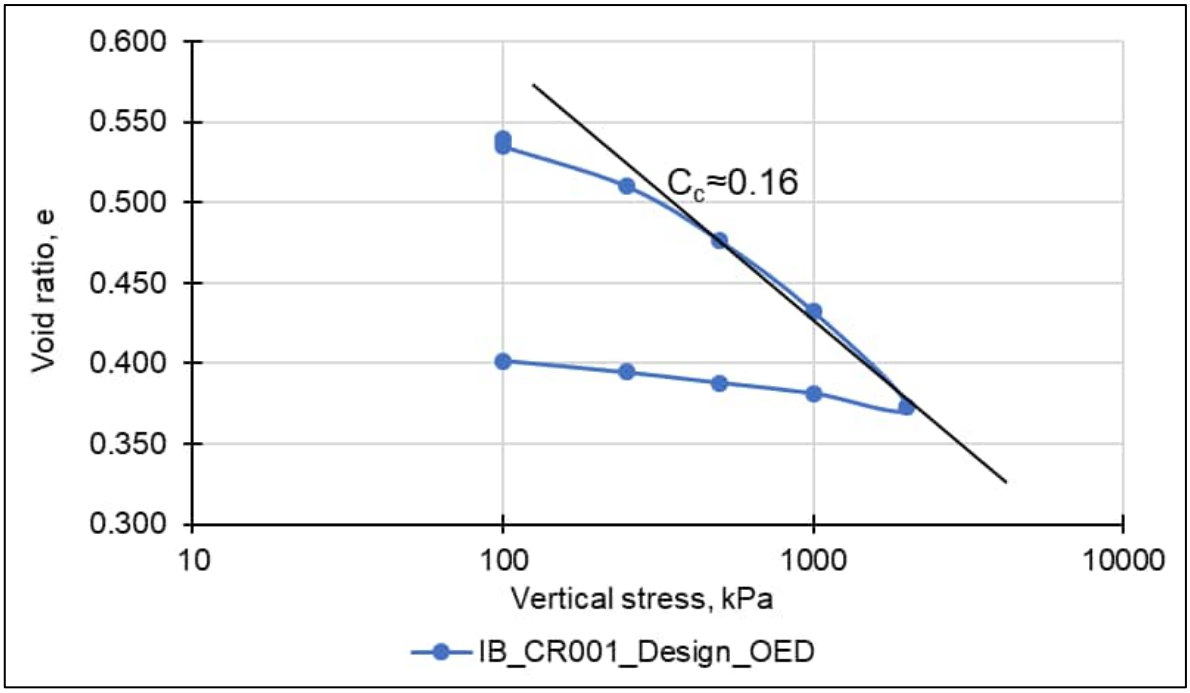


Figure 3-4: Compressibility curve from oedometer test (using EPL raw data)

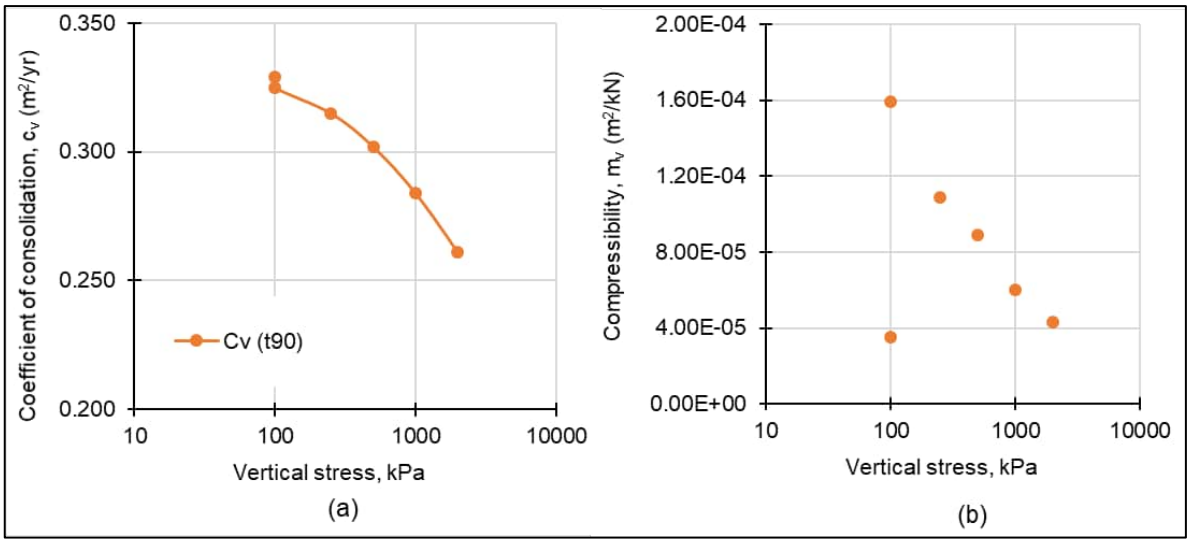


Figure 3-5: Consolidation properties: (a) Coefficient of consolidation and (b) compressibility

A compression index (C_c) value of 0.16 is obtained from the compression curve by estimating the slope of the normal compression line. As expected, the coefficient of consolidation (c_v) reduces as the stress level increases. For c_v based on 90% primary consolidation, c_v ranges between 0.33 and 0.26, a difference of 0.07. Hence, an average value of 0.3 for the coefficient of consolidation is selected. Compressibility reduces with effective stress and is in the order magnitude of 1 $\times 10^{-4}$ to 1 $\times 10^{-5}$.

3.7 Shearing properties using multi-stage drained direct shear tests

A multi-stage drained direct shear test was performed on a sample prepared at minimum dry density and 3.0% moisture content. The sample was sequentially confined to three confining pressures (Stage 1 - 100 kPa, Stage 2 - 200 kPa and Stage 3 - 400 kPa), alternating a shearing phase up to 15% of strain for every phase. Peak and ultimate shear stress obtained for each stage are plotted in Figure 3-6 and estimated effective shear strength parameters are shown in Table 3-3. The peak friction angle is approximately 46° and the residual friction angle is approximately 44°. Even when interception of the failure line with the zero normal stress indicated some cohesion, SRK has discarded it as the material is uncemented.

SRK notes that given that the sample has been fully sheared to failure (to obtain residual strength) prior to the application of the subsequent confinement pressure, the interpretation of these results is not standard, and therefore may not be comparable to results obtained from triaxial testing.

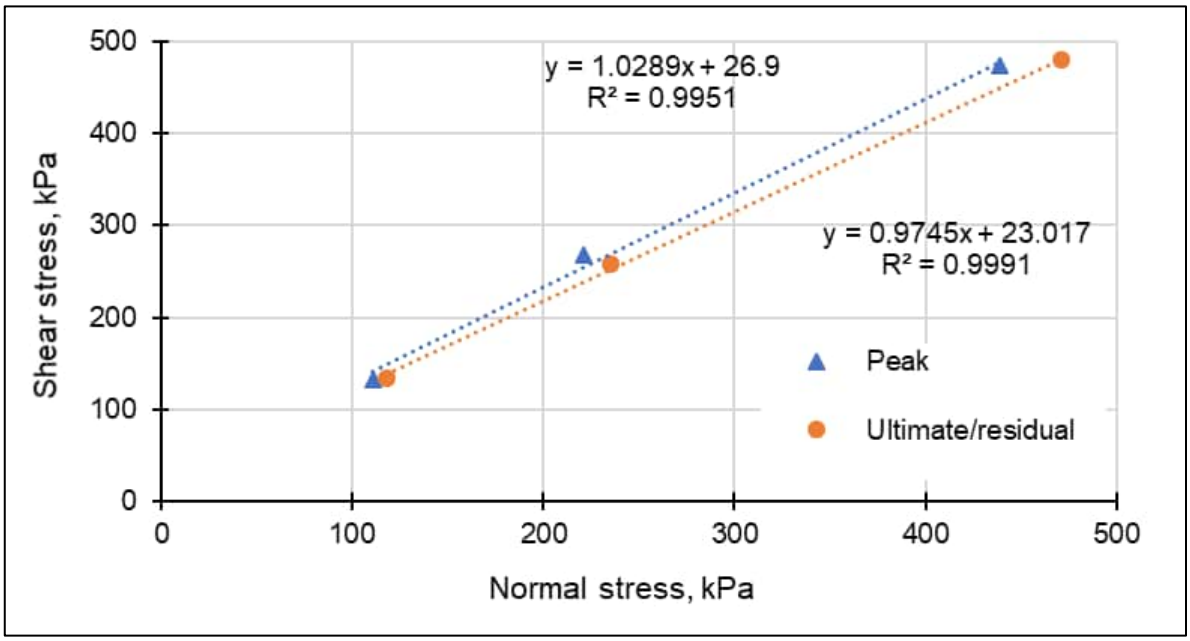


Figure 3-6: Peak/ ultimate normal stress vs shear stress curves (using EPL raw data)

Table 3-3: Strength parameters obtained from multi-stage direct shear tests

Strength	Obtained values	
	Cohesion, c (kPa)	Shear angle, φ (°)
Peak	0	46
Ultimate/ residual	0	44

3.8 Strength properties based on consolidated undrained and drained triaxial tests

Five consolidated undrained (CU) triaxial test and five consolidated drained (CD) triaxial tests were performed at five different confining effective stresses – 50 kPa, 100 kPa, 250 kPa, 500 kPa and 1000 kPa.

Figure 3-7 and Figure 3-8 show the variation of stress ratio, q/p', with strain for every stage in the CU and CD tests. Although the stress ratio curves indicate a continuing upwards trend and do not show peaks (due to the tests being stopped at relatively low strains), maximum ranges have been interpreted from pore pressure and volume reduction.

Based on the available data, the true peak strength may be higher if the test had been allowed to continue to higher strain.

For CU tests, the peak values of the stress ratio range from 1.7 to ~2.3, while for CD tests, it ranges between 1.9 and 2.1. The peak ratios for CU tests correspond to the peak friction angles ranging from 42° to 56°, while the peak ratio for CD tests correspond to the peak friction angles ranging from 46° to 50°

SRK considers that because the shearing of the specimen stopped at low strain, development of fully sheared planes was not established, and residual strengths therefore could not be measured.

Figure 3-9 shows the Mohr circles for all the triaxial tests – either drained or undrained shearing – using principal stresses at failures as reported by EPL. Two failure envelopes were estimated based on the Mohr circles drawn which have peak friction angles of 42° and 44°.

Based on the q/p' stress ratio and Mohr circles from interpretation of the direct shear and triaxial data, SRK selected an effective friction angle of 44° with zero cohesion.

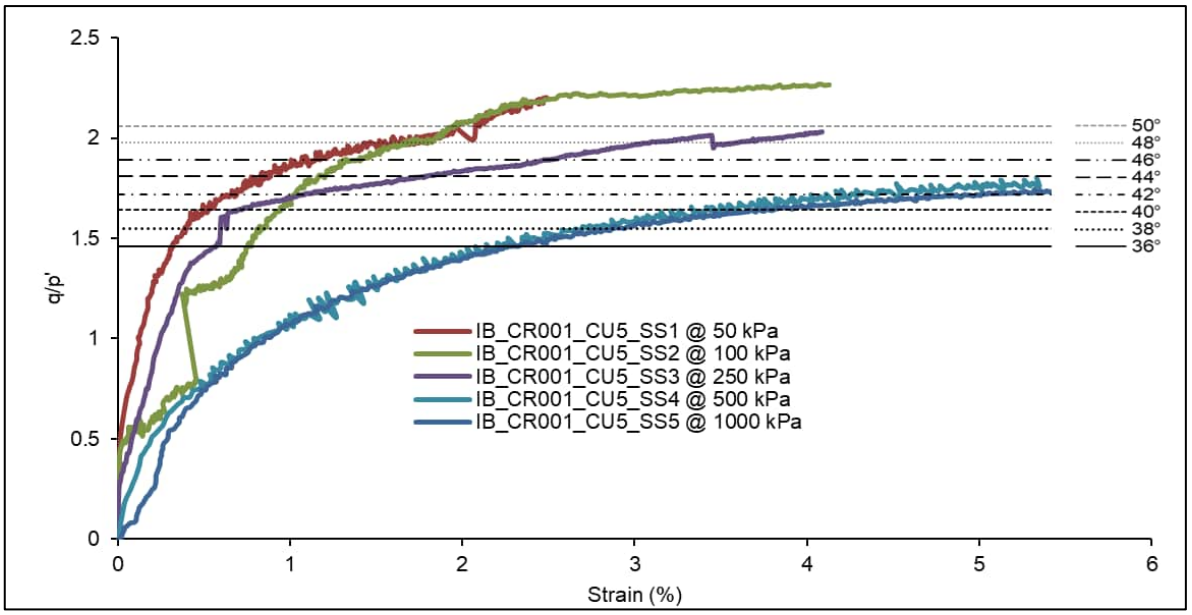


Figure 3-7: Stress ratio with strain for CU triaxial tests

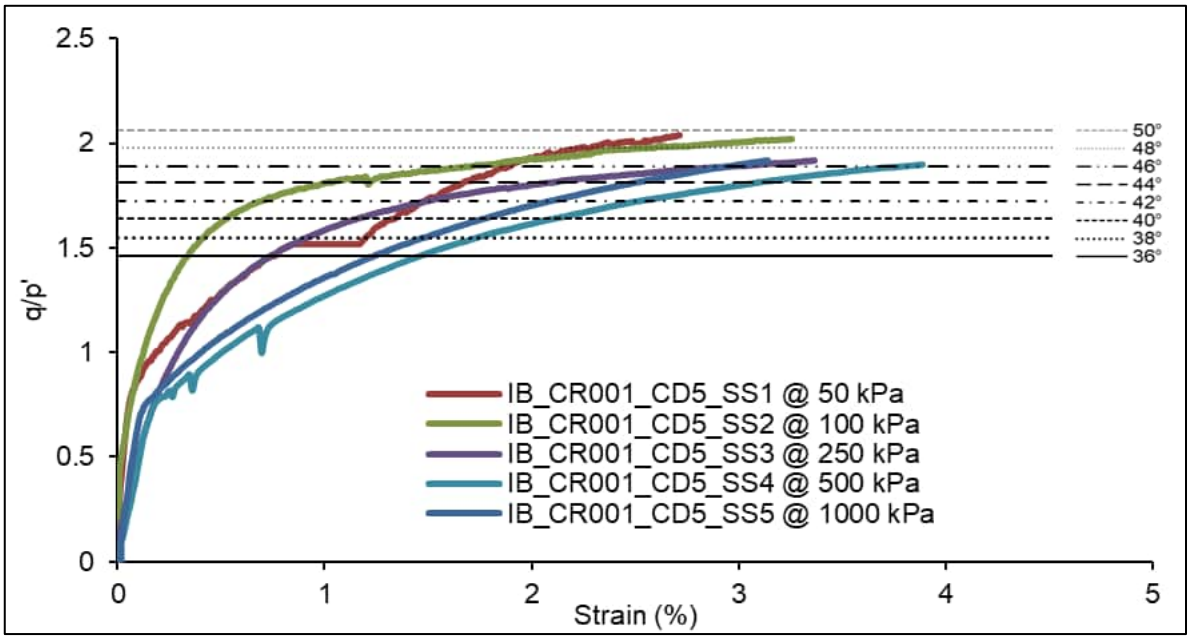


Figure 3-8: Stress ratio with strain for CD triaxial tests

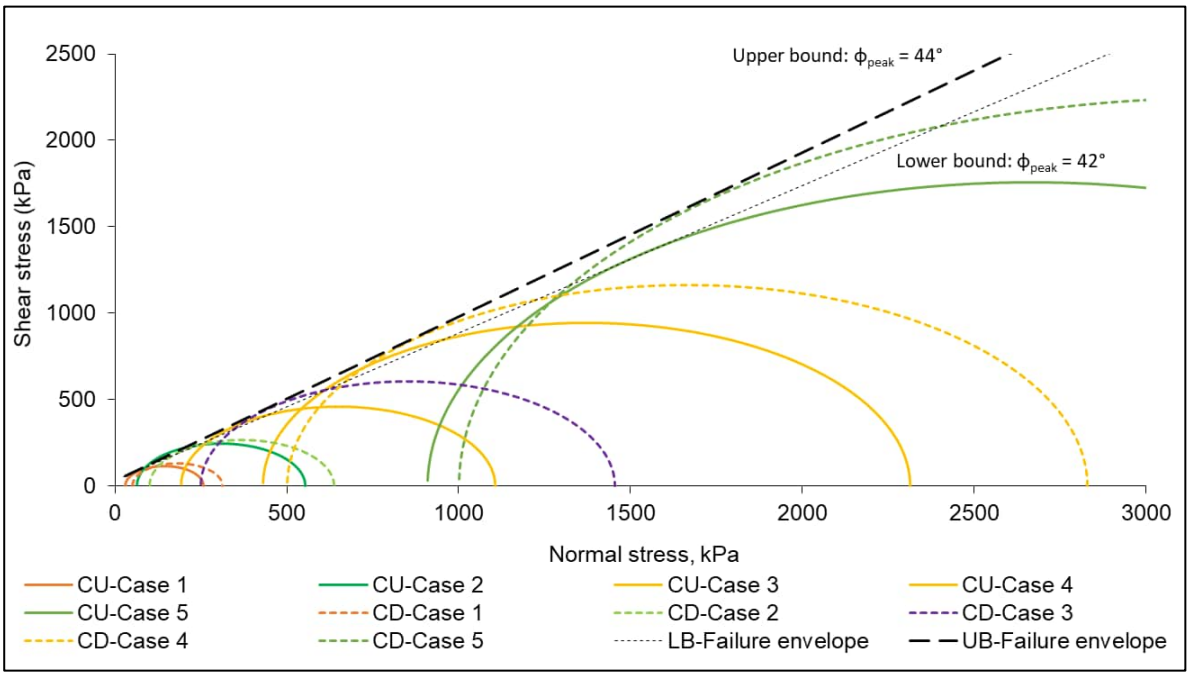


Figure 3-9: Mohr-Coulomb failure envelopes

4 Summary of design parameters to be used

The geotechnical parameters to be adopted in the design of the stockpile are presented in Table 4-1.

Based on the laboratory data provided, SRK can proceed with the design of the stockpile. However, for robustness of the geotechnical interpretation of the shear strength parameters, SRK recommends CU triaxial tests be repeated with shearing to higher strain levels, aligned with the AS 1289.6.4.2.2016.

Table 4-1: Design parameters based on laboratory test data

Properties	Sub-properties	Design Values	Units	Comments
PSD	% Clay	5	%	Based on Australian Standards
	% Silt	9	%	
	% Sand	50	%	
	% Gravel	36	%	
Atterberg limits	Liquid limit, w_L	16.2	%	Fines fraction is low plasticity
	Plasticity index, I_p	8.5	-	
Density	Minimum dry density, $\rho_{dry,min}$	1.86	t/m^3	
	Maximum dry density $\rho_{dry,max}$	2.13	t/m^3	
Permeability	Value at min density, $k_{\rho,min}$	2.4×10^{-6}	m/s	Using results from falling head test
	Value at max density, $k_{\rho,max}$	8.3×10^{-7}	m/s	
Consolidation	Compression index, C_C	0.16	-	Average interpreted value
	Coefficient of consolidation, c_v	0.3	m^2/yr	Average interpreted value
	Compressibility	8.0×10^{-5}	m^2/kN	Average value
Strength	Effective friction angle, φ_{peak}	44	°	Interpreted value
	Cohesion, c	0	kPa	No cohesion for uncemented materials

Yours faithfully

SRK Consulting (Australasia) Pty Ltd

Signed by:



Nick Thompson
Senior Consultant

Signed by:



Pepe Moreno
Principal Consultant

Appendix A: Laboratory reports by E-Precision Laboratory

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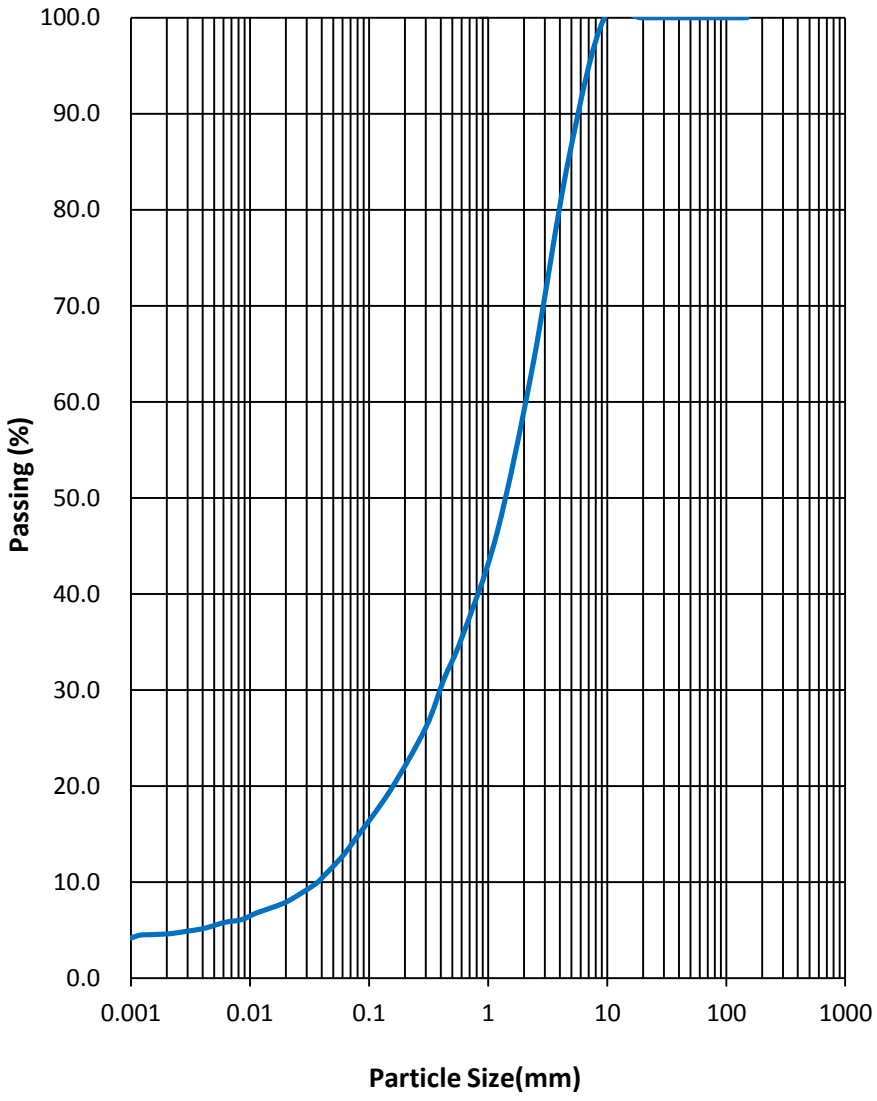
PARTICLE SIZE DISTRIBUTION TEST REPORT

Test Method: AS 1289 3.6.3, 3.5.1

Client:	Fortescue Metals Group	Date Tested:	26/11/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design PSD	Depth(m):	-
Lab ID:	IB_DESIGN_FMG_PSD	Room Temperature at Test:	19°C
Tested by:	Raymond	2.36mm Particle Density (t/m³):	2.91
Checked by:	Phil		

Sieve Size (mm)	Passing %
150	100.0
75	100.0
53	100.0
37.5	100.0
26.5	100.0
19	100.0
9.5	100.0
4.75	85.3
2.36	63.6
1.18	46.2
0.6	35.4
0.425	31.1
0.3	26.1
0.15	19.5
0.075	14.3
0.05896	12.6
0.04213	10.7
0.03543	9.8
0.02144	8.1
0.01658	7.5
0.01143	6.8
0.00852	6.1
0.00611	5.8
0.00417	5.2
0.00301	4.9
0.00201	4.6
0.00122	4.5
0.00113	4.4
0.00101	4.2
0.00089	4.0

PSD Graph



Notes:
Stored and Tested the Sample as received
Samples supplied by the Client

NATA: 19078

Authorized Signature:

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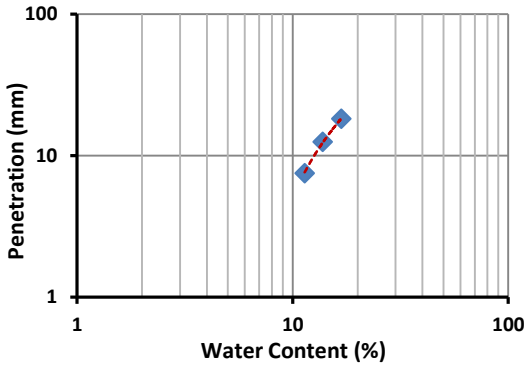
ATTERBERG LIMITS TEST REPORT

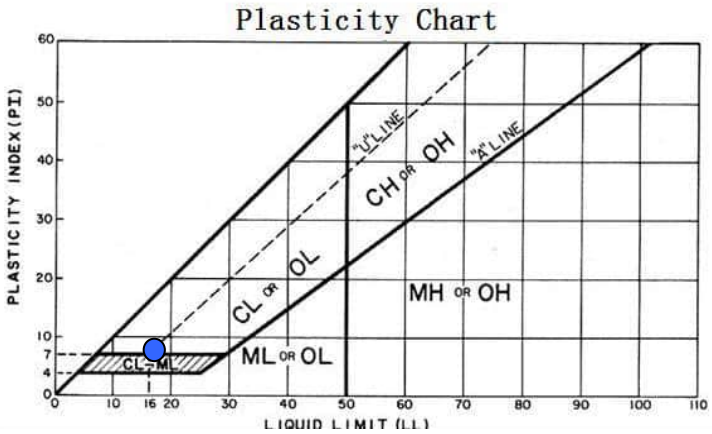
Test Method: BS1377 AS1289.2.1.1 7.1.1 3.1.1 3.2.1 3.4.1

Client:	Fortescue Metals Group	Date Tested:	26/11/2018
Project:	Iron Bridge Coarse Rejects	Lab:	EPLAB
Sample No:	Design PSD	Job Number:	FMG
Lab ID:	IB_DESIGN_ATT		
Depth(m):	-	Room Temperature at Test:	19°C
Tested by:	Phil	Sample Description:	-
Moisture Content (%):	-	Wet Density (t/m³):	-
		Dry Density (t/m³):	-

Liquid Limit (%):	16.16
Plastic Limit (%):	8.52
Plasticity Index (%):	7.64
Liquidity Index (%):	-
Shrinkage Limit (%):	7.74
Linear Shrinkage(%):	3.93

Results Chart





Notes: The sample/s were tested oven dried, dry sieved and in a 125-250mm mould.

Stored and Tested the Sample as received

Samples supplied by the Client NATA: 19078 **Authorised Signature:**

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E-Precision Laboratory

RELATIVE DENSITY TEST REPORT

Test Method: AS1289 5.5.1

Client:	Fortescue Metals Group	Date Tested:	23/11/2018
Project:	Iron Bridge Coarse Rejects	Date Reported:	28/11/2018
		EP Lab Job Number:	FMG

Lab: EPLAB
Tested by: Phil

Lab ID:	IB_DESIGN_MAX_MIN				
Test Type:	MAX / MIN DENSITY				
Depth (m):	-				
Lithology/Description:	-				
Moisture Content (%):	-				
Max Dry Density (t/m³)	**2.134**				
Min Dry Density (t/m³)	**1.860**				

Notes:
Stored and Tested the Sample as received

Samples supplied by the Client

Authorised Signatory (Geotechnical Engineer):

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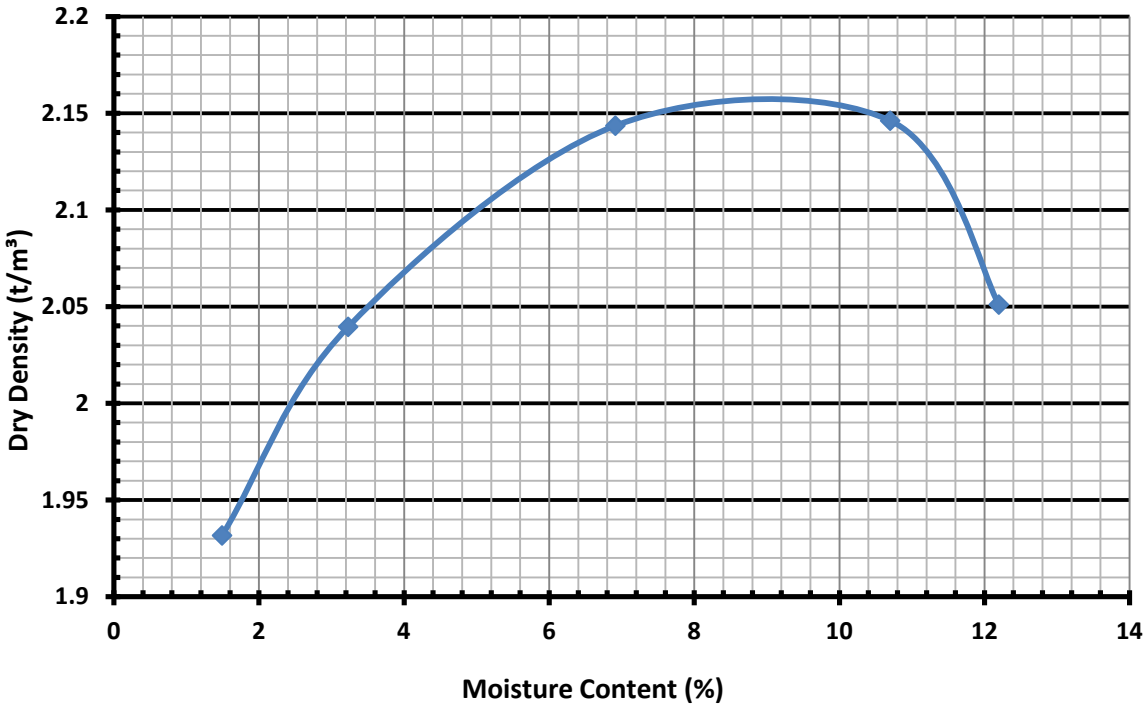
MOISTURE DENSITY RELATIONSHIP REPORT

Test Method: AS1289.5.1.1

Client:	Fortescue Metals Group	Date Tested:	25/11/2018
Project:	Iron Bridge Coarse Rejects	Lab:	EPLAB
Sample No:	Tailing Sample	Job Number:	FMG
Lab ID:	IB_DESIGN_SMDD		
Depth(m):	-	Room Temperature at Test:	20°C
Checked by:	Phil	Sample Description:	Tested in Mould A
Moisture Content (%):	-	Wet Density (t/m³):	-
		Dry Density (t/m³):	-

Results

Maximum Size (mm):	19.00	**Maximum Dry Density (t/m³):**	**2.120**
Oversize dry (%):	0.00	**Optimum Moisture Content (%):**	**9.00**



Notes:

Stored and Tested the Sample as received

Samples supplied by the Client

NATA: 19078

Authorised Signature:

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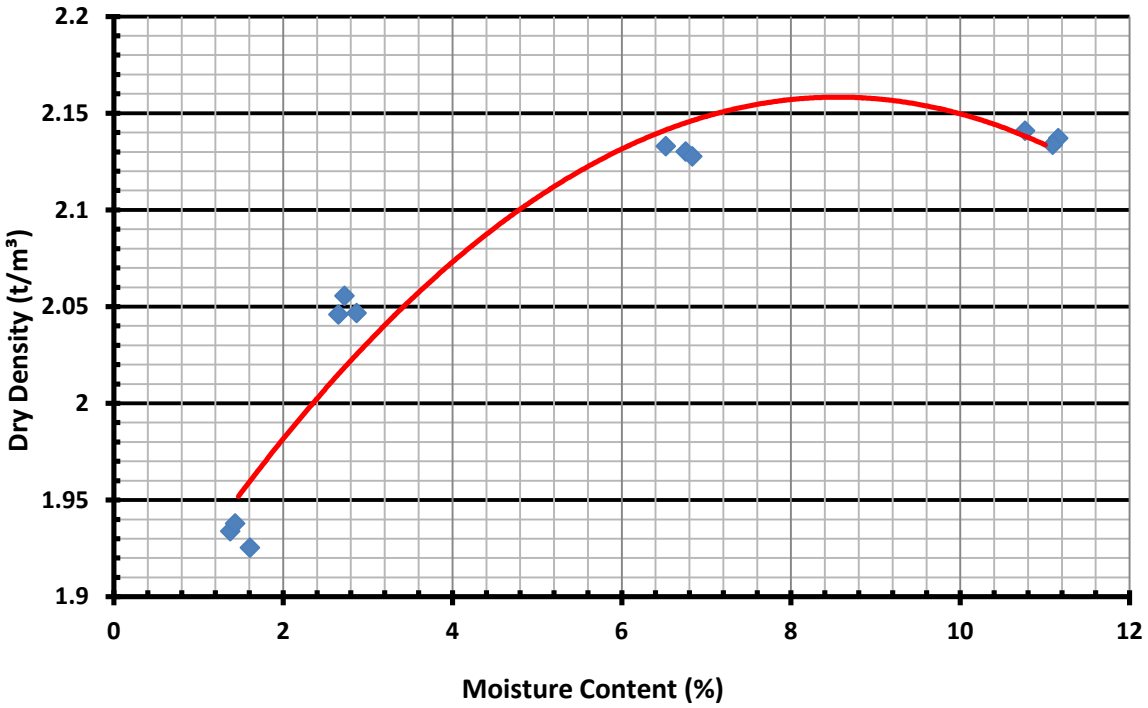
MOISTURE DENSITY RELATIONSHIP REPORT

Test Method: AS1289.5.1.1

Client:	Fortescue Metals Group	Date Tested:	2018/12/9
Project:	Iron Bridge Coarse Rejects	Lab:	EPLAB
Sample No:	Coarse Rejects Design Sample 2	Job Number:	FMG
Lab ID:	IB_DESIGN_2_SMDD		
Depth(m):	-	Room Temperature at Test:	20°C
Checked by:	Phil	Sample Description:	Tested in Mould A
Moisture Content (%):	-	Wet Density (t/m³):	-
		Dry Density (t/m³):	-

Results

Maximum Size (mm):	19.00	**Maximum Dry Density (t/m³):**	**2.150**
Oversize dry (%):	0.00	**Optimum Moisture Content (%):**	**9.00**



Notes: Sample tested via 3 points of MC per point

Stored and Tested the Sample as received

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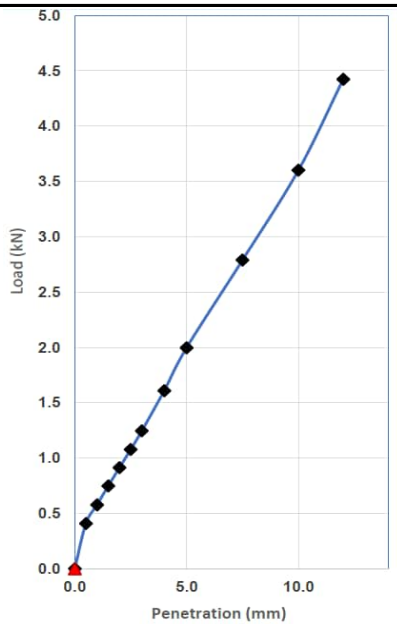
E-Precision Laboratory

CALIFORNIA BEARING RATIO REPORT

Test Method: AS1289 6.1.1

Client:	Fortescue Metals Group	Date Tested:	21/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Rejects	Lab:	EPLAB
Sample ID:	IB_CR001_DESIGN_SCBR_1.94		
Depth (m):	-	Room Temperature at Test:	22
Tested by:	Takahiro	**Sample Description:**	Coarse Rejects
Checked by:	Phil		

Max Dry Density (t/m³):	1.94
Optimal Moisture Content (%)	3
Compactive Effort:	Standard
Percentage of MDD (%):	As specified
Percentage of OMC (%):	100
Dry Density before Soak (t/m³)	1.93
Dry Density after Soak (t/m³)	1.95
Moisture before Soaking (%):	3.04
Moisture after Soaking (%):	11.36
Soak Condition:	Soaked
Soak Period (days):	4
Swell (%):	0
CBR Surcharge (kg):	4.5
Top 30mm moisture content (%)	8.8
Remaining moisture content (%)	11.4



Penetration Calculated @ (mm)	**5**
CBR Value (%):	**10**

Notes: ***Client supplied nominated density values for CBR remolding***

Stored and Tested the Sample as received

Samples supplied by the Client

NATA: 19078 **Authorised Signatory (Geotechnical Engineer):**

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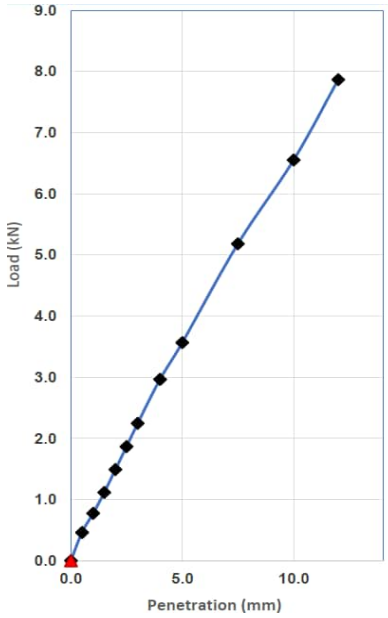
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CALIFORNIA BEARING RATIO REPORT

Test Method: AS1289 6.1.1

Client:	Fortescue Metals Group	Date Tested:	21/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Rejects	Lab:	EPLAB
Sample ID:	IB_CR001_DESIGN_SCBR_2.02		
Depth (m):	-	Room Temperature at Test:	22
Tested by:	Takahiro	**Sample Description:**	Coarse Rejects
Checked by:	Phil		

Max Dry Density (t/m³):	2.02
Optimal Moisture Content (%)	3
Compactive Effort:	Standard
Percentage of MDD (%):	As specified
Percentage of OMC (%):	100
Dry Density before Soak (t/m³)	2.01
Dry Density after Soak (t/m³)	2.02
Moisture before Soaking (%):	2.97
Moisture after Soaking (%):	10.65
Soak Condition:	Soaked
Soak Period (days):	4
Swell (%):	0
CBR Surcharge (kg):	4.5
Top 30mm moisture content (%)	9.4
Remaining moisture content (%)	11.8



Penetration Calculated @ (mm)	**5**
CBR Value (%):	**18**

Notes: ***Client supplied nominated density values for CBR remolding***

Stored and Tested the Sample as received

Samples supplied by the Client

NATA: 19078 **Authorised Signatory (Geotechnical Engineer):**

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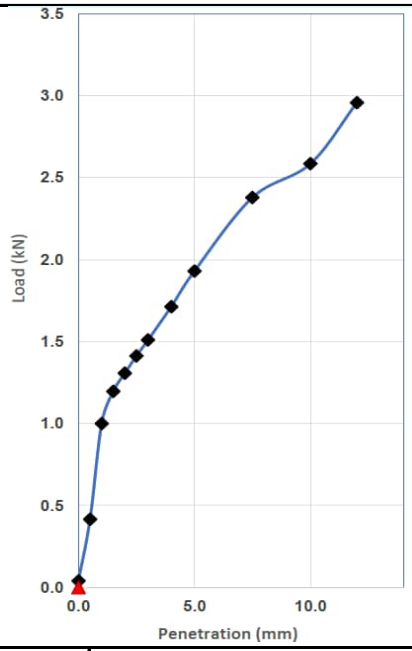
E-Precision Laboratory

CALIFORNIA BEARING RATIO REPORT

Test Method: AS1289 6.1.1

Client:	Fortescue Metals Group	Date Tested:	24/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Rejects	Lab:	EPLAB
Sample ID:	IB_CR001_DESIGN_UCBR_1.94		
Depth (m):	-	Room Temperature at Test:	20
Tested by:	Takahiro	**Sample Description:**	Coarse Rejects
Checked by:	Phil		

Max Dry Density (t/m³):	1.94
Optimal Moisture Content (%)	3
Compactive Effort:	Standard
Percentage of MDD (%):	As specified
Percentage of OMC (%):	100
Dry Density before Soak (t/m³)	1.92
Dry Density after Soak (t/m³)	1.94
Moisture before Soaking (%):	3.05
Moisture after Soaking (%):	-
Soak Condition:	Unsoaked
Soak Period (days):	-
Swell (%):	0
CBR Surcharge (kg):	4.5
Top 30mm moisture content (%)	1.9
Remaining moisture content (%)	2.5



Penetration Calculated @ (mm)	**5**
CBR Value (%):	**11**

Notes: ***Client supplied nominated density values for CBR remolding***

Stored and Tested the Sample as received

Samples supplied by the Client

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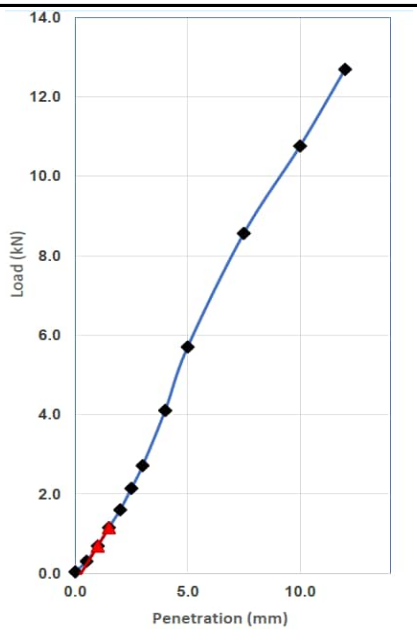
E-Precision Laboratory

CALIFORNIA BEARING RATIO REPORT

Test Method: AS1289 6.1.1

Client:	Fortescue Metals Group	Date Tested:	24/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Rejects	Lab:	EPLAB
Sample ID:	IB_CR001_DESIGN_UCBR_2.02		
Depth (m):	-	Room Temperature at Test:	20
Tested by:	Phil	**Sample Description:**	Coarse Rejects
Checked by:	Phil		

Max Dry Density (t/m³):	2.02
Optimal Moisture Content (%)	3
Compactive Effort:	Standard
Percentage of MDD (%):	As specified
Percentage of OMC (%):	100
Dry Density before Soak (t/m³)	2.03
Dry Density after Soak (t/m³)	2.03
Moisture before Soaking (%):	2.98
Moisture after Soaking (%):	-
Soak Condition:	Unsoaked
Soak Period (days):	-
Swell (%):	0
CBR Surcharge (kg):	4.5
Top 30mm moisture content (%)	2.2
Remaining moisture content (%)	2.7



Penetration Calculated @ (mm)	**5**
CBR Value (%):	**30**

Notes: ***Client supplied nominated density values for CBR remolding***

Stored and Tested the Sample as received

Samples supplied by the Client

NATA: 19078 **Authorised Signatory (Geotechnical Engineer):**

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E-Precision Laboratory

FALLING HEAD PERMEABILITY TEST REPORT

Test Method: AS1289 6.7.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	10/01/2019
Project:	Iron Bridge Coarse Rejects	Date Reported:	14/01/2019
Lab:	EPLAB	EP Lab Job Number:	FMG
Tested by:	Phil		
Checked by:	Phil		

Lab ID:	CR001_MIN_FH	CR001_MAX_FH		
Client ID:	Design Material Rejects	Design Material Rejects		
Depth (m):	-	-		
Cylinder Diameter (mm):	100	100		
Sample Conditions:	Minimum Dry Density @ 3% MC	Max Dry Density @ 3% MC		
Surcharge Pressure (kPa):	12.5	13.1		
Initial Dry Density (t/m³):	1.863	2.130		
Initial Moisture Content (%):	3.06	3.11		
Saturation (Skempton's B):	1.00	0.98		
K_{20} (10^{-6} m/s):	**2.407**	**0.831**		

Notes:
Stored and Tested the Sample as received
Samples supplied by the Client

NATA: 19078

Authorised Signatory (Geotechnical Engineer):

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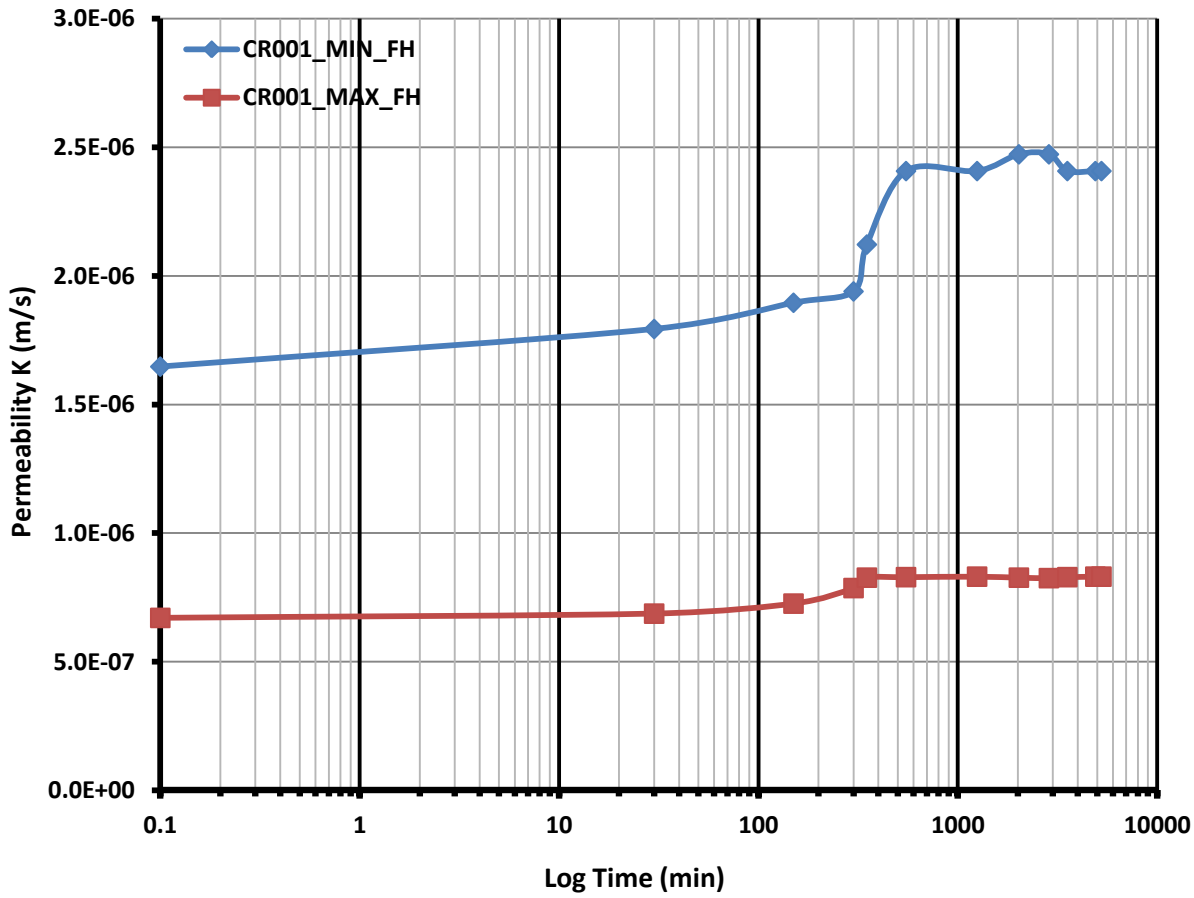
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E-Precision Laboratory

FALLING HEAD PERMEABILITY TEST REPORT

Test Method: AS1289 6.7.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	10/01/2019
Project:	Iron Bridge Coarse Rejects	Date Reported:	14/01/2019
Lab:	EPLAB	EP Lab Job Number:	FMG



Notes:

Stored and Tested the Sample as received

Samples supplied by the Client

Authorised Signatory (Geotechnical Engineer):

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E-Precision Laboratory

TRIAXIAL PERMEABILITY TEST REPORT

Test Method: AS1289 6.7.3 / KH. Head

Client:	Fortescue Metals Group	Date Tested:	14/12/2018
Project:	Iron Bridge Coarse Rejects	Date Reported:	29/12/2018
Lab:	EPLAB	EP Lab Job Number:	FMG
Tested by:	Phil		
Checked by:	Phil		

Lab ID:	IB_CR001_A_TP	IB_CR001_B_TP	IB_CR001_C_TP	
Client ID:	C1	C2	C3	
Sample Conditions:	Remolded to Min. Density 3% @ MC	Remolded to Min. Density 3% @ MC	Remolded to Min. Density 3% @ MC	
Effective Cell Pressure (kPa):	250	1000	2000	
Inlet Pressure / Outlet Pressure (kPa):	500 / 100	500 / 100	700 / 100	
Initial Bulk Density (t/m³):	1.91	1.92	1.92	
Initial Moisture Content (%):	3.06	3.11	3.02	
Dry Density (t/m³):	1.85	1.86	1.86	
Final Saturated Density (t/m³):	1.93	1.93	1.93	
Saturation (Skempton's B):	0.99	0.99	0.98	
K_{20} (m/s):	**$4.566\ E^{-8}$**	**$1.993\ E^{-8}$**	**$0.8073\ E^{-8}$**	

Notes:
Stored and Tested the Sample as received
Samples supplied by the Client
NATA: 19078

Authorised Signatory (Geotechnical Engineer):

The results of tests performed apply only to the specific sample at time of test unless otherwise clearly stated. Reference should be made to E-Precision Laboratory's "Standard Terms and Conditions" E-Precision Laboratory ABN 431 559 578 87

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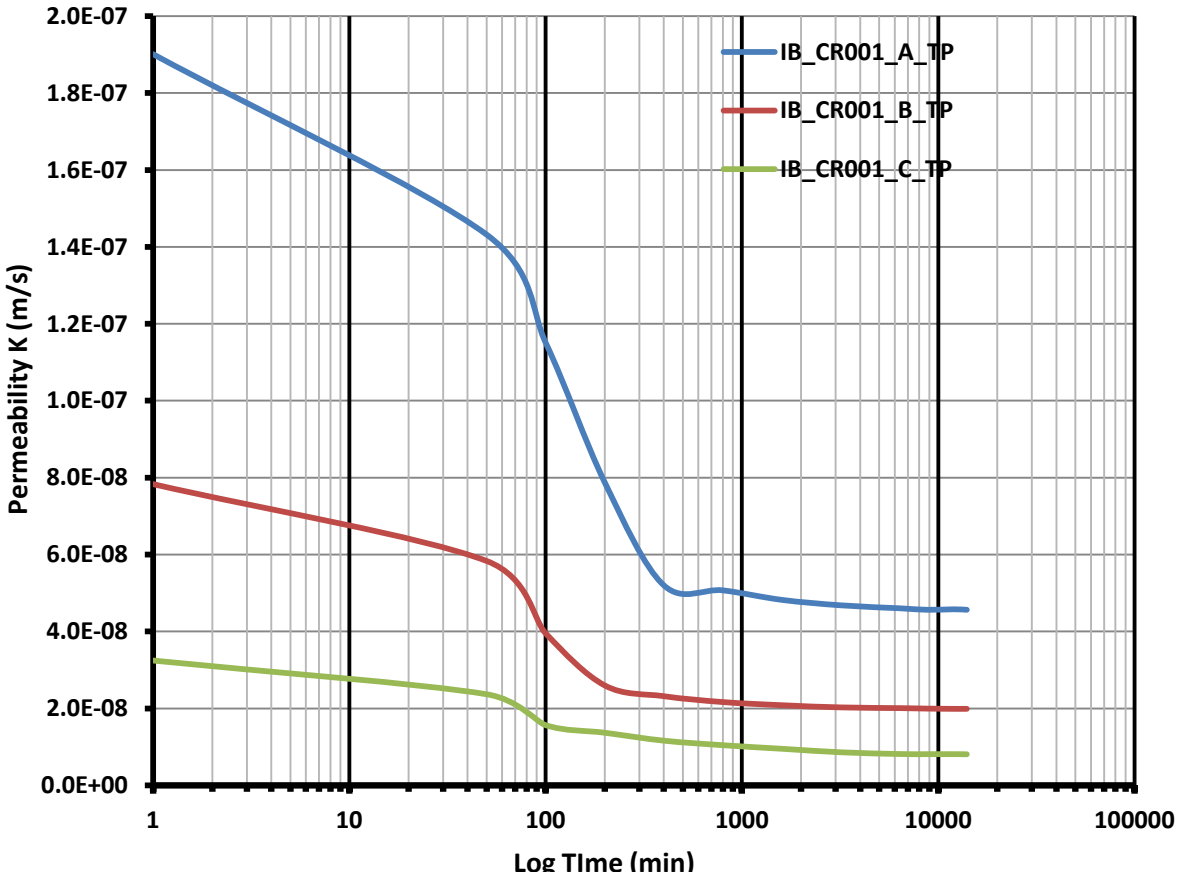
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E-PRECISION LABORATORY

TRIAXIAL PERMEABILITY TEST REPORT

Test Method: AS1289 6.7.3 / KH. Head

Client:	Fortescue Metals Group	Date Tested:	14/12/2018
Project:	Iron Bridge Coarse Rejects	Date Reported:	29/12/2018
Lab:	EPLAB	EP Lab Job Number:	FMG



Notes:

Stored and Tested the Sample as received

Samples supplied by the Client

Authorised Signatory (Geotechnical Engineer):

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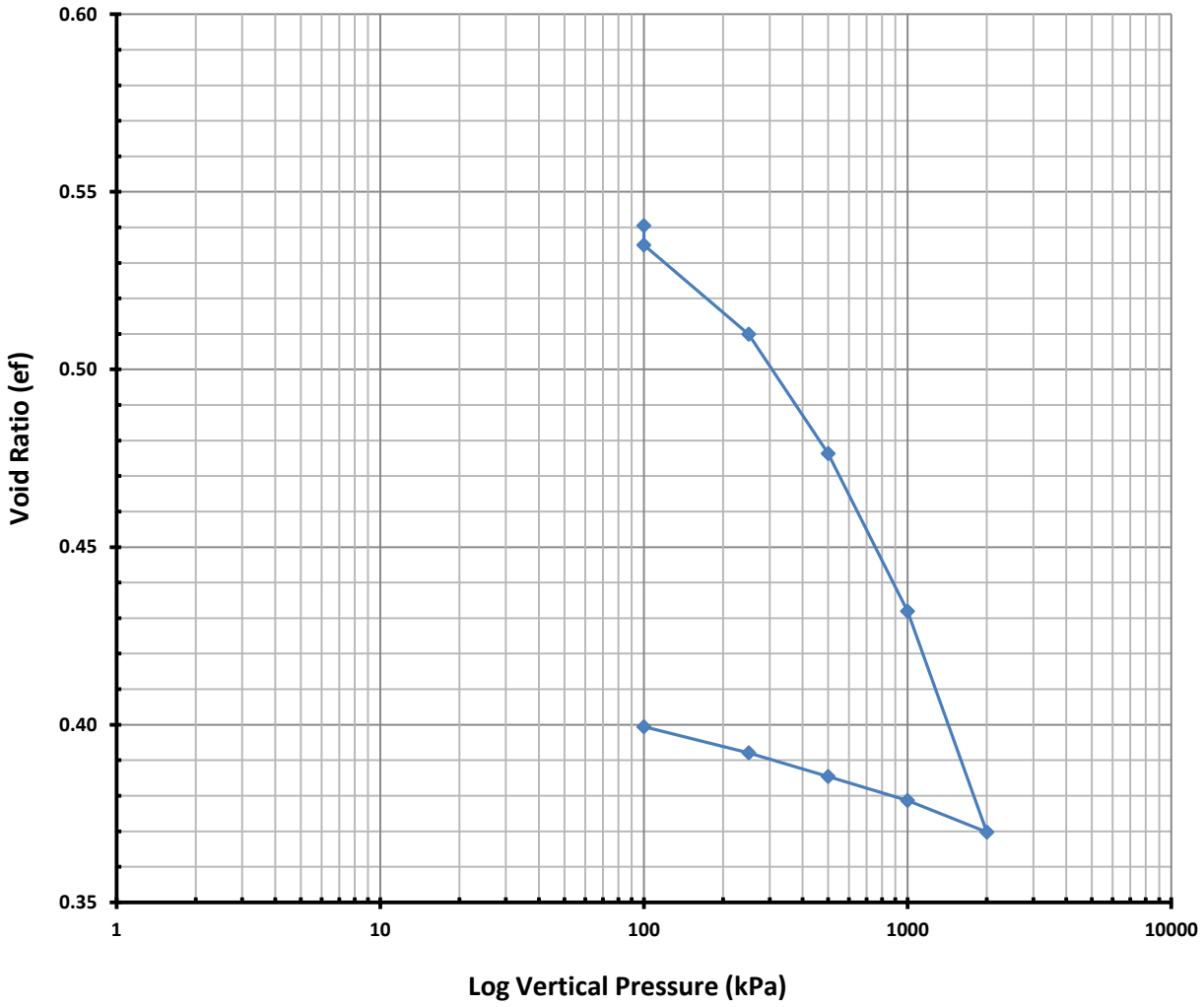
ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°c

Tested by:	Phil	Initial Moisture (%):	3.04	Test Condition:	As instructed
Height (mm):	19.01	Final Moisture Content (%):	8.49	Sample Condition:	Remolded
Diameter (mm):	61.80	Bulk Density (t/m³):	1.93	Particle Density (t/m³):	2.91
Direction:	Vertical	Dry Density (t/m³):	1.87	Sample Type:	-

Void Ratio (e_f) Vs Log of Vertical Pressure (kPa)



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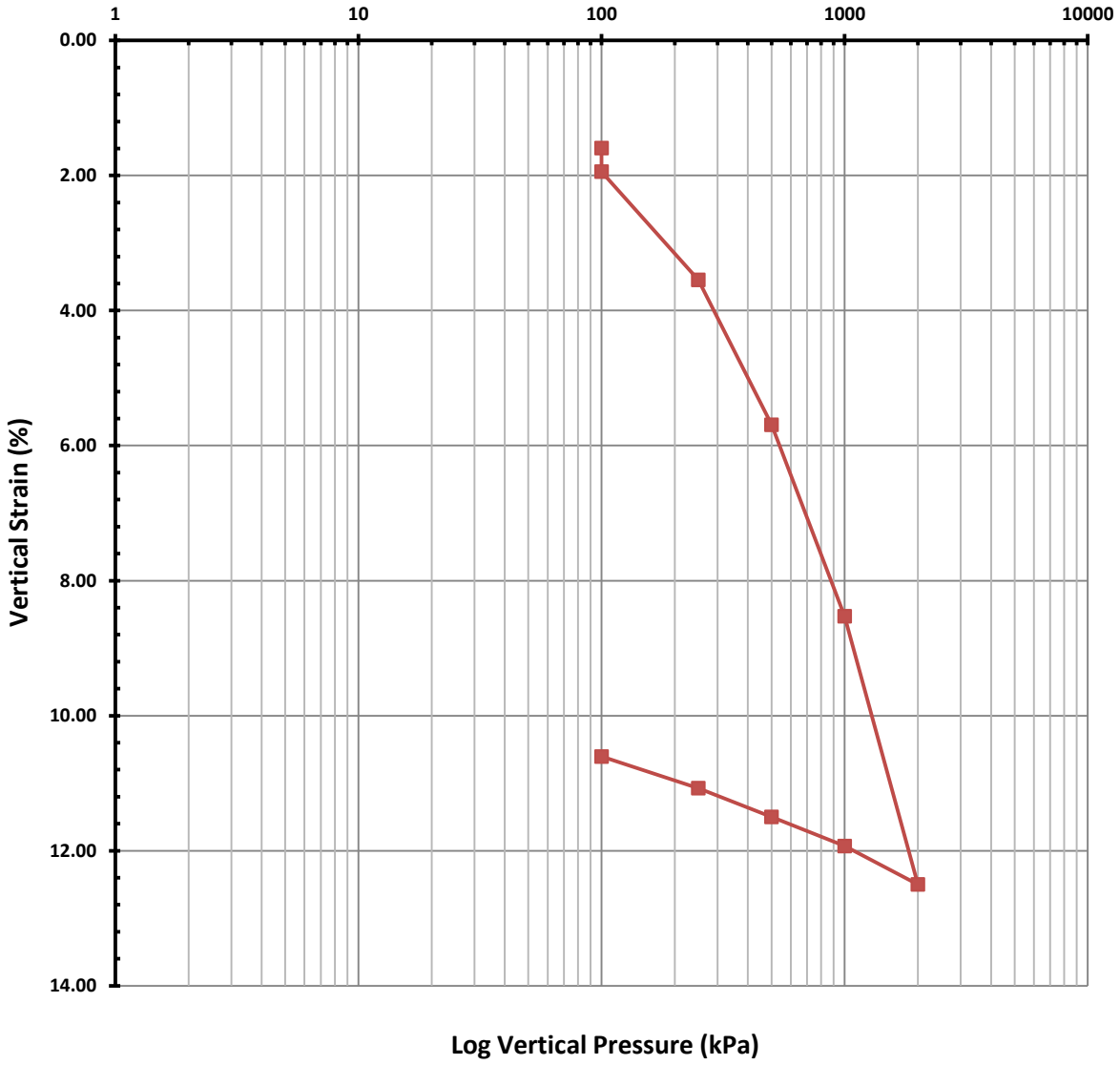
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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°c

Vertical Strain (%) Vs Log of Vertical Pressure (kPa)



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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C

Test Results

Stages	Vert Disp (mm)	Cv (m^2/yr)		Compressibility Mv (m^2/kN)	K (m/s)	Cα (10^{-3})	Void Ratio (e_f)	Vertical Strain (%)
		t_{50}	t_{90}					
Stage 1 @ 100kPa	0.30	0.915	0.329	1.59E-04	4.6E-11	15.94	0.540	1.59
Stage 2 @ 100kPa SAT	0.37	0.905	0.325	3.54E-05	1.0E-11	19.42	0.535	1.94
Stage 3 @ 250kPa	0.67	0.877	0.315	1.09E-04	3.0E-11	35.46	0.510	3.55
Stage 4 @ 500kPa	1.08	0.840	0.302	8.90E-05	2.4E-11	56.92	0.476	5.69
Stage 5 @ 1000kPa	1.62	0.791	0.284	6.01E-05	1.5E-11	85.27	0.432	8.53
Stage 6 @ 2000kPa	2.38	0.728	0.261	4.34E-05	1.0E-11	124.99	0.370	12.50
Unloading @ 1000kPa	2.27							
Unloading @ 500kPa	2.19							
Unloading @ 250kPa	2.11							
Unloading @ 100kPa	2.02							

Comments: **Sample saturated after 100kPa of initial loading**
Sample remolded to minimum dry density @ 3% MC

K (m/s) calculated based on Cv (t_{50})

Samples supplied by the Client

Authorised Signatory (Geotechnical Engineer): NATA: 19078

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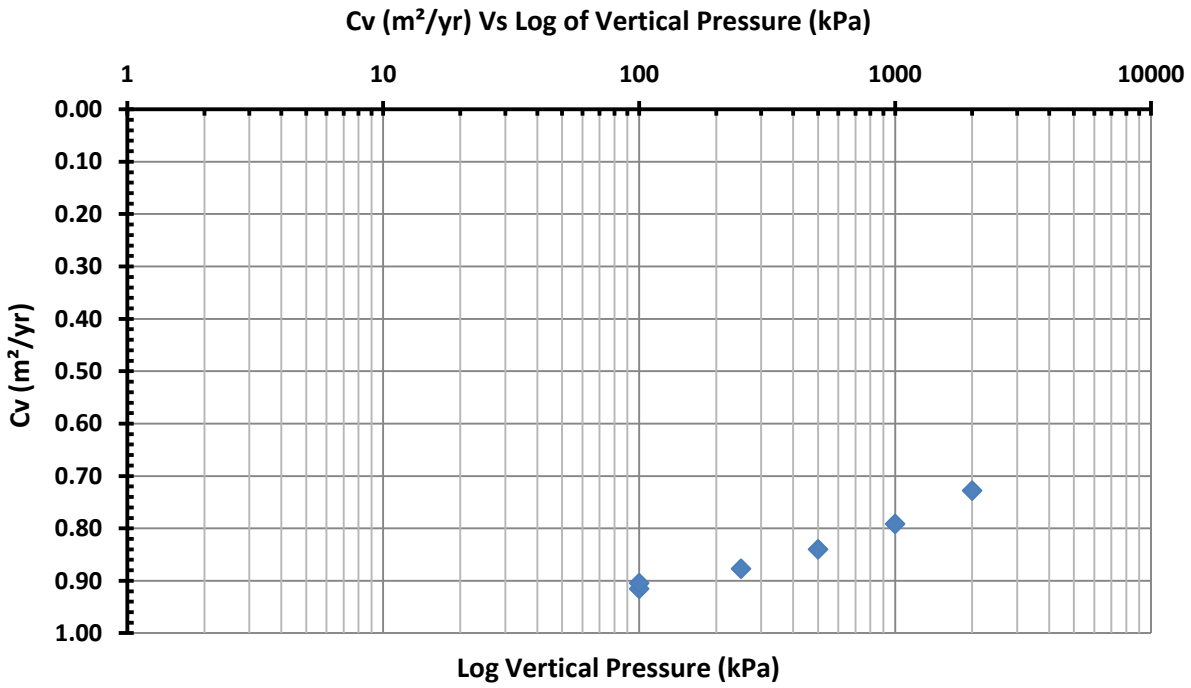
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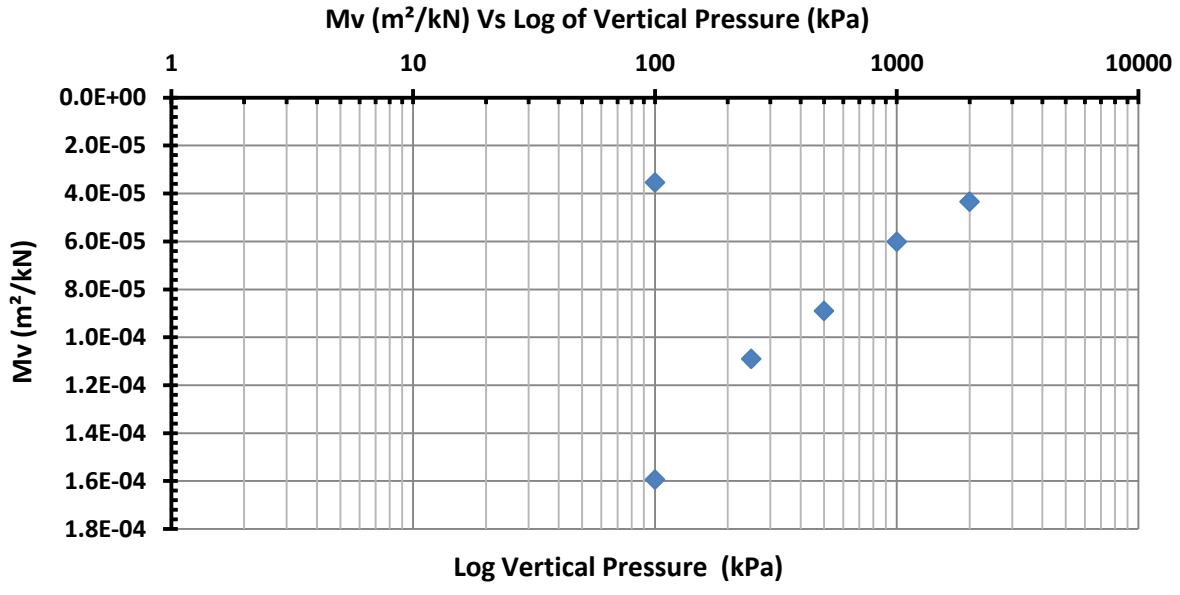
ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C



* Plot based on Log (time) data



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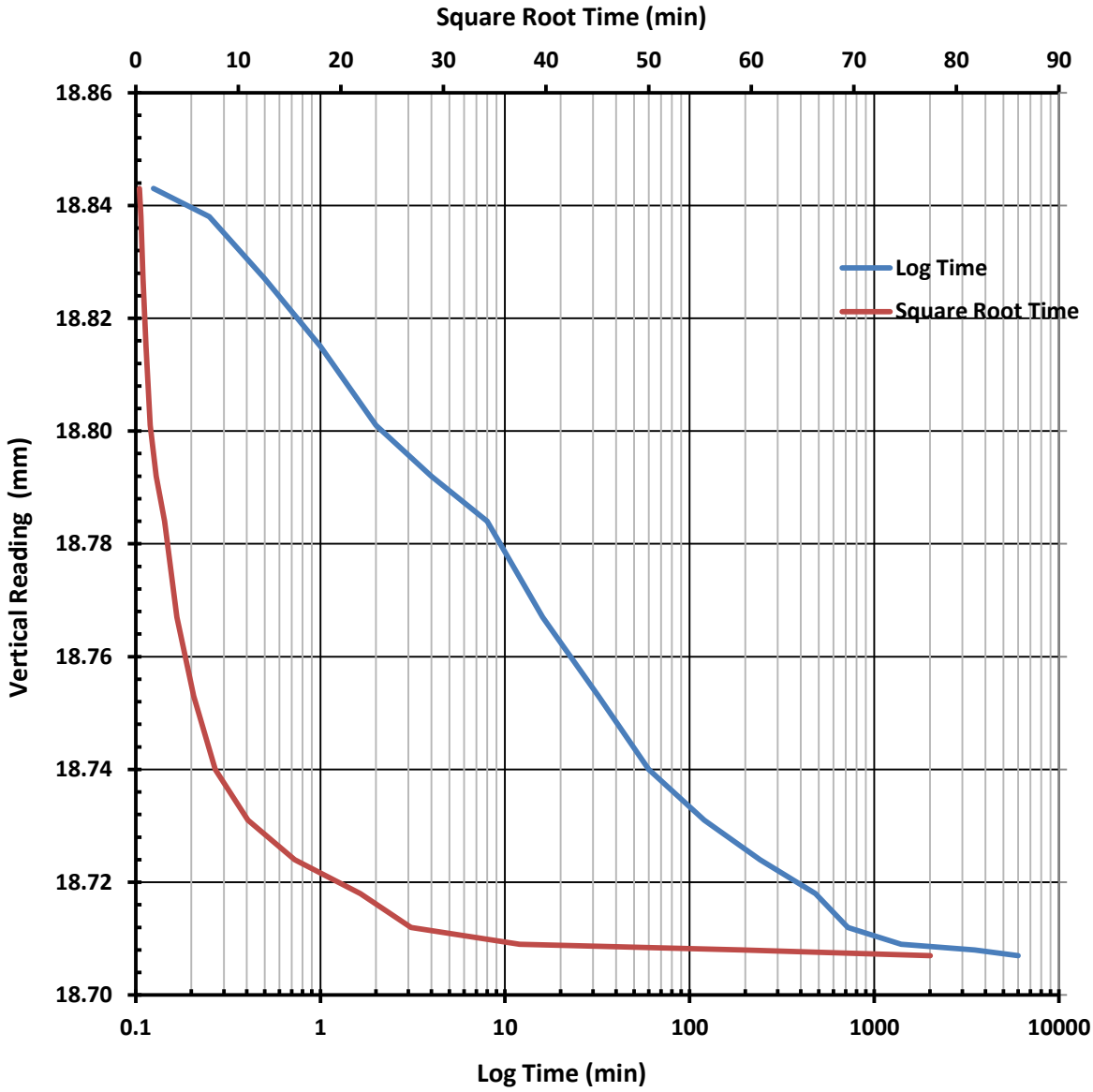
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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C

Stage 1 @ 100kPa



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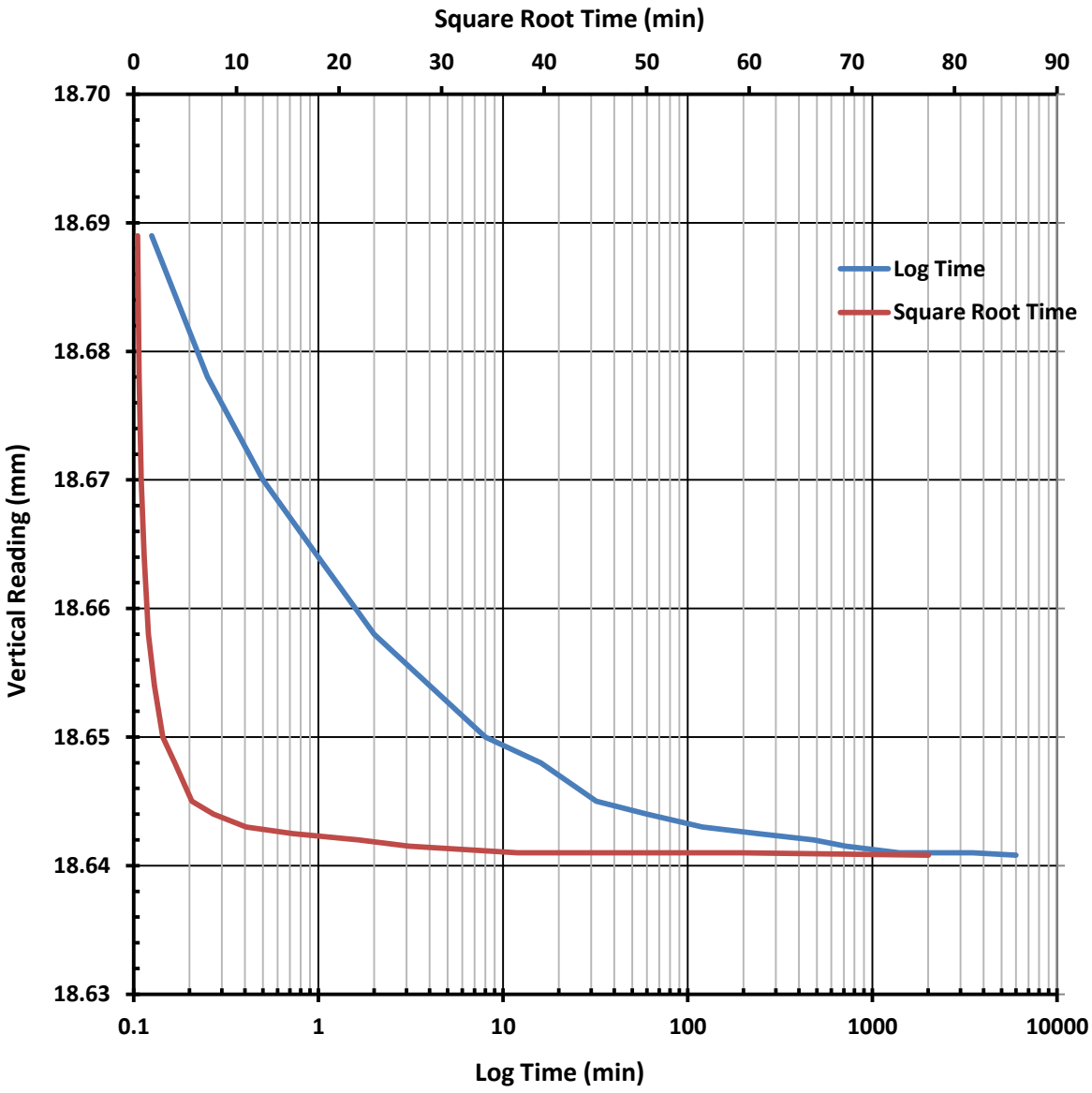
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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C

Stage 2 @ 100kPa SAT



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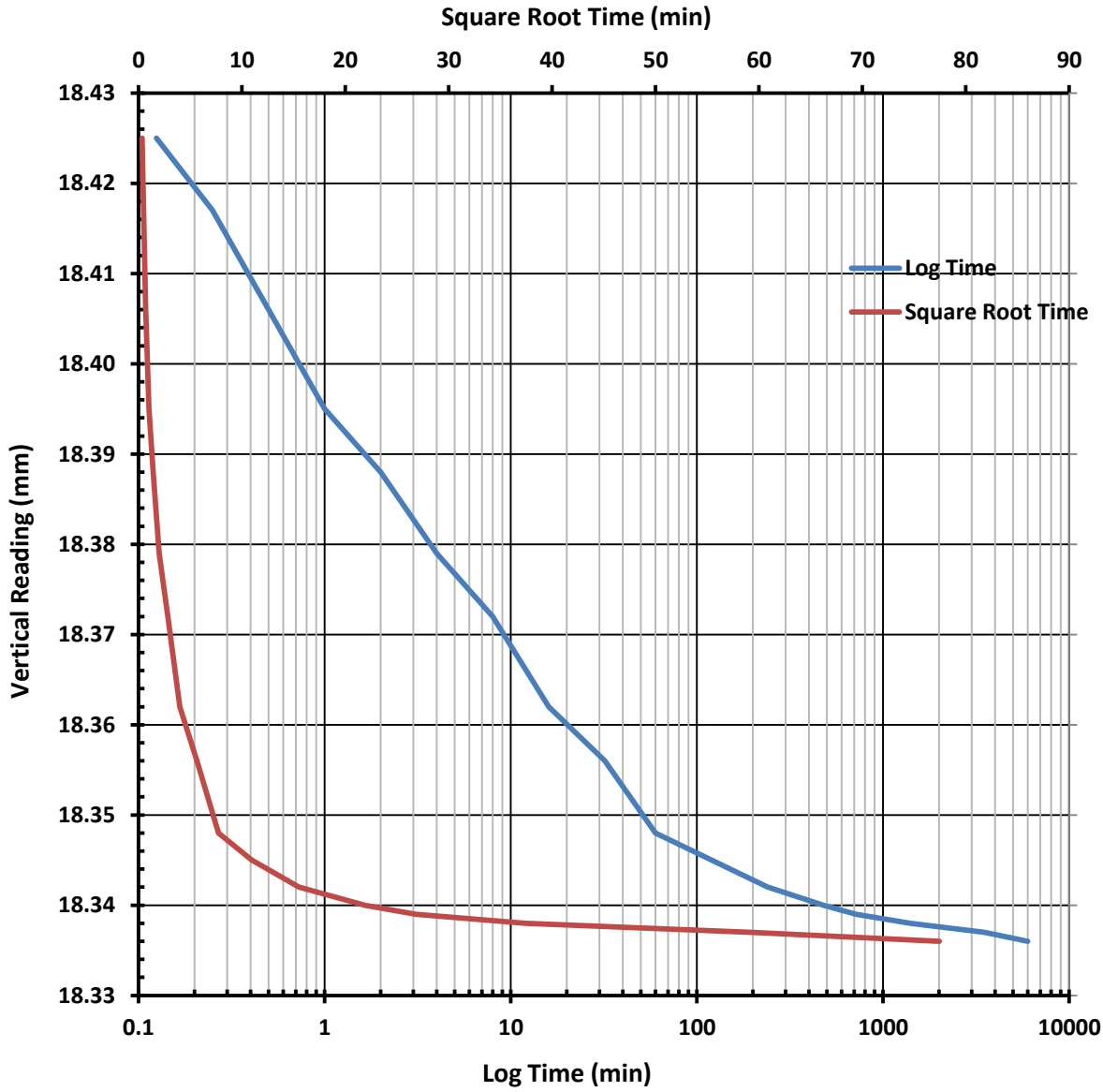
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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C

Stage 3 @ 250kPa



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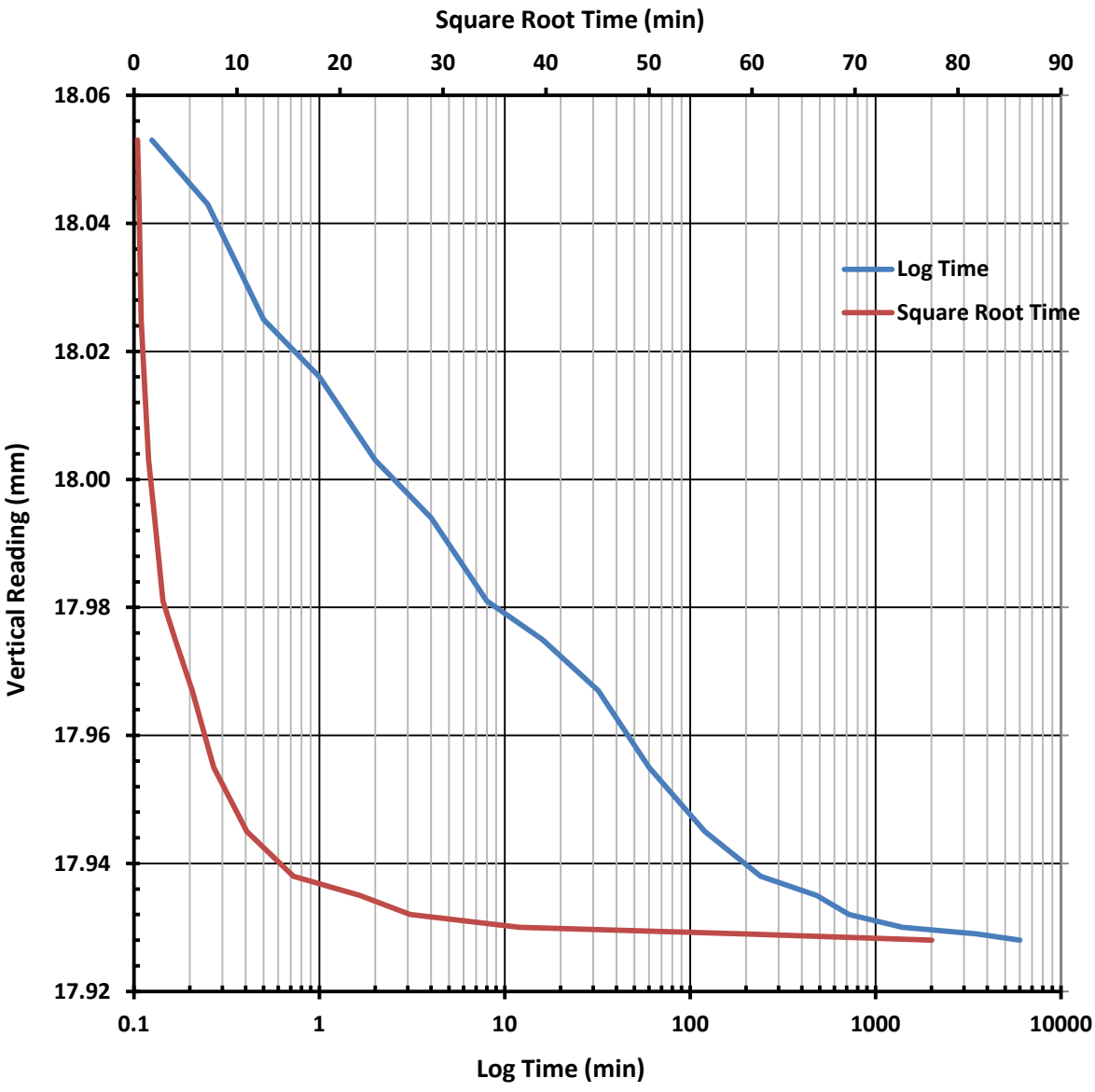
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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group Iron Bridge Coarse Rejects	Date Tested:	16/12/2018
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C

Stage 4 @ 500kPa



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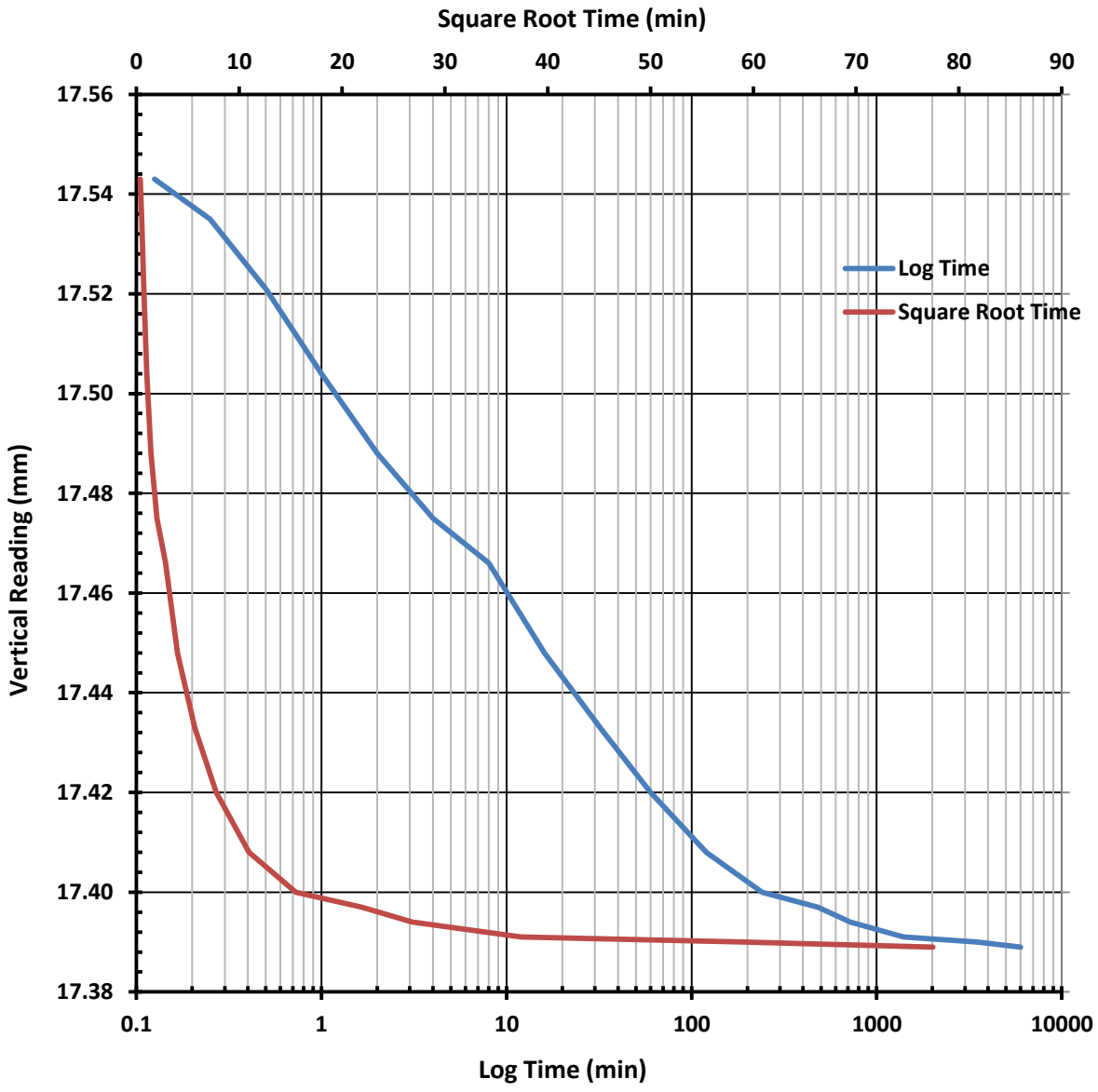
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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C

Stage 5 @ 1000kPa



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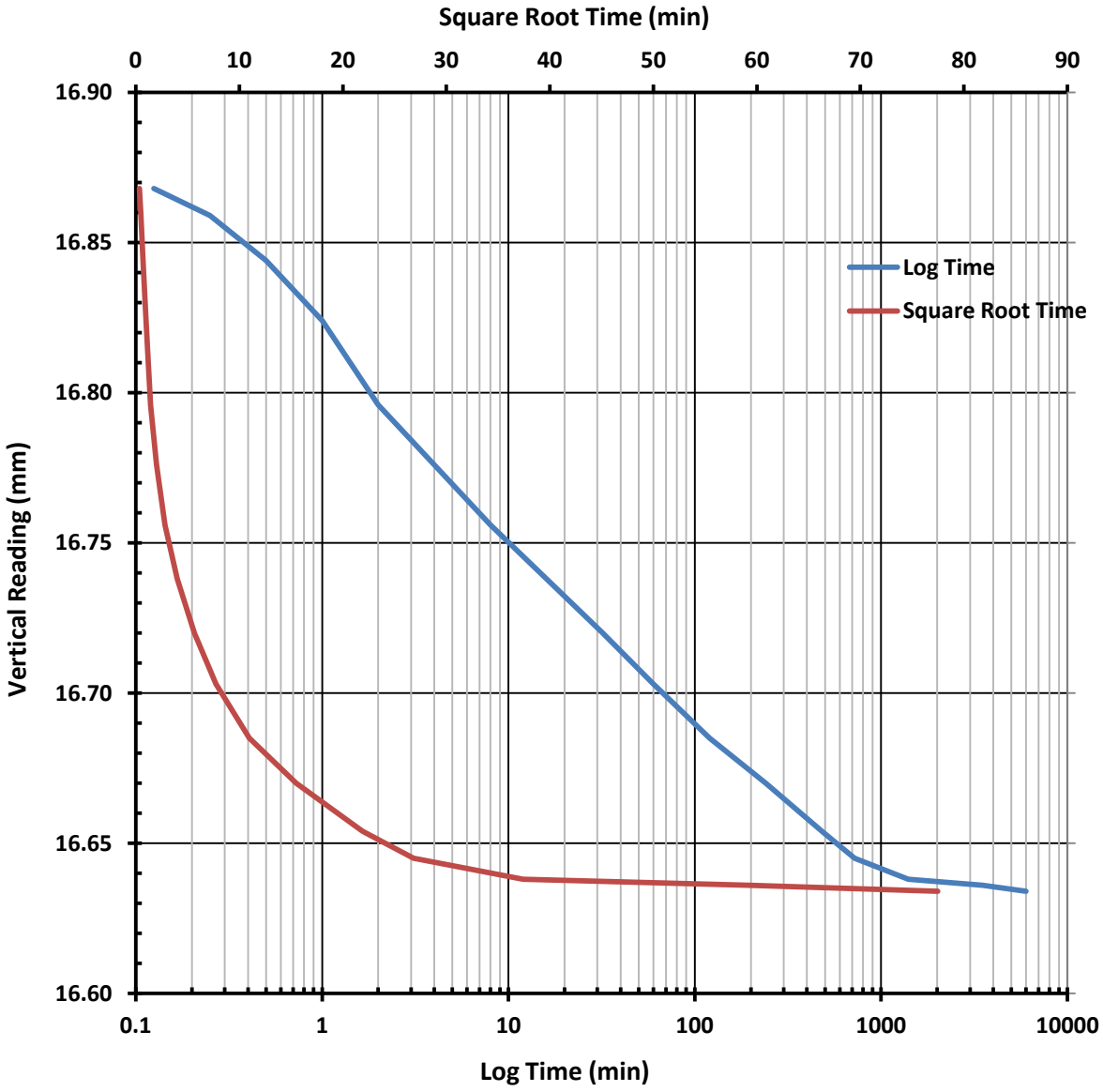
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ONE-DIMENSIONAL CONSOLIDATION REPORT

Method: AS1289 6.6.1

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects		
Location:	-	EP Lab Job Number:	FMG
Lab ID:	IB_CR001_DESIGN_OED	Lab:	EPLab
Depth (m):	-	Room Temperature at Test:	~ 19°C

Stage 6 @ 2000kPa



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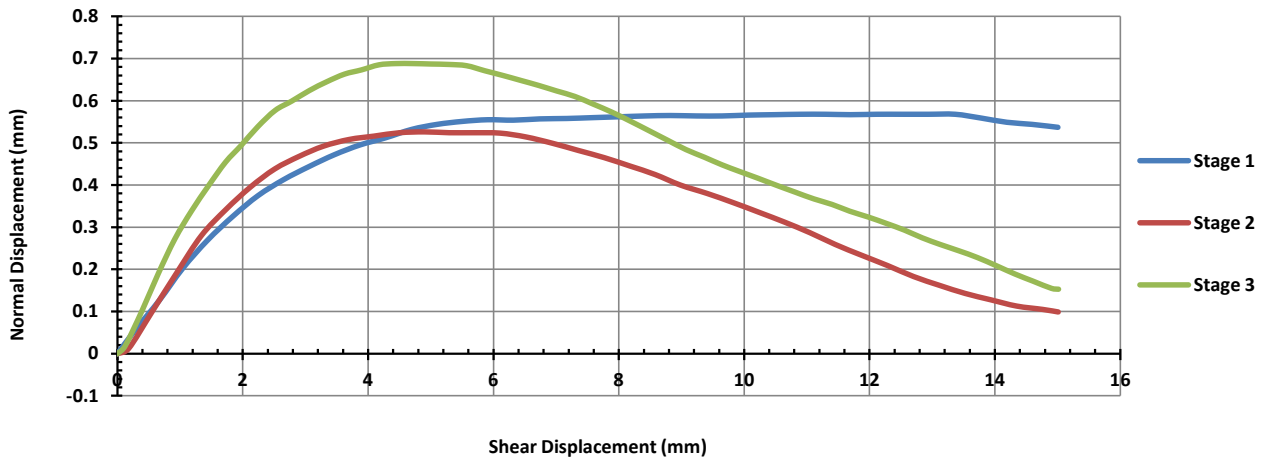
MULTISTAGE DRAINED DIRECT SHEAR TEST REPORT

Method: AS1289.6.2.2 / In-house Method

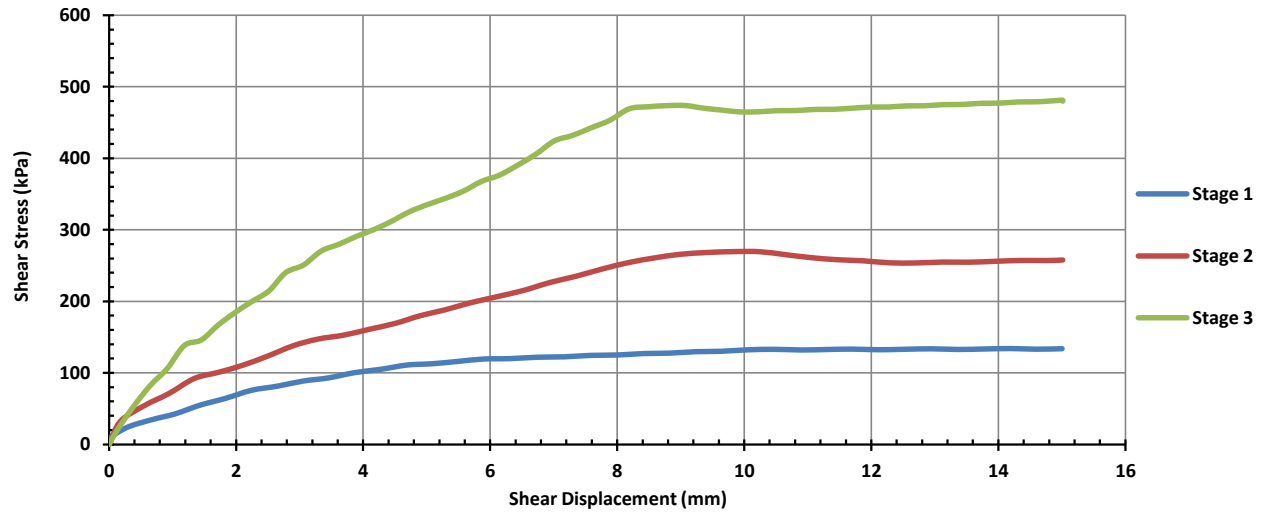
Client:	Fortescue Metals Group	Date Tested:	18/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Reject Sample	Lab:	EPLab
Sample ID:	IB_DESIGN_CR001_DDST3		
Depth (m):	-	Room Temperature at Test:	20°

Type of Test:	Intact Multistage Drained	**Sample Description:**	Remolded
Dimensions (mm):	100 x 100	**Shear Plane Dip Angle (°):**	N/A
Rate of Strain (mm/min):	0.0085	**Initial Bulk Density (t/m³):**	1.92
Failure Criteria:	Horizontal Shear	**Moisture Content (%):**	3.06

Normal Displacement Vs Shear Displacement Plot



Shear Stress Vs Shear Displacement Plot



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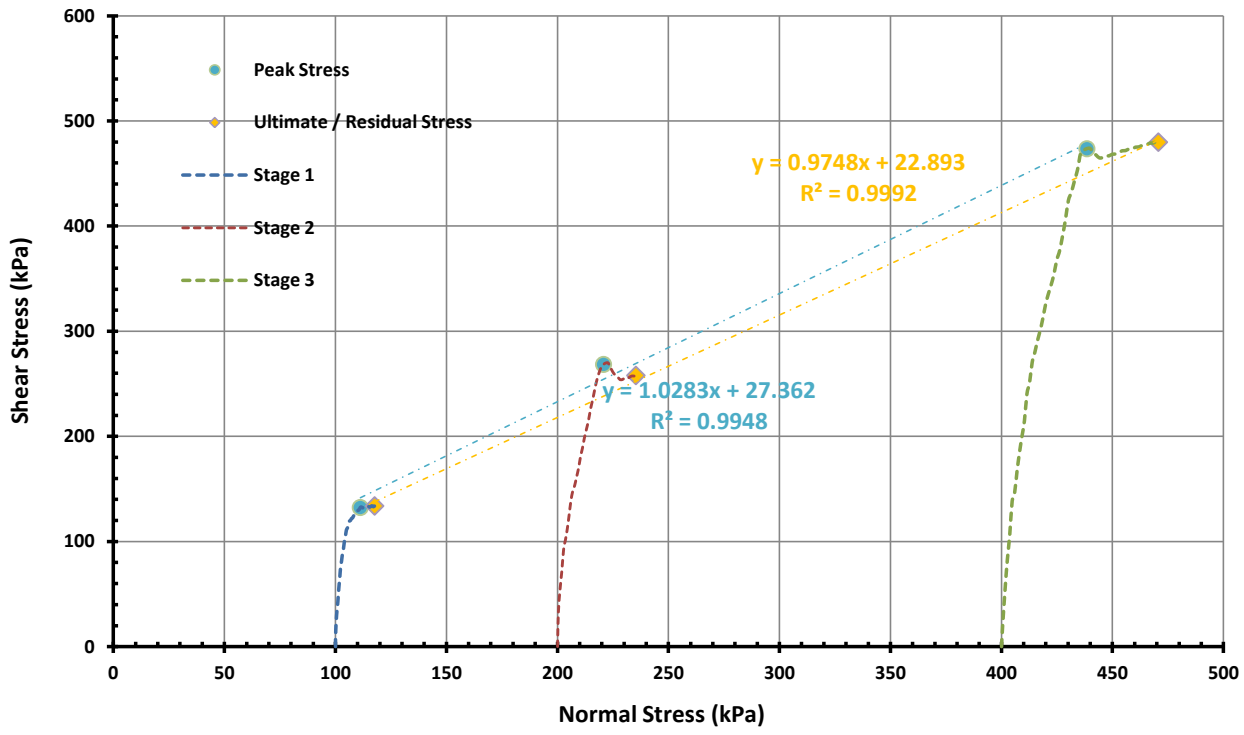
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MULTISTAGE DRAINED DIRECT SHEAR TEST REPORT

Method: AS1289.6.2.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	18/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Reject Sample	Lab:	EPLab
Sample ID:	IB_DESIGN_CR001_DDST3		
Depth (m):	-	Room Temperature at Test:	20°

(Peak / Ultimate) Normal Stress Vs Shear Stress



Defect Surface: N/A

Dip Angle (°): N/A

Peak	**Shear Angle (°)**	45.79	**Normal Stress (kPa)**		**Shear Stress (kPa)**	
	Cohesion (kPa)	27.36	Stage 1	111	Stage 1	132
	R^2	0.9948	Stage 2	221	Stage 2	268
*** selected at POI**			Stage 3	439	Stage 3	474
Ultimate / Residual	**Shear Angle (°)**	44.27	**Normal Stress (kPa)**		**Shear Stress (kPa)**	
	Cohesion (kPa)	22.89	Stage 1	118	Stage 1	134
	R^2	0.9992	Stage 2	235	Stage 2	258
			Stage 3	471	Stage 3	480

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MULTISTAGE DRAINED DIRECT SHEAR TEST REPORT

Method: AS1289.6.2.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	18/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Reject Sample	Lab:	EPLab
Sample ID:	IB_DESIGN_CR001_DDST3		
Depth (m):	-	Room Temperature at Test:	20°

Photo of Sample Post Testing (shear box)



Notes: Sample placed in mould at Minimum Dry Density @ 3% MC as requested

Stored and Tested the Sample as received

Samples supplied by the Client

Authorised Signature (Geotechnical Engineer): NATA: 19078

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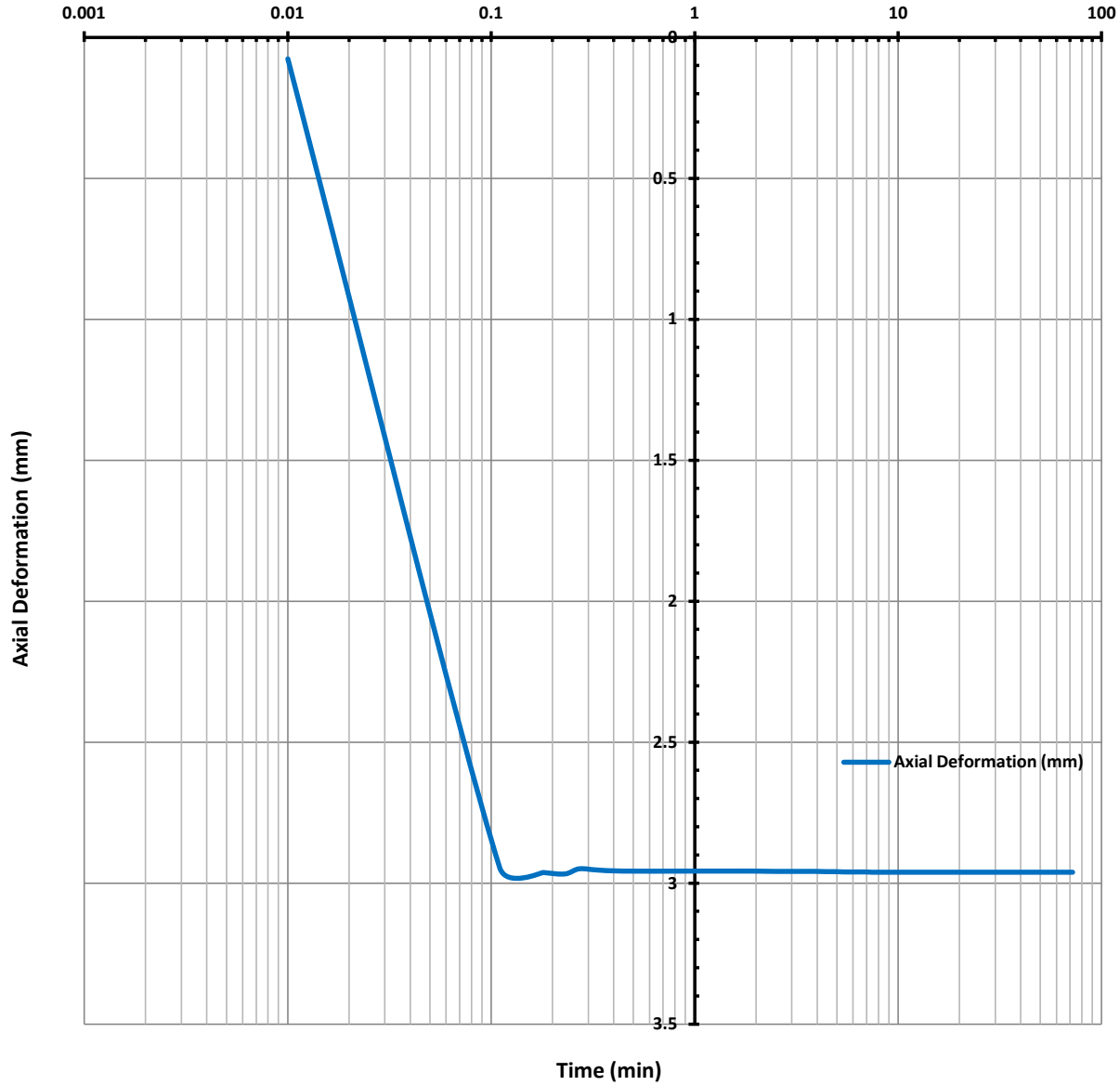
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MULTISTAGE DRAINED DIRECT SHEAR TEST REPORT

Method: AS1289.6.2.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	18/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Design Coarse Reject Sample	Lab:	EPLab
Sample ID:	IB_DESIGN_CR001_DDST3		
Depth (m):	-	Room Temperature at Test:	20°

Consolidation Graph (Axial Deformation Vs Time)



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SINGLE-STAGE CONSOLIDATED UNDRAINED TRIAXIAL TEST

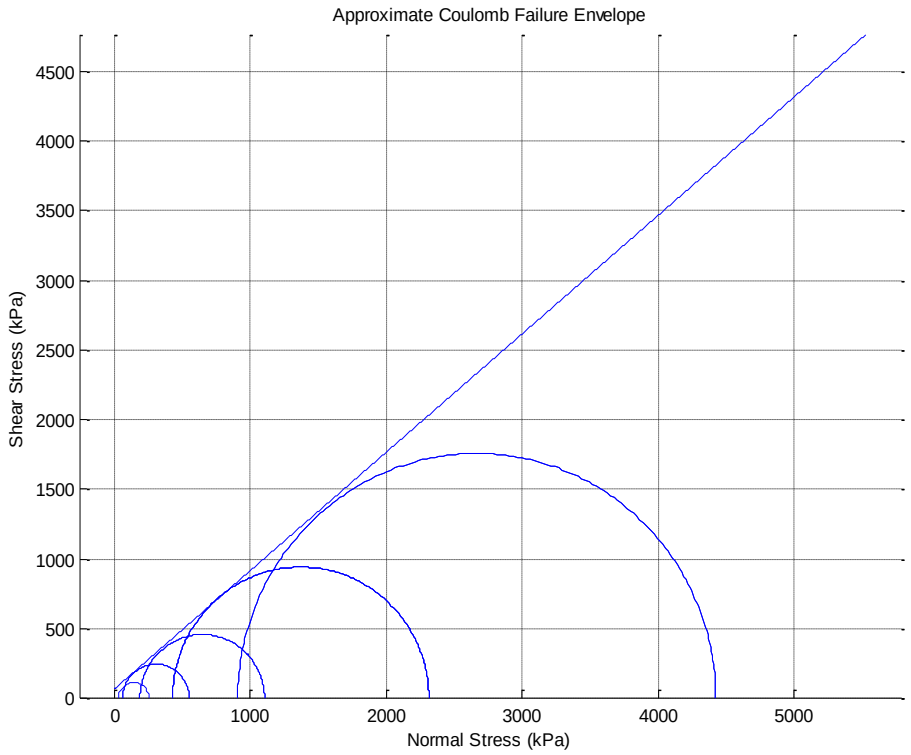
Method: AS1289.6.4.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	13/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CU5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Tested by:	PHIL	Initial Moisture (%):	3.03	Strain Rate (mm/min):	0.0085
Height (mm):	125.23	Final Moisture (%):	2.54	Skempton's (B):	0.99
Diameter (mm):	61.82	Bulk Density (t/m³):	1.92	Geology:	-
L/D Ratio:	2.03	Dry Density (t/m³):	1.86		

Failure Criteria used: Peak Principle Stress Ratio

Mohr Circle Diagram



Interpretation from Mohr Circle:	**Regression R >0.95**
Cohesion C' (kPa):	60.78
Angle of Shear Resistance Φ' (Degrees) :	40.36

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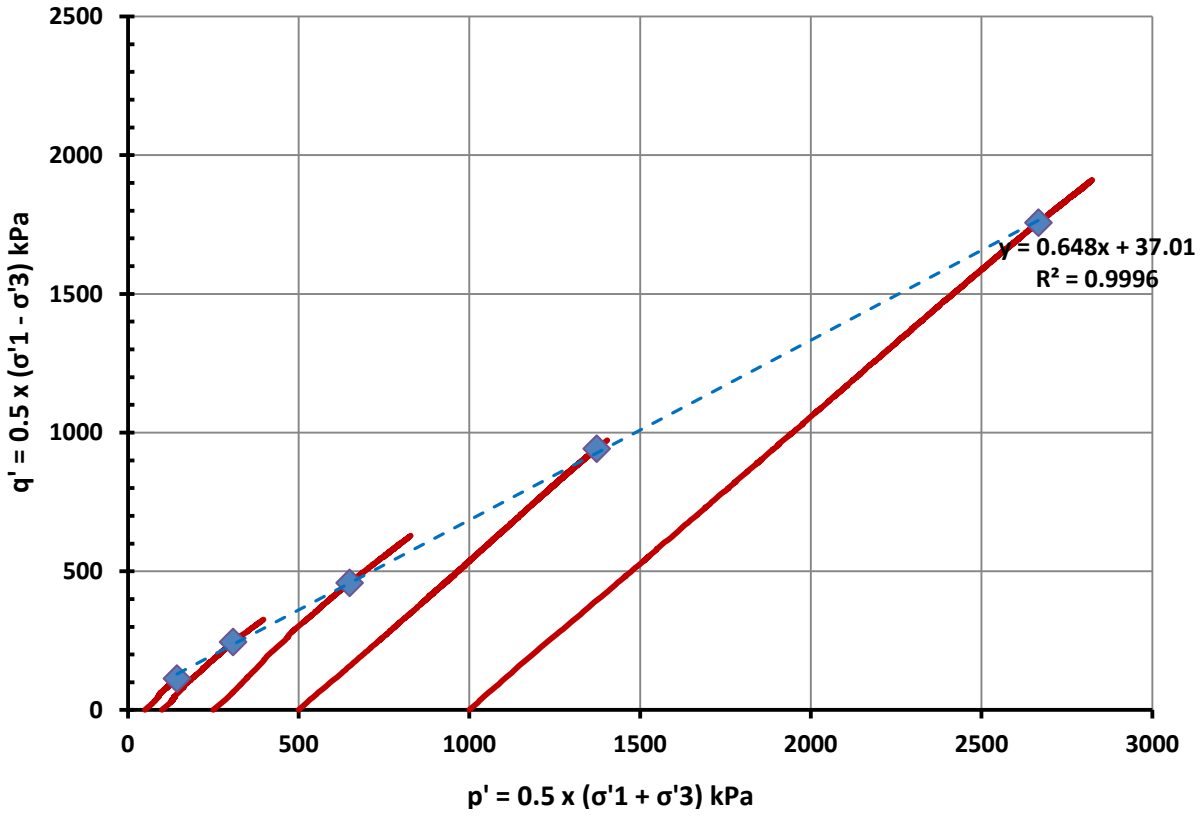
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SINGLE-STAGE CONSOLIDATED UNDRAINED TRIAXIAL TEST

Method: AS1289.6.4.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	13/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CU5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

MIT Effective Stress Path (q' vs p' diagram)



MIT Stress Path - Using Stress Path Tangency Method

Cohesion C' (kPa) : 48.59

Angle of Shear Resistance Φ' (Deg) : 40.39

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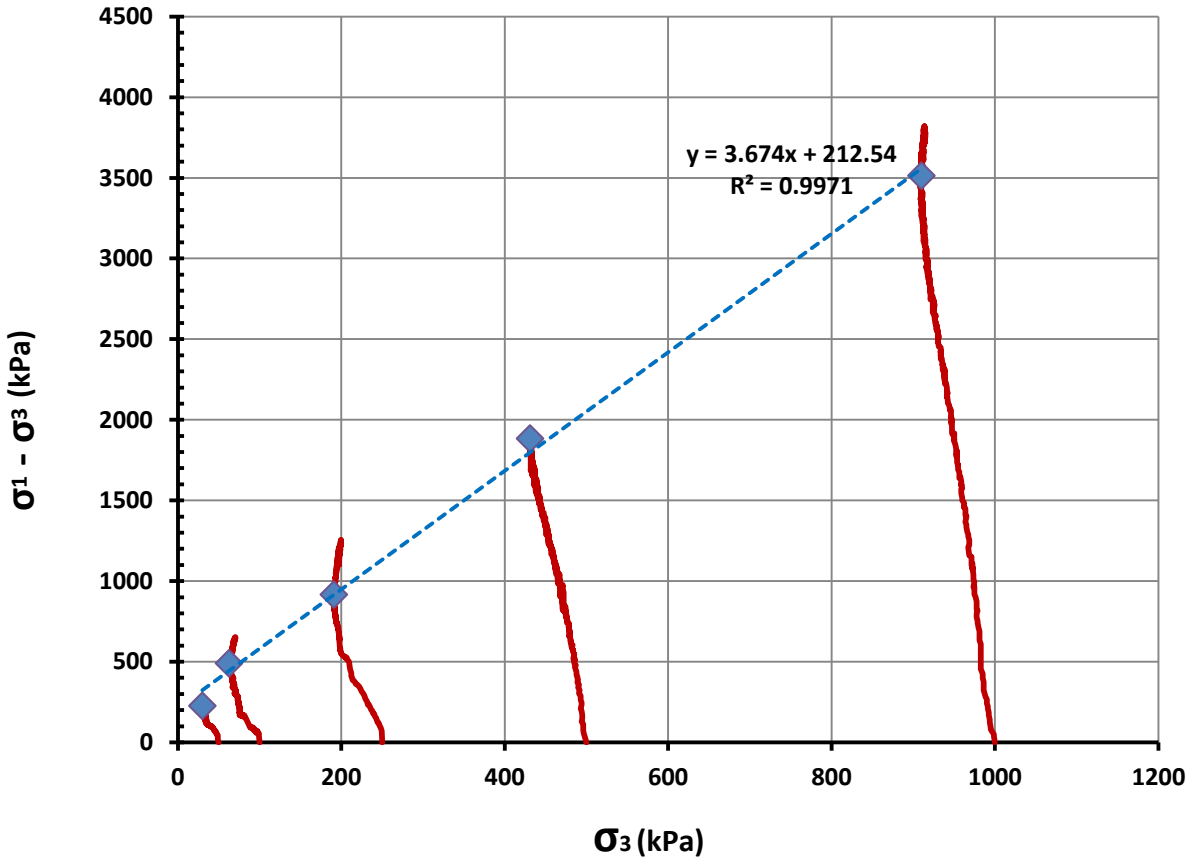
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SINGLE-STAGE CONSOLIDATED UNDRAINED TRIAXIAL TEST

Method: AS1289.6.4.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	13/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CU5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Modified Mohr Coulomb Stress Path



Modified Mohr Coulomb Path - Using Stress Path Tangency Method

Cohesion C' (kPa) :	**49.18**
Angle of Shear Resistance Φ' (Deg) :	**40.34**

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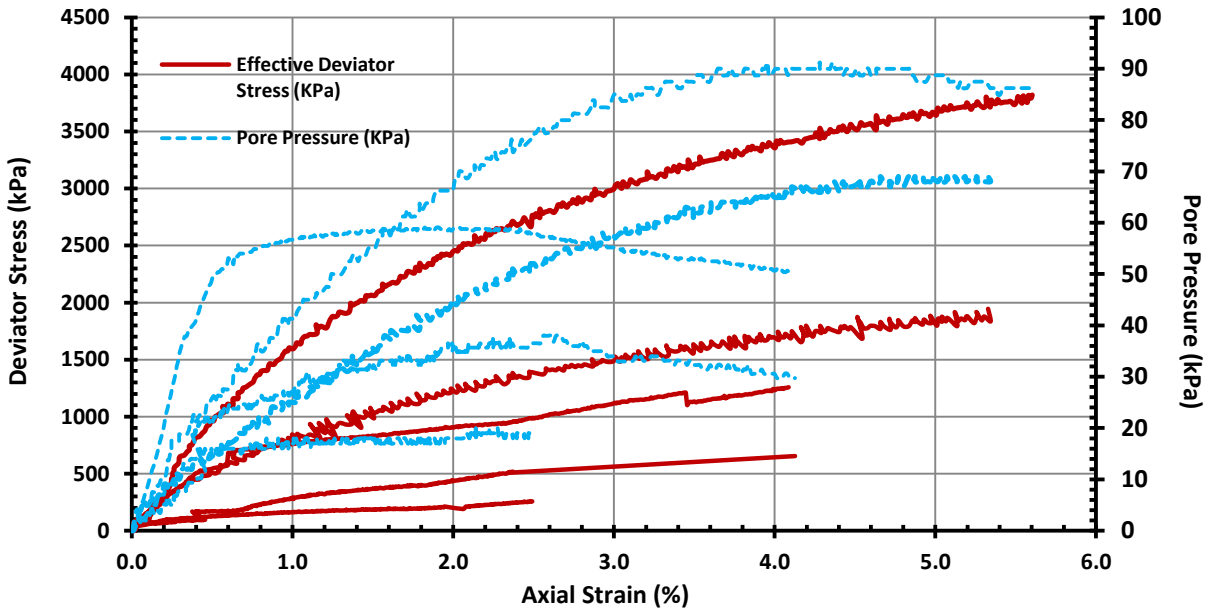
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SINGLE-STAGE CONSOLIDATED UNDRAINED TRIAXIAL TEST

Method: AS1289.6.4.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	13/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CU5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Deviator Stress Vs Strain Diagram



SHEAR STAGE DATA AND STRESS MEASUREMENTS (kPa)

Shear Stage	Confining Pressure	U'0	U'f	Principal Effective Stresses			σ'1 - σ'3	Strain (%)
				σ'1	σ'3	σ'1 / σ'3		
1	50	0	20	257	30	8.56	227	2.22
2	100	0	37	553	63	8.83	490	2.25
3	250	0	59	1107	191	5.80	917	2.04
4	500	0	69	2315	431	5.37	1884	4.97
5	1000	0	90	4424	910	4.86	3514	4.42

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SINGLE-STAGE CONSOLIDATED UNDRAINED TRIAXIAL TEST

Method: AS1289.6.4.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	13/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CU5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Photo After Test

Sample ID: Coarse Rejects Design **Depth (m):** -
Lab ID: IB_CR001_CU5 **Date Tested:** 13/12/2018



Failure Mode: **N/A** **Bulging**

Notes: **Sample remolded to minimum dry density @ 3% MC**

Stored and Tested the Sample as received

Samples supplied by the Client

NATA: 19078 **Authorised Signatory (Geotechnical Engineer):**

The results of tests performed apply only to the specific sample at time of test unless otherwise clearly stated. Reference should be made to E-Precision Laboratory's "Standard Terms and Conditions" E-Precision Laboratory ABN 431 559 578 87

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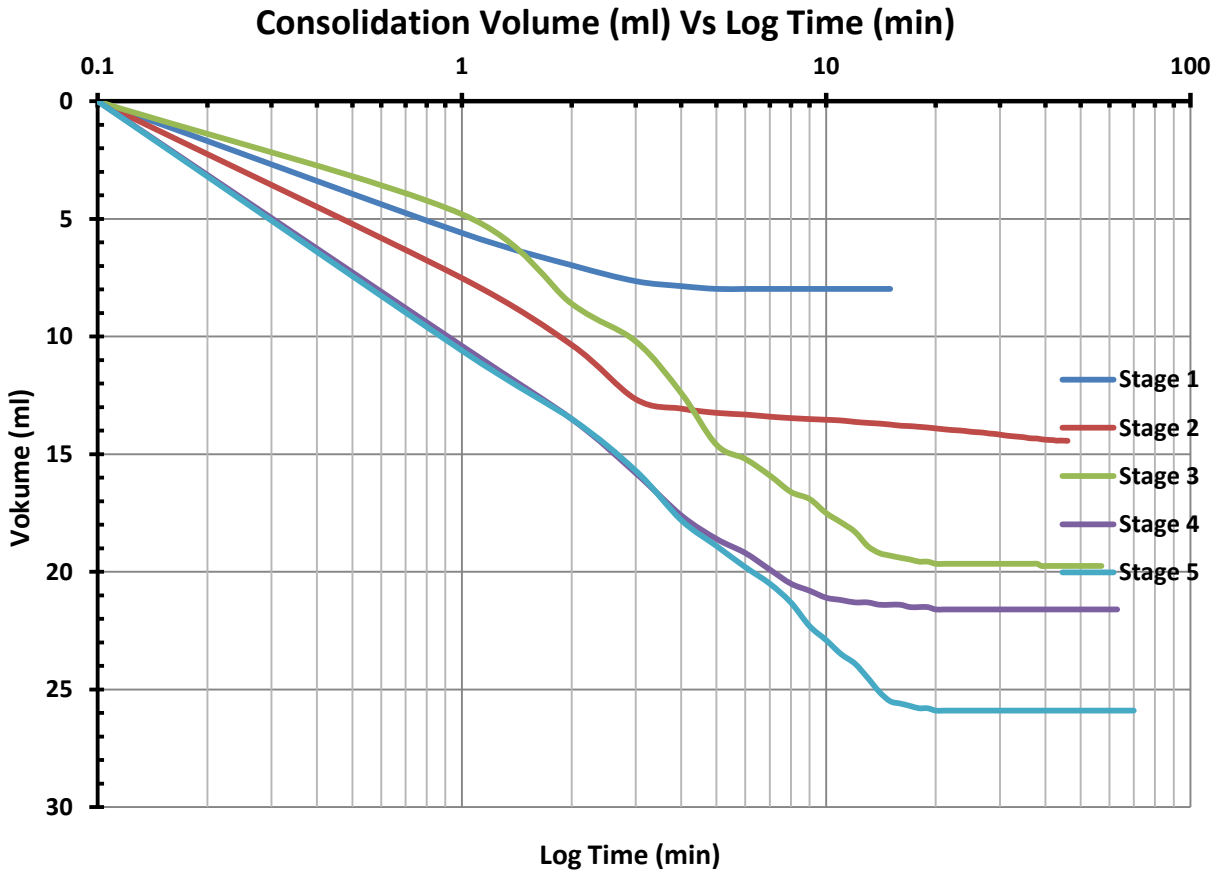
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SINGLE-STAGE CONSOLIDATED UNDRAINED TRIAXIAL TEST

Method: AS1289.6.4.2 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	13/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CU5		
Depth (m):	-	Room Temperature at Test:	~ 18°C



Stage 1	**Cv (cm²/s):**	0.963	based on t_{90}
Stage 2	**Cv (cm²/s):**	0.760	based on t_{90}
Stage 3	**Cv (cm²/s):**	0.309	based on t_{90}
Stage 4	**Cv (cm²/s):**	0.262	based on t_{90}
Stage 4	**Cv (cm²/s):**	0.230	based on t_{90}

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SINGLE-STAGE CONSOLIDATED DRAINED TRIAXIAL TEST

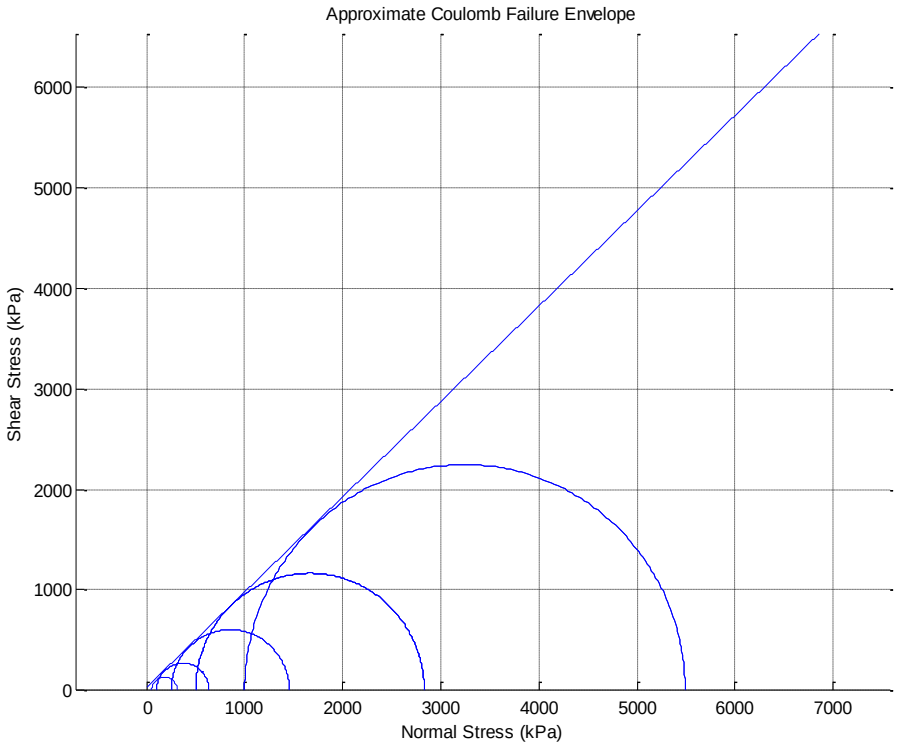
Method: ASTM D7181-11 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CD5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Tested by:	PHIL	Initial Moisture (%):	3.11	Strain Rate (mm/min):	0.005
Height (mm):	125.54	Final Moisture (%):	2.64	Skempton's (B):	0.99
Diameter (mm):	61.80	Bulk Density (t/m³):	1.93	Geology:	-
L/D Ratio:	2.03	Dry Density (t/m³):	1.87		

Failure Criteria used: Peak Principle Stress Ratio

Mohr Circle Diagram



Interpretation from Mohr Circle:	**Regression R >0.95**
Cohesion C' (kPa):	23.43
Angle of Shear Resistance Φ' (Degrees) :	43.53

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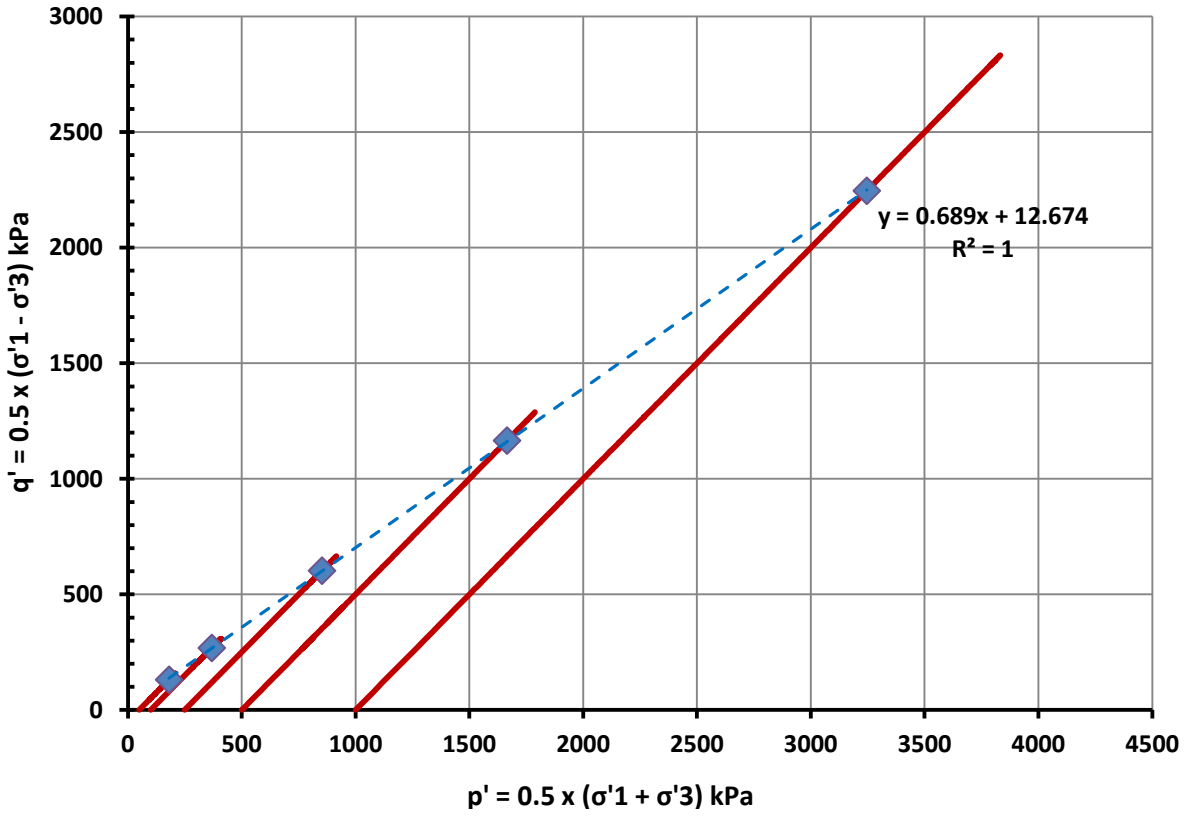
E-Precision Laboratory

SINGLE-STAGE CONSOLIDATED DRAINED TRIAXIAL TEST

Method: ASTM D7181-11 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CD5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

MIT Effective Stress Path (q' vs p' diagram)



MIT Stress Path - Using Stress Path Tangency Method

Cohesion C' (kPa) :	**17.48**
Angle of Shear Resistance Φ' (Deg) :	**43.55**

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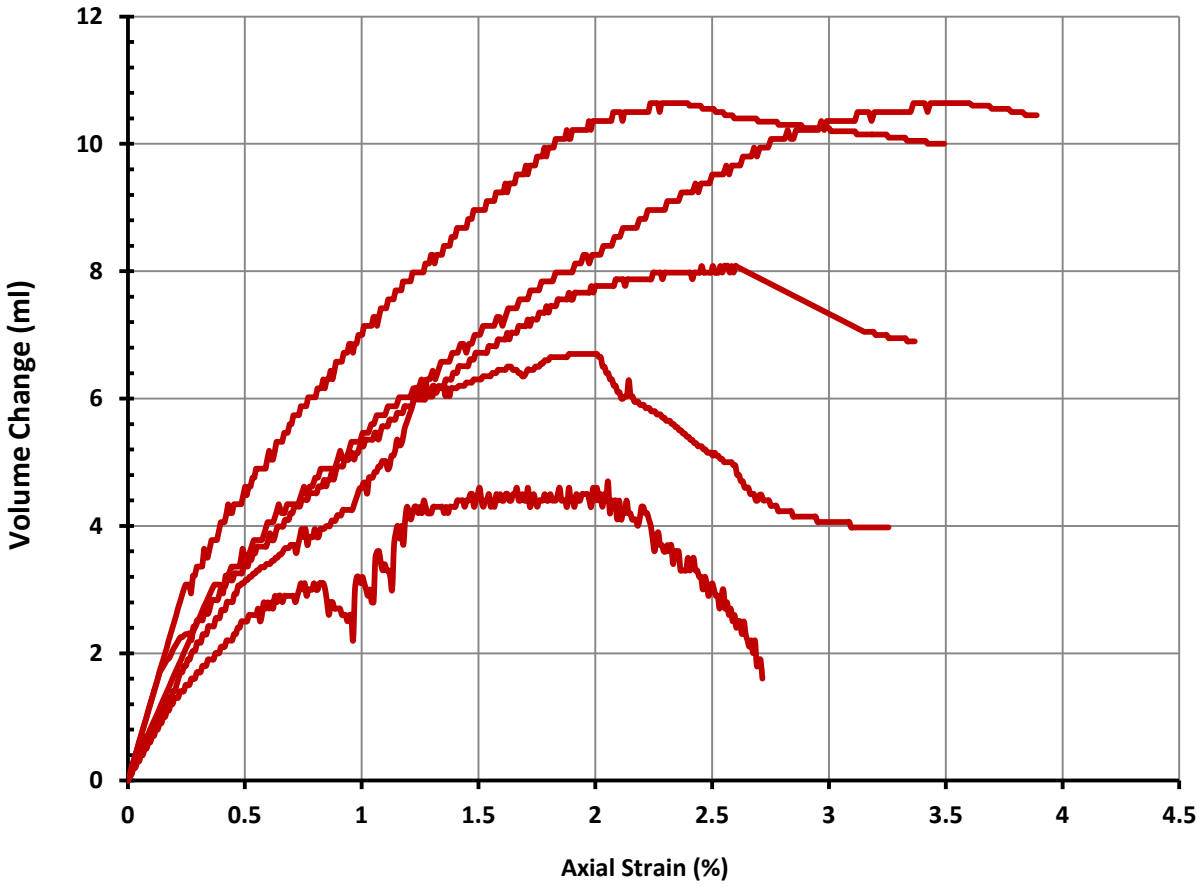
E-Precision Laboratory

SINGLE-STAGE CONSOLIDATED DRAINED TRIAXIAL TEST

Method: ASTM D7181-11 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CD5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Volume Change (ml) vs Axial Strain (%)



Modified Mohr Coulomb Path - Using Stress Path Tangency Method

Cohesion C' (kPa) : **17.57**

Angle of Shear Resistance Φ' (Deg) : **43.55**

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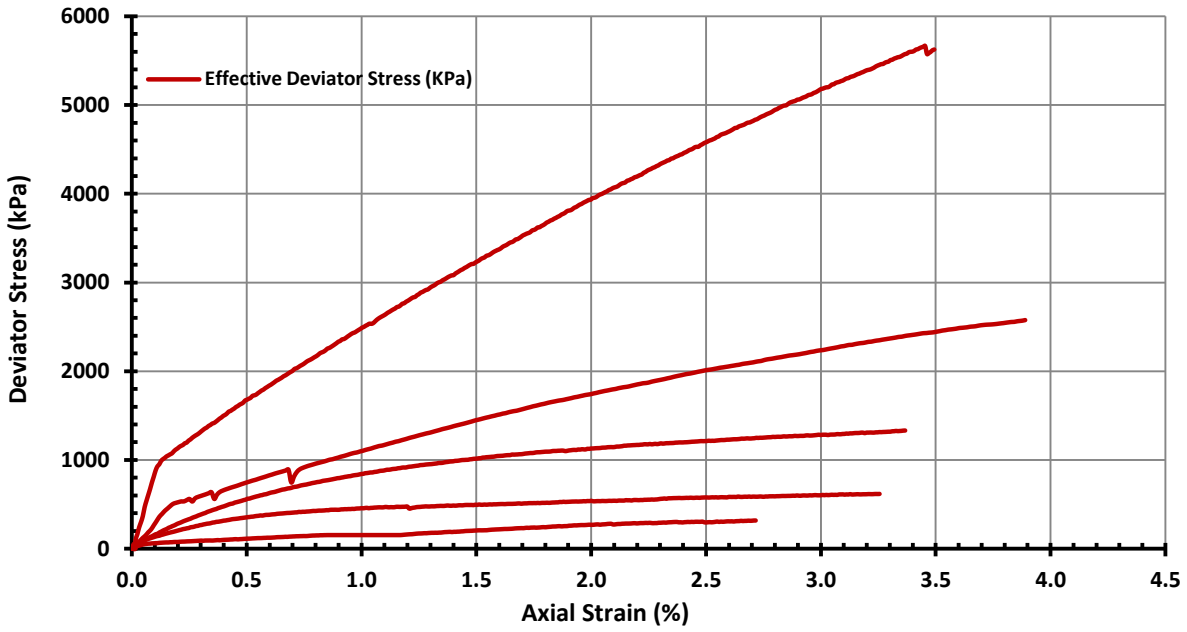
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SINGLE-STAGE CONSOLIDATED DRAINED TRIAXIAL TEST

Method: ASTM D7181-11 / In-house Method

Client:	Fortescue Metals Group	Date Tested:	16/12/2018
Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CD5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Deviator Stress Vs Strain Diagram



SHEAR STAGE DATA AND STRESS MEASUREMENTS (kPa)

Shear Stage	Confining Pressure	U'0	U'f	Principal Effective Stresses			σ'1 - σ'3	Strain (%)
				σ'1	σ'3	σ'1 / σ'3		
1	50	0	0	312	50	6.24	262	1.92
2	100	0	0	637	100	6.37	537	1.98
3	250	0	0	1455	250	5.82	1205	2.44
4	500	0	0	2831	500	5.66	2331	3.21
5	1000	0	0	5492	1000	5.49	4492	2.43

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SINGLE-STAGE CONSOLIDATED DRAINED TRIAXIAL TEST

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Project:	Iron Bridge Coarse Rejects	EP Lab Job Number:	FMG
Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CD5		
Depth (m):	-	Room Temperature at Test:	~ 18°C

Photo After Test

Sample ID: Coarse Rejects Design **Depth (m):** -
Lab ID: IB_CR001_CD5 **Date Tested:** 16/12/2018



Failure Mode: **N/A** **Bulging**

Notes: **Sample remolded to minimum dry density @ 3% MC**

Stored and Tested the Sample as received

Samples supplied by the Client

NATA: 19078 **Authorised Signatory (Geotechnical Engineer):**

The results of tests performed apply only to the specific sample at time of test unless otherwise clearly stated. Reference should be made to E-Precision Laboratory's "Standard Terms and Conditions" E-Precision Laboratory ABN 431 559 578 87

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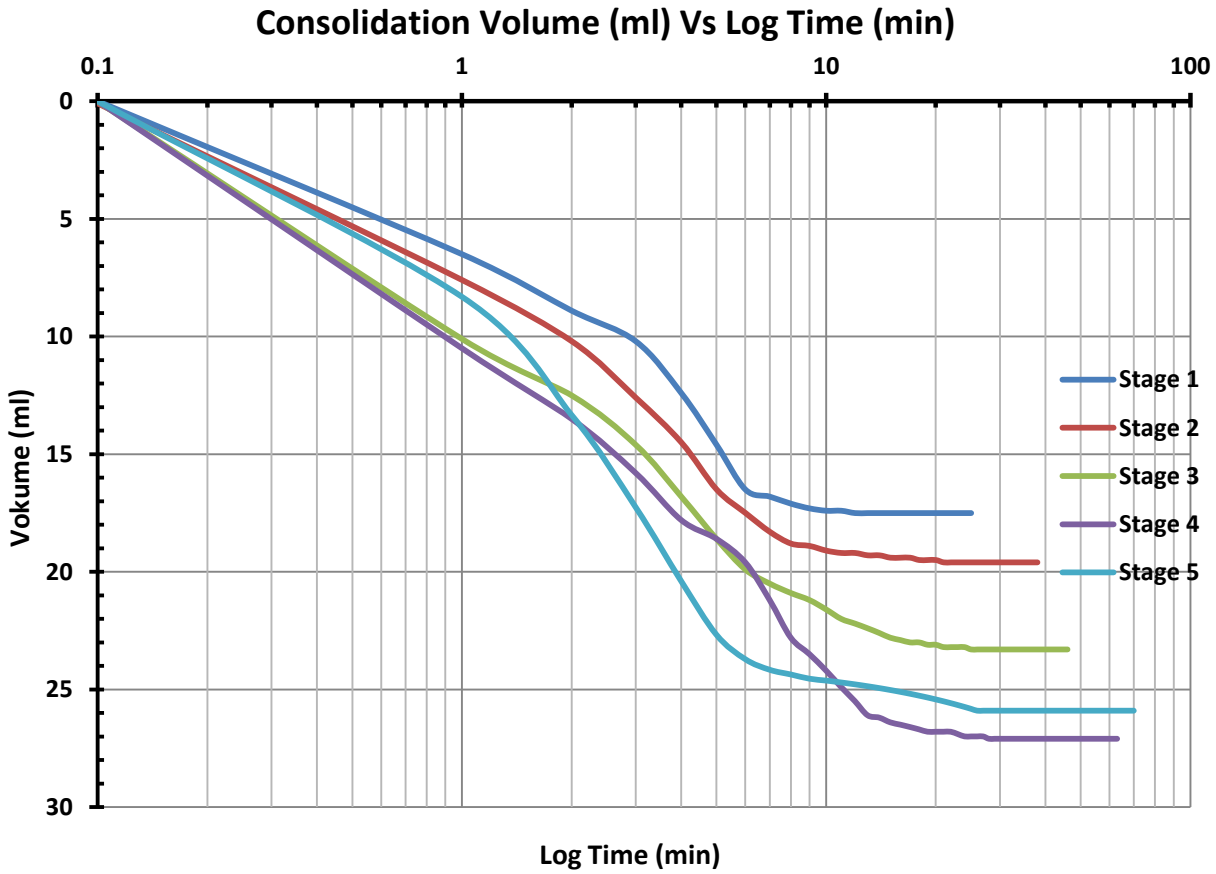
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Sample No:	Coarse Rejects Design	Lab:	EPLab
Sample ID:	IB_CR001_CD5		
Depth (m):	-	Room Temperature at Test:	~ 18°C



Stage 1	**Cv (cm²/s):**	0.634	based on t_{90}
Stage 2	**Cv (cm²/s):**	0.468	based on t_{90}
Stage 3	**Cv (cm²/s):**	0.217	based on t_{90}
Stage 4	**Cv (cm²/s):**	0.193	based on t_{90}
Stage 4	**Cv (cm²/s):**	0.175	based on t_{90}

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Appendix C: Infiltration assessment

1 Infiltration assessment

An infiltration assessment using SEEP/W (GeoStudio, 2018) was undertaken using a true climate boundary at the surface to reasonably replicate the expected field conditions. This analysis was used to assess the response of the dry rejects and the degree of saturation of the stockpile due to various climate scenarios, including extreme storm events. This is important to understand in relation to assessing the liquefaction potential and stability of the dry rejects material, as well as to determine the requirement for any sub-surface drainage measures. The degree of saturation of the dry rejects was monitored at selected depths in the model to assess the spatial distribution of moisture in the soil layers as well as any potential development of phreatic surface in the stockpile.

1.1 Scenarios

Four scenarios were proposed to demonstrate the indicative behaviour of the stockpile under potential climatic conditions. The scenarios were simulated by changing the boundary condition of climate data in each model:

1. Scenario 1: Typical operating year (based on 2018 climate data)
2. Scenario 2: Wettest climate year (based on SILO[1] database)
3. Scenario 3: Extreme storm event (based on ARI 100-year, 72-hour event)
4. Scenario 4: Extreme storm event (based on ARI 500-year, 72-hour event).

Scenario 1 and Scenario 2 were run for a duration of 365 days using a daily time-step to enable the stockpile to be assessed over a full year. Scenario 3 and Scenario 4 were run for a duration of 33 days using a 3-hour time-step. These scenarios include a 3-day storm event and use 30 days of wet month climate data.

1.2 Modelling input parameters

1.2.1 Numerical model

A conceptual one-dimensional seepage model was developed to show the progress of infiltration from precipitation and evaporation through a soil column with a nominal height of 15 m. The conceptual model showing boundary conditions is illustrated in Figure 1-1.

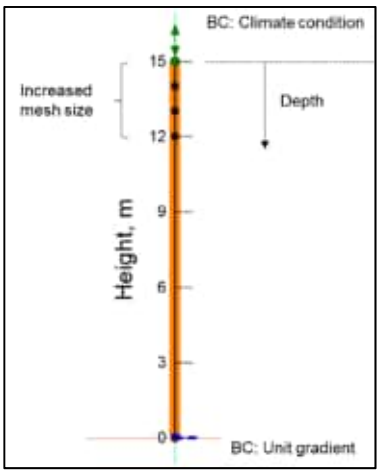


Figure 1-1: SEEP/W finite element model geometry

[1] ATC Williams, North Star 100 Year Climate data – SILO Hillside Weather Station.xlsx

1.2.2 Material properties

The unsaturated/ saturated properties of the dry rejects were defined in terms of saturated permeability (K_{sat}), initial volumetric water content (VWC), and a soil-water characteristic curve (SWCC), from the laboratory data (E-Precision laboratory test certificates provided as an appendix). A saturated permeability of 2.4×10^{-6} m/s was adopted from the falling head permeability test at the minimum density. The dry rejects are expected to arrive at the stockpile with a moisture content of 3% (w/w). The SWCC used in the model is illustrated in Figure 1-2.

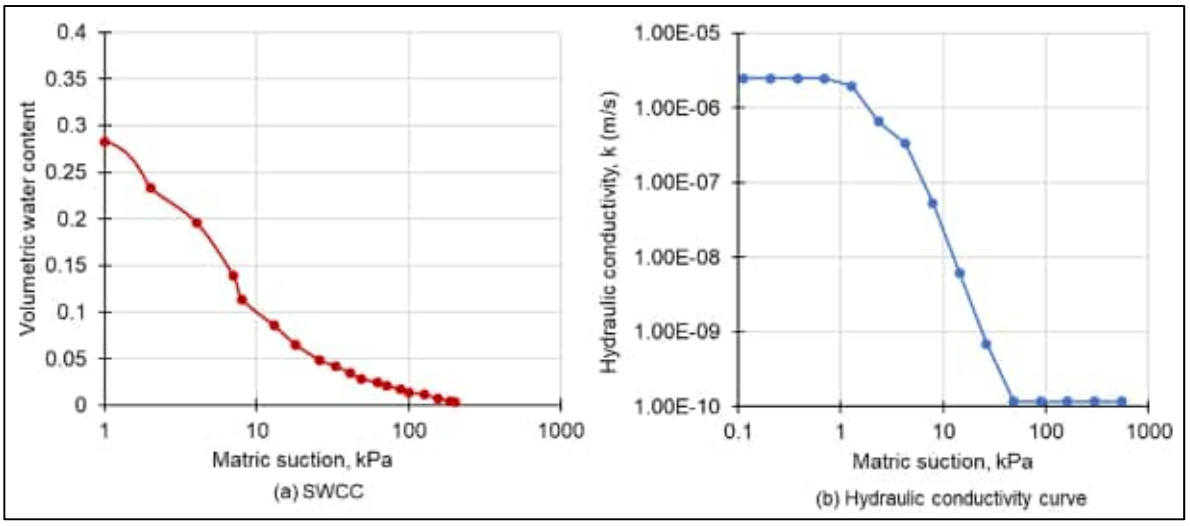


Figure 1-2: Properties for unsaturated/ saturated coarse rejects used in the infiltration model

1.2.3 Initial boundary conditions

The soil columns were initially set to the conditions expected in the field, with an initial degree of saturation of 15.6% (corresponding to the initial moisture content). A transient analysis with a true climate boundary condition applied to the top surface of the soil column was modelled. This boundary condition allows actual evaporation to be calculated from first principles; the evaporation is influenced by climatic conditions and the reluctance of the soil surface to release moisture. A 'unit gradient' condition was adopted for the lower boundary of the model. This boundary condition allows the model to show a flux and the rate if any water becomes available.

1.2.4 Climate data

Climatic boundary conditions in the model comprised precipitation data, potential evaporation data, average temperature, average humidity, average wind speed and solar radiation obtained from the Bureau of Meteorology (BOM) database. Figure 1-3 and Figure 1-4 show the key climate data, i.e. the precipitation and potential evaporation, applied to each model.

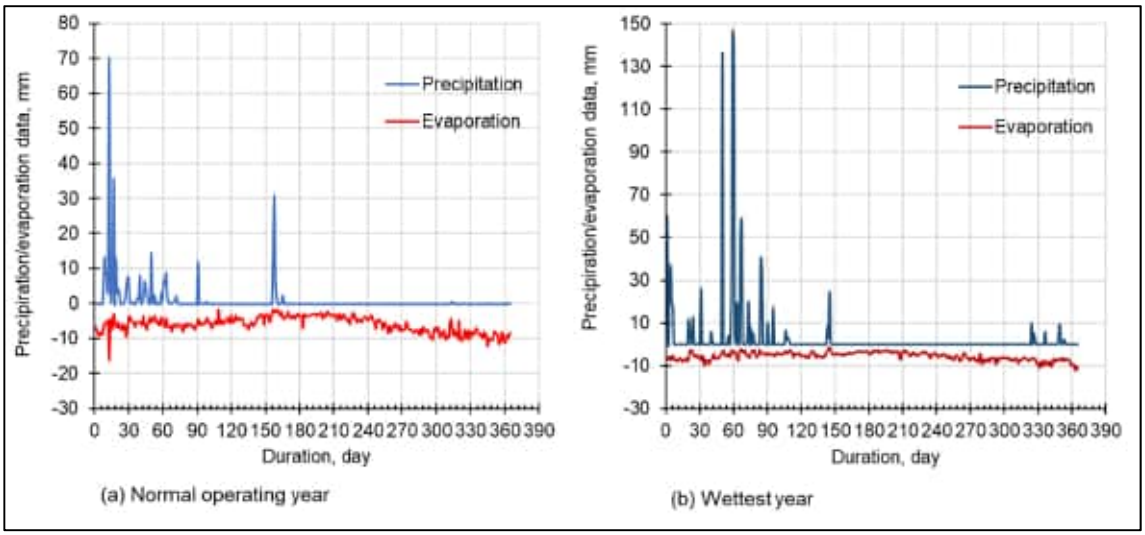


Figure 1-3: Precipitation and evaporation data: (a) Scenario 1 and (b) Scenario 2

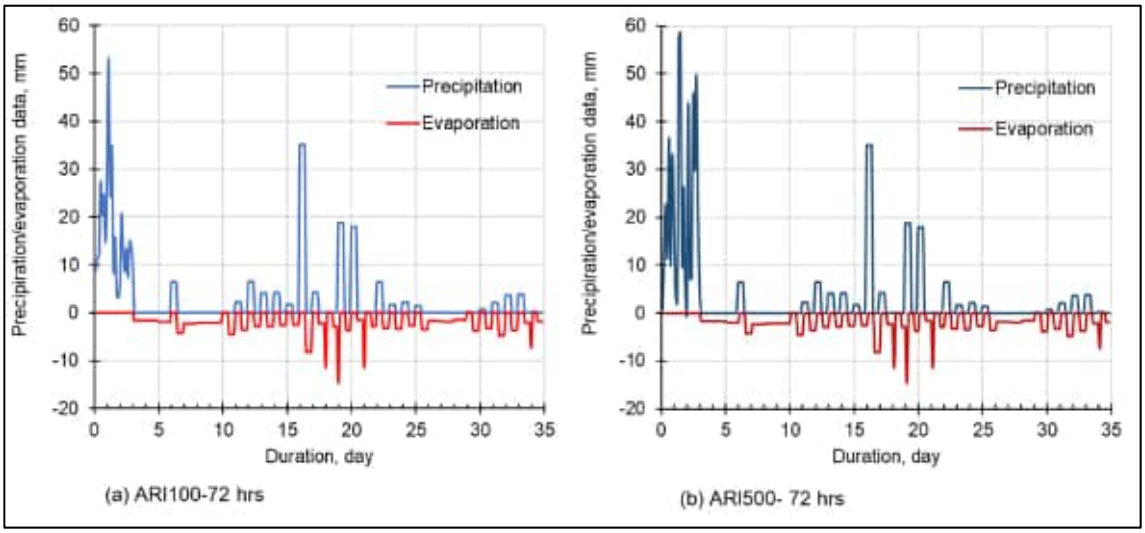


Figure 1-4: Precipitation and evaporation data: (a) Scenario 3 and (b) Scenario 4

1.3 Infiltration assessment results

The degree of saturation at different depths was evaluated to assess the effects of different climatic conditions on the stockpile. Various depths were selected for each case to highlight the distribution and evolution of the degree of saturation within the soil column.

1.3.1 Scenario 1 – Typical operating year

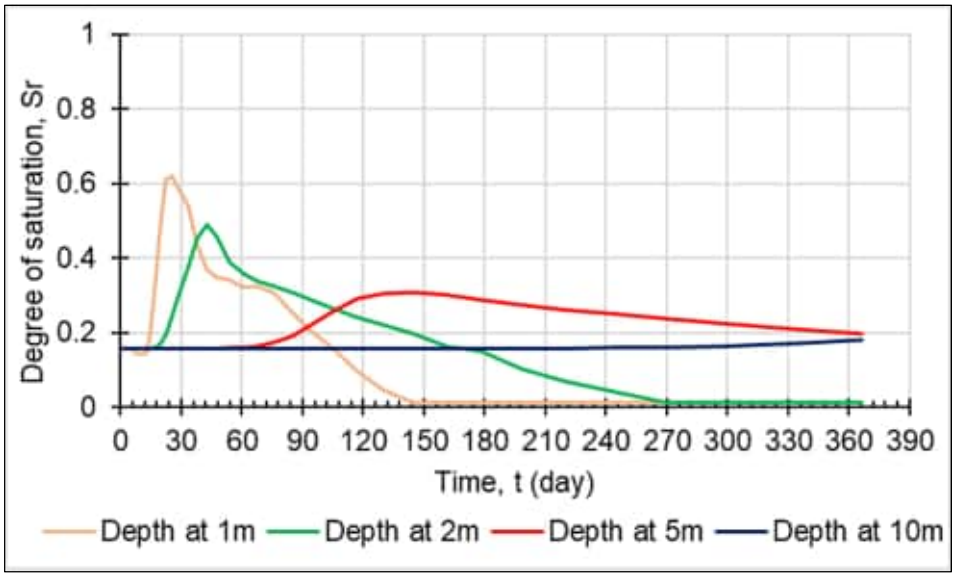


Figure 1-5: Degree of saturation at different depths in Scenario 1

Scenario 1 represents the typical operating condition using the 2018 climate data. Obvious spikes which occur during the wet season were observed for soil layers at 1 m and 2 m depths. Subsequent evaporation and lack of precipitation in later periods resulted in the material at these depths being highly unsaturated. The layer at a 5 m depth experienced a slight increase of saturation that steadily reduces with time, while the degree of saturation for a layer at a depth of 10 m remains unchanged.

1.3.2 Scenario 2 – Wettest climate year

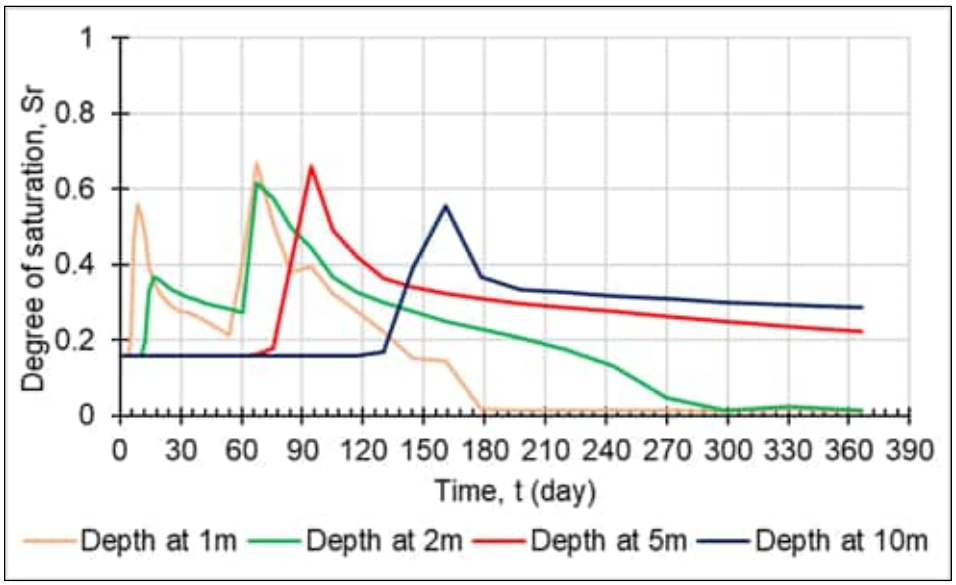


Figure 1-6: Degree of saturation at different depths in Scenario 2

Scenario 2 represents a climatic condition with the highest annual precipitation based on SILO data. The derived annual precipitation was 1,040 mm for this particular year with a maximum daily precipitation of nearly 150 mm. Obvious spikes were observed for all layers, even at a 10 m depth, following high rainfall events. For every spike observed, a higher desaturation rate was observed for soil layers at shallow depths because of the high evaporation rate compared to a slow and steady desaturation rate at the deeper depths.

1.3.3 Scenario 3 – ARI 100-year, 72-hour event

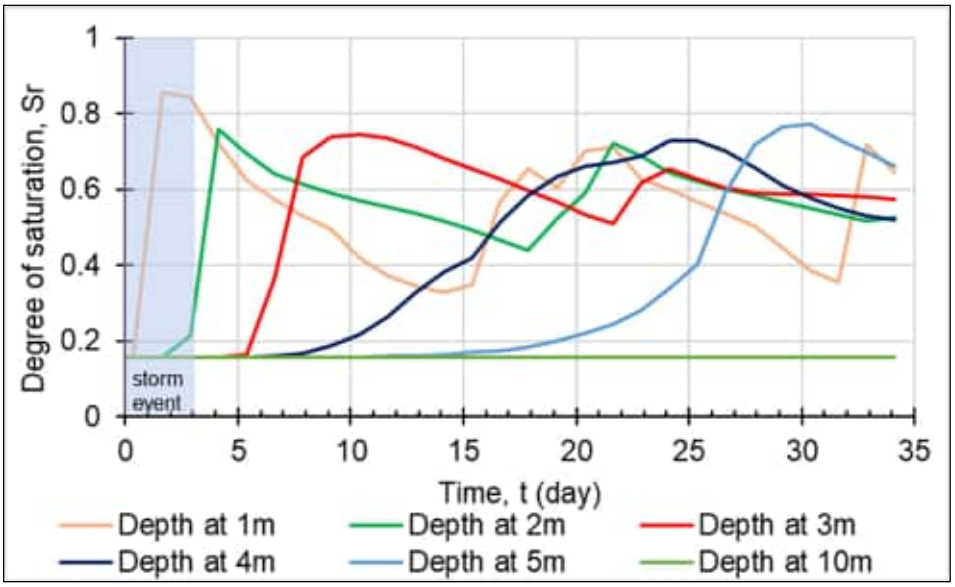


Figure 1-7: Degree of saturation at different depths in Scenario 3

Scenario 3 represents an ARI 100-year, 72-hour storm event with the precipitation of 399 mm followed by a typical wet month. During the storm event, the shallow layers to a 1 m depth reached a near-saturated state. However, flat peaks observed in these layers suggest that the saturation was momentary and reduced rapidly with time. The near-saturated layers, approximately 85% saturation, are due to the infiltration of the large volume of water into the layers following the storm events. Subsequent rainfall events during the wet month shortly after the extreme storm event did not affect the overall degree of saturation in the deeper layer, i.e. degree of saturation for soil layers at a 10 m depth remained unchanged.

1.3.4 Scenario 4 – ARI 500-year, 72-hour event

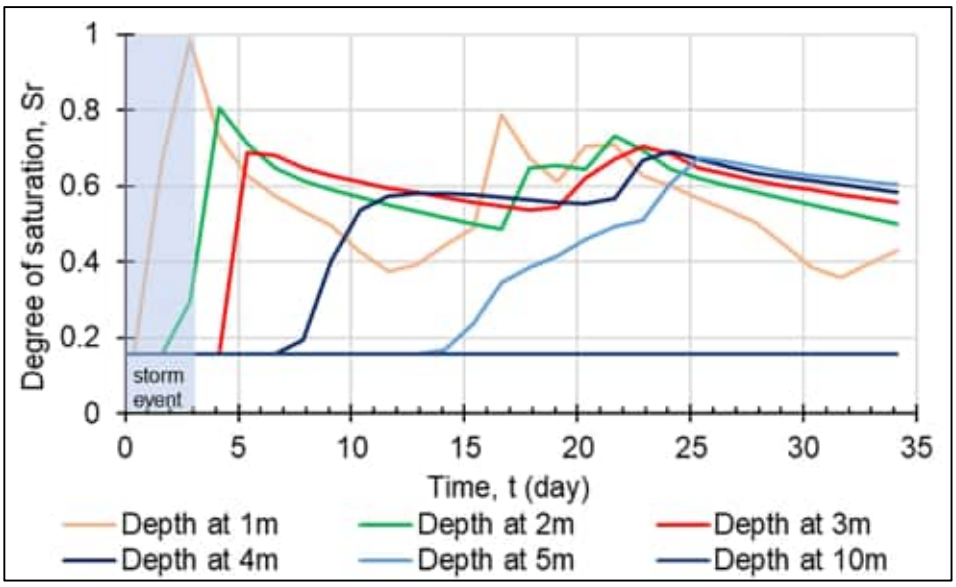


Figure 1-8: Degree of saturation at different depths in Scenario 4

Scenario 4 represents an ARI 500-year, 72-hour storm event with precipitation of 523 mm followed by a typical wet month. During the storm event, the shallow layers to 1 m depth became saturated. Similar to Scenario 3, the saturated layers are due to the infiltration of the significantly large volume of

water into the soil layers in a short time. However, from 2 m depth onward, the soil layers remained partially saturated while a lower degree of saturation occurs at a deeper depth.

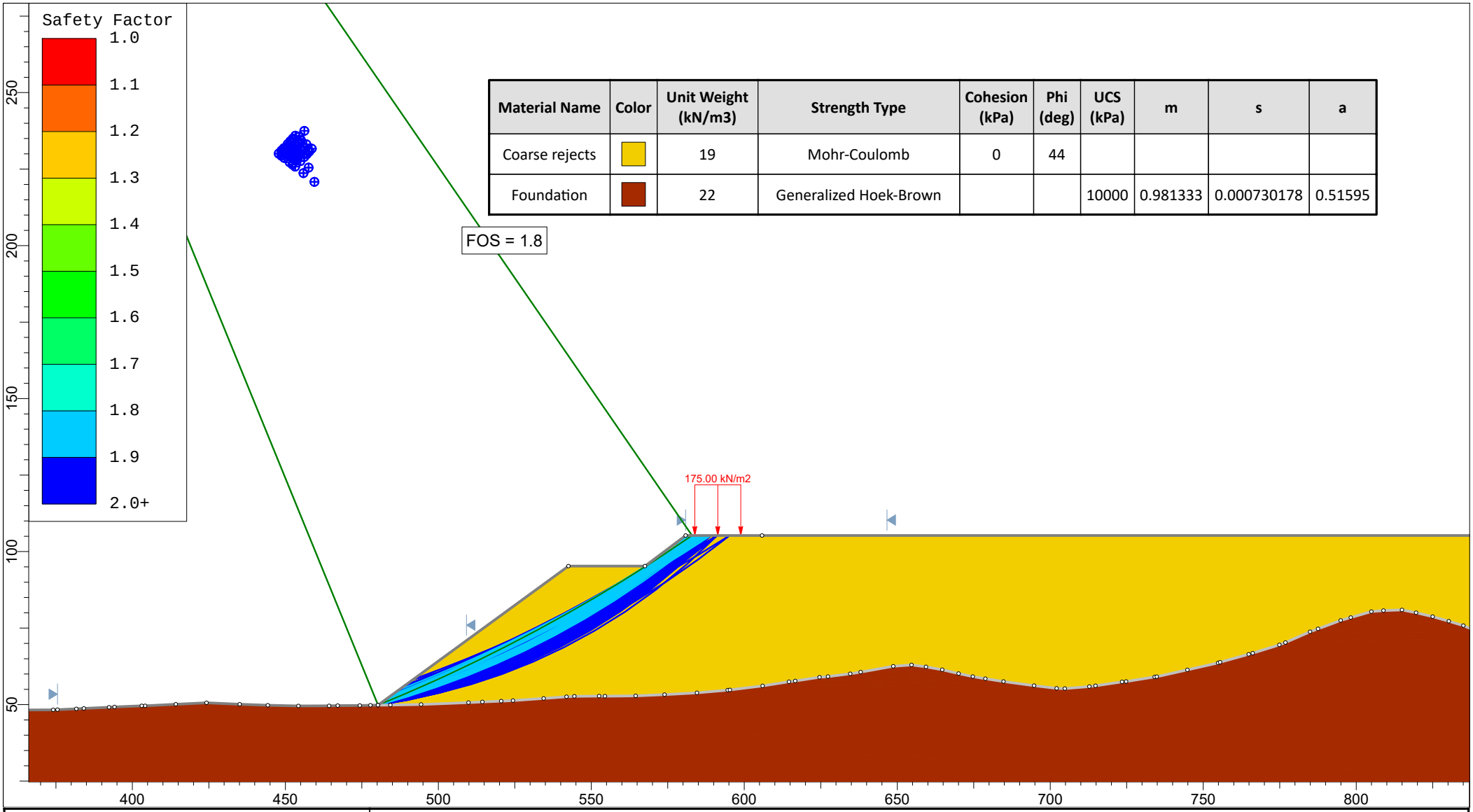
1.4 Conclusion

Based on the outcomes of the infiltration assessment, the stockpile will not experience fully saturated conditions under any conceivable scenario, including the following:

a. Typical operating year (based on 2018 climate data)
b. Wettest climate year (based on SILO database)
c. Extreme storm event (based on ARI 100 year, 72-hour event)
d. Extreme storm event (based on ARI 500 year, 72-hour event).

The only scenario that led to any section of the stockpile becoming saturated was the ARI 500-year, 72-hour storm event. In this case, the upper 1 m material layer may reach a near-saturated state. However, due to the transient and very limited depth of this saturation, the impact is considered negligible and would not have an adverse effect on the stockpile's stability, even during a seismic event.

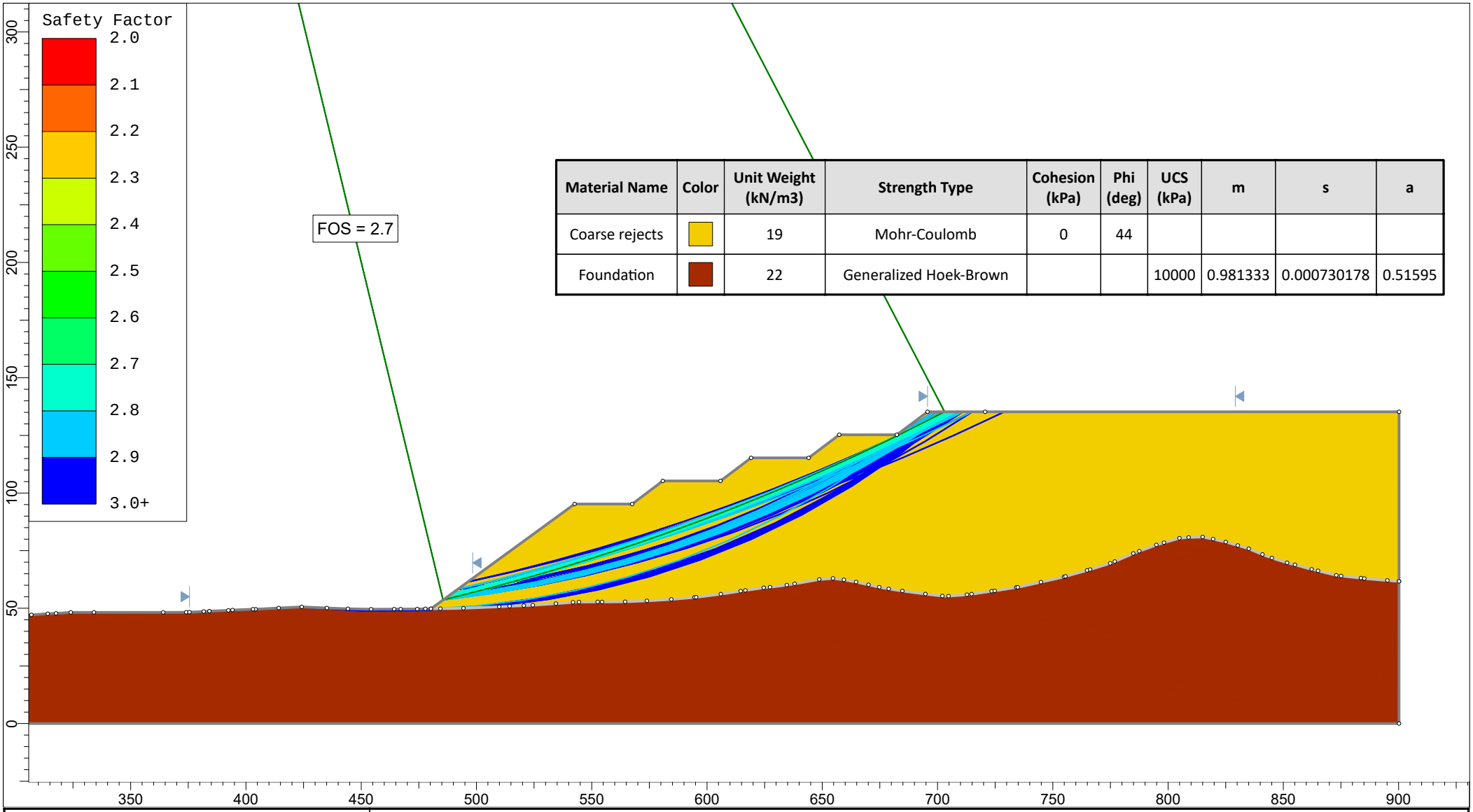
Appendix D: Slope stability assessment



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44				
Foundation		22	Generalized Hoek-Brown			10000	0.981333	0.000730178	0.51595

srk consulting

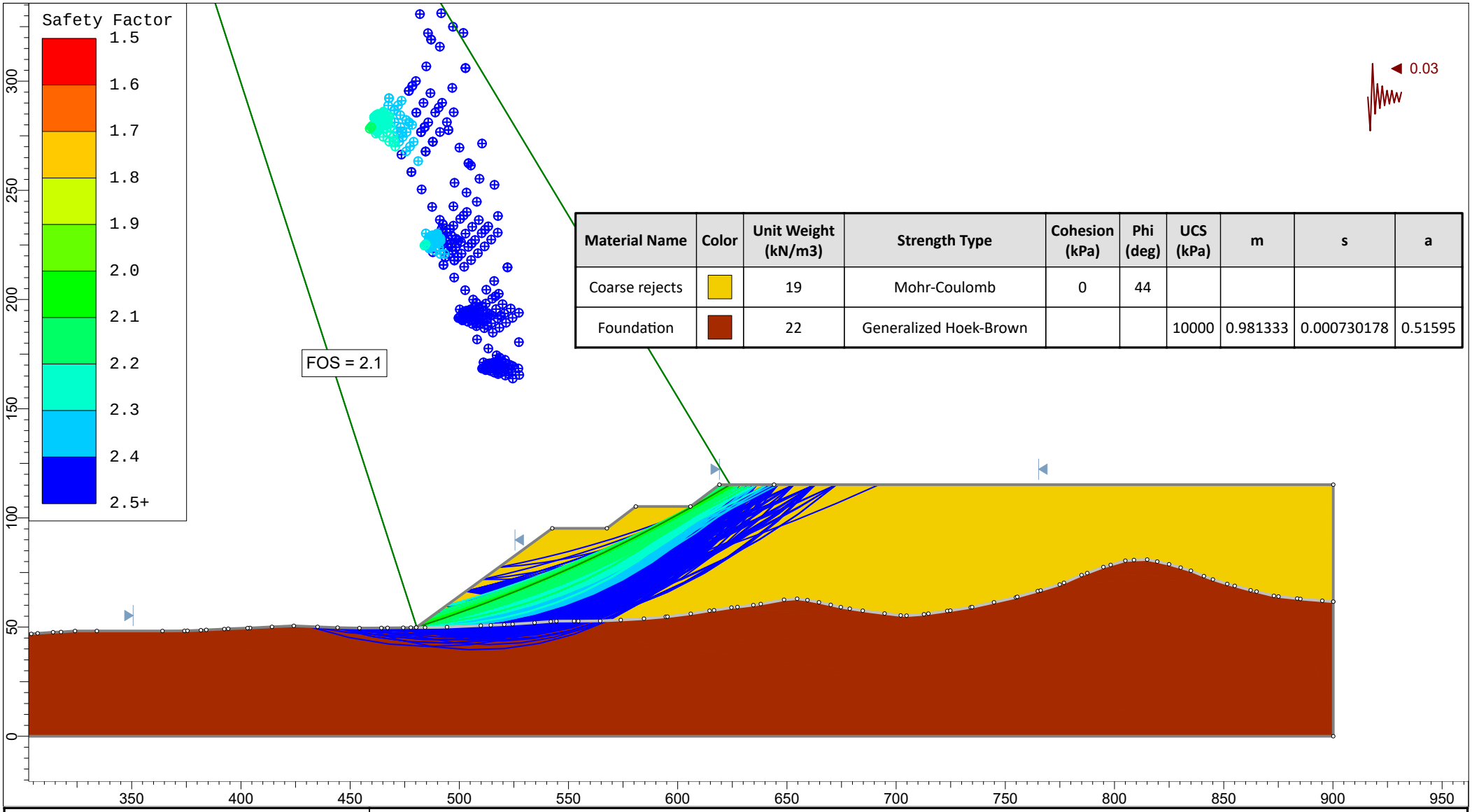
Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 1 - Static - Interim operational, multiple lifts failure		
Drawn By	A Lim	*Company*	SRK Consulting
Date	27/03/2019	*File:*	Model 1 - Static - Interim operational, multiple lifts failure.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44				
Foundation		22	Generalized Hoek-Brown			10000	0.981333	0.000730178	0.51595

srk consulting

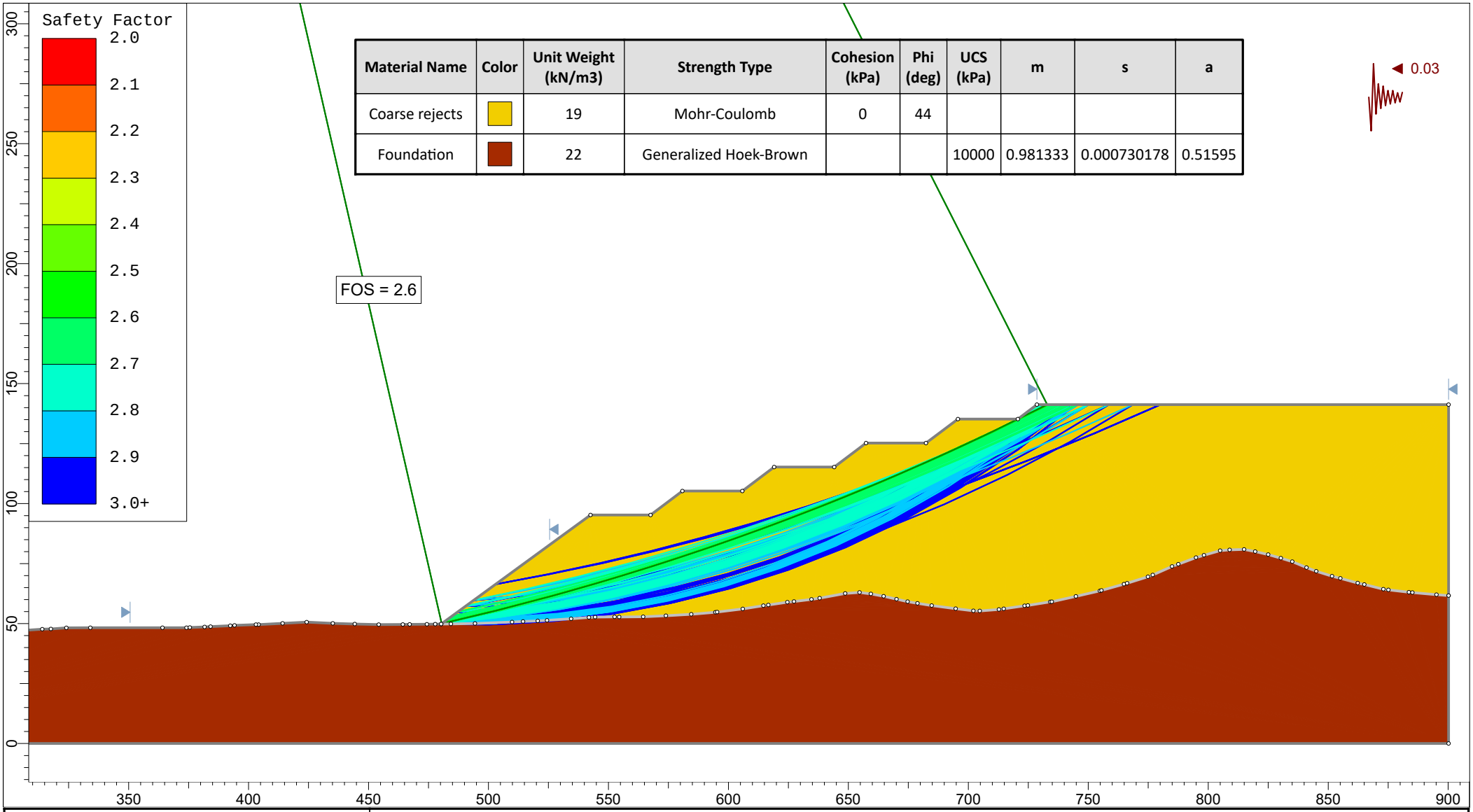
Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 2 - Static - final operational, global failure		
Drawn By	A Lim	*Company*	SRK Consulting
Date	27/03/2019	*File Name*	Model 2 - Static - final operational, global failure.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44				
Foundation		22	Generalized Hoek-Brown			10000	0.981333	0.000730178	0.51595

srk consulting

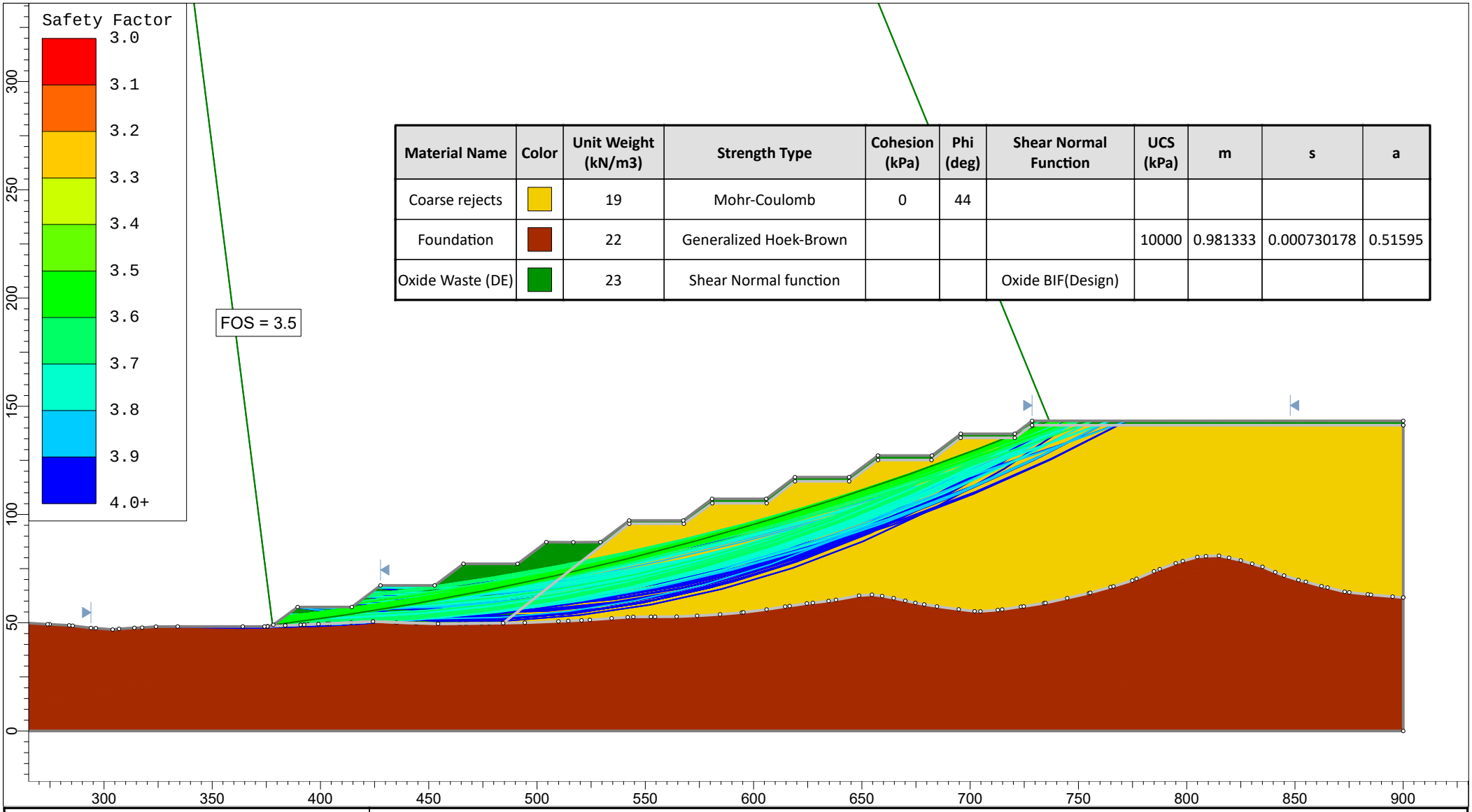
Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 3 - Pseudo-static (OBE) - interim operational, multiple lifts failure		
Drawn By	A Lim	*Company*	SRK Consulting
Date	27/03/2019	*File Name*	Model 3 - Pseudo-static (OBE) - interim operational, multiple lifts failure.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44				
Foundation		22	Generalized Hoek-Brown			10000	0.981333	0.000730178	0.51595

srk consulting

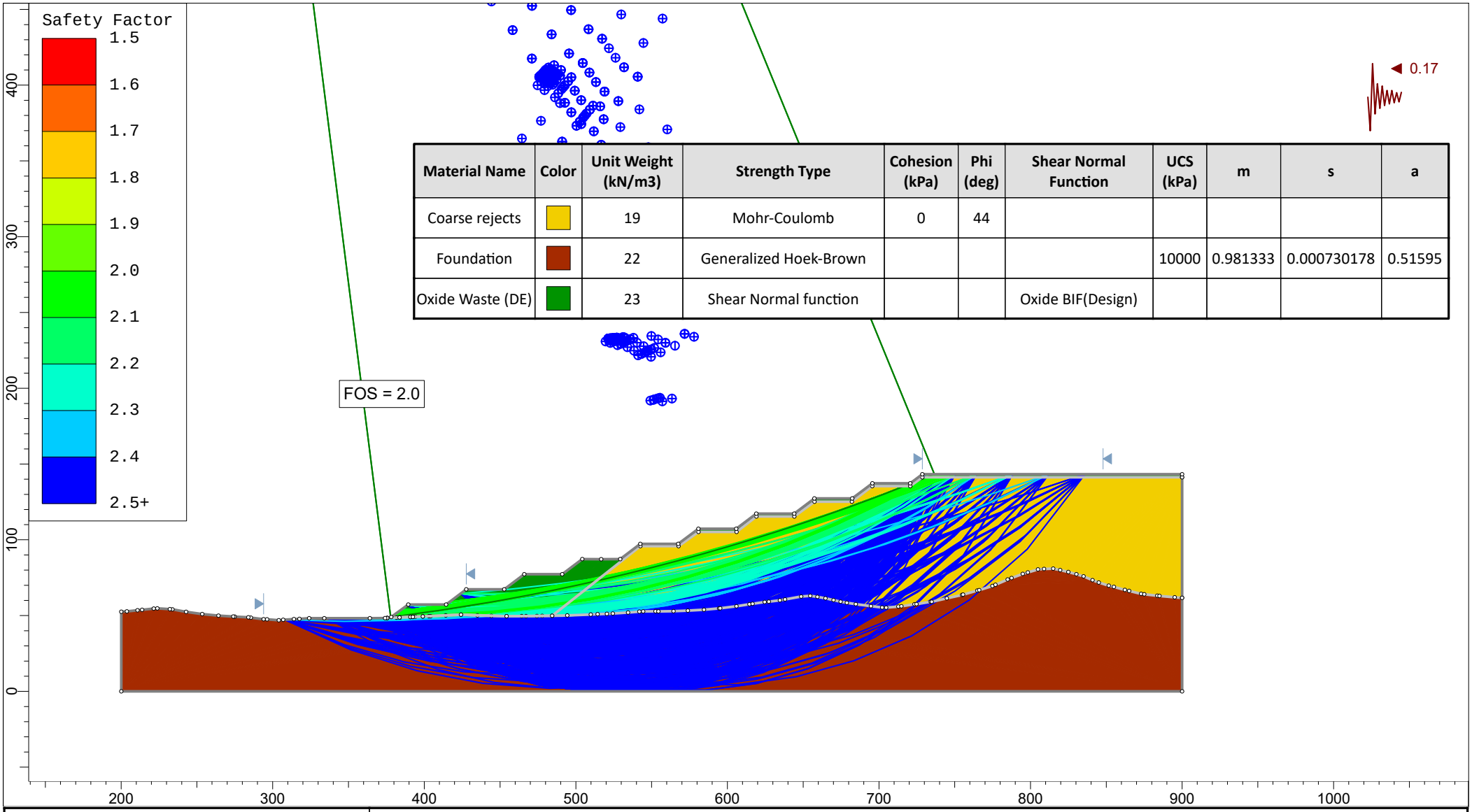
Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 4 - Pseudo-static (OBE) - final operational, global failure		
Drawn By	A Lim	*Company*	SRK Consulting
Date	27/03/2019	*File Name*	Model 4 - Pseudo-static (OBE) - final operational, global failure.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Shear Normal Function	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44					
Foundation		22	Generalized Hoek-Brown				10000	0.981333	0.000730178	0.51595
Oxide Waste (DE)		23	Shear Normal function			Oxide BIF(Design)				

srk consulting

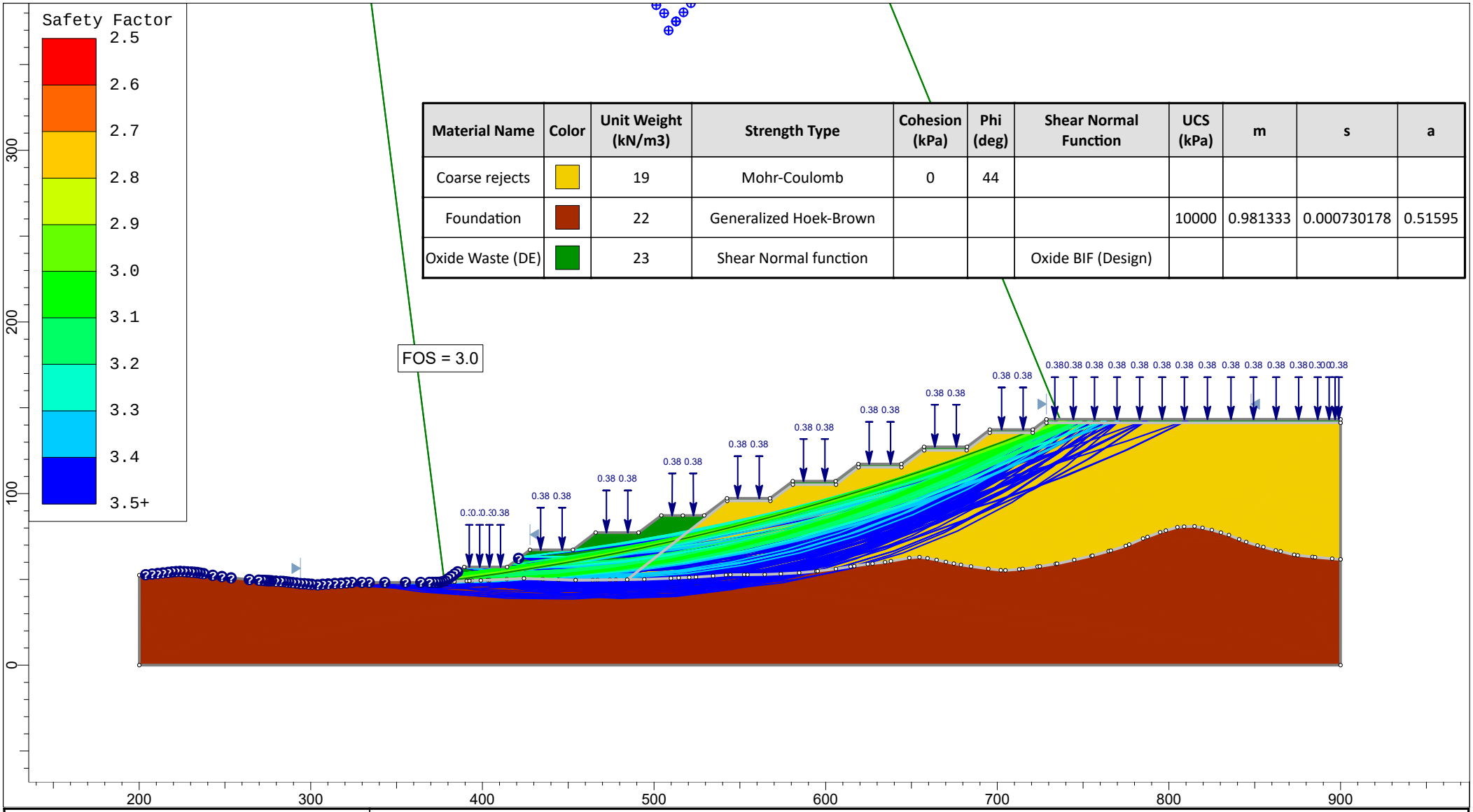
Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 5 - Static - Closure, global failure		
Drawn By	A Lim	*Company*	SRK Consulting
Date	24/04/2019	*File Name*	Model 5 - Static - closure, global failure.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Shear Normal Function	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44					
Foundation		22	Generalized Hoek-Brown				10000	0.981333	0.000730178	0.51595
Oxide Waste (DE)		23	Shear Normal function			Oxide BIF(Design)				

srk consulting

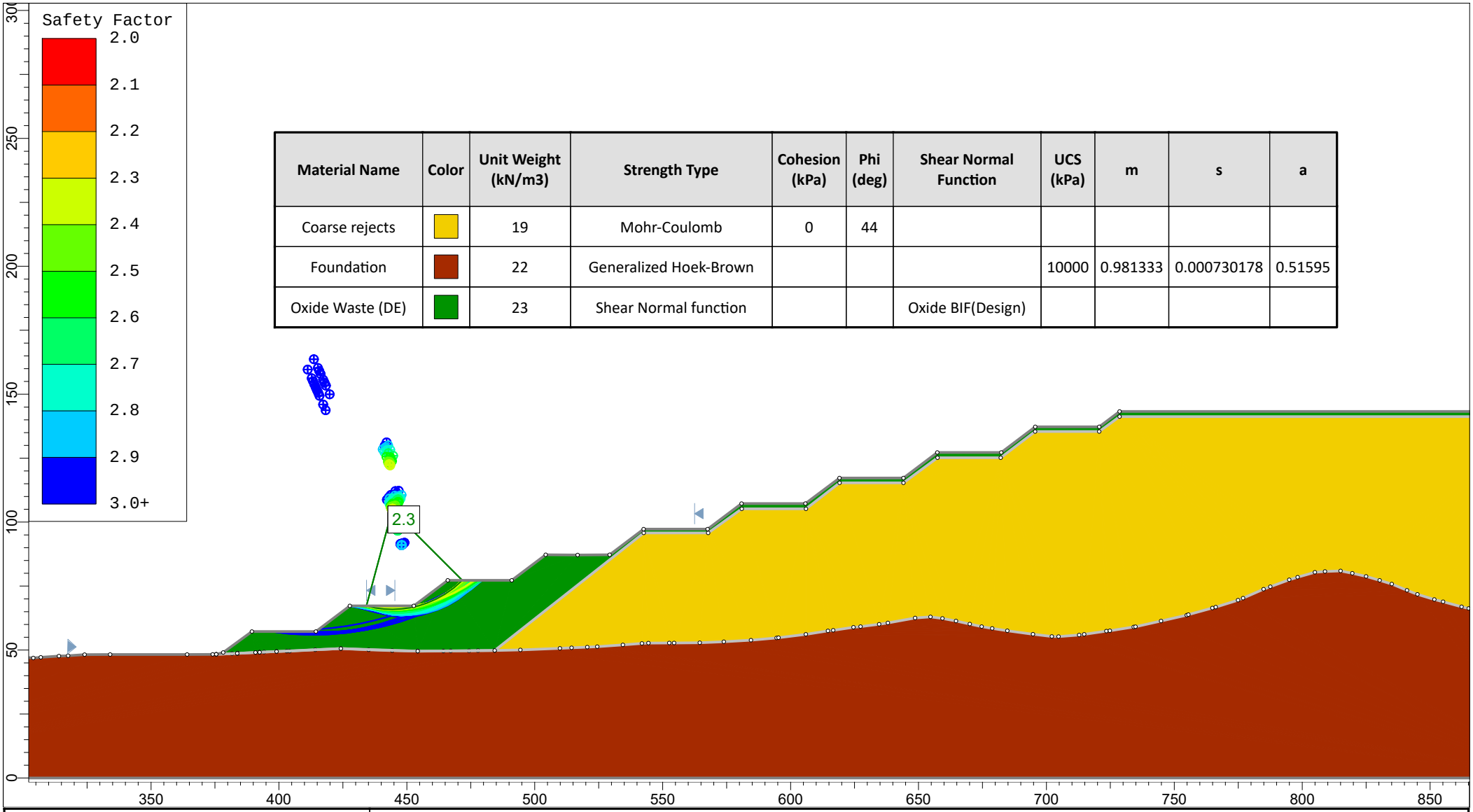
Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 6 - Pseudo-static (MCE) - closure, global failure		
Drawn By	A Lim	*Company*	SRK Consulting
Date	24/04/2019	*File Name*	Model 6 - Pseudo-static (MCE) - closure, global failure.slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Shear Normal Function	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44					
Foundation		22	Generalized Hoek-Brown				10000	0.981333	0.000730178	0.51595
Oxide Waste (DE)		23	Shear Normal function			Oxide BIF (Design)				

srk consulting

Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 7 - Static (PMP pore pressure) - closure, global failure		
Drawn By	A Lim	*Company*	SRK Consulting
Date	24/04/2019	*File Name*	Model 7 - Static(PMP pore pressure) - closure, global failure.slim

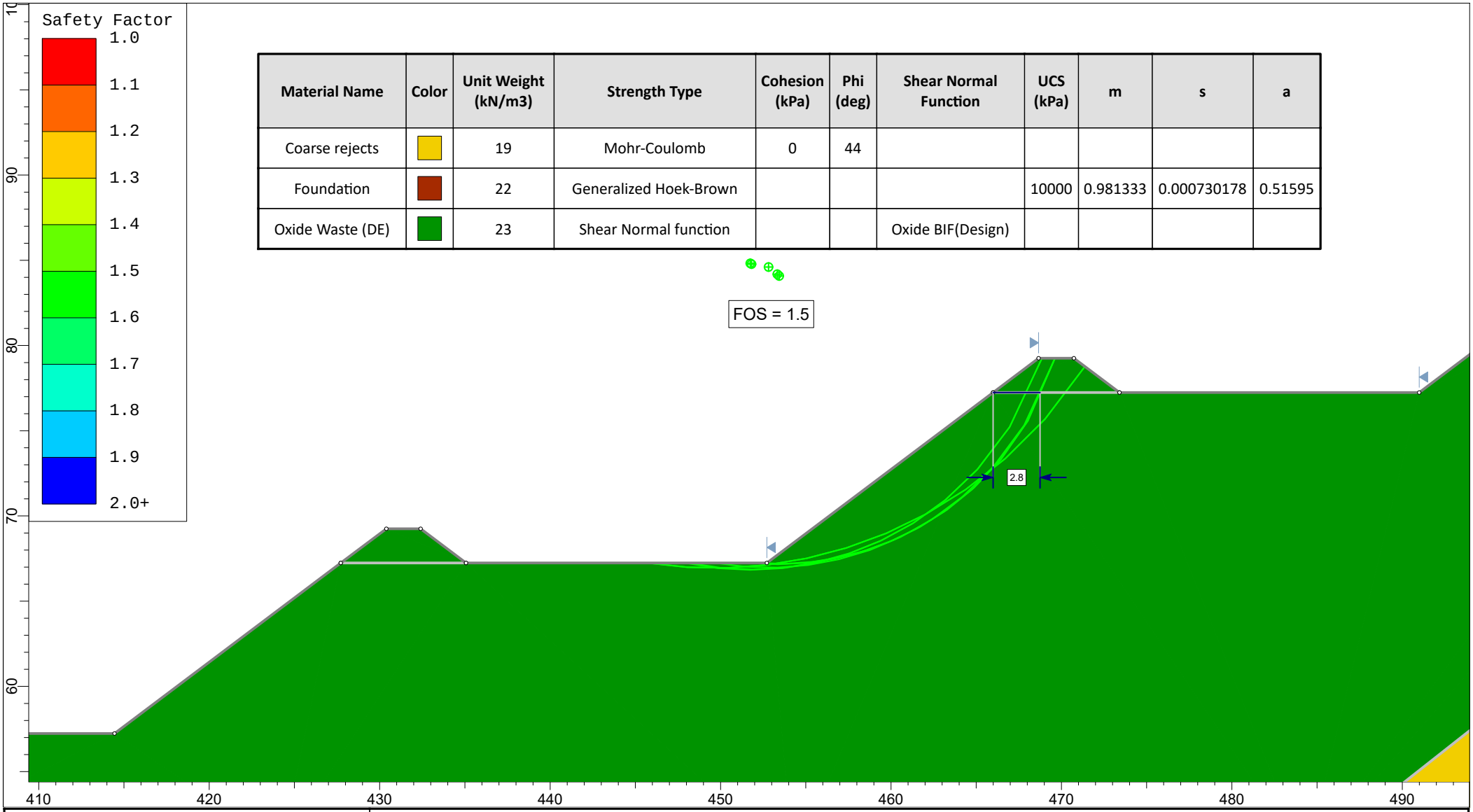


Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Shear Normal Function	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44					
Foundation		22	Generalized Hoek-Brown				10000	0.981333	0.000730178	0.51595
Oxide Waste (DE)		23	Shear Normal function			Oxide BIF(Design)				

srk consulting

Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 8 - Static - Closure, local failure through oxide waste		
Drawn By	A Lim	*Company*	SRK Consulting
Date	24/04/2019	*File Name*	Model 8 - Static - closure, localised failure through oxide waste.slim

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Shear Normal Function	UCS (kPa)	m	s	a
Coarse rejects		19	Mohr-Coulomb	0	44					
Foundation		22	Generalized Hoek-Brown				10000	0.981333	0.000730178	0.51595
Oxide Waste (DE)		23	Shear Normal function			Oxide BIF(Design)				



srk consulting

Project	IBO057-Iron Bridge Stockpile Detailed Design		
Analysis Description	Model 9 - Static - Closure, localised failure to estimate minimum standoff distance for FOS = 1.5		
Drawn By	A Lim	*Company*	SRK Consulting
Date	26/04/2019	*File Name*	Model 9 - Static - closure, localised failure to estimate minimum standoff distance.slim

Appendix E: Settlement analysis

1 One-dimensional settlement analysis

One-dimensional settlement of the stockpile was estimated based on the elastic settlement and primary settlement of the coarse-grained material.

1.1 Elastic settlement

Elastic settlement was estimated using the elastic stiffness measured from the stress-strain curves of the consolidated drained triaxial data at five different confining stresses (50 kPa, 100 kPa, 250 kPa, 500 kPa and 1,000 kPa). The elastic stiffness was measured at 0.1% strain, which is within the elastic region of the material.

The method[1] suggested by the Canadian Geotechnical Society, which is based on the elastic strain theory, was followed. The elastic settlement was computed using Equation 1.

$$s_e = \Sigma\, \varepsilon_z h_z = \Sigma\, \frac{\Delta\sigma_z}{E_s} h_z \qquad (1)$$

where

s_e=elastic settlement for the whole layer (m)

h_z = height of the sublayer (m)

$\Delta\sigma_z$= applied stress at mid-point of each sublayer (kPa)

E_s= elastic stiffness at 0.1% strain

1.2 Primary settlement

The primary settlement was estimated using the one-dimensional consolidation theory. The calculation used the laboratory oedometer data in which a sample was prepared at minimum density with 3% moisture content and compressed to the maximum vertical stress of 2,000 kPa.

The dry rejects material was assumed to be placed to a maximum height of 80 m. The unit weight of the dry rejects material is 19 kN/m^3 and each progressive layer (assumed 1 m thickness) generates a vertical effective stress of 19 kPa. The first layer will experience an initial stress of 19 kPa due to self-weight and an overburden stress of 1,500 kPa at the full stockpile height of 80 m.

Table 1 summarises the soil parameters estimated from the reported laboratory data.

Table 1: Soil parameters used for elastic and primary settlement analysis

Oedometer data			Triaxial data	Comments
Effective stress, σ (kPa)	**Void ratio, e (-)**	**Strain, ε (-)**	**Elastic stiffness, E (MPA)**	
0	0.56	0	0	Initial void ratio was calculated based on the initial moisture content of 3% at a minimum density of 1.86 t/m^3.
50	0.55	0.0064	60.2	Void ratio was interpolated for 50 kPa effective stress because the sample was prepared at the initial stress level of 100 kPa.
100	0.535	0.0096	131.9	Oedometer data was obtained from laboratory data while elastic stiffness was calculated from triaxial data.
250	0.51	0.0160	156.2	
500	0.476	0.0219	288.0	
1,000	0.434	0.0269	849.1	
2,000	0.373	0.0391	1,950	Elastic stiffness for 2,000 kPa was interpolated because the maximum confining stress for triaxial test was 1,000 kPa.

1.3 Settlement analysis results

For each placement of 1 m layers above the underlying layer, the calculated relative settlement is approximately 0.0025 m, which is insignificant. The first layer placed will experience settlement up to 0.03 m due to the cumulative placement of layers above it (Figure 1.) This estimated settlement corresponds to the change of void ratio from 0.56 to 0.4. Similar trends could be seen for different layers at various heights (layers at 20 m, 40 m and 60 m) in the same figure.

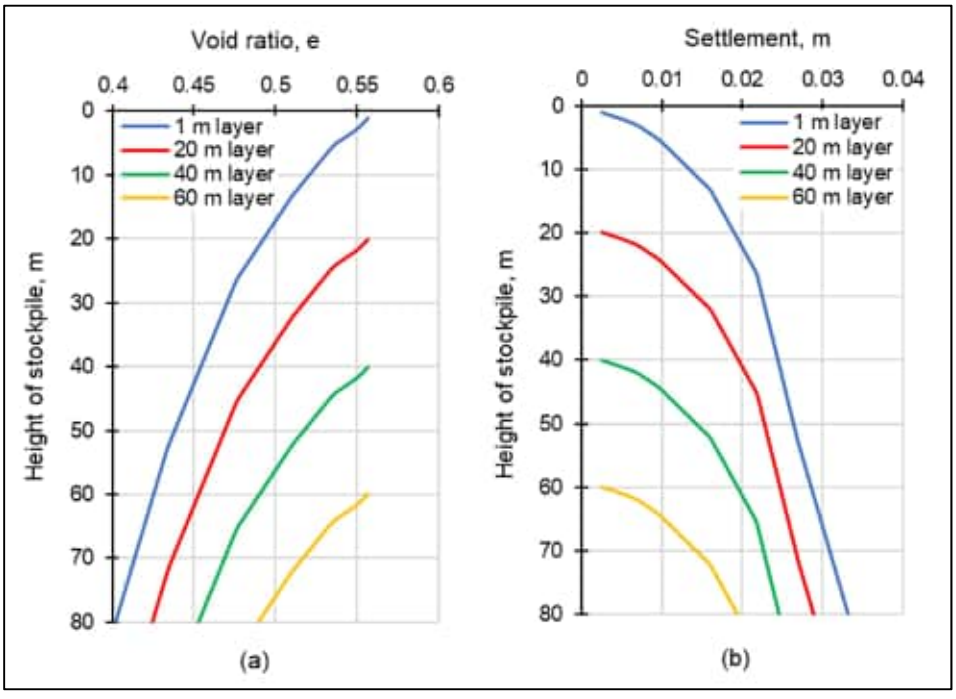


Figure 1: (a) Change of void ratio and (b) primary settlement in different soil layers

The cumulative total settlement expected for an 80 m high stockpile is approximately 2 m, comprising 0.15 m elastic settlement and 1.85 m primary settlement (Figure 2).

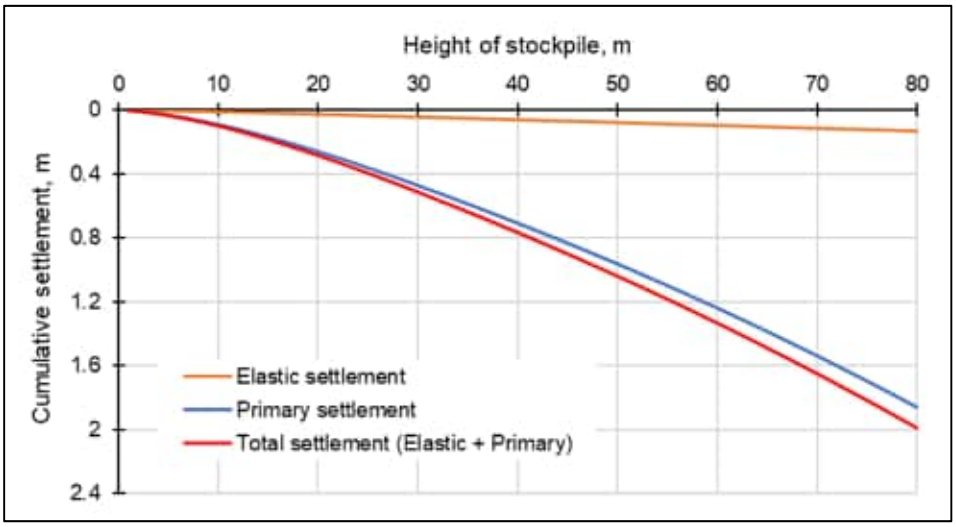


Figure 2: Elastic, primary and total settlement of stockpile

1.4 Conclusion

Given that the stockpile will be developed in stages and the dry rejects material is predominantly granular, settlement will occur almost immediately after placement due to equipment loading and self-weight. The cumulative settlement of 2.2 m is the sum of instantaneous settlements for every layer placed of dry rejects by the radial stacker. The magnitude of each instantaneous settlement is minimal and would have an adverse impact on the operation or stability of the stockpile.

Appendix F: Runout estimate

1 Runout estimate

The potential runout distance and volume (should failure of the stockpile occur) was estimated using empirical correlations recommended by CSIRO (2017)[1]. Predicting potential runout of a stockpile failure is critical for risk assessment and developing a mitigation plan for potential landslides.

1.1 Established runout parameters

Empirical correlations based on quality historical data can be used in the analysis as suggested by CSIRO[1]. However, it is noted that empirical correlations can only provide approximate means of predicting runout of stockpile landslides since mobilisation processes acting in stockpile slides are widely variable.

The potential distance was undertaken using two empirical correlations by Hunter and Fell (2003) and Devoli et al. (2009).

The following three parameters (Figure 1-1) were used to establish the empirical correlations:

1. Travel distance angle, α, which is the vertical angle measured from the crown of the landslide source to the toe of the deposit
2. Overall fall height, *H*
3. Horizontal distance between the crown of the source volume and the toe of the deposit, *L*.

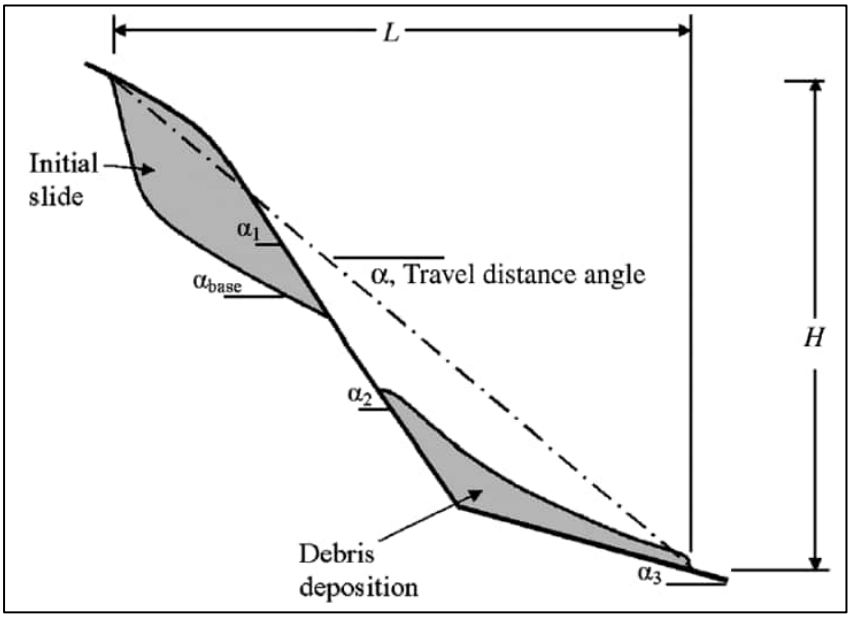


Figure 1-1: Definition of travel distance, travel distance angle and slope geometry

Source: Hunter and Fell, 2003

[1] Hawley, M and Cunning, J, 2017. *Guidelines for Mine Waste Dump and Stockpile Design*. CSIRO Publishing.

1.2 Runout distance and volume predictions

SRK used empirical correlations based on the Hunter and Fell (2003)[2] technical paper, which was recommended by CSIRO[1]. The empirical correlations are based on the analysis of 350 landslides, most of which had soil slopes.

The appropriate empirical correlations can be determined based on the following criteria:

a. Whether a landslide will travel at a "rapid" post-failure velocity

b. Whether the materials on the surface of rupture are contractive or dilative on shearing

c. Type of slope

d. Slide volume

e. Geometry of the slope at and below the slide source area

f. Degree of confinement of the travel path of the landslide.

The type of slope considered for the stockpile is similar to a mine waste spoil pile which comprises loosely placed filled materials that are contractive during shearing. As the geometry of the stockpile is relatively constant, the correlation by Hunter and Fell (2003)[2] was used to estimate the *H/L* ratio and from that, the runout distance (Figure 1-2).

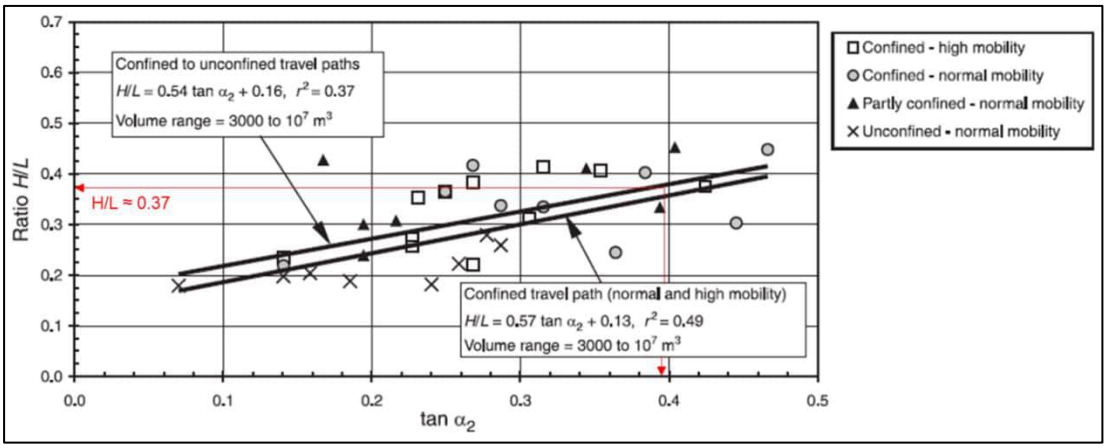


Figure 1-2: *H/L* ratio versus the tangent of the downslope angle below the toe of the spoil pile, α_2, for flow slides in coarse-grained coal mine waste spoil piles

Source: Hunter and Fell, 2003

Figure 1-2 shows that the *H/L* ratio is approximately 0.37 based on an overall slope angle of the stockpile of 21.6°. The overall slope angle is lower than the angle of repose due to the additional horizontal distance of bench width for every lift. For an 80 m high stockpile, it is expected that the potential runout distance is approximately 214 m and the runout volume would range significantly with a maximum of approximately 10^7 m^3.

Another empirical correlation (Devoli et al.,2009[3]) was used to estimate the predicted runout distance. Devoli et al. (2009) used data from 527 events to establish the relationship between the fall height and the runout distance as well as the relationship between the *H/L* ratio and the landslide volume. The data was derived from analysis of rock falls and rock avalances, plane

[2] Hunter, G and Fell, R, 2003. Travel distance angle for" rapid" landslides in constructed and natural soil slopes. *Canadian Geotechnical Journal*, *40*(6), pp 1123-1141.
[3] Devoli, G, De Blasio, F V, Elverhøi, A and Høeg, K, 2009. Statistical analysis of landslide events in Central America and their run-out distance. *Geotechnical and Geological Engineering*, *27*(1), pp 23-42.

slides, debris flow and debris avalances in volcanic and non-volcanic environments, earthflows and mudflows.

The correlation between *H* and *L* shows a fairly linear trend for rotational and planar slides (Figure 1-3). The standard least square regression method of this relationship provides an empirical relationship of log *L* = 1.1172log *H* + 0.228 with r^2 = 0.8526.

Figure 1-4 compares the relationship between *H/L* and volume of the 527 landslides. The best fit equation based on this relationship is log *H/L* = -0.0916 log V – 0.041 with r^2 = 0.532.

Based on the empirical correction by Devoli et al. (2009), a runout distance of 226 m and a potential runout volume of 3 × 10^4 m^3 were predicted for an 80 m high stockpile.

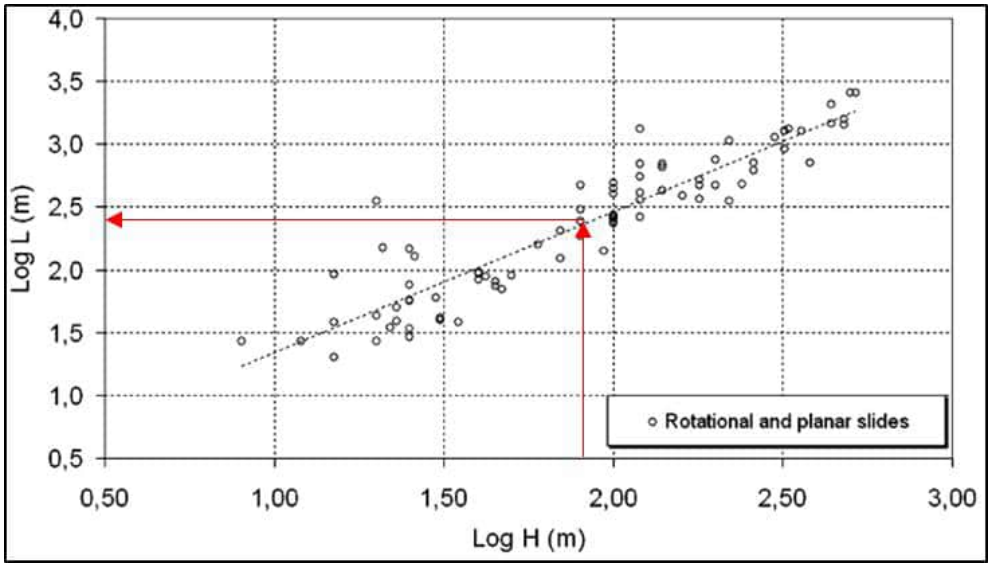


Figure 1-3: Relationship between fall height and runout distance for rotational and planar slides

Source: Devoli et al., 2009

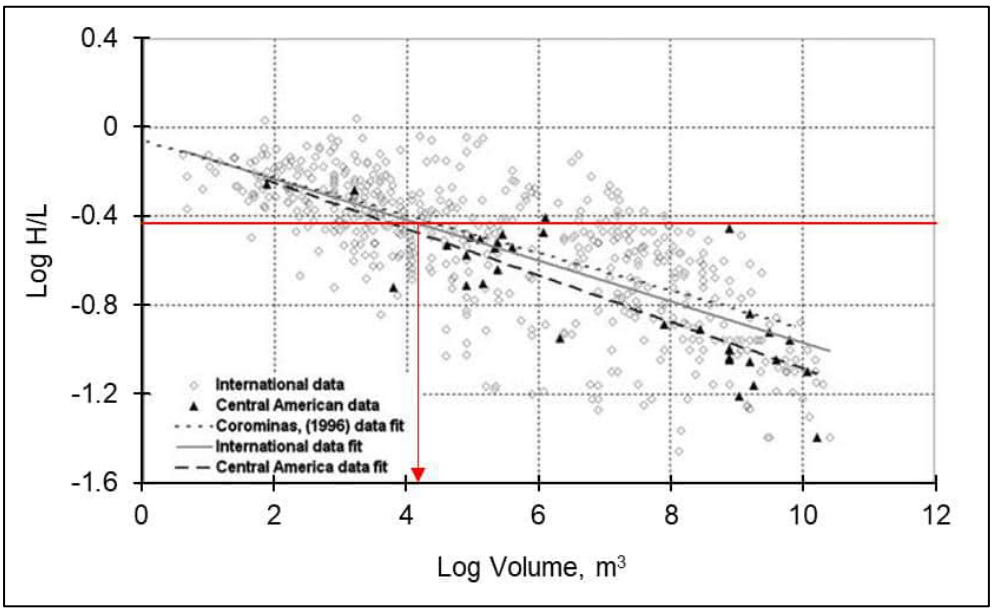


Figure 1-4: Relationship between *H/L* ratio and landslide volume – comparison between 527 events

Source: Devoli et al., 2009

1.3 Conclusion

Using two different empirical correlations, the potential runout distance of approximately 230 m can be estimated for a stockpile with a height of 80 m, with a maximum potential runout volume of approximately 1×10^7 m^3. A 250 m offset distance from the stockpile footprint should be considered during the planning of the surrounding infrastructures to minimise the potential damages to infrastructure and equipment, and potential loss of life. While failure and runout could potentially occur anywhere around the stockpile perimeter, the locations where the runout would be of higher consequence are where the stockpile is near the maximum height, for example, at the western flank, central southern flank and central northern flank. These are shown indicatively in Figure 1-5.

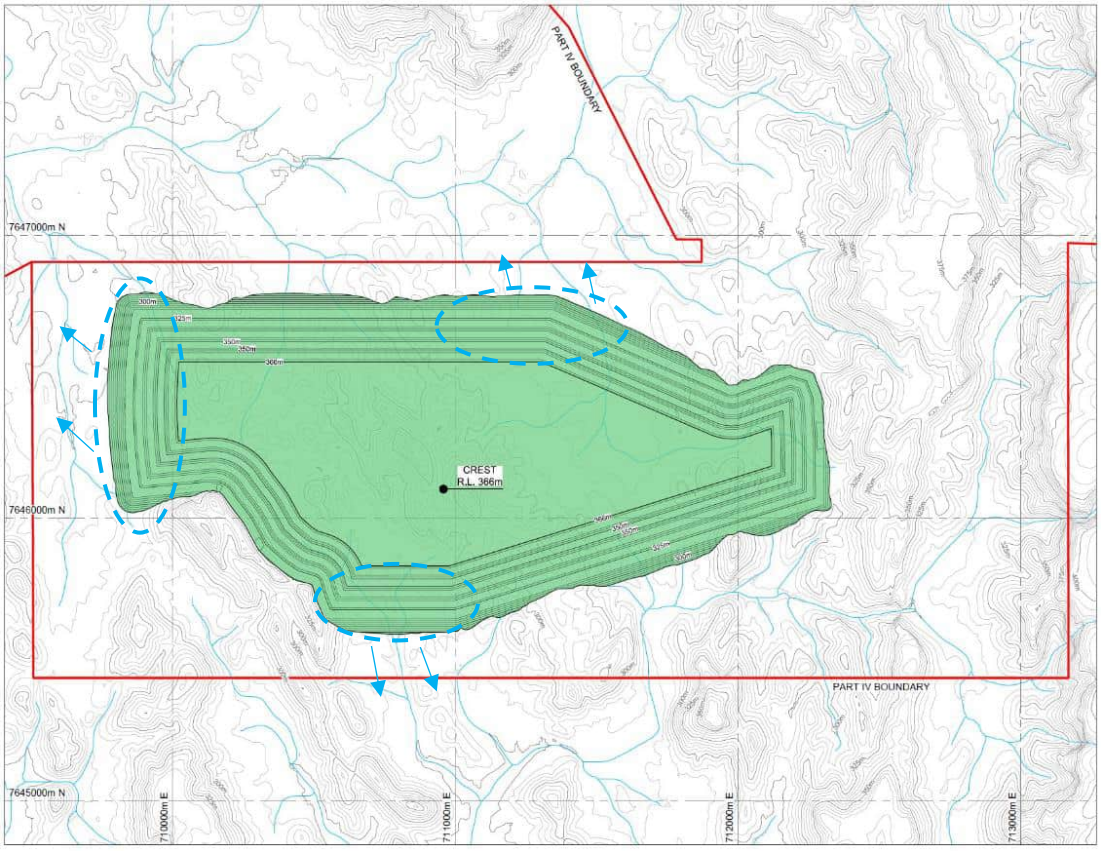


Figure 1-5: Indicative locations of the highest zones of the stockpile, where failure would likely have the largest consequence. This should be considered schematic only.

SRK Report Client Distribution Record

Project Number: IBO057

Report Title: Iron Bridge Dry Rejects Stockpile Design

Date Issued: 8 May 2019

Name/Title	Company
Daniel Dwumfour	Fortescue Metals Group Ltd
Justin Dixon	Fortescue Metals Group Ltd

Rev No.	Date	Revised By	Revision Details
0	17/04/2019	Nick Thompson	Draft Report
1	03/05/2019	Nick Thompson	Final Report
2	08/05/2019	Nick Thompson	Revised Final Report

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Memo

GEOTECHNICAL DESIGN REVIEW – IRON BRIDGE DRY REJECT ADDENDUM MEMO

OUR REF	IB-GE-0001	**DATE**	28/10/2020
TO	Kirsty Becket, Michael Fistonich	**CC**	Justin Dixon, Kyle Nesa, Mudit Tandon
FROM	Daniel Dwumfour		

1. REVIEW SUMMARY

Key points from the design review are:

- Both the operational and closure landform meets the design acceptance criteria in both the 2D and 3D assessment in all the scenarios assessed.
- The standoff provided for the radial stacker from the edge of the dry reject for various lift heights meet the design acceptance criteria based on the updated design loadings provided.
- All the previous design recommendations in the SRK report with reference NS-SW-GE-0003 are still valid.

2. INTRODUCTION

The following memorandum outlines the results of the geotechnical design review for the updated operational (Operational Stockpile V2) and closure dry reject dump (Closure stockpile V3). The closure design landform was updated to revise the northern slope to a flatter angle (see figure 1 below). The operational stockpile was also modified to suit the new closure design landform.

This memo is an addendum to the Iron Bridge Dry Reject Stockpile design report Rev 2 (NS-SW-GE-0003) completed by SRK consulting in May 2019. The assessment and recommendations in the SRK report remain valid.

This assessment also evaluates the proposed standoffs from the edge of the dry reject based on a new radial stacker design working load of 150kPa and proposed design lifts as per the Iron Bridge technical query (6624SP2025-0000-TQ-PM-0010).

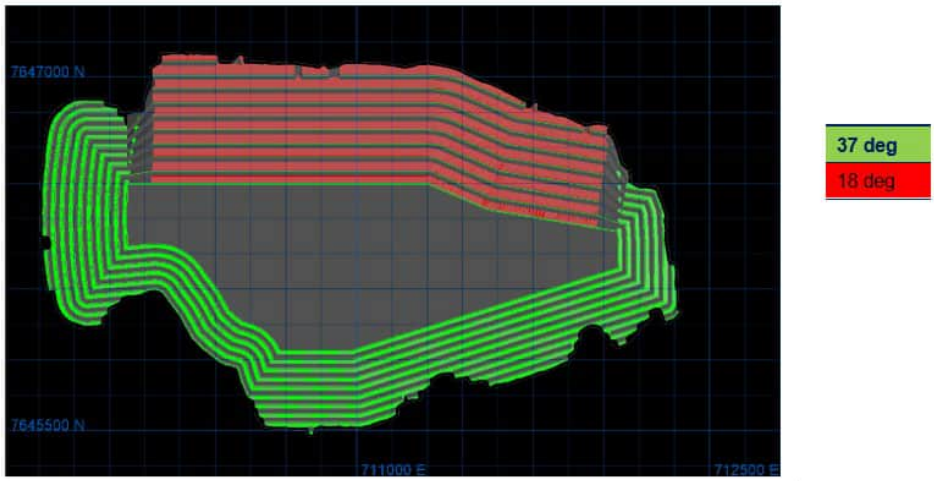


Figure 1: Westend Stage dump and initial PAF pad designs

This memorandum details the following.

- A 2-dimensional stability assessment for both the operational and closure dump.
- Additional 3-dimension stability analysis on these landforms.
- The assessment of the standoff provided for the proposed radial stacker design.

3. PROPOSED DESIGN

The revised operational and closure landform designs are as shown in figure 2 and 3. The main changes is the slight increase in footprint due to the changes in the northern slope profile of the closure landform from angle of repose to a 18 degree slope for the batter angles.

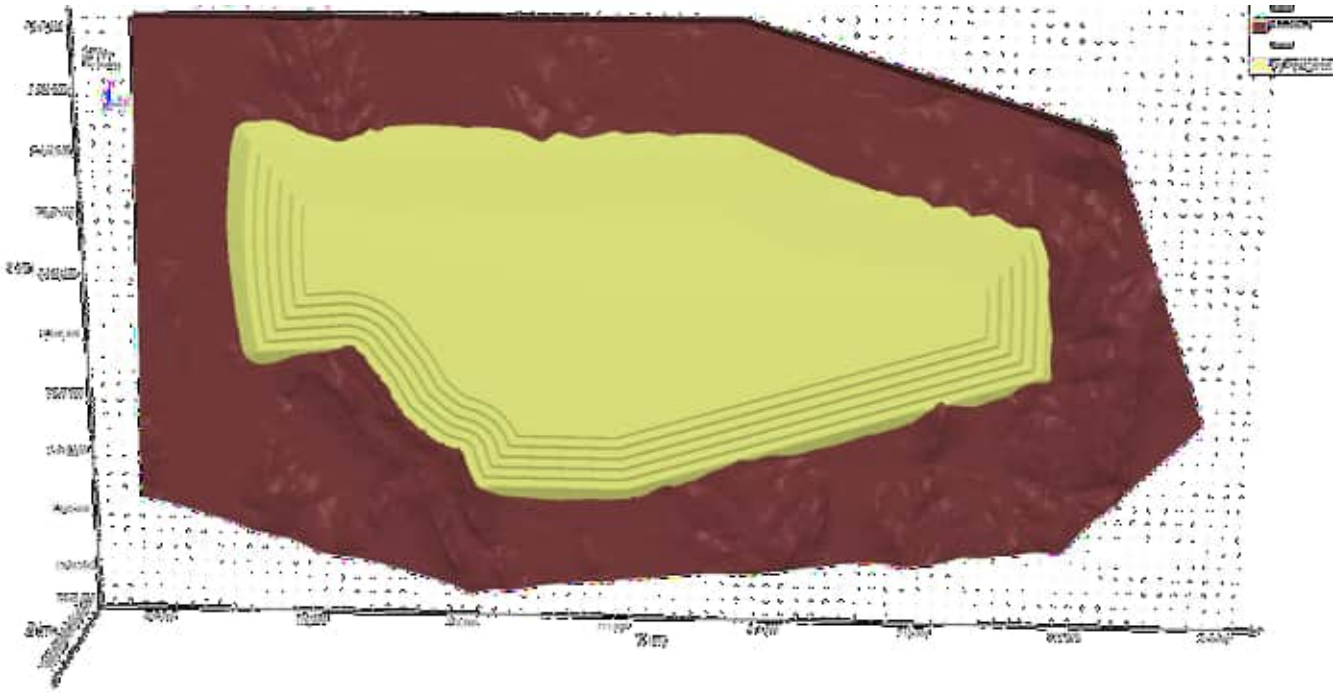


Figure 2: Operational Dry Reject Stockpile

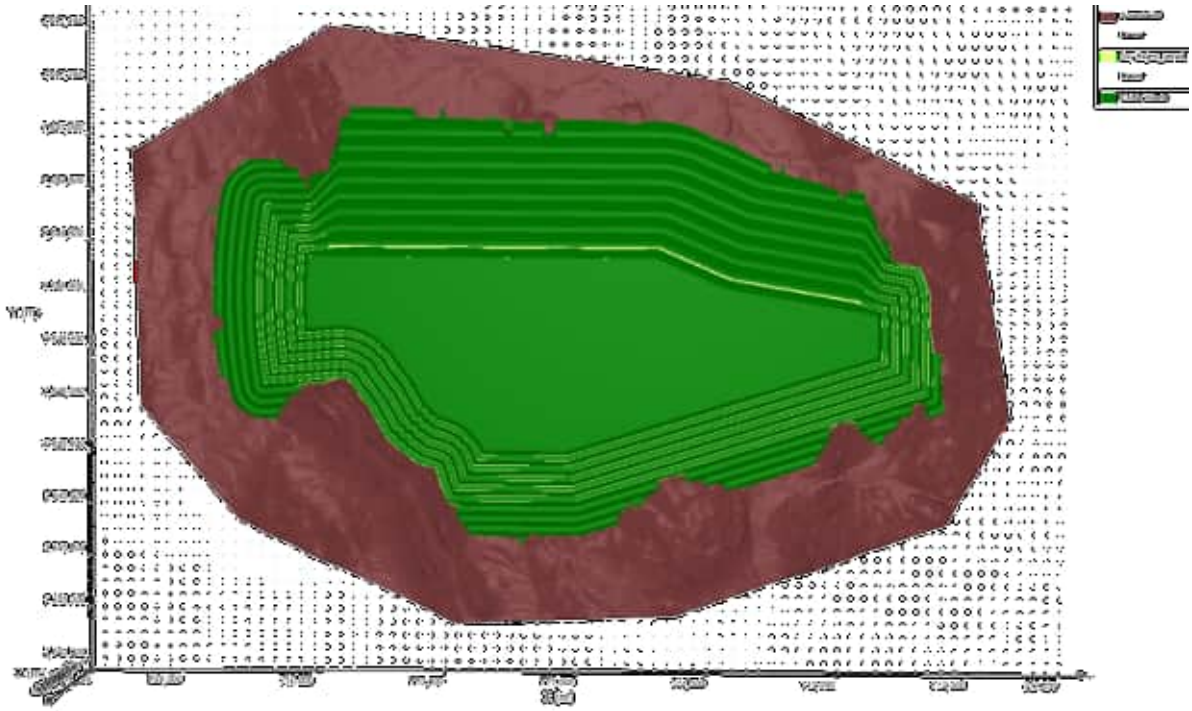


Figure 3: Closure Dry Reject Stockpile

The proposed main radial stacker is as shown in figure 4 below.

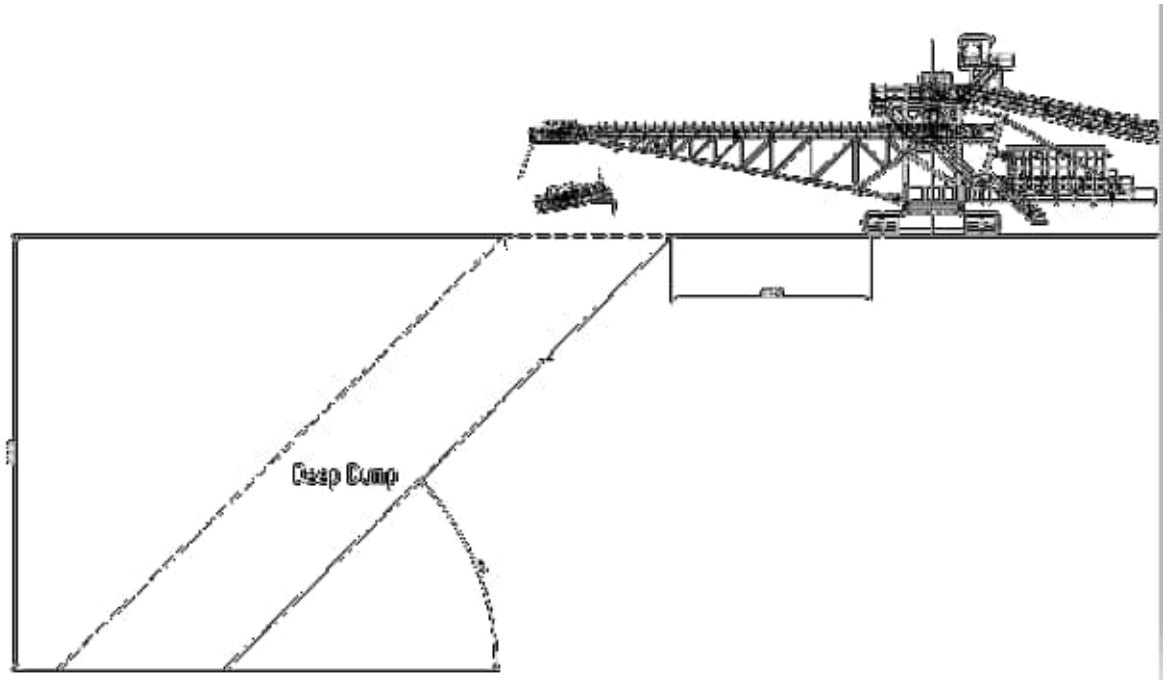


Figure 4: Drawing of spreader at 35m lift height at working level 320m

4. GEOTECHNICAL PROPERTIES FOR ASSESSMENT

The geotechnical properties for the stability assessment are detailed in the Iron Bridge Dry Reject Stockpile design report Rev 2 (NS-SW-GE-0003, SRK May 2019) and Iron Bridge Project-Geotechnical Characterization of Waste Rock Materials(NS-0000-RP-GE-0001) and have not been repeated here.

5. STABILITY ASSESSMENT

5.1 Assessment Approach

A 2-D/3-D limit equilibrium slope stability software *SVSLOPE* has been utilised for the analysis. The reported factor of safety results are for the Morgenstern-Price method analysis for non-circular failure.

Results are reported for the following scenarios:

- Static drained conditions for both operational and closure stockpile
- Pseudo-static drained conditions for OBE for the operational stockpile
- Pseudo-static drained conditions for MCE for the operational stockpile
- A 1 in 500-year storm and PMP storm event for the Closure Stockpile.

Representative cross-sections have been defined for the stockpiles targeting various sections for both the operational and closure stockpile.

5.2 Geotechnical Acceptance Criteria

The design acceptance criteria are based on recommendations within the *Guidelines for Mine Waste dump and Stockpile (*CSIRO, 2017).

Based on the overall height of the slope being greater than 100m and the maximum annual precipitation for the site a Moderate consequence of failure is applicable. The design parameters have also been evaluated to have a moderate confidence level based on the laboratory test work as documented in NS-SW-GE-0003, SRK May 2019.

The table below provides the acceptable design criteria based on the above consequence and confidence for both the operational and closure stockpile.

	Operational Stockpile	Closure Stockpile
Stability of the Dump Face	>1.0	1.5*
Static, inter ramp or overall, within radial stacker footprint	1.3-1.5	-
Static Overall Stability	1.3	1.5
Pseudostatic Overall Stability	1.1(OBE)	>1.0(MCE)
Static (Storm Event, 1 in 500-years)	-	1.5
Static (Strom Event, PMP)	-	1.1

*standoff included from stockpile edge

Table 1: Acceptance Criteria

5.3 Stability Assessment Results

The stability assessment results for the design scenario for both 2-D and 3-D are presented below.

Minimum Factor of Safety	Acceptance Criteria	Operational Stockpile
2D Assessment Results		
2D Batter scale	>1.0	1.35
2D Overall	1.3	3.65
2D Pseudostatic Inter ramp/Overall, OBE	1.1	1.68
3D Assessment Results		
3D Overall/inter ramp	1.3	3.76
3D Pseudostatic inter ramp/overall, OBE	1.1	1.70

Table 2: Operational Stockpile design stability assessment results

Minimum Factor of Safety ***2D Assessment Results***	Acceptance Criteria	Operational Stockpile
2D Batter scale *	1.5	1.85
2D Overall	1.5	3.65
2D Pseudostatic inter ramp Overall, MCE	1.1	1.80
2D 1 in 500 Storm **	1.5	2.00
2D PMP Storm**	1.1	1.91
3D Assessment Results		
3D Overall	1.5	3.97

*With crest standoff **worse case as it assumes a steady state and not transient

Table 3: Closure Stockpile design stability assessment results

All the reported Factor of Safety are well in exceedance of the acceptance criteria for the operational and closure stockpile; hence the waste dump designs are deemed geotechnically stable. Details of the stability results are presented in Appendix A.

Table 4 below is the returned factor of safety for the proposed standoff for both a 37- and 44-degrees angle of repose at various lift heights for the radial stacker whilst in operations.

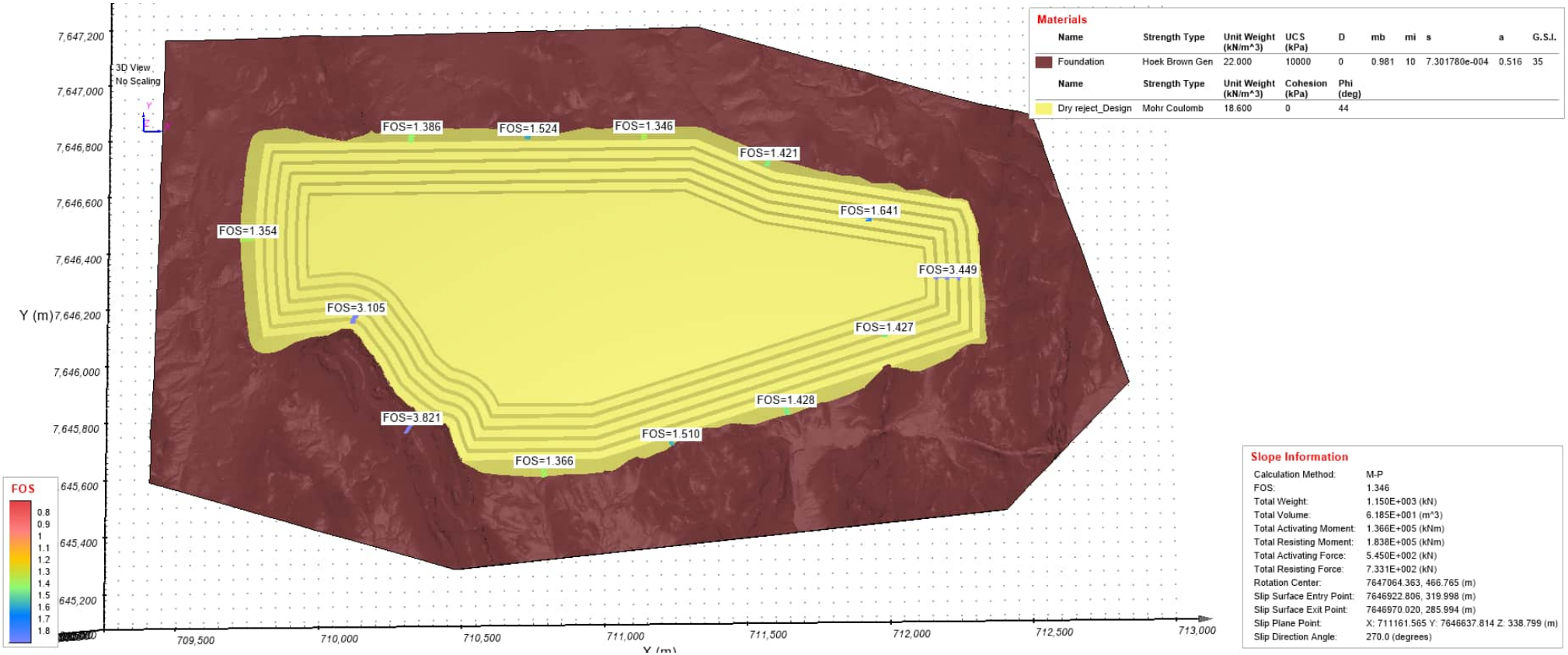
Stockpile Depth, m	37° Angle of repose for batter		44° Angle of repose for batter	
	Proposed Standoff for 37 angle repose	Minimum Factor of Safety within Radial Stacker	Proposed Setback distance, m	Minimum Factor of Safety within Radial Stacker
10	4.5	1.64	6	1.59
25	6.75	1.49	12.00	1.43
30	8.50	1.50	14.50	1.42
35	9.25	1.50	16.75	1.42
40	10.50	1.52	19.00	1.45

Table 4: Factor of safety within main radial stacker for the proposed crest standoffs

From the results all the proposed set back distances ensure the factor of safety within the main radial stacker met the design acceptance criteria. It is recommended that good surface drainage should be implemented around the stockpile crest as well as the working platform at all times, thus drainage should be away from stockpile edge and working platform of the main radial conveyor.

APPENDIX: STABILITY ASSESSMENT RESULTS

Operational Stockpile – 2D Batter Scale Results



Materials

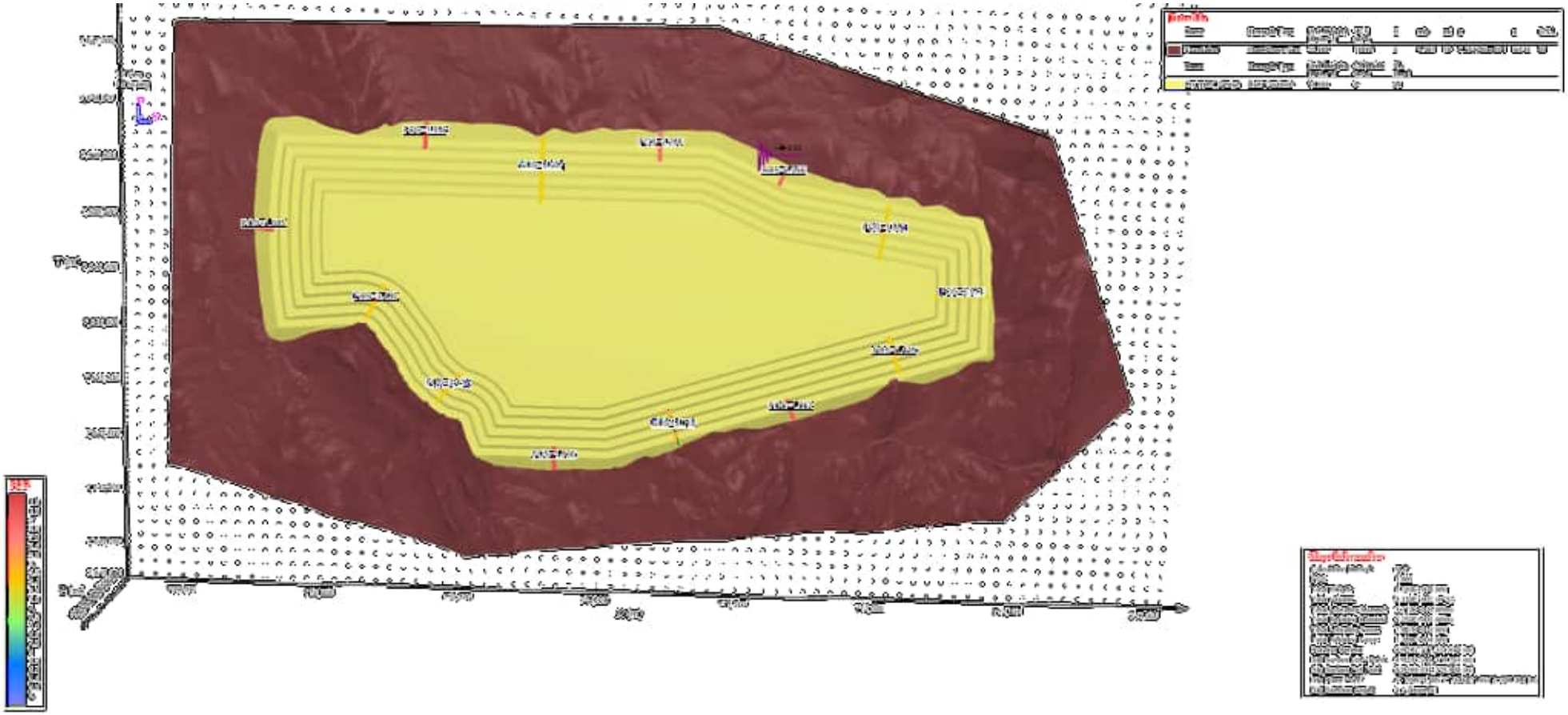
Name	Strength Type	Unit Weight (kN/m^3)	UCS (kPa)	D	mb	mi	s	a	G.S.I.
Foundation	Hoek Brown Gen	22.000	10000	0	0.981	10	7.301780e-004	0.516	35

Name	Strength Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Phi (deg)
Dry reject_Design	Mohr Coulomb	18.600	0	44

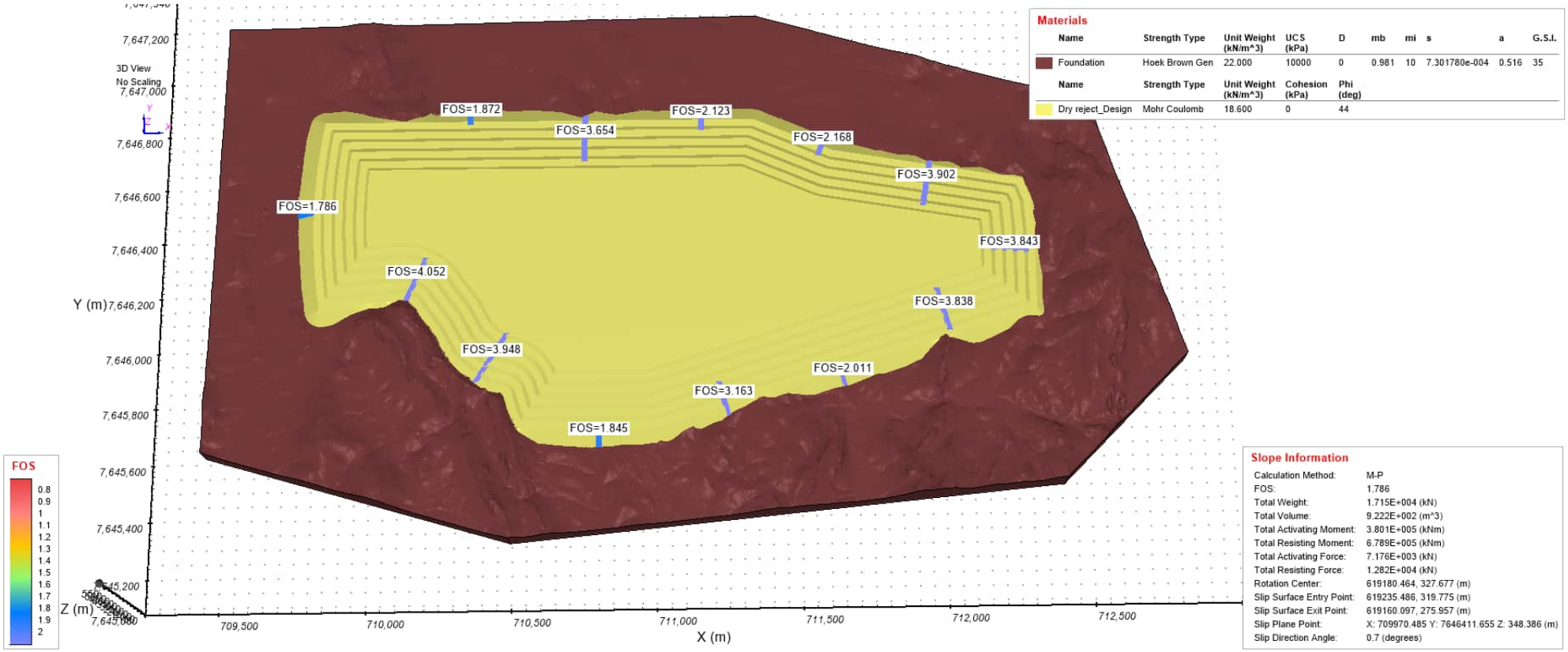
Slope Information

Calculation Method:	M-P
FOS:	1.346
Total Weight:	1.150E+003 (kN)
Total Volume:	6.185E+001 (m^3)
Total Activating Moment:	1.366E+005 (kNm)
Total Resisting Moment:	1.838E+005 (kNm)
Total Activating Force:	5.450E+002 (kN)
Total Resisting Force:	7.331E+002 (kN)
Rotation Center:	7647064.363, 466.765 (m)
Slip Surface Entry Point:	7646922.806, 319.998 (m)
Slip Surface Exit Point:	7646970.020, 285.994 (m)
Slip Plane Point:	X: 711161.565 Y: 7646637.814 Z: 338.799 (m)
Slip Direction Angle:	270.0 (degrees)

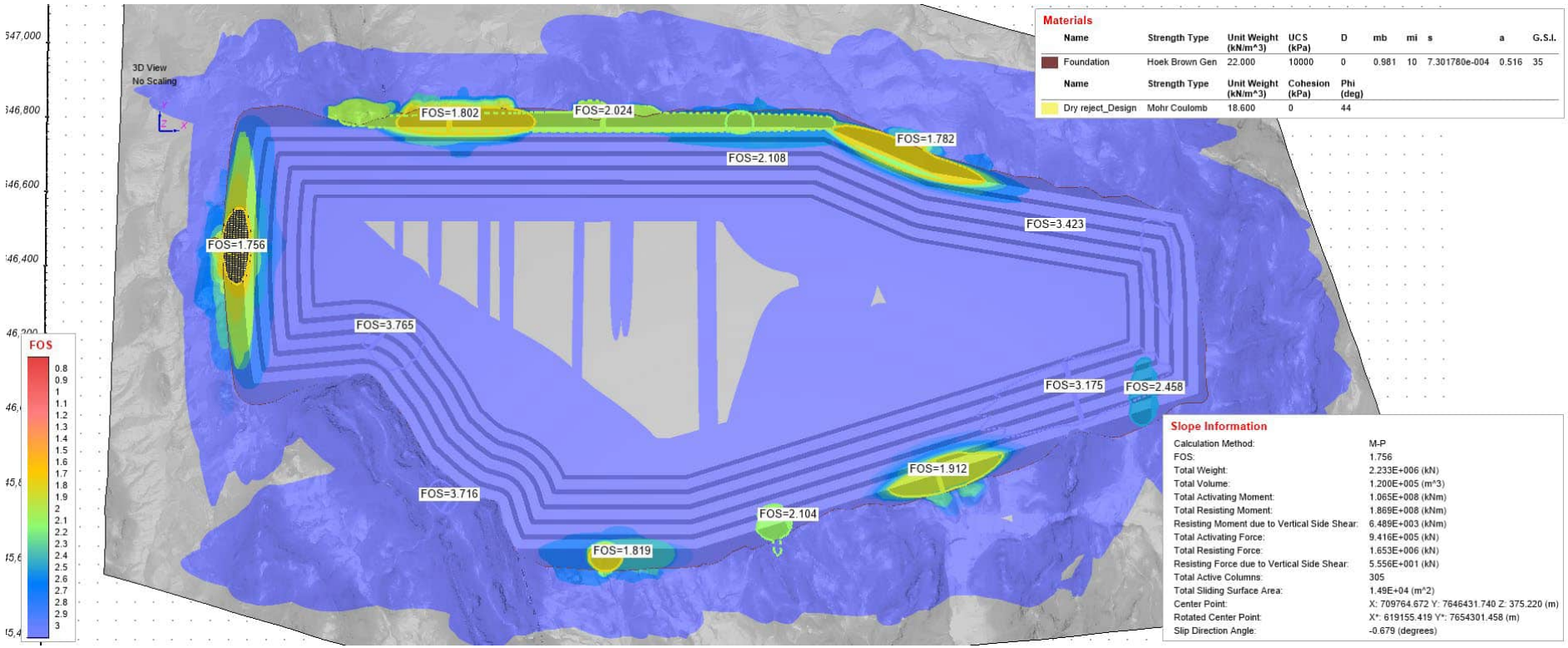
Operational Stockpile – 2D Overall OBE Results



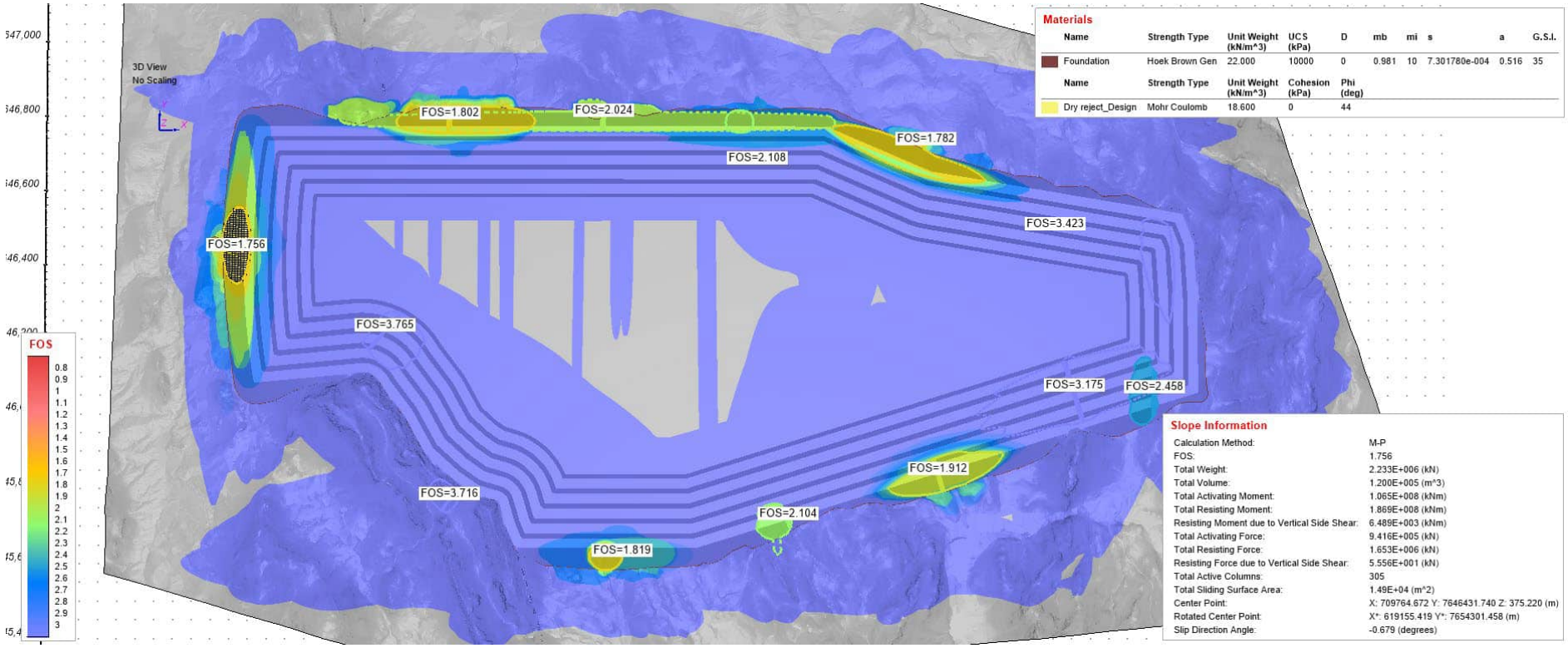
Operational Stockpile – 2D Overall Results



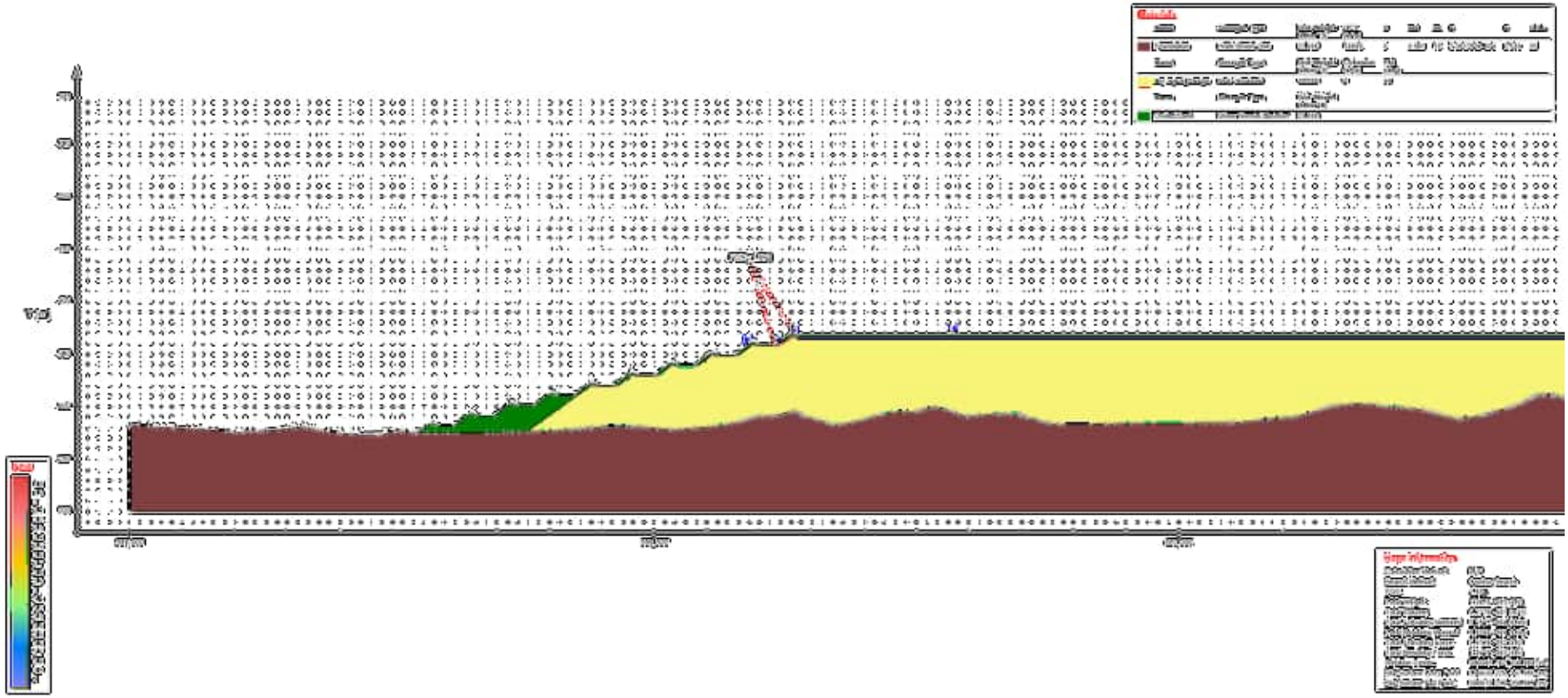
Operational Stockpile – 3D Overall Results



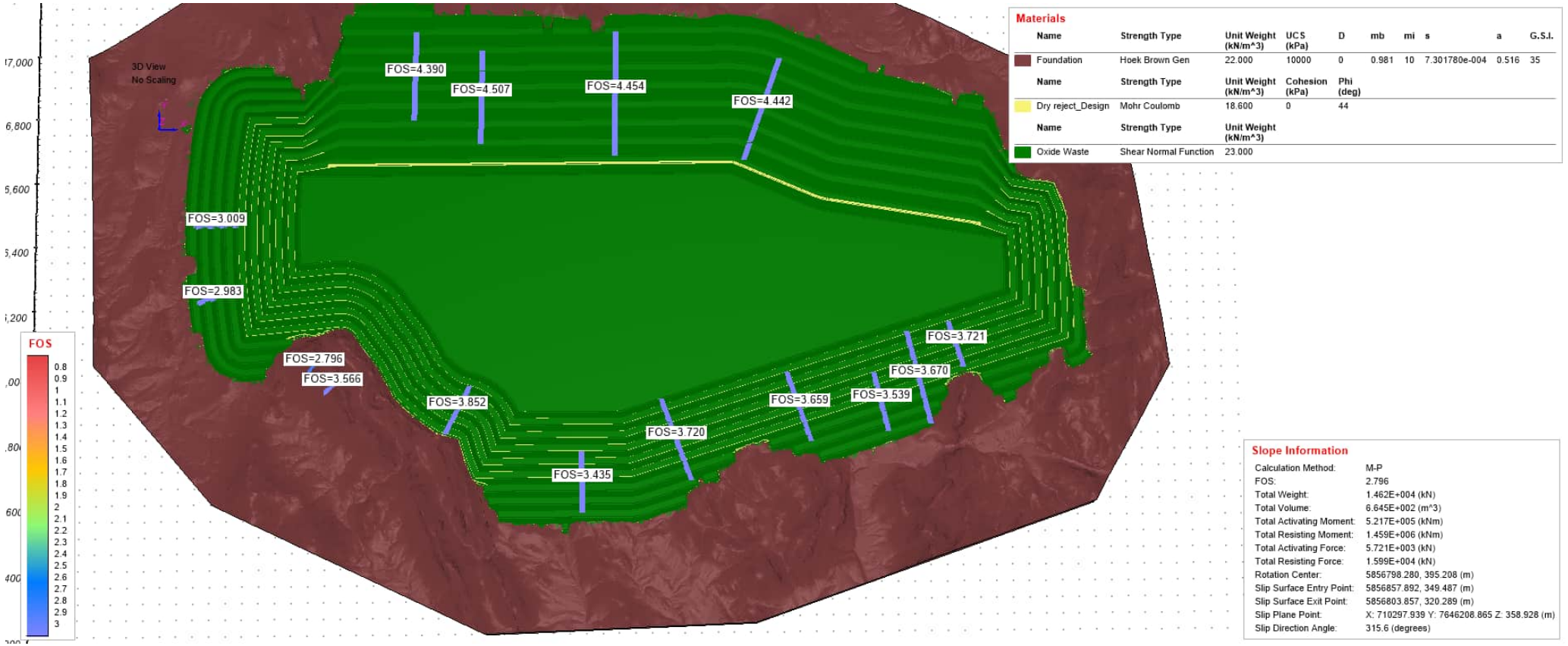
Operational Stockpile – 3D Overall OBE Results



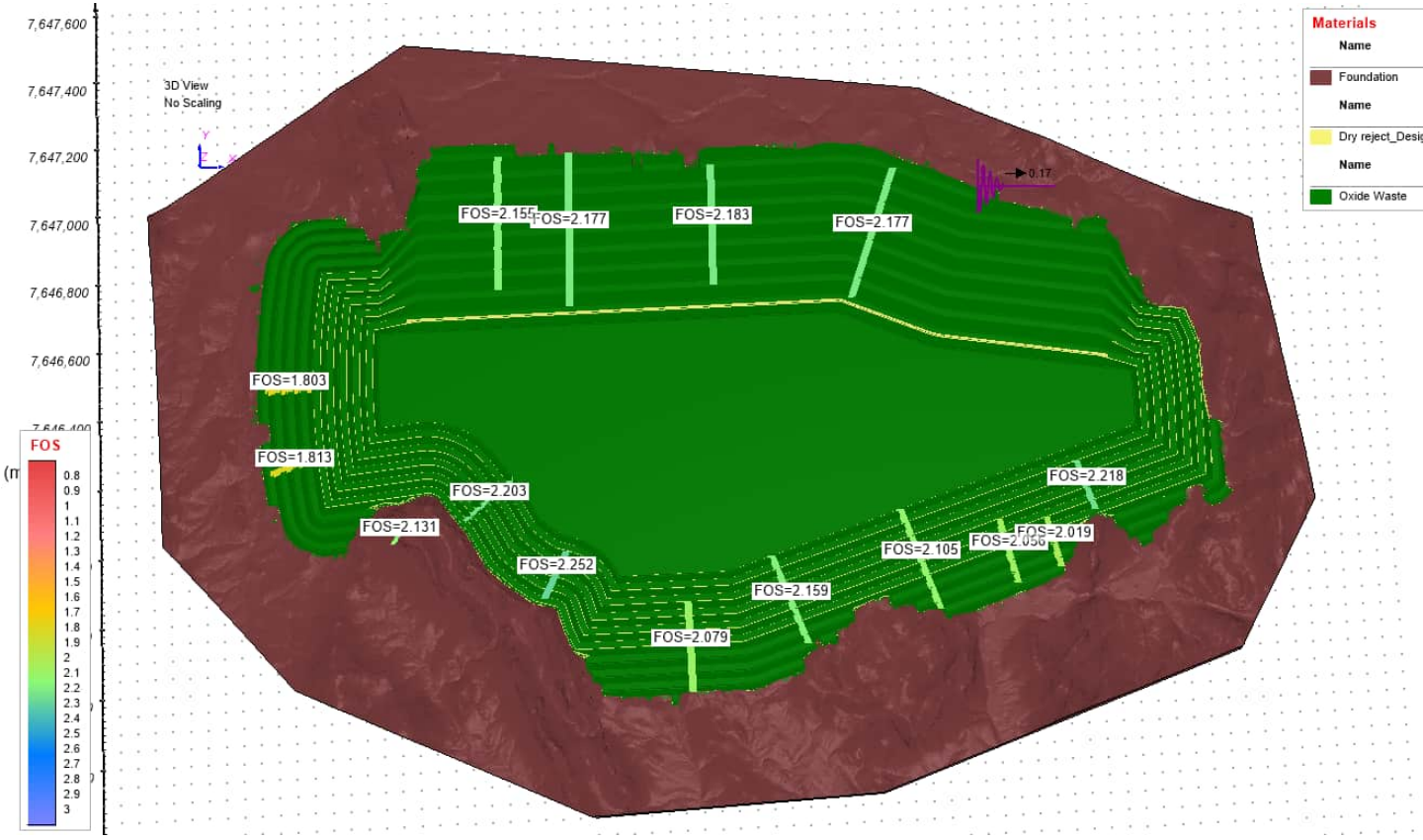
Closure Stockpile – 2D batter scale results



Closure Stockpile – 2D overall results



Closure Stockpile – 2D overall MCE results



Materials

Name	Strength Type	Unit Weight (kN/m^3)	UCS (kPa)	D	mb	mi	s	a	G.S.I.
Foundation	Hoek Brown Gen	22.000	10000	0	0.981	10	7.301780e-004	0.516	35

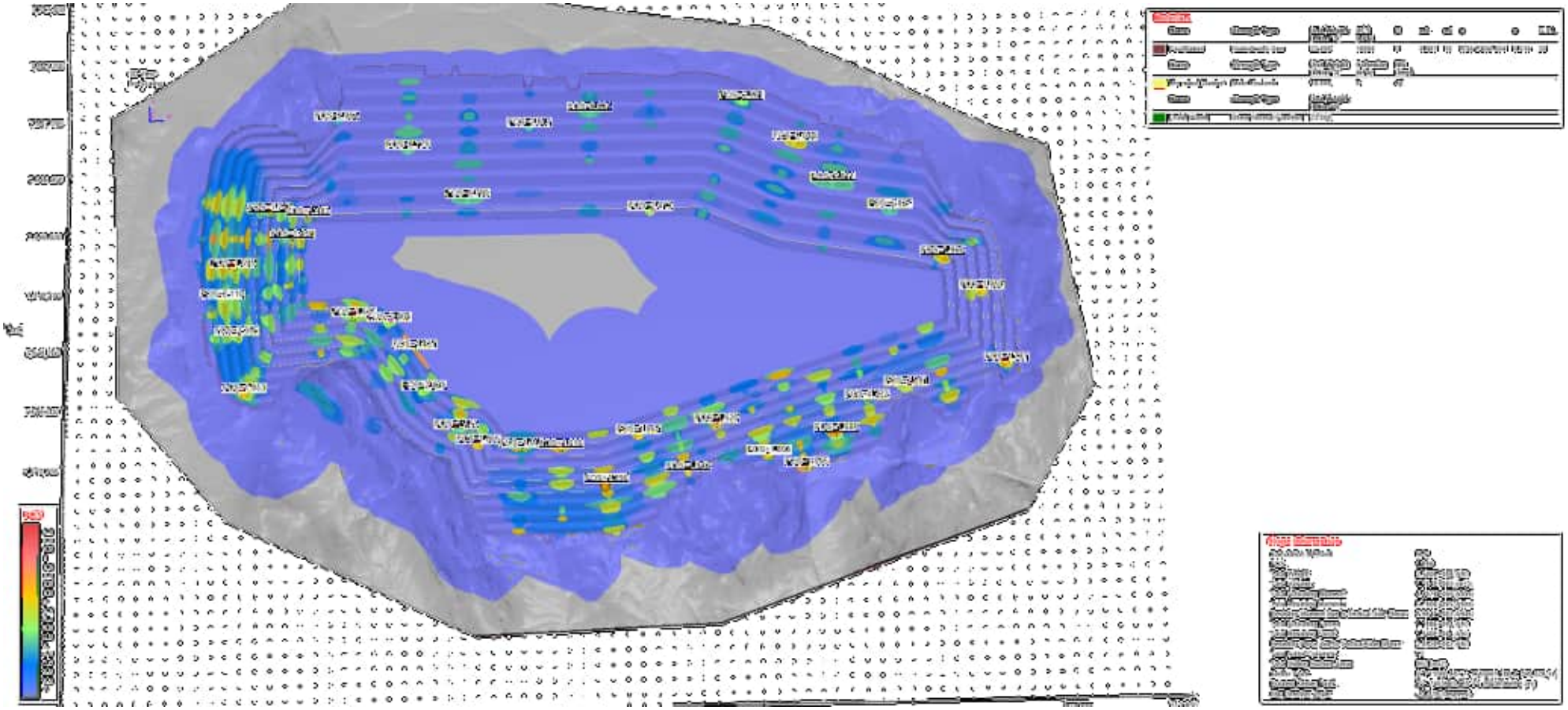
Name	Strength Type	Unit Weight (kN/m^3)	Cohesion (kPa)	Phi (deg)
Dry reject_Design	Mohr Coulomb	18.600	0	44

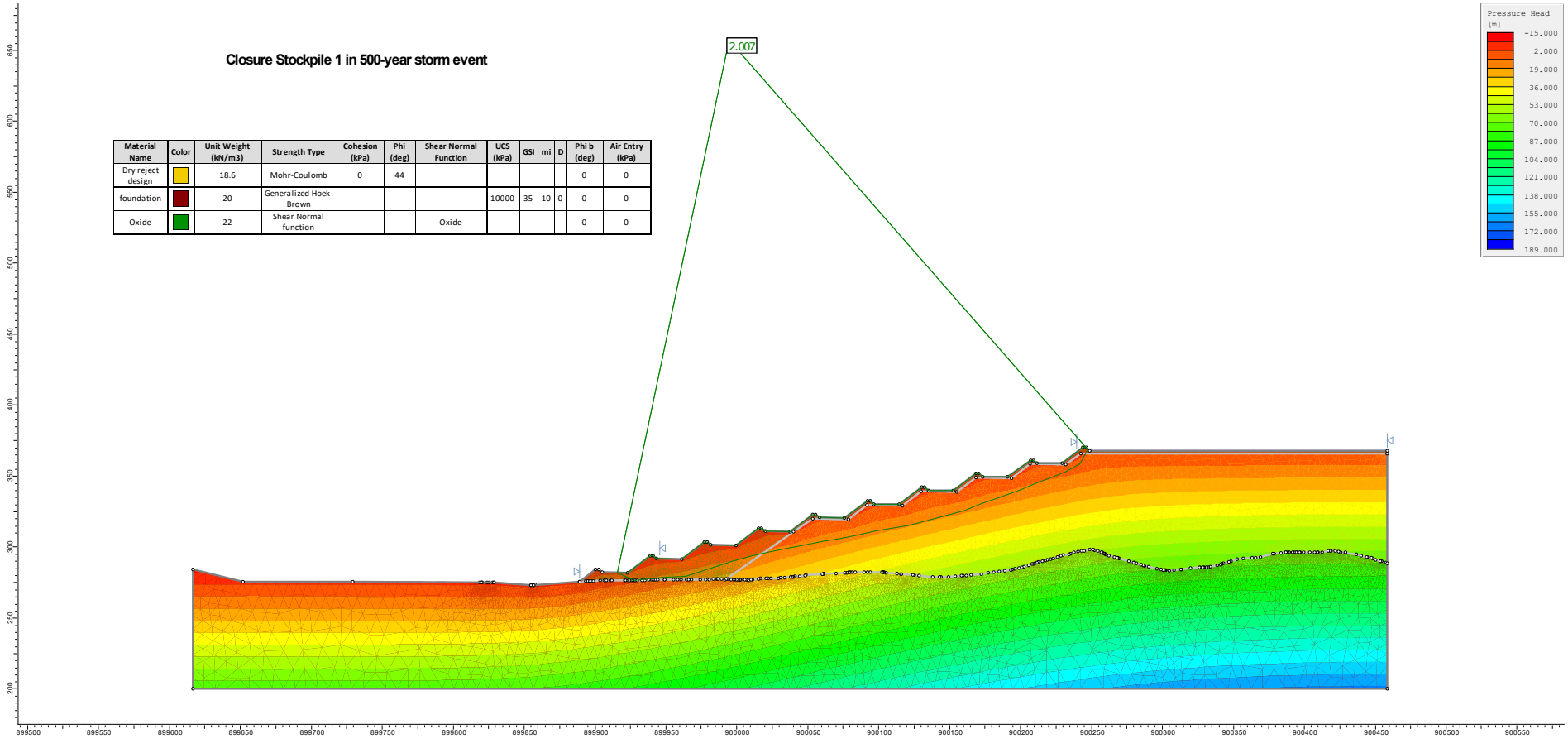
Name	Strength Type	Unit Weight (kN/m^3)
Oxide Waste	Shear Normal Function	23.000

Slope Information

Calculation Method:	M-P
FOS:	1.803
Total Weight:	3.685E+004 (kN)
Total Volume:	1.614E+003 (m^3)
Total Activating Moment:	1.840E+006 (kNm)
Total Resisting Moment:	3.317E+006 (kNm)
Total Activating Force:	1.429E+004 (kN)
Total Resisting Force:	2.576E+004 (kN)
Rotation Center:	586344.109, 403.252 (m)
Slip Surface Entry Point:	586443.397, 321.618 (m)
Slip Surface Exit Point:	586301.862, 281.854 (m)
Slip Plane Point:	X: 709892.620 Y: 7646409.543 Z: 330.784 (m)
Slip Direction Angle:	0.9 (degrees)

Closure Stockpile – 3D overall results

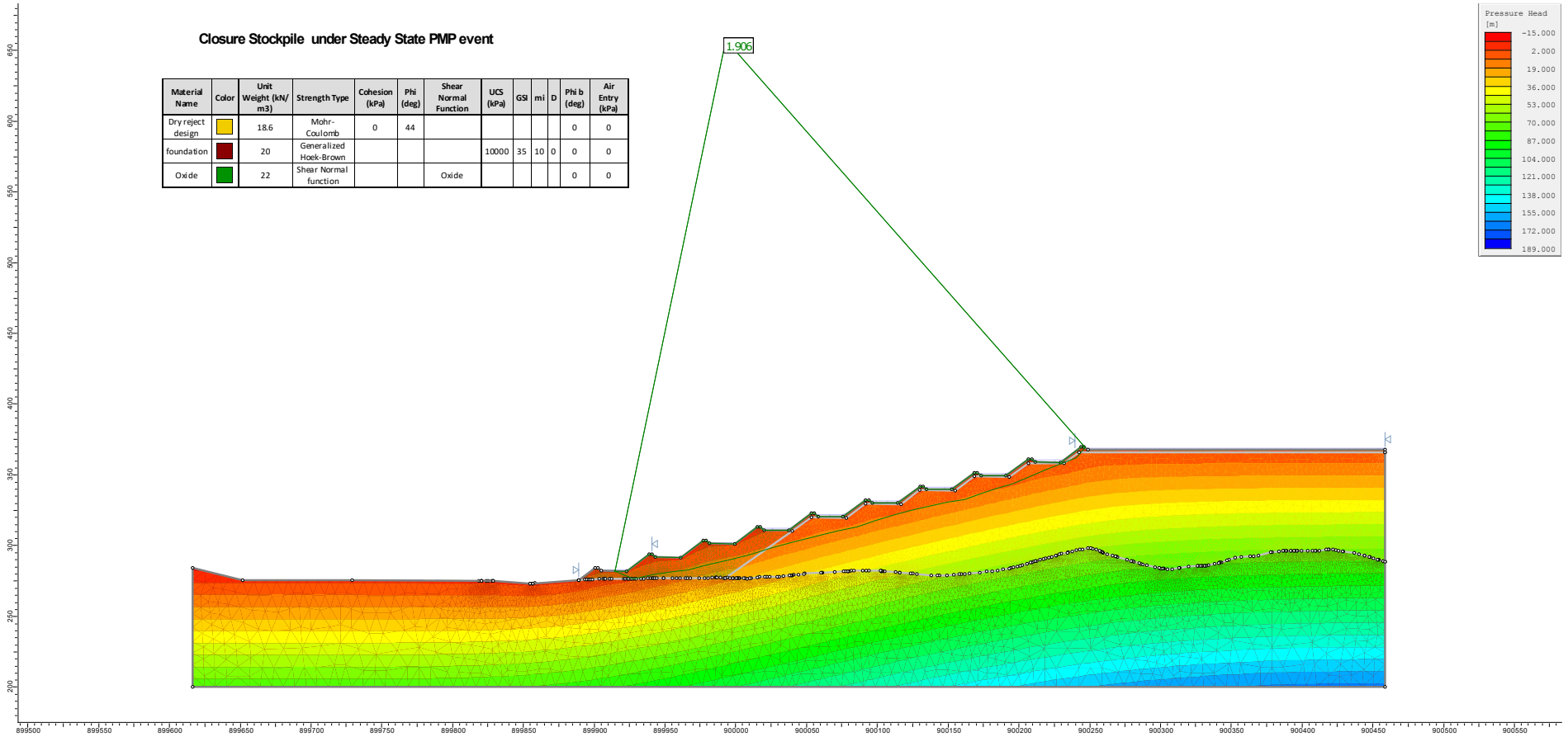




Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Shear Normal Function	UCS (kPa)	GSI	mi	D	Phi b (deg)	Air Entry (kPa)
Dry reject design		18.6	Mohr-Coulomb	0	44						0	0
foundation		20	Generalized Hoek-Brown				10000	35	10	0	0	0
Oxide		22	Shear Normal function			Oxide					0	0

Closure Stockpile under Steady State PMP event

Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Shear Normal Function	UCS (kPa)	GSI	mi	D	Phi b (deg)	Air Entry (kPa)
Dry reject design		18.6	Mohr-Coulomb	0	44						0	0
foundation		20	Generalized Hoek-Brown				10000	35	10	0	0	0
Oxide		22	Shear Normal function			Oxide					0	0



Appendix 11b: Dry Rejects Landform – First Lift Design

Memo

Dry Rejects Landform – First Lift Design

OUR REF	Insert Doc# here	**DATE**	14/07/2022
TO	Sophie Monaco; Vladimir Rios Vera	**CC**	Sophie Gaunt
FROM	Mudit Tandon; Daniel Dwumfour; Ying Yu		

1. DRL LANDFORM REVISED DESIGN

The first lift of the Dry Reject Landform (DRL) has been redesigned to achieve the objectives below:

- To meet batter berm configuration of closure design.
- The closure footprint shall be located outside of the creek bed to the south east of the landform.

The DRL first lift operational design uses a 37° batter slope. The total fill volume available is 51.5 Mm^{3} and disturbance area of ~213 Ha. The maximum height is 46.5 m.

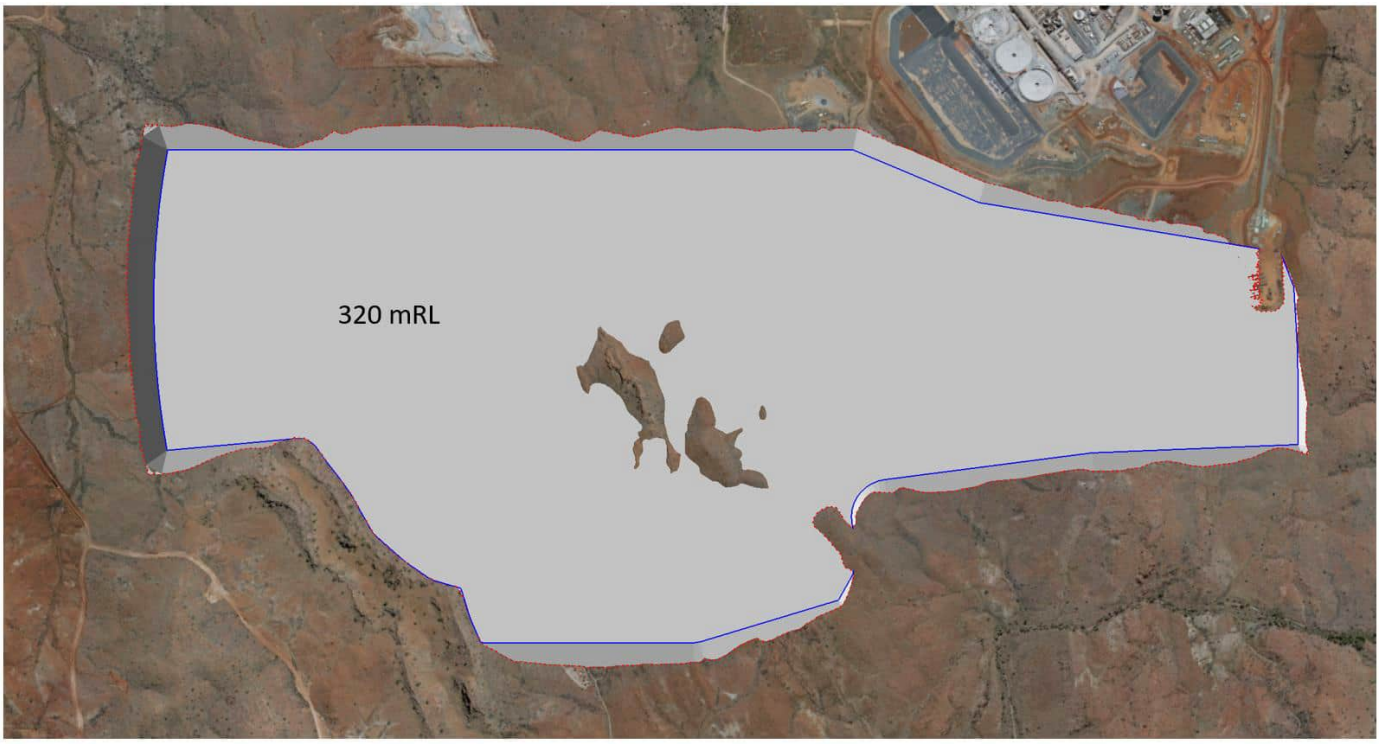


Figure 1: First Lift (320 mRL) Operational Design – Dry Reject Landform (DRL_OPS_DESIGN_1ST_LIFT_V2)

The DRL first lift closure design uses closure design parameters as below:

Table 1: Closure design parameters

Design parameters	
Slope height	10 m
Batter slope	18º
Berm width	15 m
Berm backslope	5º
Operational slope offset for oxide cover	2 m

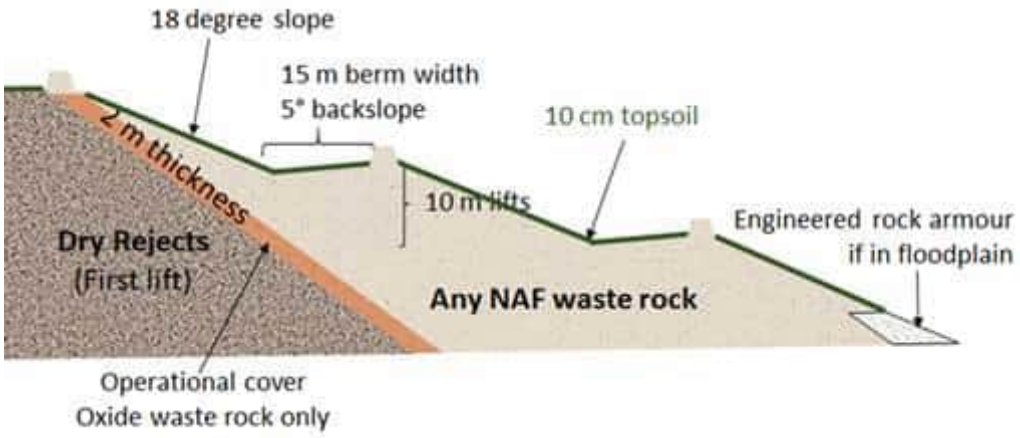


Figure 2: Dry Reject Landform Closure Design Diagram

The closure design of the DRL first lift is completed as shown below in Figure 3. The closure footprint is located outside of the creek bed and the total closure disturbance is 283 Ha.

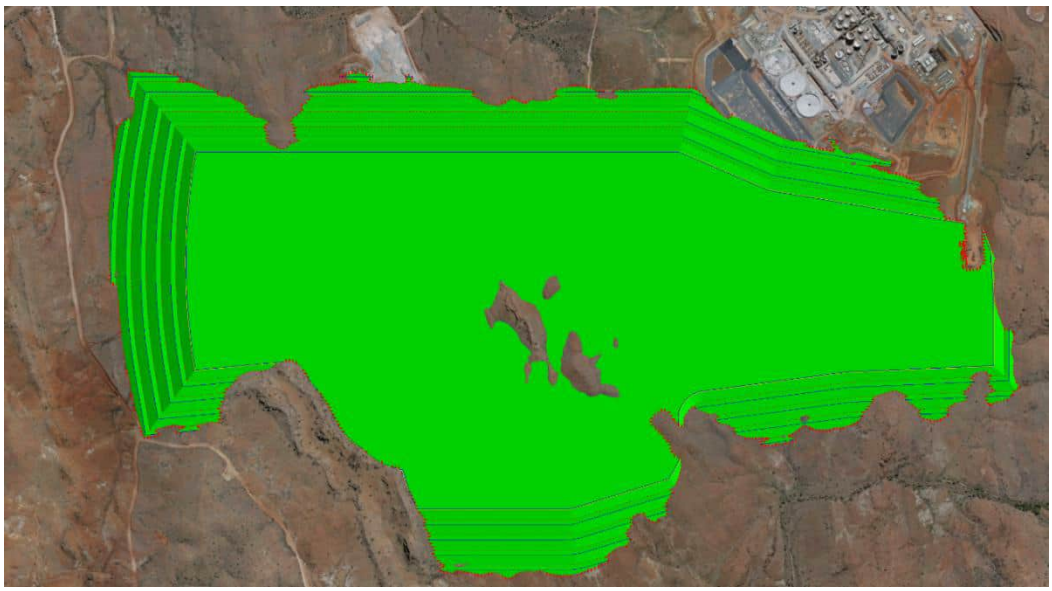


Figure 3: First Lift (320 mRL) Closure Design – Dry Reject Landform (DRL_CL_DESIGN_1ST_LIFT_V2)

Figure 4 demonstrates that the dry reject operational design is maintained inside the post closure profile.

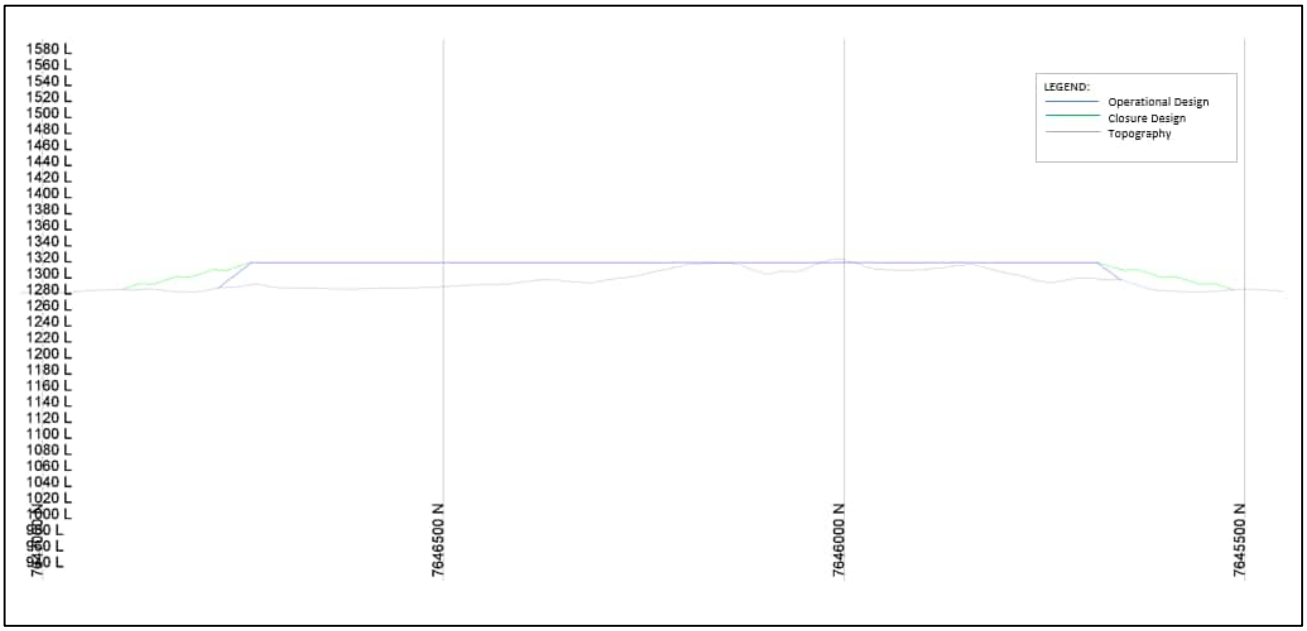


Figure 4: North/South Cross-sectional view

2. COMPARISON WITH ORIGINAL DESIGN (SRK DESIGN)

2.1 Operational Design Comparison

Below, Table 2, provides the operational design comparison against the original SRK design. Figure 5 below provides the comparison between the spatial extent of two operational designs. While the northern part of the design remained unchanged, substantial changes have been made to the south-eastern part of the design to ensure the closure design is acceptable from a surface water perspective and in line with DRL surface water management criteria.

Table 2: Operational Design comparison

Design parameters	Proposed Design	SRK design (First lift)
Batter slope	37°	35°
Volume	51.5 Mm^3	54.6 Mm^3
Distance to creek	~300 m	~100 m
Disturbance footprint	213 Ha	223 Ha



Figure 5: First Lift (320 mRL) Operational Design Comparison

2.2 Closure Design

The closure design comparison is summarised as below in Table 3. Figure 6 below provides the comparison between the spatial extent of two closure designs. In line with the changes in the operational design, the south-eastern part of the design is modified to bring it in line with DRL surface water management criteria.

Table 3: Closure Design comparison

Design parameters	Proposed Design	SRK design **(First lift)**
Slope height	10 m	10 m
Batter slope	18º	18º
Berm width	15 m	15 m
Berm backslope	5º	5º
Operational slope offset for oxide cover	2 m	2 m
Distance to creek	~170 m	encroach the creek bed channel
Disturbance footprint	283 Ha	298 Ha

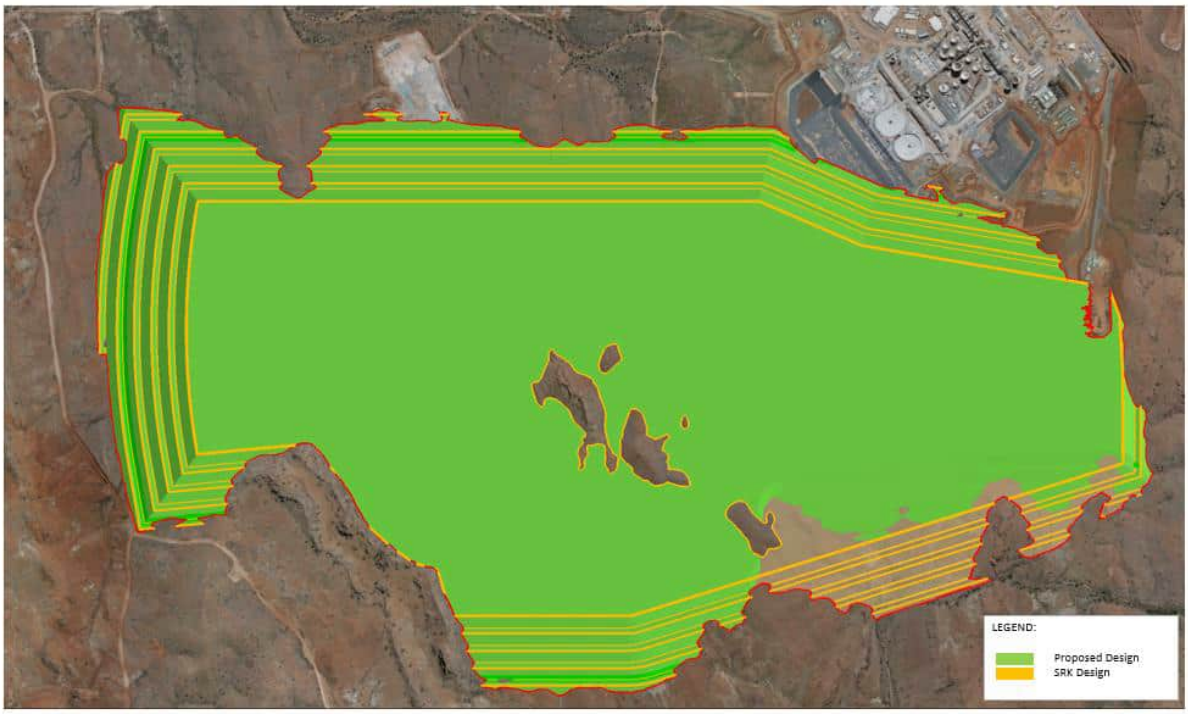


Figure 6: First Lift (320 mRL) Closure Design Comparison

3. GEOTECHNICAL

Stability assessments based on a section through the highest dump batter face at the west of the landform (Figure 7) were undertaken for both the operational and closure dump design profiles to determine Factor of Safety (FoS). Two-dimensional Limit Equilibrium methods were used in Roscience Slide 2 software using dry conditions.

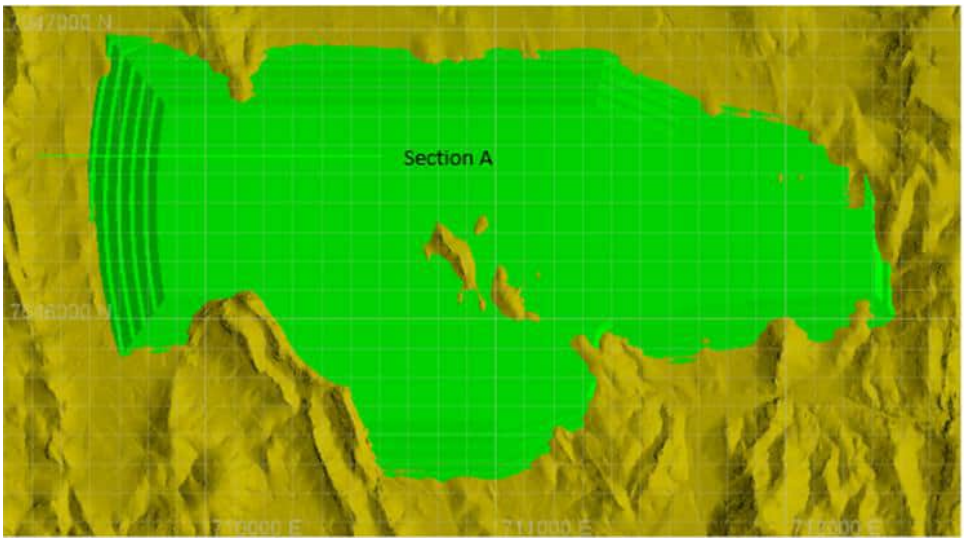


Figure 7: Closure dump showing section A

Material properties and shear strength parameters used in the stability analyses were developed by SRK (2019) and are based on available laboratory data and observations in the field.

A summary of the stability results for the dry conditions is presented in Table 4 below and shows that the achieved FoS for both the operational and closure designs exceed minimum design acceptance criteria, hence the first lift landform of the dry reject is stable geotechnically.

Table 4: Summary of static stability assessment dry conditions

Design	Design Acceptance Criteria	Factor of Safety
Operation dump	1.2-1.3	1.32
Closure dump	1.5	4.03

Ponding adjacent to the crest provides a potential stability risk if left unmanaged. Surface water management during construction of the operational dump will include grading the dump surface away from the crest to prevent ponding from occurring near the edge.

4. SURFACE WATER

While the original operational design (SRK design) met the surface water management criteria, the closure design footprint was found to be encroaching the southern creek bed channel – conflicting with the committed surface water management criteria for closure (Figure 9).

In comparison, the 'proposed' operation and closure design are acceptable from a surface water perspective. This design is in line with the DRL surface water management criteria.

- The proposed operational footprint is located outside of 1 in 100 AEP flood extent
- The proposed closure footprint is be located outside of the creek bed (Figure 8)

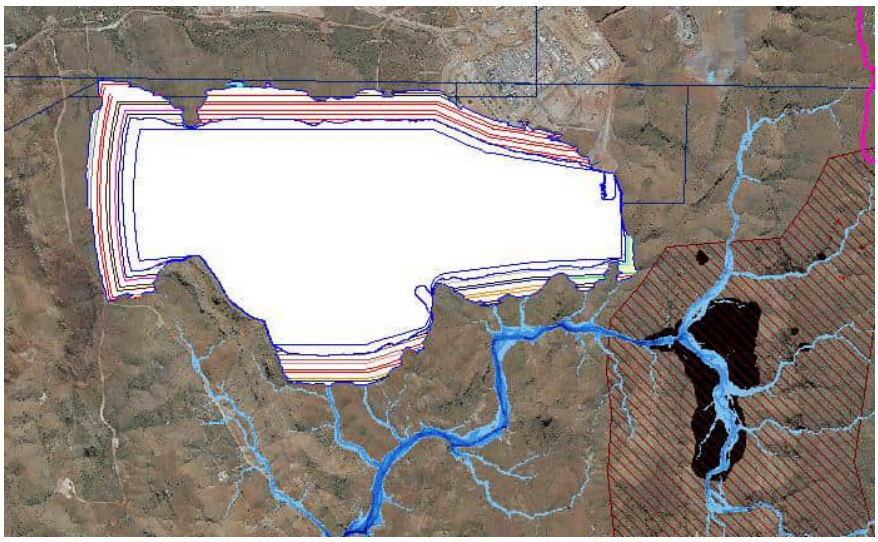


Figure 8: First Lift (320 mRL) Proposed Closure Design overlay with creek

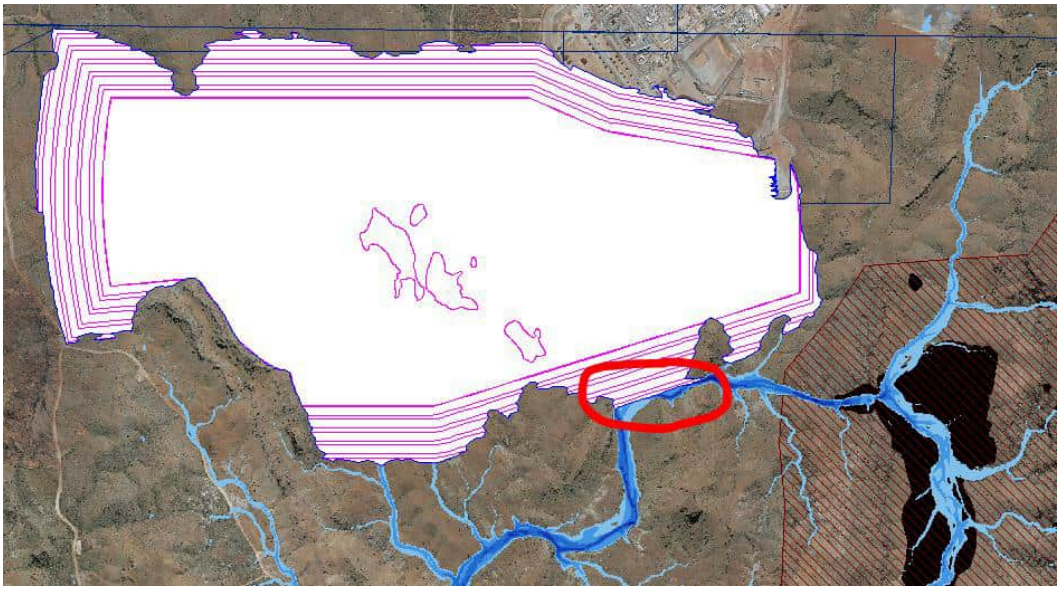


Figure 9: First Lift (320 mRL) SRK Closure Design overlay showing encroachment with the creek

Appendix 12: Coarse Rejects as Growth Media Trial

SOILWATER CONSULTANTS

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w: www.soilwatergroup.com

MEMO

TO:	Ian Zlatnik	COMPANY:	Fortescue Metals Group	
FROM:	Adam Pratt	PROJECT TITLE:	North Star Coarse Rejects Trial	
DATE:	18 April 2016	PROJECT & DOCUMENT NO:	FMG-005-01-01	001
SUBJECT:	Coarse Rejects Trial – Laboratory Results and Initial Assessment of Growth Potential			

1 INTRODUCTION

Dry (coarse) rejects are produced during the ore beneficiation process and comprise primarily quartz sand, gravels or oversize (>2mm fraction), with a finer fraction (i.e. <75µm) of <10%. Based on these physical properties they are typically freely draining and have limited water holding and plant available water (PAW) content, which is required to support revegetation germination and establishment. Although they are not ideal from a revegetation perspective they are likely to be structurally stable and resist erosion; hence they are good rock-armouring materials for use on batter slopes.

To achieve closure, landforms must be safe, stable, non-polluting and sustainable. The physical and geochemical properties favour the formation of safe, stable and non-polluting landforms, but whether they can support a functioning, sustainable ecosystem is uncertain

2 STUDY OBJECTIVE

Given the uncertainty regarding the rehabilitation potential of dry (coarse) rejects, the primary objective of this proposed work is to establish the growth parameters of this material and undertake/coordinate glasshouse trials to be completed at Murdoch University.

3 STUDY METHODOLOGY

3.1 GROWTH POTENTIAL OF COARSE REJECTS

The key parameters that were assessed from a revegetation growth perspective are provided in Table 1. All analysis was undertaken at Soilwater Analysis laboratory in East Perth and the Chemistry Centre of Western Australia.

Table 1: Key growth parameters assessed

Physical properties	(Geo)Chemical properties	Hydraulic properties
Particle size distribution - Gravel fractionation - Sand fractionation - Pipette analysis (% sand, % silt, % clay)	pH	Water retention properties
	Electrical conductivity (EC; salinity)	Saturated hydraulic conductivity (constant head permeameter)
	Major Nutrients - Nitrogen (Total N, Mineralised N) - Phosphorus (Total P, Colwell P) - Potassium (Total K, Colwell K) - Sulphur (Total S, SO4-S, Extractable S)	Unsaturated hydraulic conductivity (tension/disk permeameter)
Particle density†		
Structural stability (Emerson Class)		
	Total carbon, Organic C and Total Inorganic C (TIC)	
	Trace nutrients (Mehlich suite)‡	
	Total (solid-phase) metals	
	ASLP (to test for metal mobility)	

†Needed for Total Porosity calculations. ‡Mehlich suite (bio-available nutrients) – As, B, Ca, Cd, Co, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Zn.

3.2 EROSION STABILITY

In addition to the above growth parameters, the erosion potential of the dry (coarse) rejects was also established to inform the design of suitable slopes that the dry rejects can be used on and inform the rehabilitation prescription for the reshaping of the dry rejects landform.

Erosion testing was carried out on bulk samples of the dry (coarse) rejects at SWC's in-house laboratory in East Perth. Two tests were carried out on each sample:

- Inter-rill Erodibility: A rainfall simulator (Plate 1) was used to apply water at a known intensity (usually 80-100 mm/hr) to a 75 x 75 cm soil plot, set to known slope angles, mimicking the expected waste dump slopes (typically 12-18° slope). Subsequent water and sediment runoff are collected and measured, and Saturated Hydraulic Conductivity (K_{sat}) and Inter-rill Erodibility (K_i) are determined.
- Rill Erodibility: An erosion flume (Plate 2) is used to subject the soil sample to a range of overland flow conditions, simulating sheet flow or rill flow over the rehabilitated land surface. Subsequent water and sediment runoff are collected and measured, and the Detachment Strength (T_c, shear stress) and Rill Erodibility (K_r) are determined.

The results of this testing fed directly into the Watershed Erosion Prediction Project (WEPP) (Flanagan and Livingston, 1995) slope erosion model, which was used to predict the long-term (100 year duration) erosion rates (t/ha/yr) from the

surface of the proposed landform. The WEPP model uses a series of site-specific input files describing the soils, climate, slope geometry, and land management regime for the site. The two key inputs to this model are:

- A description of key soil properties relevant to water infiltration and erosion, including the K_{sat}, K_i, T_c, and K_r, which were measured at the SWA laboratory as described above.
- A synthetic 100-year climate file for the North Star site, which was generated using the CLIGEN stochastic weather generator (Yu, 2003), and was used in the WEPP model to simulate 100 years of rainfall, runoff, and erosion. Figure 1 demonstrates that the CLIGEN file used in this investigation is consistent with local climate data, with average yearly and monthly rainfall totals falling in between the Port Hedland (50 years of data) and Wittenoom (46 years of data) averages (BOM, 2016a), and 24-hour storm intensity following a similar frequency distribution to the BOM Intensity-Frequency-Duration predictions for the site (BOM, 2016b).

3.3 GLASSHOUSE AND POT GROWTH TRIALS

Glasshouse and pot growth and trials will likely be undertaken at Murdoch University, coordinated by Professor Richard Bell. These trials will test various seed/species mixes and potentially the use of soil fertilisers, to determine whether germination and continued establishment of keystone revegetation species can occur on this material. The results from the testing proposed above will feed directly into the glasshouse and pot trials and help establish the treatments to be applied.

4 STUDY RESULTS

4.1 PHYSICAL PROPERTIES

The physical properties of the four coarse rejects samples are summarised in Tables 2-4. In general, the coarse rejects are classified as a gravelly sand, comprising 35-48% gravels. Sample A contained slightly less gravel than average, at 35.2%, whilst the remaining three samples contained between 45-47% gravel.

The fines fraction (<2 mm fraction) was comprised primarily of coarse sand-sized particles, with total sand content ranging from 94.7-96.2% (Table 3). Around 60% of the sand fraction was categorised as “coarse sand” (> 425 um). Silt content was low, making up < 5% in all samples. Clay content was negligible, at < 1% on average, and thus the material was non-cohesive, and can be classed as generally non-dispersive (Emerson Class 5).

Particle density was measured at 2.98 g/cm^3 in all four samples, indicating that iron was a primary constituent of these material, in addition to quartz and kaolinite. This value can be used to calculate the expected total porosity of the material, which will vary according to the final *in situ* bulk density of the material. Figure 2 shows how the total porosity is expected to vary, according a range of likely bulk density values. More detail on the water holding potential of the coarse rejects material is discussed in Section 4.3, *Hydraulic Properties*.

Table 2: Particle size distribution of gravel fraction (> 2 mm)

Material ID	Total Gravel	Gravel fractionation (% retained by sieve size, mm)								
	(%)	26.5	19	16	13.2	9.5	6.7	4.75	2.36	<2.36
A	35.2	0.6	0.9	0.8	1.2	2.8	5.1	6.4	16.7	64.8
B	46.3	0.8	1.7	1.5	3.0	5.3	8.2	8.3	17.3	53.7
C	46.5	0.5	2.3	1.9	2.7	6.0	7.8	9.1	16.1	53.5
D	46.7	1.2	2.8	2.2	3.4	5.8	7.3	7.7	16.2	53.3
A (replicate)	36.4	0.3	1.0	0.8	1.1	3.3	5.9	7.1	23.5	63.6
B (replicate)	47.5	0.4	2.0	1.4	2.5	6.4	8.0	8.8	17.2	52.5
C (replicate)	46.6	1.9	2.1	1.5	3.0	5.9	7.0	8.6	16.2	53.4
D (replicate)	45.1	1.3	2.9	2.3	3.4	5.6	7.0	7.7	14.6	54.9
Average	**43.8**	**0.9**	**2.0**	**1.6**	**2.5**	**5.1**	**7.0**	**8.0**	**17.2**	**56.2**
Standard Deviation	**5.0**	**0.6**	**0.7**	**0.6**	**0.9**	**1.3**	**1.1**	**0.9**	**2.7**	**5.0**

Table 3: Particle size distribution of fines fraction (< 2 mm)

Material ID	Sand %	Silt %	Clay %	Texture
A	94.9	4.3	0.8	Sand
B	95.5	2.9	1.6	Sand
C	94.7	3.7	1.6	Sand
D	95.9	3.7	0.4	Sand
A (replicate)	94.9	4.9	0.2	Sand
B (replicate)	96.2	3.6	0.2	Sand
C (replicate)	95.4	3.7	0.9	Sand
D (replicate)	95.3	3.7	1.0	Sand
Average	**95.4**	**3.8**	**0.8**	**-**
Standard Deviation	**0.5**	**0.6**	**0.6**	**-**

Table 4: Sand particle size fractionation (%)

Material ID	> 2 mm	> 1.18 mm	> 600 µm	> 425 µm	> 300 µm	> 200 µm	> 150 µm	> 75 µm	< 75 µm
A	6.2	18.6	23.1	12.3	9.9	7.7	5.5	4.7	11.8
B	5.2	19.2	24.6	12.5	9.7	8.5	5.9	5.2	9.2
C	6.6	16.7	21.8	11.9	10.0	8.8	6.9	6.8	10.6
D	6.1	20.4	24.3	12.9	10.6	8.3	5.8	4.5	7.1
Average	**6.0**	**18.7**	**23.5**	**12.4**	**10.0**	**8.3**	**6.0**	**5.3**	**9.7**
Standard Deviation	**0.6**	**1.6**	**1.3**	**0.4**	**0.4**	**0.4**	**0.6**	**1.1**	**2.0**

4.2 CHEMICAL PROPERTIES

The measured chemical properties of the coarse rejects materials are summarised in Tables 5-10. In general, the materials were moderately alkaline (pH = 9.1-9.6) and non-saline (EC = 145-162 uS/cm). This is somewhat unexpected, as iron-rich materials such as these typically have an acidic pH due to ferrolysis. This possibly implies that these materials have been either sprayed or processed using a highly alkaline water source.

The cation exchange capacity (CEC) was relatively low, at 6.1-6.7 meq/100g, indicating a dominance of kaolinite in the clay mineral fraction and the materials weak ability to retain nutrients within the soil matrix. The exchangeable sodium percentage (ESP) was considered to be very high, indicating the potential for dispersion. However, as there is very little silt and clay content (< 5%), this is not likely to be a problem for this material. The low Ca and Mg, compared to Na and particularly K, is also unexpected, as the alkaline pH is likely to have been attributed to calcrete (CaCO3) or dolomite (CaMgCO3). This result further suggests that these materials have been chemically modified by process or dust suppression water.

Nutrient analysis indicated that coarse rejects have low organic C content, low Total N, and low plant available P and S (KCl-extractable). This is expected, given that they are typically not surface soils and have been processed during ore beneficiation. However, Total P and K in the sample (representing the total 'pool' or 'reservoir' of P and K) were high. Only a very small fraction of the P is available for plant uptake, whilst a significant fraction of the K is readily available.

Total metal analysis indicated that the coarse rejects are made up of predominately iron (Fe) and contain some kaolinite; hence the slightly elevated Total Al levels. All total metals concentrations were below the DEC Ecological Investigation Levels (EILs) for soil, and the potential for metalliferous drainage to occur from these materials is also low.

Table 5: Basic chemical properties

Material ID	pH	EC	Exchangeable Cations (meq/100g)					ESP
		(uS/cm)	Ca	Mg	Na	K	CEC	(%)
A	9.3	158.2	0.34	0.24	1.6	4.3	6.5	25%
B	9.4	144.8	0.33	0.30	1.6	3.9	6.1	26%
C	9.3	162.0	0.36	0.30	1.6	3.9	6.2	26%
D	9.1	151.7	0.33	0.27	1.7	4.4	6.7	25%
Average	**9.4**	**152.9**	**0.36**	**0.28**	**1.6**	**4.1**	**6.4**	**26%**
Standard Deviation	**0.2**	**7.9**	**0.33**	**0.03**	**0.0**	**0.3**	**0.3**	**1%**

Table 6: Macro-nutrients and organic carbon content

Material ID	Organic C (%)	Total N (%)	Total P (mg/kg)	Colwell P (mg/kg)	Total K (mg/kg)	Colwell K (mg/kg)	Total S (%)	S (KCl extractable) (mg/kg)	SO_4 (mg/kg)
A	0.07	0.006	1,200	<2	1,800	1,100	0.16	19	<0.01
B	0.11	<0.005	1,000	<2	1,700	1,000	0.21	23	<0.01
C	0.02	0.005	1,100	<2	1,600	970	0.24	26	<0.01
D	<0.02	<0.005	1,100	<2	1,600	1,000	0.26	23	<0.01
Average	**0.05**	**0.004**	**1,100**	**<2**	**1,675**	**1,018**	**0.22**	**23**	**<0.01**
Std. Deviation	**0.05**	**0.001**	**82**	**-**	**96**	**57**	**0.04**	**3**	**-**

Table 7: Micro-nutrients in soil (mg/kg) (Mehlich Suite Analysis)

Material ID	Al	B	Ca	Cd	Co	Cu	Fe	K	Mg	Mn	Mo
A	100	0.9	760	<0.01	0.33	0.3	>550	>550	320	130	0.02
B	86	0.3	960	<0.01	0.33	0.2	>550	>550	370	150	<0.01
C	82	0.2	890	<0.01	0.3	0.2	>550	>550	340	160	<0.01
D	84	0.7	880	<0.01	0.27	0.3	>550	>550	340	140	<0.01

Material ID	Na	Ni	P	S	Zn	As	Pb	Se
A	260	0.6	59	18	4.6	0.1	0.1	<0.1
B	240	0.5	37	22	6.9	0.2	0.2	<0.1
C	210	0.5	37	22	6	0.1	0.1	<0.1
D	240	0.6	39	18	4.4	<0.1	0.2	<0.1

Table 8: Total Metals in soil (mg/kg)

Material ID	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Mg
A	3,490	<5	5	40	<50	<1	12	6	11	79,500	6,190
B	3,010	<5	<5	40	<50	<1	9	6	5	78,000	7,100
C	3,340	<5	6	40	<50	1	10	6	6	78,400	7,210
D	3,270	<5	9	40	<50	1	10	7	10	83,500	7,250

Material ID	Mo	Ni	Se	Ag	Sn	V	Zn	Tl	Th	U
A	<2	20	<5	<2	<5	<5	13	<5	0.4	<0.1
B	<2	16	<5	<2	<5	<5	14	<5	0.2	0.1
C	<2	19	<5	<2	<5	<5	15	<5	0.2	0.1
D	<2	19	<5	<2	<5	<5	14	<5	0.2	0.1

Table 9: DI-leachable metals (percentage of solid phase leached) (bd = solid phase metal content is below detection)

Material ID	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Mg
A	0.3%	bd	bd	10.0%	bd	bd	bd	bd	bd	0.1%	< 0.1%
B	0.2%	bd	bd	bd	bd	bd	bd	bd	bd	< 0.1%	< 0.1%
C	0.2%	bd	bd	bd	bd	bd	bd	bd	bd	< 0.1%	< 0.1%
D	0.2%	bd	bd	bd	bd	bd	bd	bd	bd	< 0.1%	< 0.1%

Material ID	Mo	Ni	Se	Ag	Sn	V	Zn	Tl	Th	U
A	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
B	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
C	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
D	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd

Table 10: Acid-leachable metals (percentage of solid phase leached) (bd = solid phase metal content is below detection)

Material ID	Al	Sb	As	Ba	B	Cd	Cr	Co	Cu	Fe	Mg
A	0.2%	bd	bd	35.0%	bd	bd	bd	bd	bd	1.1%	3.5%
B	0.2%	bd	bd	40.0%	bd	bd	bd	bd	bd	1.4%	4.2%
C	0.2%	bd	bd	35.0%	bd	bd	bd	bd	bd	1.4%	4.2%
D	0.2%	bd	bd	35.0%	bd	bd	bd	bd	bd	1.3%	3.6%

Material ID	Mo	Ni	Se	Ag	Sn	V	Zn	Tl	Th	U
A	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
B	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
C	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
D	bd	bd	bd	bd	bd	bd	bd	bd	bd	bd

4.3 HYDRAULIC PROPERTIES

Water retention results are summarised in Table 11. Due to the relatively coarse-grained nature of the material, total water holding capacity under atmospheric pressure is low, averaging around 6.5%, and corresponding plant available water (PAW) is very low, averaging only 4.3%. Thus, a 1 m thick profile constructed using coarse rejects would hold a maximum of approximately 43 mm of plant available water.

The measured saturated hydraulic conductivity was high, K_{sat} of fines = 3.9 m/day (162.5 mm/hr) (Table 12). Unsaturated Permeability test results are shown in Figure 3, along with the fitted van Genuchten function. These results indicate that whilst the material has a high permeability when saturated, as soon as it starts to drain (i.e. resulting in a slight increase in pressure head) its permeability decreases rapidly such that by only 0.6kPa the effective conductivity is approaching 0 mm/hr. Given that the site is in the Pilbara, which experiences hot dry conditions, the surface soils will be very dry and have pressure heads well below permanent wilting point (1,500 kPa). Hence, when a storm comes through, the permeability of the dry surface is so low that water cannot readily infiltrate, and infiltration-excess overland flow occurs until the surface soil becomes saturated. Thus, significant infiltration may only occur during prolonged constant rainfall periods in which the surface soil is allowed to wet up slowly.

This result is characteristic of coarse textured soils which have large total (and macro/meso porosities) which drain/dry rapidly resulting in air disconnecting the connectivity of the pore system. Significant lateral flows can be expected in the initial phases of a storm when the soils are dry. Surface drainage features (i.e. bems, contour-ripping) will be necessary to collect water and build up a pressure head to drive water down into the surface soils.

Table 11: Water retention properties

Material ID	Water Retention Data (v/v, %)					PAW (%)	
	0 kPa	10 kPa	33 kPa	100 kPa	1500 kPa	10-1500 kPa	33-1500 kPa
A	34.0	10.2	7.7	6.6	2.1	8.1	5.6
B	37.6	5.1	5.7	4.8	2.9	2.2	2.8
C	36.4	6.8	7.0	5.4	2.1	4.7	4.8
D	38.9	5.5	5.7	4.5	2.2	3.3	3.5
A (replicate)	30.7	5.9	8.1	6.5	2.1	3.8	6.1
B (replicate)	35.0	6.3	5.8	4.4	2.2	4.2	3.6
C (replicate)	34.9	6.2	6.6	5.3	2.2	4.0	4.4
D (replicate)	36.0	5.4	5.6	4.6	2.2	3.2	3.4
Average	**35.4**	**6.4**	**6.5**	**5.3**	**2.2**	**4.2**	**4.3**
Standard Deviation	**2.5**	**1.6**	**1.0**	**0.9**	**0.3**	**1.7**	**1.2**

Table 12: Permeability of fines fraction (< 2 mm)

	Saturated Hydraulic Conductivity (fines fraction, < 2 mm)	
Material ID	**(m/day)**	**(mm/hr)**
A	1.48	61.8
B	4.88	203.4
C	2.93	122.1
D	9.28	386.6
A (replicate)	1.87	78.1
B (replicate)	3.32	138.3
C (replicate)	3.91	162.8
D (replicate)	3.52	146.5
Average	**3.90**	**162.5**
Standard Deviation	**2.43**	**101.1**

4.4 EROSION STABILITY

The results of laboratory measurement of erosion-related parameters are presented in Table 13. The high sand and gravel content resulted in high steady-state infiltration rates (K_{eff}), which ranged from 30 mm/hr to over 95 mm/hr across the four rainfall simulation tests. The noticeably lower K_{eff} in Sample A is thought to be due to the lower gravel content. The material self-armoured under simulated rainfall, and correspondingly the measured inter-rill erodibility (Ki) values were low. A low Ki, combined with high infiltration rate, means that very little raindrop impact erosion should be expected from these materials.

However, the measured rill erodibility (Kr) was high for all samples. This is thought to be due to a lack of a significant clay fraction, which tends to bind a soil matrix together and makes it more resistant to shear stresses. As the infiltration rate is high, overland flow is not likely to form very often on these materials (most of it infiltrates, rather than running off the surface), however, when it does occur, riling and gullying are also likely to occur.

The result of WEPP slope erosion modelling are summarised in Tables 14-17. The results indicated moderate erosion rates, ranging from around 7-27 t/ha/yr, depending on the slope configuration, and taking into account the variability in measured erosion parameters discussed previously. The vast majority of this erosion was predicted to occur as rill or gully erosion, and only occurred during the more intense rainfall events (around 1-3 erosion events per year, on average).

In general, the modelling indicated that steeper slope angles resulted in higher average erosion rates, and greater variability, than the lower slope angles.

Table 13: Laboratory-derived soil parameters, used as input to the WEPP model

Material ID	Sand (%)	Clay (%)	OM (%)	CEC (meq/100g)	K_{eff} (mm/hr)	$K_i \times 10^5$ (Kg s / m4)	K_r (s / m)	τ_c (Pa)
A	94.9	0.5	0.07	6.5	30.2	0.37	0.0187	4.9
B	95.8	0.9	0.11	6.1	> 95	0.22	0.0107	6.8
C	95.1	1.2	0.02	6.2	73.4	0.07	0.0108	6.0
D	95.6	0.7	0.01	6.7	74.1	0.08	0.0053	7.6
Average	**95.4**	**0.8**	**0.05**	**6.4**	**68.2**	**0.19**	**0.0114**	**6.3**
Std. Deviation	**0.5**	**0.3**	**0.05**	**0.3**	**27.2**	**0.14**	**0.0055**	**1.2**

Table 14: WEPP model erosion predictions for 12° slope, 10 m high lift

Material ID	Rainfall (mm/yr)	Rainfall-runoff (mm/yr)	Sediment loss (t/ha/yr)	Sediment loss (mm/yr)
A	436	33	18.2	1.1
B	436	14	7.4	0.5
C	436	15	8.9	0.6
D	436	14.4	6.6	0.4
Average	**-**	**19.1**	**10.3**	**0.7**
Standard Deviation	**-**	**9.3**	**5.4**	**0.3**

Table 15: WEPP model erosion predictions for 15° slope, 10 m high lift

Material ID	Rainfall (mm/yr)	Rainfall-runoff (mm/yr)	Sediment loss (t/ha/yr)	Sediment loss (mm/yr)
A	436	34	23.0	1.4
B	436	14	9.0	0.6
C	436	15	11.1	0.7
D	436	14.4	8.0	0.5
Average	**-**	**19.3**	**12.8**	**0.8**
Standard Deviation	**-**	**9.8**	**6.9**	**0.4**

Table 16: WEPP model erosion predictions for 18° slope, 10 m high lift

Material ID	Rainfall (mm/yr)	Rainfall-runoff (mm/yr)	Sediment loss (t/ha/yr)	Sediment loss (mm/yr)
A	436	34	27.1	1.7
B	436	14	10.6	0.7
C	436	15	13.0	0.8
D	436	14.4	9.2	0.6
Average	**-**	**19.4**	**15.0**	**0.9**
Standard Deviation	**-**	**9.8**	**8.2**	**0.5**

5 CONCLUSIONS

Based on the results presented in Section 4 the following conclusions can be drawn:

- The coarse rejects are classified as a gravelly sand, comprising 35-48% gravels (>2mm fraction). The fines fraction (<2 mm fraction) was comprised primarily of coarse sand-sized particles, with total sand content ranging from 94.7-96.2%
- The materials were strongly alkaline (pH = 9.1-9.6) and non-saline (EC = 145-162 uS/cm). This is somewhat unexpected, as iron-rich materials such as these typically have an acidic pH. This possibly implies spraying or processing with a highly alkaline water source.
- Nutrient analysis indicated that coarse rejects have low organic C content, low Total N, and low plant available P and S (KCl-extractable). This is expected, given that they are typically not surface soils and have been processed during ore beneficiation.
- Total P and K in the sample (representing the total 'pool' or 'reservoir' of P and K) were high. Only a very small fraction of the P is available for plant uptake, whilst a significant fraction of the K is readily available.
- All total metals concentrations were below the DEC Ecological Investigation Levels (EILs), and the potential for metalliferous drainage to occur from these materials is also low.
- Due to the relatively coarse-grained nature of the material, total water holding capacity at field capacity is low, averaging around 6.5%, and corresponding plant available water (PAW) is very low, averaging only 4.3%.
- Whilst the material has a high permeability when saturated (average Ksat = 162.5 mm/hr), as soon as it starts to drain (i.e. resulting in a slight increase in pressure head) its permeability decreases rapidly such that by only 0.6kPa the effective conductivity is approaching 0 mm/hr. Given that the site is in the Pilbara, which experiences hot dry conditions, the surface soils will be very dry and have pressure heads well below permanent wilting point (1,500 kPa). Hence, when a storm comes through, the permeability of the dry surface is so low that water cannot readily infiltrate, and infiltration-excess overland flow occurs until the surface soil becomes saturated. Thus, significant infiltration may only occur during prolonged constant rainfall periods in which the surface soil is allowed to wet up slowly.
- Erosion testing and subsequent modelling indicated moderate erosion rates under the local climate. Predicted erosion rates ranged from around 7-27 t/ha/yr. The vast majority of this erosion was predicted to occur as rill or gully erosion, and only occurred during the more intense rainfall events (around 1-3 erosion events per year, on average).

6 RECOMMENDATIONS

Based on the above conclusions the following recommendations are suggested:

- Appropriate rehabilitation species should be selected based on the measured physical, chemical, and hydraulic properties of the coarse rejects. Some key characteristics of the selected species are likely to include:
  - Tolerance for alkaline soils
  - Low Nitrogen, Phosphorus, and Sulfur requirements
  - High tolerance for Potassium
  - Very low water use requirements
- Landform slopes should be constructed specifically to maximise water infiltration and reduce surface water runoff velocity so that erosion of the material is reduced. Some potential measures that can be implemented to achieve this include:

- Construct slopes to lowest practicable angle
- Utilise berms and cross-ripping to create surface roughness and trap down-slope flows of water to promote infiltration and reduce gully formation

Should you have any queries regarding this report, please do not hesitate to contact us.

Yours sincerely,



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Plate 1: Coarse rejects Sample A being subjected to simulated rainfall at SWA Laboratory in Perth



Plate 2: Coarse rejects Sample A undergoing a rill erosion test at SWA Laboratory in Perth



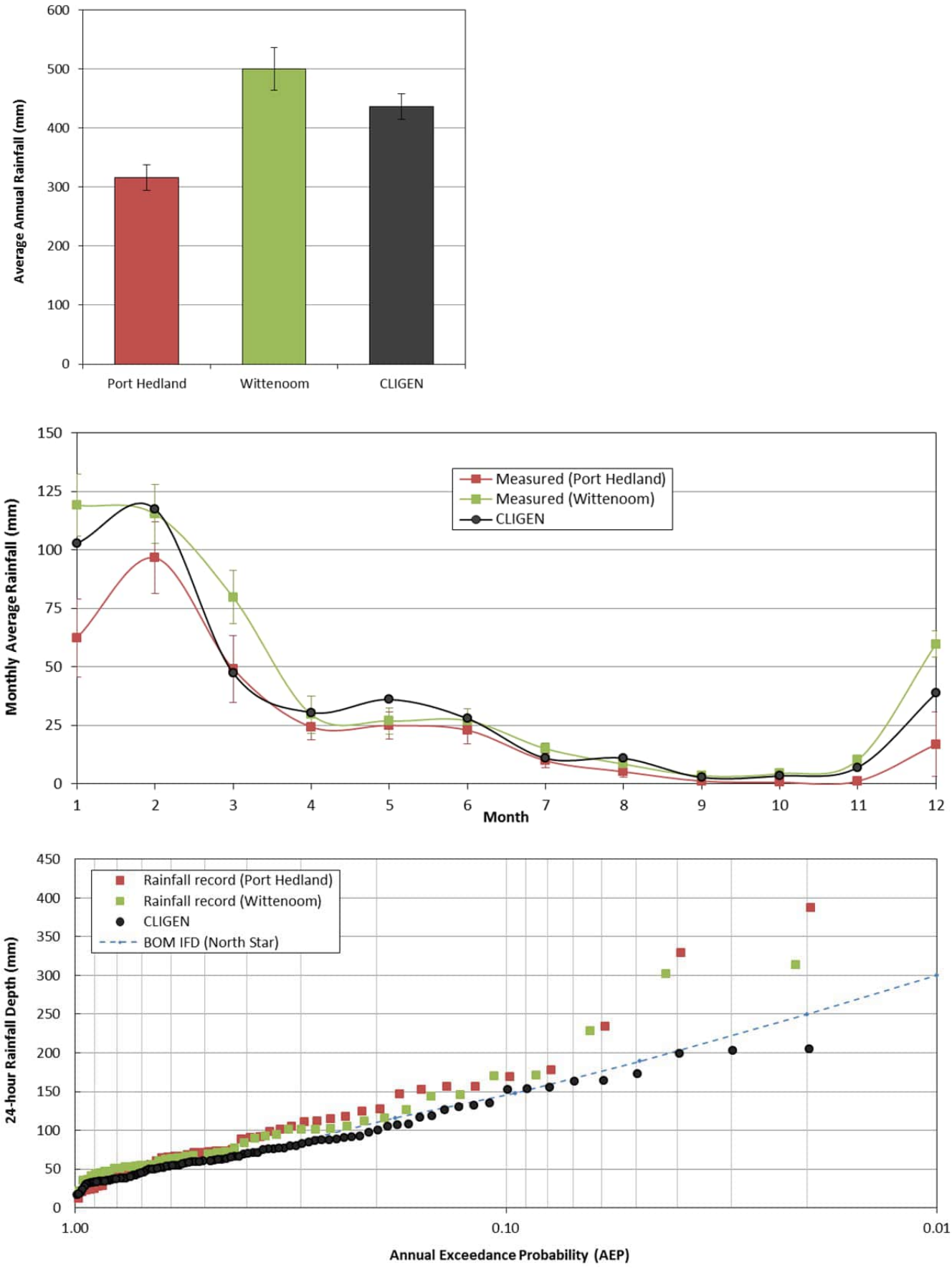


Figure 1: Analysis of CLIGEN synthetic climate statistics for the North Star mine site

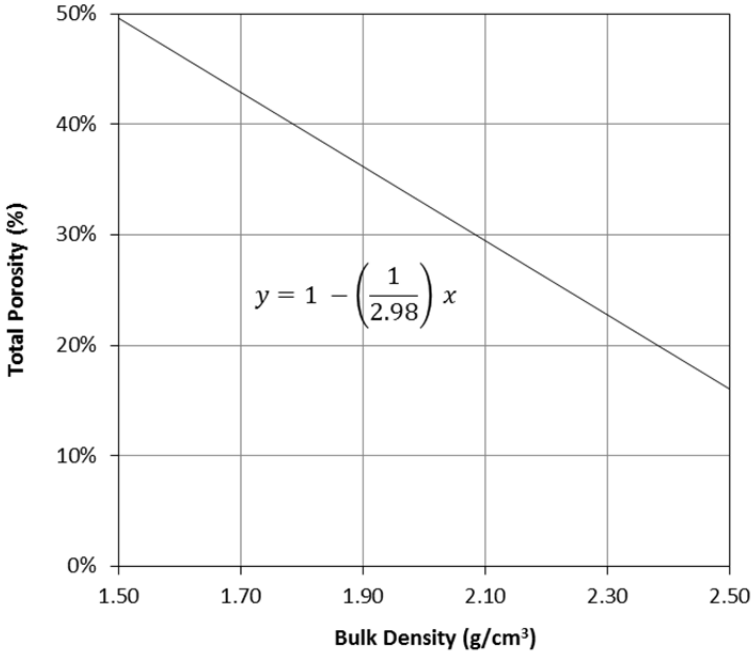


Figure 2: Total porosity (%) of the coarse rejects, according to a range of potential *in situ* bulk density values

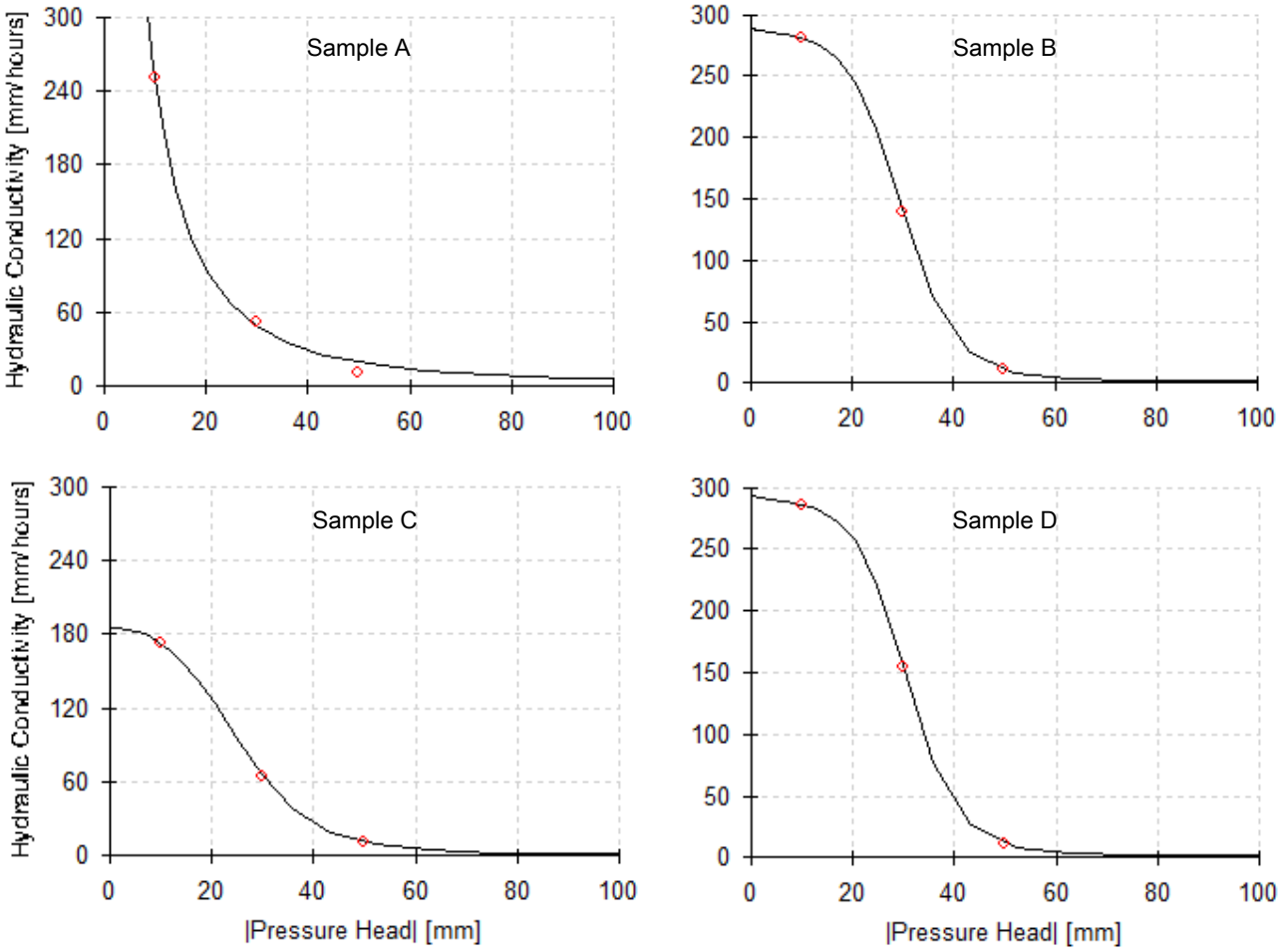


Figure 3: Unsaturated hydraulic conductivity data, fitted using RETC software

Appendix 13: TSF2 Closure Design

Memo

Ironbridge TSF2 Closure Construction – DMIRS Commitments

OUR REF	N/A	**DATE**	4/07/2022
TO	Kirsty Beckett	**CC**	Louise McDonald
FROM	Justin Dixon		

The Iron Bridge Operation (IBO) Tailings Storage Facility & Return Water Pond design submitted to DMIRS as part of the North Star Mining Proposal Amendment 2 is documented within the ATC Williams Consultants *Tailings Storage Facility & Return Water Pond Mining Proposal Design Report* (662NSC2007-2900-RP-CI-0002) and accompanying *Tailings Storage Facility Closure Design Report (6662NSC2007-2990-RP-0002)*.

The closure TSF downstream embankment is to be constructed to form a stable, erosion resistant long-term landform within Fresh BIF waste. The downstream embankment closure profile is primarily differentiated from the operation profile in that it is a "benched" profile as opposed to the continuous slope. The TSF design assess the stability of both the operational and closure designs as independent analysis.

Given the long operational life of the TSF (>20yrs), the design reports provide flexibility in terms of the timing of execution of the closure embankment profile. The option exists to construct as part of the operational raise (i.e. with no requirements for future construction), or through construction post operations. The stability assessments completed remain valid regardless of the implementation strategy. The key driver for executing the closure profile at the end of operations is to reduce upfront capital costs. However, if minimising closure costs becomes priority it will be possible to adopt the closure profile earlier.

Following consultation on the 10th May 2022 DMIRS expressed two primary concerns with regards to the closure design, the mechanisms for verification of design parameters and the construction strategy. In response to these concerns the following commitments are to be incorporated into the MCP. Fortescue acknowledges that verification of design parameters is a critical requirement of the design process, reconciling operational performance with design expectations. This includes validation of closure design assumptions, including the stability analysis, to ensure that the objectives are achieved.

1. **Fortescue will provide a detailed closure design validation report (prepared in accordance with the DMIRS requirements) to address any variation in the design parameters prior to the Stage 7 raise. This report will be provided to DMIRS for approval prior to construction.**

2. **Fortescue will construct the Stage 7 raise to the closure profile without compromising the stability of the embankment.**

JUSTIN DIXON B. Eng MAusIMM(CP)

Manager Geotechnical Engineering & Closure, Strategic Planning



REPORT

IRON BRIDGE OPERATIONS PTY LTD

North Star Magnetite - Stage 2
Pilbara, Western Australia

Tailings Storage Facility &
Return Water Pond

Mining Proposal Design Report

June 2020

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2	**Amended to include updated basis of design information, results of consolidation testing and modelling, updated seepage analyses and updated staging.**	**IBO**	**3.06.20**	**AF**	**CN**

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EXECUTIVE SUMMARY

1. GENERAL

Iron Bridge Operations Pty Ltd (IBO) is developing its North Star Magnetite Stage 2 Project (The Project), located 120 km south of Port Hedland in the Pilbara region of Western Australia (WA). North Star will produce high-grade iron ore concentrate. A Stage 1 pilot plant has previously been constructed, with minor amounts of tailings produced and stored in a small tailings storage facility (TSF) designated TSF 1. ATC Williams (ATCW) have been commissioned to design the Stage 2 wet tailings storage facility (TSF 2A), with the objective being the investigation, analyses, design and documentation of a working Life of Mine (LOM) tailings storage and process water management scheme.

2. TAILINGS STORAGE REQUIREMENTS

The Project proposes to use conventional open-cut mining and both dry and wet ore processing techniques to produce a high-grade iron ore concentrate. It is proposed to process ore over a 20 year LOM, with contingency extension of up to 24 years. The process plant has a nominal concentrate production capacity of 18 Mtpa, with a 50 percent ramp-up in production over the first six months as advised by IBO.

The TSF has been designed for a 20-year life, with a design minimum tailings tonnage of 538 Mt and contingency to extend to a 24 year LOM capacity.

Tailings characterisation test work on samples produced from bench scale metallurgical test work indicates that the tailings will comprise low plasticity silt with a P_{80} of approximately 40 µm. Geochemical characterisation test work on "oxide" tailings samples has indicated that the tailings will be non-acid forming (NAF). The tailings will be thickened to a target solids content of 65% at discharge. Overall in-situ dry densities of 1.5 t/m^3 during the initial TSF stage (Stage 1A), increasing to 1.7 t/m^3 by Stage 3, have been determined for TSF design purposes. The required TSF capacity is thus 318 Mm^3. The actual capacity of the TSF at the end of filling the final Stage 7 is 330 Mm^3, equating to 558 Mt (i.e. slightly higher than the minimum requirement).

Bleed water and incidental rainfall run-off from the tailings storage area will be transferred via gravity decant systems to a downstream return water pond (RWP) area and pumped back to the process plant to supplement raw water input from remote borefields. The nominated maximum pump capacity to cater for normal bleed water production and excess rainfall run-off is 1,980 m^3/hr.

3. SITE CONDITIONS

The proposed TSF site is located in an area consisting of a series of flat-topped elongated plateaus (mesas) of banded iron sediments (BIF) and intervening wide valley areas containing localised hills of erosion resistant sandstone and relatively flat areas underlain by weathered shale. The mesas and valleys in the TSF area are aligned in an east-west direction with approximately 1% westward gradient in drainage channels which meander across the valley floor. Ground elevation in the area ranges between 270 m AHD in the valley floor at the western end of the TSF area and 400 m AHD in the mesa crest at the eastern end of the TSF area. The TSF valley is approximately 5 km north of the proposed Stage 2 process plant.

Geotechnical investigations indicate that significant thickness of surficial soil deposits are limited in extent, generally confined to the valley floor areas and typically less than 1 m in thickness. Alluvial deposits of gravelly sand are present in narrow creek channels but are typically less than 2 m in depth.

Colluvial deposits, primarily of sandy gravel and cobbles of sandstone are present on the sides of the valley floor, reducing in thickness up the valley sides. The thin (or absent) alluvial and colluvium deposits overlay a shallow metasedimentary rock profile generally comprising moderately to slightly weathered sandstone in the elevated hill areas with interbedded moderately weathered shale units in

the valley floor areas. The overall strike of the metasediments is east-west with a nominal dip of 70˚ northwards. On a smaller scale, tight sinuous folding and deformation as a result of east to west compression is evident, particularly in the shale units.

The sandstone exposures on the hills have an open blocky fabric with intersecting open joints and the near surface rock mass is highly permeable as a result; whereas the near surface interbedded, folded shale deposits are generally of low permeability. At the proposed downstream RWP embankment locations, based on in-situ testing, the sandstone units forming the embankment abutments have inferred permeability of up to 2 x 10^{-5} m/s to a depth of approximately 20 m below the valley floor. Permeability is an order of a magnitude lower in the intervening shale units. At depths greater than 20 m below the valley floor, where the joint spacing in the sandstone rock mass is "tight" the inferred rock mass permeability in the sandstone units is approximately 2 x 10^{-7} m/s.

At the proposed alignment of the main tailings retaining embankment, relatively low permeability shales are predominant across the valley floor.

Where present, near surface alluvial and colluvial deposits are typically dense to very dense, hence nominal foundation stripping depths of 0.5 m are expected to reveal a competent foundation profile beneath the proposed embankments. In the elevated abutment areas, a stripping depth of no greater than 0.2 m should generally reveal competent foundation material.

Groundwater in the valley floor area occurs at depths typically ranging from 2.3 m to 6.6 m. The inferred groundwater elevation ranges from RL 241.7 m to RL 270.4 m across the TSF and RWP area, with an inferred hydraulic gradient of 1:100 towards the north west.

4. REGULATORY DESIGN CRITERIA

The design has been prepared to comply with the relevant WA regulatory technical and environmental guidelines issued by the WA Department of Mines, Industry Regulation and Safety (DMIRS) **[27]**, and also the applicable guidelines developed by the Australian National Committee on Large Dams (ANCOLD) **[28]**.

Specific design requirements for tailings storage facilities are given by DMIRS and ANCOLD, which relate to the risk classification of the facility. These classifications determine the level of detail applied to design (specifically storm water storage, spillway and earthquake design criteria) and operation, maintenance and surveillance requirements.

With respect to the DMIRS guidelines, a hazard rating of '**Medium**' has been derived based on the highest perceived impact of release of tailings, water or seepage and embankment structural failure. Based on consideration of hazard rating and maximum embankment height (over 68 m at the end of the life of the facility), TSF 2A is considered as a **Category 1** facility.

The ANCOLD Guidelines assign consequence categories for (a) dam failure and (b) environmental spill of contained water.

Based on the results of dam break analyses and consideration of the environmental impact of water spillage, consequence categories of "**High C**" and "**Significant**" have been derived for dam failure and water spillage respectively.

5. TSF OPERATIONAL CONCEPT

The TSF concept will involve down-valley discharge on a rotational basis from three primary discharge points at the head of tributary creek valleys at the eastern end of the TSF area. Tailings will flow down existing drainage lines and accumulate against the main cross-valley TSF embankment.

The initial (Stage 1) construction of the TSF embankment will be approximately 27 m high. At LOM, the TSF embankment will be approximately 68 m high.

All decant and runoff water collecting on the tailings beach will be conveyed via two gravity decant structures constructed on the upstream face of the main TSF embankment to the RWP directly downstream. Confinement for accumulated water in the RWP is achieved by the construction of two small embankments (16 m and 10 m high respectively) approximately 1.5 km m downstream of the TSF embankment. These embankments will be constructed to full height during the initial construction works.

The return water pumping system will consist of a pontoon-mounted pumping station located within a channel excavated to access the central part of the RWP area from its southern perimeter.

The facility has a large catchment of over 20 km^2 comprised of 13.5 km^2 in the tailings storage area and 7.1 km^2 in the water storage area. Bleed water from the tailings and excess rainfall run-off from both sub-catchments will be captured behind the RWP for use as return water to the process plant.

The TSF Embankment will be constructed in seven stages. To minimise initial capital expenditure, construction of the Stage 1 TSF embankment will be divided into two sub-stages, Stage 1A and Stage 1B, which will provide storage to 16 months and 2 years, respectively. The Stage 1A works incorporate a small sacrificial embankment within the tailings impoundment which will restrict Stage 1A tailings deposition to the northern part of the overall valley area. Stage 2A construction will expand the deposition area to include the southern part of the main valley area. Subsequent construction stages will each have a design life of 3 years. Each stage will include emergency spillways constructed in cut through natural rock exposure along the alignment of the final embankment. The interim stage spillways will be infilled as part of the construction works for the subsequent stage embankment raise.

6. RETURN WATER POND

The design RWP storage capacity and hence required embankment height is a function of the operational intent and regulatory water storage requirements, and has been assigned based on various trade-off studies considering the availability of return water, capital cost, spillway discharge risk, and regulatory requirements with respect to environmental impact of water discharge. In order to determine the crest level for the RWP Embankment, the following process was conducted:

(i) Undertake water balance modelling and trade-off studies to develop RWP inflow volume and spillway outflow statistics, assign a practical maximum return water pump capacity and assign a “normal” operating pond level;

(ii) Assign the design dam failure and dam spill consequence categories and hence the relevant hydrologic design criteria for storm water storage and spillway operation;

(iii) Estimate the contingency freeboard requirements for the RWP to be applied above the “normal” operating level to establish the required spillway invert level; and

(iv) Complete hydrological and wave run-up analyses and design of the spillway to establish the final RWP Embankment crest level.

An initial study, whereby the RWP was considered as an independent water storage facility considered the trade-off between return water pumping capacity and operational spill frequency as a result of concentrated rainfall events to minimise RWP embankment height. The study outcomes indicated that with allowance for infrequent spillway flows, the maximum RWP embankment height could be reduced to 9 m. This was however inconsistent with the perceived regulatory requirement to have zero operational discharge from the overall facility (other than emergency discharge to prevent catastrophic embankment failure).

A second study comprised additional modelling of configurations to achieve a "no operational spill" RWP arrangement in compliance with the DMIRS guidelines applicable to tailings storage facilities, from which the current design heights were derived.

A subsequent trade off study addressed whether any significant reduction in RWP embankment volume could be realised by creating a RWP sub-catchment diversion system; however, this concluded that the cost of diversion infrastructure works did not improve the cost effectiveness of the RWP design.

The water balance model was also queried as to the effectiveness of adding supplementary stand-by pumps to limit pond depth resulting from extreme storm events. The outcome was that providing contingency for two operational pumps with a combined maximum capacity of 1980 m^3/hr was the optimum configuration whilst still meeting the regulatory objective of providing sufficient contingency storage capacity for extreme storm events.

In order to assess the required RWP capacity and hence embankment crest level, it is first necessary to define a "nominal" operating pond level upon which to impose extreme storage contingency freeboard. To assess this, an iterative water balance approach was adopted, with the primary independent variables being the spillway invert level (i.e. the maximum storage capacity of the RWP) and the maximum return water pumping rate.

From the trade-off studies, the adopted design RWP capacity is 5,100 ML. Specific design criteria established for the RWP, conforming to the DMIRS requirements for stormwater storage in tailings storage facilities and ANCOLD Guidelines for spillway capacity are summarised in **Table S1**.

Table S1
RWP Freeboard Design Criteria

Freeboard to Assign Spillway Invert Level			Spillway Depth to Assign Embankment Crest Level		
Nominal Operating Pond	**Wet Freeboard**	**Dry Freeboard**	**Operating Pond**	**Spillway Capacity**	**Wave Run-up**
Mean RWP elevation from "Average LOM Rainfall" water balance scenario	1:100 AEP, 72 hr duration	1 m	1 in 10 AEP RWP elevation from "Average LOM Rainfall" water balance scenario	1 in 100,000 AEP, critical duration	1 in 10 AEP

The "nominal" operating level was adopted by ranking and assigning a probability to the daily RWP volume data for the average (mean) and maximum LOM total rainfall scenarios, generated from LOM water balance modelling. The "nominal" operating pond level was thereby selected as the average (mean) pond volume from the average LOM total rainfall scenario (260 ML), which equates to a water level of RL 250 m. The desired or target normal operating pond level is 246 m AHD which represents a 3 m pond depth against the RWP South embankment.

As there is insufficient clayey material available in the project area, the RWP embankments will be constructed of rockfill with an upstream filter and cushion layer of select sand and gravel size material (coarse rejects) upon which a thin, impermeable Bituminous Geomembrane (BGM) will be placed.

The rockfill will be sourced from selected sandstone hills within the TSF impoundment area and the filter material will be sourced from the existing North Star Stage 1 mine coarse rejects stockpile.

At the RWP South embankment, against which the permanent operational pond will lie, the BGM liner will be anchored onto a concrete plinth, constructed in a trench along the upstream toe of the embankment. A grout curtain will be installed through the concrete plinth, the alluvial and colluvial valley deposits and the highly permeable sandstone rock mass to a nominal depth of 20 m.

The base of the RWP North embankment is approximately 9 m above that of the South embankment at a higher elevation than a 1 in 10 AEP average LOM pond level. It is therefore unlikely that water will be ponded against the north embankment frequently, or for extended periods of time, hence no concrete plinth and grout curtain has been included at this location. Instead, the BGM Liner will be anchored in a trench, excavated along the upstream toe of the embankment.

During normal operation, pond levels are generally expected to be lower than the design nominal pond elevation and in the event of significant accumulation of excess rainfall run-off, the pond will be drawn down as quickly as possible by operating both the normal duty and the standby pump set (the proposed return water pipe has design capacity to accommodate the combined flow rate).

Ground water monitoring bores proposed immediately downstream of the RWP will be drilled to sufficient diameter and screened to allow conversion to seepage recovery bores as a contingency in the event of seepage occurring around the South embankment abutments or through the hill between the South and North embankments. Contingency seepage monitoring and collection trenches and sumps will also be provided.

7. TSF CIVIL WORKS

The Stage 1A and 1B TSF embankment will be primarily constructed of competent sandstone rockfill sourced from hills within the TSF impoundment area. Subsequent construction stages will utilise an increasing proportion of mine waste rock as access to the TSF impoundment for quarrying becomes restricted due to accumulation of tailings. The TSF embankment crest level for each stage has been assigned using the following process:

(i) Assign the TSF category (DMIRS) and spill consequence category (ANCOLD) and hence the relevant hydrologic design criteria;

(ii) Conduct tailings beach development modelling for deposition within the TSF, in terms of rate of rise at the TSF embankment, tailings level and volume as a function of time;

(iii) Estimate the contingency storage freeboard requirements for the TSF to establish the required spillway invert level for each stage; and

(iv) Complete analyses and design of the TSF embankment spillways to establish the TSF embankment crest level for each stage.

Specific design criteria established for the TSF embankments are summarised in **Table S2**.

Table S2
TSF Freeboard Design Criteria

TSF Stage	"Nominal" Operating Pond	Wet Freeboard	Dry Freeboard	Spillway Capacity & Depth
Stage 1A	400 mm	1:100 AEP, 72 hr duration	Incorporated in spillway freeboard allowance	1 in 100,000 AEP, critical duration
Stage 1B				1 in 1,000 AEP, critical duration
Stage 2 to 7				1 in 100,000 AEP, critical duration

The purpose of the TSF embankment is to retain tailings, whilst practically all bleed and excess rainfall run-off is transferred to the downstream RWP area. The nominal TSF operating pond depth of 400 mm represents the height of water required to effectively spill into the decant structures without carrying disturbed tailings material.

The RWP configuration has been designed to cater for extreme rainfall events which impact the TSF system as a whole (tailings impoundment and RWP catchment combined); however, in accordance with DMIRS guidelines, it is assumed that the gravity decants on the TSF embankment could become blocked and contingency storm water retention freeboard and spillway allowances have been applied to the TSF embankment independently. As per the design of the RWP embankments, the TSF embankments will be constructed from rockfill with an upstream filter and cushion layer of select sand and gravel size material (coarse rejects) upon which a thin, impermeable Bituminous Geomembrane (BGM) will be placed. The BGM Liner will be anchored into an upstream toe cut off trench.

Any lateral seepage through the foundations of the TSF embankment will be collected in the downstream RWP. Significant seepage through the BGM liner is not anticipated; nevertheless, the subgrade for the BGM Liner has been designed to act as a filter for the tailings, such that any ingress of tailings fines through liner defects which could potentially migrate further through the embankment will be minimised.

The TSF decant system will be constructed on the upstream face of the TSF main embankment. It comprises two decant inlet chutes, constructed of upturned precast concrete box culvert sections, with a reinforced concrete base slab. The decant chutes discharge to reinforced concrete-encased steel, 700 mm diameter outlet pipes through the base of the embankment, which transfer the decant water downstream to the RWP. Emergency shut-off valves will be installed at the outlet of each pipe.

The decant inlet chute arrangement has been designed to minimise heavy lifting and facilitate fine control of the pond level (to nominal 200 mm increments) by the incremental placement of small aluminium stoplog sections across the culvert. The stoplogs (and decant chutes) have been designed to accommodate the design loads imposed by the LOM tailings deposit, incorporate interconnecting seals and will be placed by sliding down rails attached to the exposed culverted edges.

8. WATER MANAGEMENT

The TSF decant system is designed to maintain the decant pond at an operating depth of 400 mm under normal operating conditions. The decant pond depth will periodically fluctuate throughout the LOM, specifically during and after significant rainfall events; however, the high capacity gravity decant system will prevent the accumulation of a sustained elevated water pond on the tailings beach. The decant system has been designed to return the TSF decant pond depth back to a normal operating level after a 1 in 100-year ARI, 2-hour storm in approximately 3 days during Stage 1A filling and between 6 to 7 days for deposition into Stages 2 to 7.

Water balance modelling has indicated that the TSF spillways are unlikely to flow during the LOM. Nonetheless, they may be required during sustained, extreme rainfall events at the end of filling of a particular stage.

In order to confirm the adopted RWP capacity conforms with the operational and regulatory intent, a detailed evaluation of the LOM water balance model has been conducted.

Various daily RWP volume statistical (stochastic) and individual simulated water balance outcomes have been assessed. Individual realisation results comprise daily output following the unique climate input for the average (mean) and maximum LOM total rainfall scenarios. The statistical results depict the percentile values based on a certain day across all realisations, and hence represent a collection of values from all realisations for the model duration rather than representing any specific realisation.

Presented in **Table S3** are predicted RWP volumes corresponding to various return periods for the Average and Maximum LOM total rainfall scenarios.

Table S3
RWP Volume - Probability of Occurrence (Once in the LOM)

Probability	Pond Volume (ML)	
	Average LOM Total Rainfall Scenario)	Maximum LOM Total Rainfall Scenario)
Mean	260	886
1 in 10	875	2,967
1 in 20	1,675	3,927
1 in 100	2,740	5,100 (Max. Capacity)

It is important to note the probabilities in **Table S3** relate to the chance of the given volume being reached or exceeded once in the 20-year LOM for that rainfall scenario. The variation in the data for the two rainfall scenarios provide an indication of the potential impact of tropical and monsoonal events within the rainfall database.

With respect to spill risk, the water balance data shows that for the average LOM total rainfall case, no spillway discharge is predicted as the pond never reaches the maximum capacity. A statistical analysis of spill events over the 1,000 water balance realisations identified that the number of potential spilling days is relatively small compared to the 20-year mine life, with a maximum stochastic number of 40 days. For the maximum LOM case, the cumulative number of spilling days is 22, which equates to a 1 in 330 chance of spilling over the 20-year LOM.

In summary, all simulated spillway discharges result from coupled events comprising high antecedent pond volume and extreme rainfall, for which the joint-probability is not able to be directly assessed, but is well beyond what could be considered "normal" operating conditions and may be considered as an emergency discharge scenario.

9. CLOSURE AND REHABILITATION

The closure and rehabilitation plan and design for the North Star TSF and RWP is in preparation at the time of issuing this draft design report. However, the following general objectives relate to the closure and rehabilitation of the TSF:

- Protect public health, safety and property;
- Ensure long term physical and chemical stability of the facility;
- Design for a sustainable ecosystem and land use;
- Employ rehabilitation methods that are technically effective and cost efficient; and
- Implement proven engineering practices to minimise on-going maintenance.

The facility closure concept includes removal of the RWP embankments, rehabilitation of the RWP impoundment, regrading of the downstream slopes of the TSF embankments and placement of an engineered cover across the tailings beach with provision for local areas of growth medium placement.

10. MATERIAL & QUANTITIES

The embankment zoning is:

BGM Bituminous Geomembrane Liner
2A Upstream BGM Support Layer (coarse rejects, < 25mm particle size)
3A Transition Rockfill (coarse rejects, waste rock, designated excavations, quarries, < 400 mm particle size)
3B General Rockfill (waste rock, designated excavations, quarries < 800 mm particle size)

A summary of major earthworks and BGM liner quantities estimated over the seven embankment construction and tailings deposition stages is presented in **Table S4**.

Table S4
Summary of Embankment Fill and BGM Liner Quantities

Storage	Stage	Zone 2A m^3	Zone 3A m^3	Zone 3B m^3	Stage Volume m^3	BGM Liner m^2
RWP	**1A**	13,500	22,000	60,000	95,000	10,000
TSF	**1A**	50,000	240,000	440,000	730,000	30,500
	1B	16,000	90,000	300,000	406,000	12,000
	2	50,000	270,000	685,000	1,005,000	38,000
	3	45,000	230,000	970,000	1,245,000	33,000
	4	45,000	235,000	1,215,000	1,495,000	33,100
	5	45,000	240,000	1,420,000	1,705,000	34,500
	6	45,000	245,000	1,710,000	2,000,000	35,500
	7	45,000	235,000	1,950,000	2,230,000	34,000
Total		354,500	1,807,000	8,750,000	10,911,000	260,600

TSF PROPOSAL SUMMARY

This report describes the Mining Proposal Design Report for Tailings Storage Facility 2A (TSF 2A) at Iron Bridge Operations' North Star Magnetite Project in Western Australia (The Project).

Summary	Details
Description of Project and TSF	The project involves construction of cross valley embankments to form an impoundment within a valley. The largest embankment will be 68 m high at the final construction stage (20 years LOM) and approximately 2.5 km in length. Embankments will be constructed in 7 stages using downstream methods. The Stage 1 (starter) is proposed to provide approximately 24 months tailings storage. The proposed deposition method comprises down valley discharge of tailings. Supernatant water will be transferred to a Return Water Pond (RWP) located immediately downstream of the TSF. The TSF site is the largest valley in the area of the mine tenement. The site is bordered on the north by high ridge mesas (maximum 93 m high), the tenement boundary to the east, North Star pit to the south and waste rock dump to the south east. Geotechnical investigations have comprised the excavation of test pits, the drilling of boreholes and engineering geology observations. Extensive rock exposures are present in the TSF area and superficial cover is typically very thin other than within the confines of current alluvial channels. There is minimal low permeability clayey material available on site for use in zoned embankments. The foundation conditions, particularly within the RWP, have high permeability. All the embankments will be founded on competent rock, with minimal requirement for removal of superficial deposits in alluvial channel areas. The TSF embankment will adopt a conventional upstream key trench to manage seepage. The RWP will be comprised of an RWP North embankment and a RWP South embankment to provide containment to the bifurcated valley. As for the TSF Embankment, the smaller RWP North embankment will adopt a conventional upstream key trench to manage seepage, however the larger RWP South embankment will require a grout curtain to manage seepage. An upstream geomembrane liner is proposed for both the RWP embankments, as well as for the TSF embankment. Groundwater was encountered in most embankment locations at depths between 2.5 m and 21.5 m depending on surface elevation. The tailings are considered non-acid forming (NAF). The tailings decant water is considered to have negligible impact on groundwater quality.
Location	The TSF is located 135 km south of Port Hedland on mining tenement M45/1226
Tailings Storage Data Sheet	In accordance with DMIRS requirements **[27]**, a certificate of design compliance and a Tailings Storage Data Sheet are given in **Appendix A**.
Rehabilitation and Closure Objectives	Rehabilitation and closure of the TSF will provide a low relief landform with a water shedding surface. A cover of sufficient thickness to prevent dust generation and promote vegetation regrowth is proposed, comprising selected, durable mine waste and topsoil. The RWP embankment will be breached to allow free flow of rainfall runoff.
Commitments	Design, operation, auditing and closure of the facility will be undertaken in accordance with DMIRS guideline requirements **[27]**. Geochemical analyses of decant water will be conducted to confirm design assumptions. An Operations Manual will be prepared.
Stakeholder Consultation	The project has been operational since 2015, operating a pilot plant, during which a robust stakeholder consultation process has been established. There are currently no known items or sites of significant state, national or aboriginal heritage impacted by the proposal. The surrounding land use is pastoral.

ATC Williams

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1 INTRODUCTION

1.1 Overview

This Report describes the results of investigations, analyses and engineering design studies for Tailings Storage Facility 2A (TSF 2A) and an associated Return Water Pond (RWP) at the North Star Magnetite Stage 2 Project (The Project), which is located approximately 120 km south of Port Hedland in the Pilbara region of Western Australia. A pilot plant has previously been constructed (Stage 1) and minor amounts of tailings produced, and then stored in a small tailings storage facility (TSF) designated TSF 1.

The Project is being developed by Iron Bridge Operations Pty Ltd (IBO), and will use conventional open-cut mining and ore processing techniques to produce high-grade iron ore concentrate. The mine production will be approximately 55 million tonnes of ore per annum over a 24-year Life of Mine (LOM). Mining will be undertaken within two open pits to provide sufficient ore for mill feed. The mined ore is treated at the process plant located approximately 5.0 km to the south of the proposed location of TSF 2A.

The design work described herein revises and expands upon the Draft Mining Proposal Design Report for the TSF 2A and RWP, which was completed by ATC Williams in April 2018 **[1]**.

1.2 Previous Studies & Project History

ATC Williams (ATCW) have previously completed the following works relating to the Project:

- An options study for a life of mine (LOM) TSF in September 2014, the outcome of which is included in ATCW report **114185.02R01 [2]**. Two potential storage areas for tailings storage were considered (Site 2A and Site 6A). The recommended site for storage of wet tailings was Site 2A.
- A 2015 TSF 2A Feasibility Design Report **[3]** with various memorandums and sub-reports:
  - **114185.03 M01** – Water Management Approach (memo dated 9/02/2015);
  - **114185.03 M02** – Topsoil Stripping Assumptions (memo dated 12/02/2015);
  - **114185.03 M03** – The Effect of Possible Process Changes on Tailings Design (memo dated 30/03/2015);
  - **114185.03 M04** – Pipe Loop Testing (memo dated 16/03/2015);
  - **114185.03 M05** – Stage 1 Laboratory Testing Results (memo dated 20/04/2015);
  - **114185.03 R01** – Interim Work– Laboratory Testing Report **[4]** (dated March 2015);
  - **114185.03 R02** - TSF Feasibility Study - Basis of Design (report dated February 2015, with Revision 2 dated April 2015).

The feasibility study design catered for storage of "all-in" tailings with P_{80} (80% of particles finer than) of 300 µm. The 'wet tailings' and 'coarse rejects' were to be combined into a single stream of slurry and pumped to TSF 2A. The design tailings storage requirement was approximately 457 Mt of "all in" tailings over 20 years.

Since the completion of the 2015 Feasibility Study, a revised mass balance scenario determined that the two tailings streams would remain separated at the process plant (i.e. coarse rejects and wet tailings).

ATCW completed preliminary modelling for deposition of wet tailings only as proposed by IBO in October 2016 and re-considered both TSFs 2A and 6A. The revised design tailings storage requirement was approximately 462 Mt of wet tailings over 24 years. The wet tailings properties were inferred from assessment of previous test work on material with P_{80} of 50 µm. IBO concluded at the end of this phase of work that tailings storage should not be split over two site locations (TSFs 2A and 6A) and that all the wet tailings should be deposited at TSF 2A.

Tailings laboratory test work on material considered representative of the wet tailings stream (2016 sample) was completed in February 2017 (**114185.08M01**) **[5]** to characterise properties and calibrate the October 2016 preliminary modelling assumptions. The resultant wet tailings P_{80} was 75 µm.

In August 2017, a high-level embankment optimisation study for a revised deposition scenario of 329 Mt of wet tailings over 21 years was carried out by ATCW using the updated wet tailings properties **[6].**

In September 2017, ATCW were commissioned to undertake a geotechnical investigation at the TSF 2A site and complete a TSF design report suitable for incorporation in a mining proposal submission.

Subsequent to the commission, IBO advised ATCW, that the wet tailings throughput had been revised to 617 Mt over 20 years, necessitating revision of the risk based TSF classification, the embankment design (increasing final height to 74 m) and the stage construction schedule.

Initial geotechnical investigation at TSF 2A was completed between December 2017 and February 2018 **[7]** and a draft Mining Proposal TSF design report issued in April 2018 **[1]**.

1.3 Current Study

As part of ongoing development of the Project, IBO advised ATCW in June 2018 that the design tailings underflow for the purposes of the revised and finalised TSF design submission would be finer than adopted for the draft report, and would sit in the P_{80} = 40 µm range.

It was further advised that the LOM total wet tailings production had been increased by almost 10%, but countering this was the instruction by IBO that the design of the TSF 2A be based on an operational life of 20 years.

The other aspects of the design proposal remain similar to the draft report **[1]**. The proposed deposition method comprises down valley discharge of tailings, with construction of cross-valley embankments to form an impoundment within a wide valley. The largest embankment will be in excess of 68 m high at the final construction stage and approximately 2.9 km in length. Embankments will be constructed in seven stages using downstream methods. Supernatant water will be transferred to the RWP located immediately downstream of the TSF main embankment.

2 DESIGN STORAGE CONSIDERATIONS

2.1 Basis of Design

The TSF 2A configuration described herein has been based on a process plant with a nominal production capacity of 18 Mtpa. A plant production ramp-up period of less than one year is anticipated, with 50% production for the first six months only.

Other pertinent Basis of Design data, as advised by IBO over the course of the project studies, can be summarised as follows:

- Life of mine (LOM) = up to 24 years;
- TSF operational life = 20 years (with contingency to extend to a 24 year LOM capacity);
- Required TSF starter (Stage 1) storage capacity = 2 years;
- Required minimum TSF Stage life (Stage 2 to 7) = 3 years;
- Annual process plant operating hours = 7,400 hrs;
- Design tailings storage capacity = 538 Mt (refer to **Section 2.2**);
- Tailings pumping rate to TSF = 3,800 to 4,000 dry tonnes per hour (dtph);
- Solids concentration at thickener underflow by weight = 62% to 65%; and
- Maximum return water pumping rate (from RWP) = 1,980 m^3/hr.

2.2 Tailings Tonnage

For detailed design purposes, the staging and rate of filling of the TSF have been based on "*Mining Schedule: LOM_0919_v8.27_rev01*" concentrate, rejects and tailings production data provided to ATCW by IBO on the 4th March 2020. These data are summarised in **Table 2.1**.

Table 2.1
Tailings Production Data

Year	Tailings to TSF	
	(Mt)	Cumulative (Mt)
1	9.4	9.4
2	26.5	35.9
3	29.6	65.5
4	30.0	95.5
5	29.0	124.5
6	27.5	152
7	28.2	180.2
8	28.7	208.9
9	27.6	236.5
10	28.6	265.1

Year	Tailings to TSF	
	(Mt)	Cumulative (Mt)
11	28.6	293.7
12	27.4	321.1
13	26.0	347.1
14	27.7*	374.8*
15	27.7*	402.5*
16	27.1*	429.6*
17	27.1*	456.7*
18	27.1*	483.8*
19	27.1*	510.9*
20	27.1*	538.0*

* Actual production estimates have provided for the first 15 years of operation. Tailings tonnages beyond the first 13 years of operation have been extrapolated based on long term average values to provide a design basis for a 20 year operational life.

As stated in **Section 2.1**, the TSF Basis of Design is an operational life of 20 years (538 Mt of tailings), with contingency embankment raises to achieve storage of for the maximum 24 year LOM tailings production.

To ensure that the performance of the TSF is in accordance with design expectations, a routine review, recalibration and verification of the fundamental TSF Basis of Design parameters must be undertaken throughout the operational life of the TSF, as detailed in **Section 16.4**.

2.3 Risk-Based Design Approach

2.3.1 Overview

A risk-based approach has been implemented in the design development the North Star TSF. This has been achieved by adopting design features that address the recognised, credible failure modes for the key elements of the TSF and RWP Embankments.

Presented in the following sections are the identified credible failure modes together with short descriptions of their associated failure mechanisms, initiators, effects and risk mitigating design features.

These are summarised in **Table 2.2**, together with qualitative (more likely / neutral / less likely) risk assessments of the influence of the relevant design features, to produce an overall picture of the likelihood of a failure initiator progressing to the ultimate failure of the TSF or RWP embankment.

The qualitative risk assessment presented in **Table 2.2** has been expanded to include construction and operational risk factors in a Semi-Quantitative Risk Assessment **[8]** completed by ATCW, the results of which are summarised in **Section 2.4**.

2.3.2 Overtopping (Water or Tailings)

The overtopping (water) failure mode for either the TSF or the RWP embankments require as initiators either an extreme storm event or a sustained, un-remediated failure of spillways, decant systems or pumps under normal operating conditions. A coupled scenario involving a large flood in conjunction with a short term decant failure at the end of filling a particular TSF embankment stage is also recognised.

In order to address this failure mode, the RWP and each stage of the TSF design have incorporated high capacity, 50 m wide emergency spillways, together with conservatively adopted freeboard allowances for both flood height and wave action. In the case of the TSF spillways, it has been assumed that the decant systems are not operating during the passage of the design flood.

A possible failure mode involving tailings overtopping the TSF embankment has been identified. This would initiate due to the post-seismic failure of the tailings beach adjacent to the decant pond area. After a large earthquake, the failure mechanism would need to involve the saturated tailings beneath the decant pond to liquefy, thus destabilising the adjacent, residual strength tailings beach. If the timing coincided with the end of filling a TSF stage, the destabilised tailings could potentially cause a wave of saturated pond tailings to overtop the embankment.

In order to address this failure mode, the extents of the sustained, saturated tailings beneath the decant pond will be minimised during normal operating conditions by the high capacity and low operating depth of the decants. This will allow for periods of evaporative beach drying adjacent to the embankment and the minimisation of hydraulic sorting of tailings particles within the pond area. The relatively flat beach slopes will also minimise the effect of any post-seismic mobilisation of tailings. At the end of a particular stage, were say, the upper 5 m of tailings within the nominal decant pond area to slump to a horizontal surface, the void space capacity below the embankment crest level would be sufficient to provide containment. Whilst such an event would result in significant volume of tailings flowing through the decants, they would not block as a result, due to the large capacity of the system.

2.3.3 Embankment Instability (Fill or Foundations)

A plausible failure mode for embankment dams is the loss of freeboard due to instability within the embankment fill or the foundations, due to static (less typically) or seismic-induced loads. Initiators are generally due to unidentified foundation weaknesses, inappropriate design criteria, construction flaws (material selection, compaction etc.), or sustained operation of the dam in contravention to the design intent.

In order to address the foundation instability failure mode, a thorough geotechnical investigation has been conducted to identify the nature and extents of potentially weak materials (such as alluvium). The design has adopted the stripping of all weak alluvials from the foundation to expose competent weathered sandstone and siltstone.

The embankment materials will comprise rockfill and granular materials which will be essentially free-draining and not capable of developing pore water pressures. Compaction specifications will be to a high standard to minimise post construction settlements and the possibility of cyclic liquefaction of the granular fill.

Embankment design has included seismic deformation assessments to ensure minimum freeboards are not compromised under the maximum design earthquake loading.

2.3.4 Internal Erosion and Piping

The TSF and RWP embankment design incorporates compacted rockfill, and upstream compacted granular filter and an exposed geomembrane liner. The liner provides the primary water and tailings retaining element, with the filter forming the liner subgrade and providing protection against tailings migration into the rockfill due to a concentrated leak in the liner.

During the initial design phase the option of omitting the geomembrane liner and designing the embankment as a filter dam was considered. However, whilst the granular filter zone has been designed with a particle size distribution appropriate for the retention of tailings particles, the option was not pursued for the following reasons:

- The additional filter width required to function with high seepage flow rates and hydraulic gradients was not economic compared to lining; and
- The granular filter would require an upstream rip-rap zone to protect it from erosion, introducing further cost impacts.

A plausible failure mode for such embankment configurations is the internal erosion and subsequent piping of the embankment fill and/or foundation materials.

Possible failure mechanisms include the development of a liner defect, earthquake-induced cracking of the embankment and associated liner rupture, or unidentified erosive foundation materials.

In order to review the role of the granular filter and the performance of the embankment/foundation system in general, a qualitative assessment of the factors influencing the likelihood of internal erosion and piping has been undertaken. This has considered the process of the initiation and continuation of erosion, progression to form a pipe and formation of a breach of the embankment.

The assessment is in **Table 2.2**, and considers potential piping locations through the embankment, through the foundation, and via the decant pipeline encasement. The mechanisms, or areas of potential weakness, are addressed, together with the relevant factors affecting the erosion and piping process.

It is noted that the majority of factors relate to design or specification issues (i.e. influences which can be controlled to varying extents) which lessen the likelihood of internal erosion and piping.

In summary, the assessment demonstrates the purpose and effect of the embankment design features specifically targeting the identified plausible failure modes for internal erosion and piping in the embankment and foundations. The compaction and quality control of the construction materials, coupled with the filter and lining system, are seen to reduce the risk of erosion progressing to an embankment breach to an acceptable level.

2.3.5 Summary and Conclusions

The risk-based design approach is summarised in **Table 2.2**, together with qualitative (more likely / neutral / less likely) risk assessments of the influence of the relevant design features.

It is evident that the risks of a failure initiator progressing to the ultimate failure of the TSF or RWP embankment has been addressed during the design process for all identified credible failure modes.

Table 2.2
Failure Modes and Defensive Design Features

Mode	Mechanism / Stage	Factor	Design Feature	Risk of Failure
Overtopping (water)	Extreme storm event	Freeboard/spillway capacity	Flood clearance capacity in accordance with ANCOLD & DMIRS for High C Dams.	Less likely
			TSF capacity exceeds guidelines except for the final stages of each raise.	Less likely
	Floating debris	Decant/spillway blockage	Two decant structures each designed with bleed water capacity. 50m wide spillways prevent blockage.	Less likely
			Design freeboards & spillways assume decants not operating.	Less likely
Overtopping (tailings)	Seismicity (liquefaction)	Material saturation	Zone of saturation minimised by decant structures capacity and min. operating depth.	Less likely
		Decant blockage	Two decants capable of passing tailings without blockage.	Less likely
		Freeboard	Freeboard is sufficient to contain liquefied tailings which mobilise to horizontal slope.	Less likely
Embankment instability	Static failure	Geometry	2 : 1 (H : V) upstream & downstream slopes, FoS > 1.5	Less likely
		Material	High strength rockfill & granular filter material sourced from site, testing performed & sensitivity analyses conducted (FoS > 1.5).	Less likely
		Compaction	Compaction specifications, good quality control & engineering supervision.	Less likely
	Seismicity	Liquefaction	Foundation & embankment materials assessed as not susceptible to liquefaction.	Less likely
		Compaction	Compaction standards to be specified to eliminate liquefaction potential	Less likely
		Deformation	Stability screening on SEE gives FoS ≈ 1.1	Less likely
			Acceptable deformations not impacting freeboard, using simplified methods of deformation analysis.	Less likely
Piping (embankment)	Concentrated leak (liner failure)	Material (subgrade)	Maximum particle size ≤ 25 mm, well graded material	Less likely
		Compaction (subgrade)	95 – 98 % standard compaction density ratio, approx.-1% to -2% of OMC	Less likely
		Construction quality	Good quality control & engineering supervision	Less likely
	Filter performance	Unfiltered Exit point	Rockfill zone	Neutral
		Design criteria	Sherard & Dunnigan (Zone 2A and Zone 3A) conforming.	Less likely
		Extents	Full embankment length, within 0.5 m of crest.	Less likely
Piping (foundations)	Concentrated leak	Geological environment	Weathered rock foundations.	Less likely
		Geological features	No evidence of presence of open-jointed rock, and surficial alluvials will be stripped.	Less likely
	Blow-out	Blow-out of D/S toe	Weathered rock foundations.	Less likely
	Filter performance	Unfiltered exit point	Yes, however not considered necessary based on foundation quality.	Neutral
	Pipe formation	Erodibility	Weathered rock foundations.	Less likely
		Crest settlement	Wide crest (10 m), minimum freeboard 3.2 m, rockfill downstream zone.	Less likely
		Unravelling	Weathered rock foundations.	Less likely
		Slope instability	Significant FoS margin, D/S free draining rockfill, wide crest (10 m).	Less likely
Piping (decant pipeline)	Decant pipeline	Conduit type	Concrete encased steel.	Less likely
		Conduit joints	High quality joints, no opening, waterstops.	Less likely
		Pipe corrosion	New steel with corrosion protection.	Less likely
		Conduit details	Little or no settlement or rock foundation.	Less likely
		Conduit trench details	Wide, side slopes flatter than 1H : 1V	Neutral
		Filter material	Zone 2A and Zone 3A filter material installed around pipeline encasement.	Less likely

2.4 Semi-Quantitative Risk Assessment & Control Analyses

2.4.1 Overview

Further to the TSF2 and RWP risk-based design presented in the previous sections, IBO has commissioned ATCW to undertake a a Semi-Quantitative Risk Assessment & Control Analyses **[8]**. The purpose of this was to identify critical or prominent risk factors related to credible release (failure-to-contain) scenarios, and to confirm that appropriate risk mitigation works have been incorporated into the design of the dams to address these factors.

The Semi-Quantitative Risk Assessment (SQRA) **[8]** adopted the technique of Fault Tree analysis. This approach systematically reconciles the potential failure mechanisms that could affect the operating performance of the system against the potential consequences of such failures. It is emphasised that the scope of the risk assessment was limited to failure-to-contain scenarios, initiated by a physical failure of one or more elements within the containment system, resulting in a catastrophic release of liquefied tailings or water into the receiving environment.

SQRA applies a disciplined approach to allow for the consideration, and where possible, the modelling of the effects of physical forces of the system, as well as those caused by human interaction that cause failure (i.e. design deficiencies, poor construction quality control, poor operational performance). Some such "system faults" could occur singularly, or as a combination of two or more faults (where a fault in this context can be generally referred to as any possible contributory cause of failure). The technique to identify critical conditions draws upon a "fault tree" to represent the potential combination of faults that can initiate the failure scenario (also referred to as the "Top Fault"). Probability analyses can then be undertaken to assess the most critical combination of faults.

2.4.2 Summary of Results

The SQRA fault tree analyses addressed failure-to-contain scenarios involving a Breach of the Return Water Pond due to TSF Failure, and Failure of the Return Water Pond directly. For each of these scenarios, embankment failure was assessed for three failure modes, these being (i) Overtopping of the embankment crest, (ii) Embankment instability and (iii) Internal erosion and geotechnical piping.

Assessed probabilities for each failure-to-contain scenario is summarised as follows:

- Breach of Return Water Pond due to TSF failure = 1.0×10^{-6}
- Failure of Return Water Pond Directly = 1.9×10^{-6}

In addition, an analysis was undertaken to assess the overall probability of ANY failure mode occurring, with the following result obtained:

- Release of either Water or Tailings from the RWP = 2.9×10^{-6}

The highest assessed probability was 1×10^{-6} for an overtopping of the embankment crest of the TSF. Being two orders of magnitude lower than the frequency of 1×10^{-4} corresponding to the Tolerability Level for a new dam (conservatively based on a PLL of 1), it is considered that the current design for both TSF and RWP are acceptable from a failure-to-contain perspective.

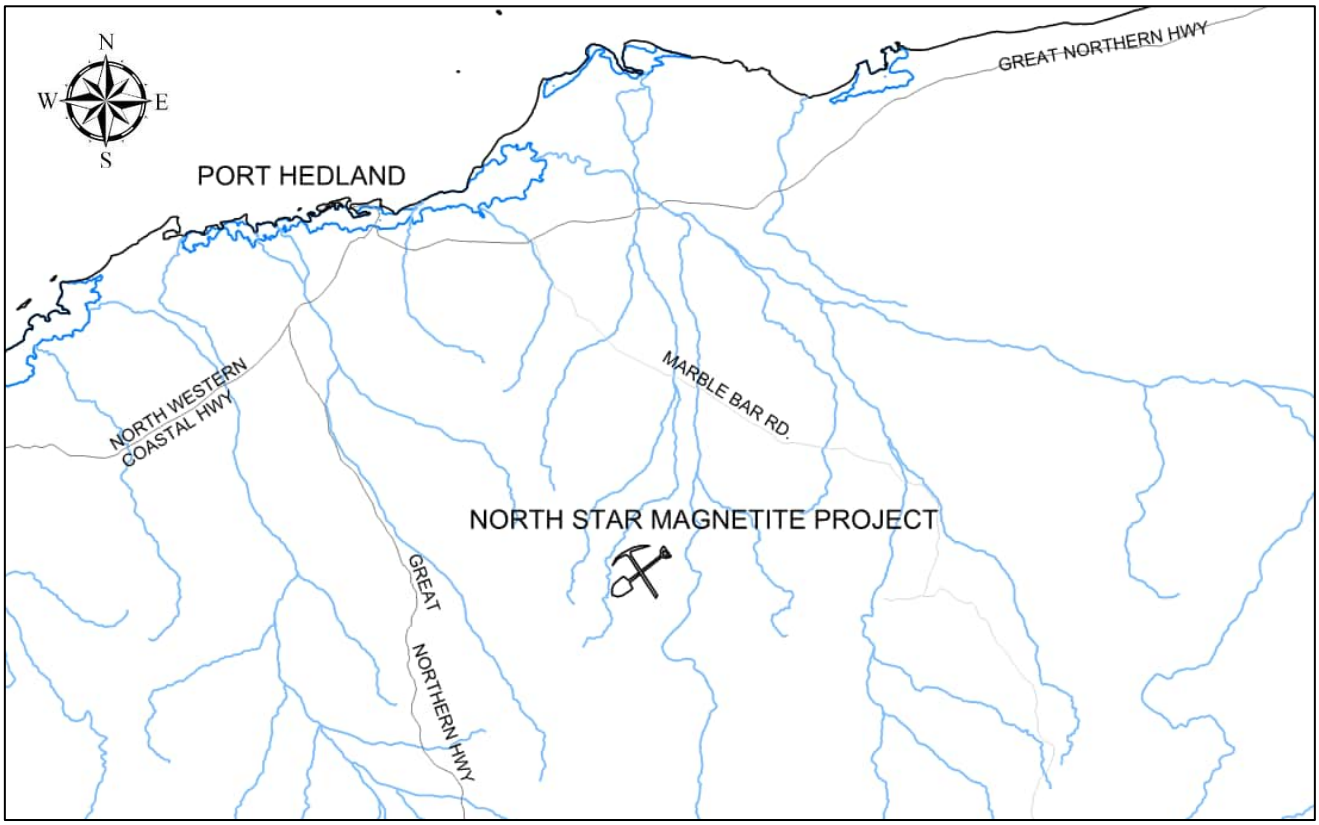
Detailed descriptions of the SQRA process and results are provided in the SQRA Report **[8]**

3 TENURE & SITE CONDITIONS

3.1 Site Location

The Project is located approximately 120 km south east of Port Hedland within the Pilbara region of Western Australia, as shown in **Map 3.1** and **Figure 114185.14_001**.

Map 3.1
Project Location



The existing pilot plant tailings storage facility (TSF 1) and Stage 1 plant site lie immediately to the south of the proposed TSF 2A. The TSF 1 and Stage 1 plant have been decommissioned and will be removed as part of Stage 2 mine development. The overall site layout is illustrated on **Figure 114185.14_002**.

The mining tenement on which these facilities are located is M45/1226.

3.2 Climate

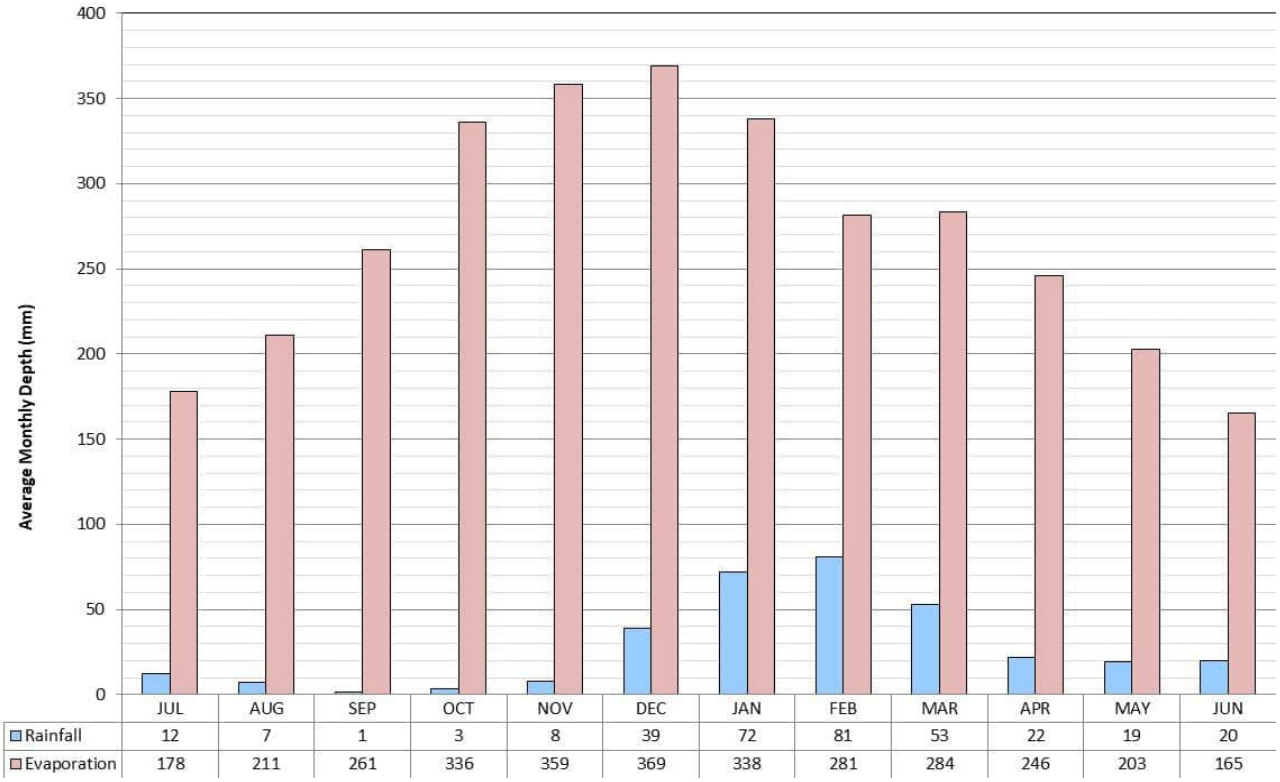
3.2.1 Rainfall and Evaporation

The Pilbara region experiences an arid climate, characterised by hot, humid summers (wet season) and relatively cooler, drier winters (dry season). Rainfall is typically low and highly variable (both spatially and temporally), and evaporation rates are high compared to rainfall. The site is within a region prone to remnant cyclonic activity, particularly between November and April.

The nearest weather stations to the site which were considered in the TSF design are Hillside, Marble Bar, Wallareenya, Indee, Carlindie, and Redmont. Hillside (BOM Station number 4015) was selected as the most relevant due to its location and integrity of rainfall data.

Average annual rainfall for the project area is approximately 347 mm (Hillside station). The majority of rainfall occurs during December to March. Evaporation greatly exceeds mean annual rainfall. Historical records from Marble Bar station indicate an average evaporation of approximately 3,300 mm per year (limited availability of data). Average monthly rainfall and evaporation totals are depicted in
Chart 3.1.

Chart 3.1
Average Monthly Rainfall & Evaporation



	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
Rainfall	12	7	1	3	8	39	72	81	53	22	19	20
Evaporation	178	211	261	336	359	369	338	281	284	246	203	165

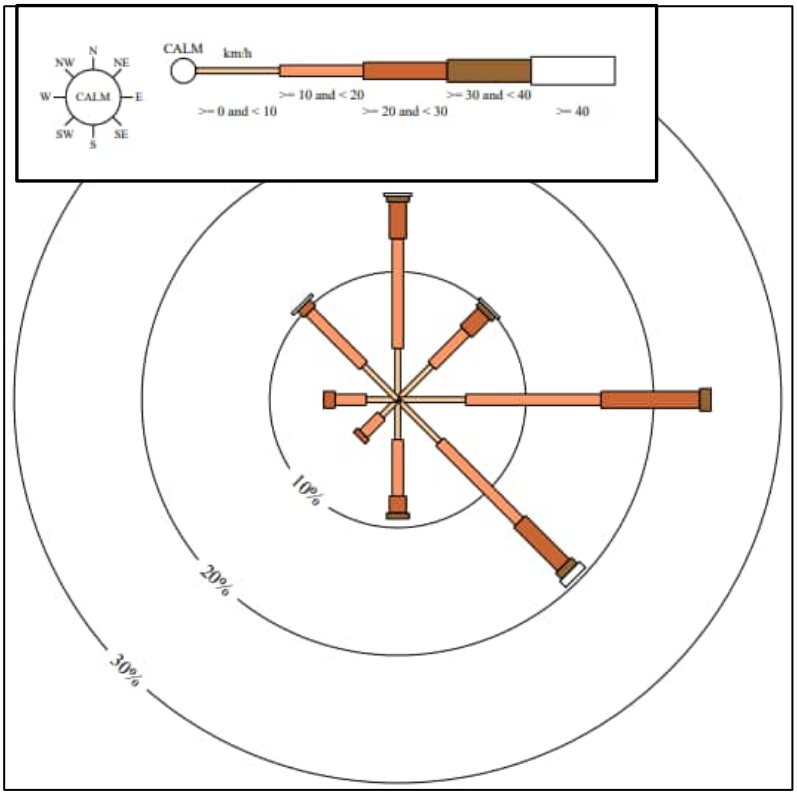
3.2.2 Wind

The Hillside Station had insufficient wind speed and direction data. Marble Bar (BOM Station number 4106), which has collected continuous data from September 2000 to current was hence selected for assessment of design winds for the North Star site.

Wind rose diagrams of wind direction versus wind speed were used to infer design wind speeds. Based on the arrangement of the TSF 2A site, south-easterly winds are considered critical for design purposes. Wind rose diagrams are based on daily 3pm wind speeds, and indicate that the highest wind speeds occur between September and December, however the highest percentage and strength of north easterly winds is greatest in February. Review of all months of wind rose data indicated that sustained (i.e. 10 minute) winds generally do not exceed 30 km/hr and very rarely exceed 40 km/hr.

Chart 3.2 presents the wind rose diagram for February, which is representative of the critical month for the North Star TSF 2A.

Chart 3.2
Wind Rose Diagram for February (Marble Bar)



3.3 Topography

The Pilbara landscape is variable and shaped by the structure of the underlying geology with moderately high relief and a number of elevated ranges, river valleys and peneplains. The project area is located within the George Range on an eroded peneplain with remnants forming plateaus (Mesas), hills and ridges within the landscape.

The local topography consists of a series of plateaus, hills, ridges and valleys. The valleys generally grade to the west and north at approximately 1%. Elevations range between RL 270 m in the western part of the valley floor to RL 400 m on the surrounding plateaus. The existing regional and site topography is illustrated in **Figures 114185.10_002** and **003**.

A general view of the RWP impoundment and TSF 2A site is presented in **Photo 1** below, looking south-east from the central hill at the RWP embankment location.



Photo 1 - RWP and TSF 2A Site Looking South-East

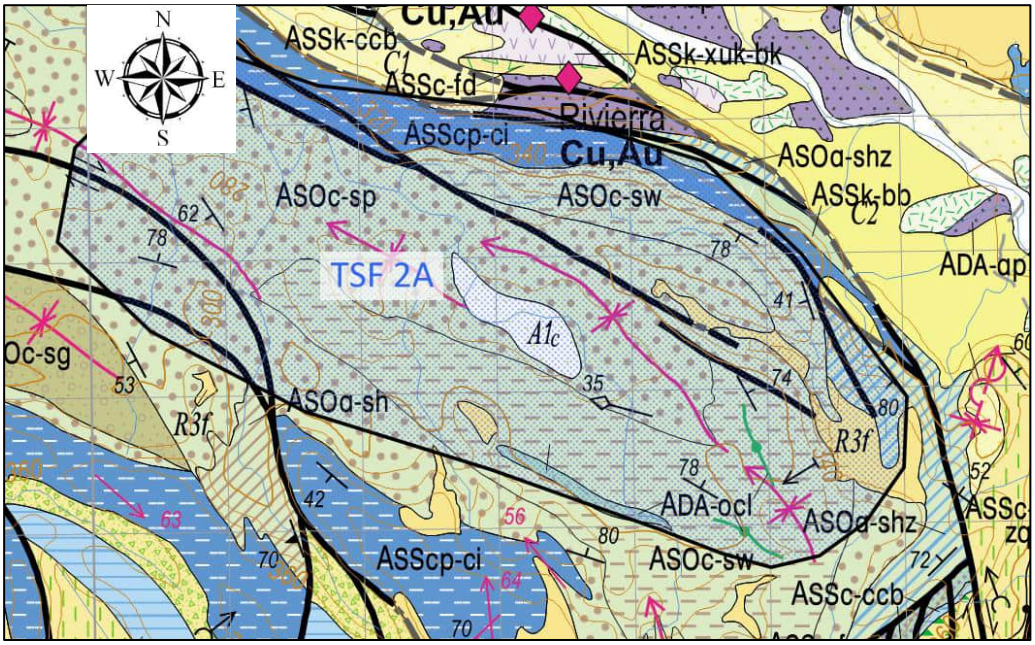
3.4 Geology

3.4.1 Regional Geology

The Project is situated within the North Pilbara terrane of the Pilbara Craton, which is Archaean in age and contains volcanic and volcanoclastic rocks of the Pilbara Super Group (greenstone belts) intruded by Archaean age felsic granitoids, to form dome and keel type structures.

The project geology is illustrated on **Map 3.2**.

Map 3.2
North Shaw Regional Geology [9]



The area has generally been regionally metamorphosed to green-schist faces and folded into sub-vertical tight to isoclinal folds that have wrapped around granitoid contacts during regional deformation and now are parallel to the granite contacts. This regional deformation was also accompanied by strike slip and reverse faulting which has dislocated the main formations in the project area.

The North Shaw 1:100,000 geological map covers the project area and the regional geology is largely based on the work in 2000 by Van Kranendonk **[9].**

3.4.2 Geology of TSF Area

Extensive rock exposures are present in the TSF 2A area and superficial cover is typically very thin other than within the confines of current alluvial channels. The area is characterised by metamorphosed sediments of the Soanesville and Sulphur Springs groups of mid Archean age.

The Soanesville group is dominant in the TSF area and is represented by rocks of the Corboy and Cardinal formations. The Corboy formation rocks (ASOc) comprise sandstones, wackes (clayey sandstone) and lithic arenites (sandstone with > 50% included rock fragments, typically of fine and medium gravel size). Local interbeds of conglomerate, siltstone and shale are also present. The Cardinal formation (ASOa) predominantly comprises ferruginised black shale with local siltstone, banded iron formations (BIF), sandstone and conglomerate. Silicified shales are also present at the eastern edge of the TSF.

Rocks of the older Sulphur Springs group are localised, poorly represented and generally confined to the perimeter of the TSF area. They include components of the Kangaroo caves formation (ASSc) including the Pincuna BIF member, layered cherts, dacite and rhyolite volcanics and also Basalts of the Kunagunarrina formation (ASSk).

3.5 Hydrology

Drainage lines in the region are ephemeral and generally only flow for short durations following rainfall events. Intermittent flows normally occur during the wet season with long periods of no flow during the dry season.

The mine area lies on the catchment boundary of the Turner River and Strelley River. The Turner River has a catchment of 4,802 km^2 and is a major river of the Port Hedland coast catchment while the Strelley River has a catchment area of 2,805 km^2 and is a sub-catchment of the Shaw River **[10]**.

Numerous ephemeral drainages are found across the site. The main drainage lines in the TSF 2A area are:

- Lost Boys Creek to the north of the proposed mine pit, within the area required for the TSF, which ultimately flows into the Turner River via Chinnamon Creek; and
- An unnamed creek which roughly parallels the mine access road and flows into the Turner River just south of Pincunah Waterhole.

Several small drainages on the eastern edge of the mine area flow into Six Mile Creek which ultimately flows into East Strelley River.

3.6 Hydrogeology

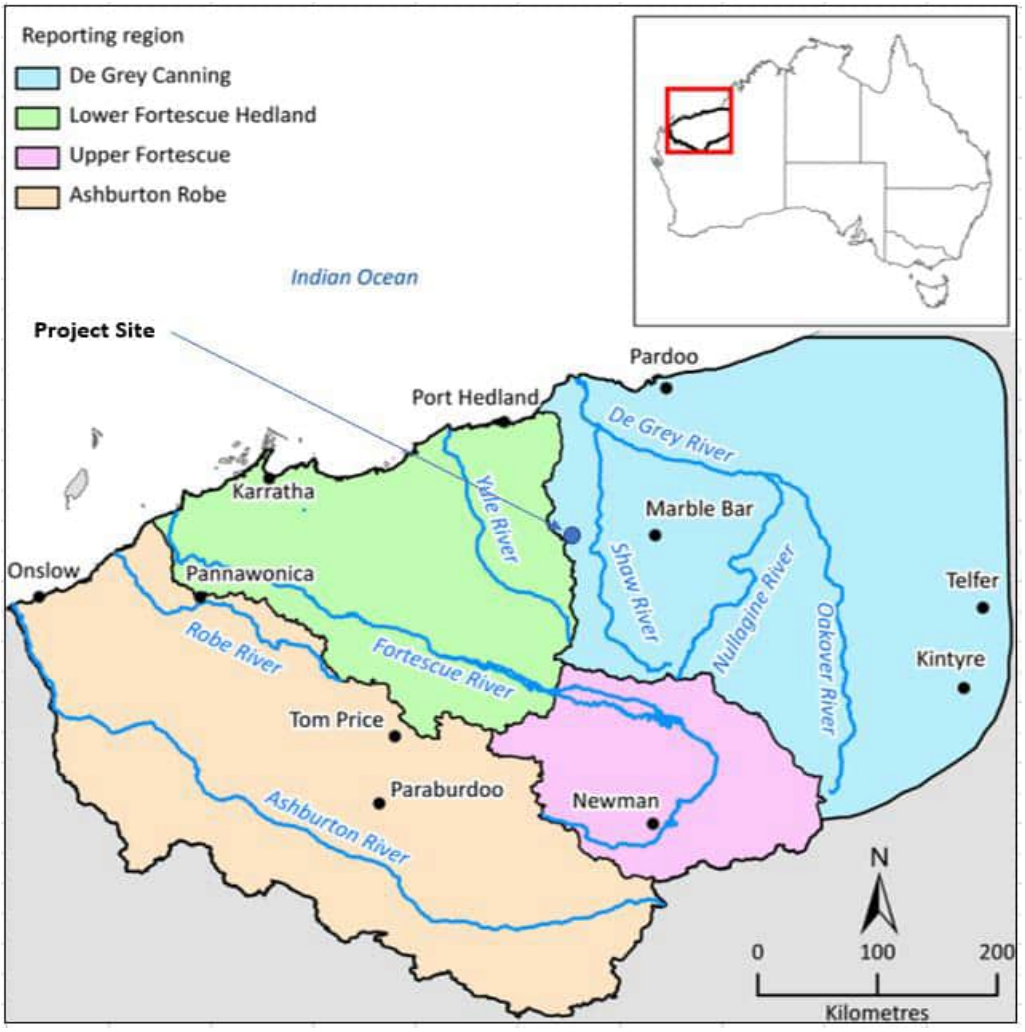
Groundwater in the Pilbara region occurs in various hydrogeological environments, the most important being alluvial aquifers (unconsolidated sediments), consolidated sediments (sedimentary rock) and fractured rock aquifers **[11]**. Although generally continuous throughout the region, the water table is sometimes absent in higher elevated areas where the weathered and fractured zone is unsaturated or where the fractures are poorly developed.

There are small supplies of variable groundwater available throughout the region (typically less than 10 m^3/day per bore). Groundwater is generally fresh, except away from the main rivers on the coastal plain where brackish to saline groundwater occurs **[12]**.

CSIRO has conducted an overview of the current and future climate and water resources of the Pilbara for the Government of Western Australia and industry partners **[13]**. They have assessed surface water and groundwater resources and their environmental significance in four regions referred to as: Ashburton Robe, Upper Fortescue, Lower Fortescue Hedland and De Grey Canning.

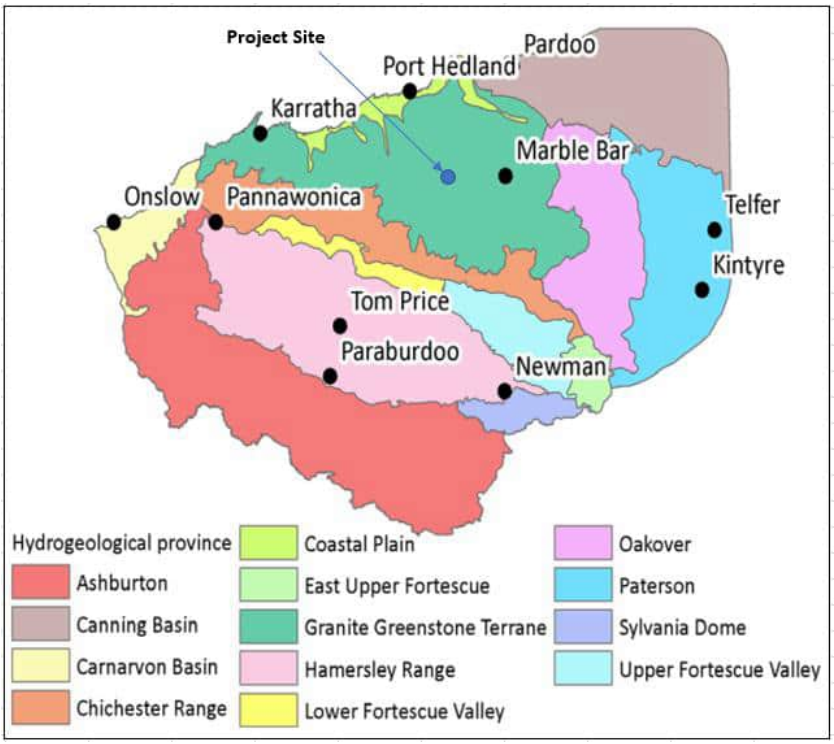
Map 3.3 shows the regions assessed by CSIRO, with the Project site being located within the De Grey Canning region. CSIRO has also defined hydrogeological provinces to integrate discrete and local information.

Map 3.3
Pilbara Water Resource Assessment Regions - CSIRO [13]



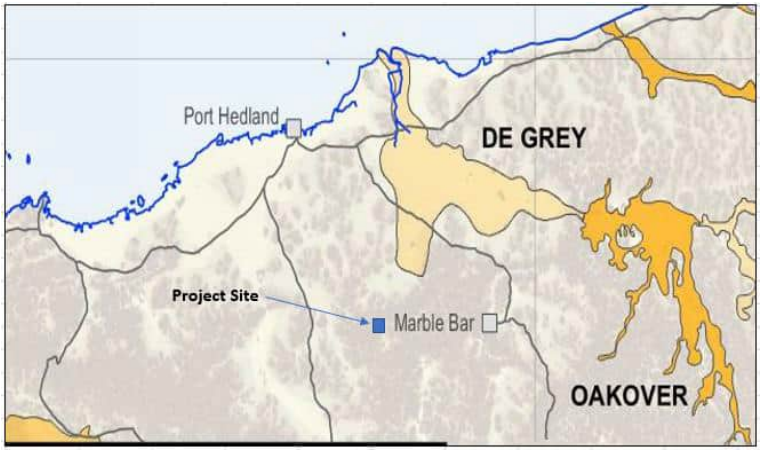
The site is also located within the granite greenstone terrane hydrological region, as shown in **Map 3.4.** Groundwater resources of this province are limited to alluvial aquifers and fracture zones in greenstones.

Map 3.4
Pilbara Hydrogeological Provinces - CSIRO [13]



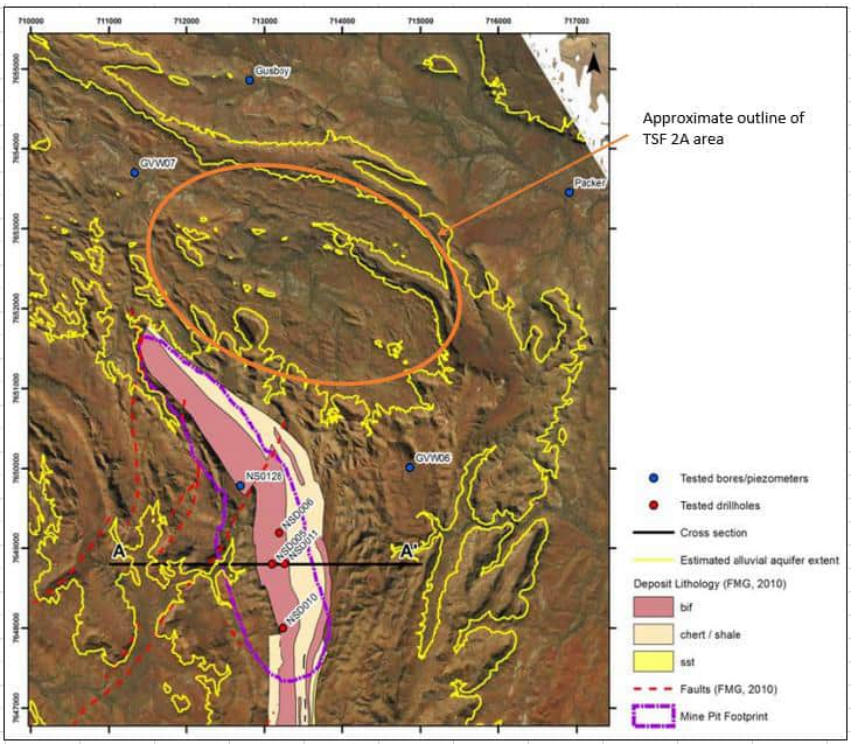
Map 3.5 shows the interpreted distribution of palaeovalleys in arid and semi-arid parts of Western Australia, South Australia and the Northern Territory (or "WASANT"), published by the National Waters Commission in 2012 **[14]**. The coloured areas are the palaeovalleys, and it is apparent that the Project site is not located within any of the identified palaeovalleys.

Map 3.5
Location Of Site Within The WASANT Palaeovalley Map [14]



A conceptual model (shown in **Map 3.6**) of the Project area hydrogeology has been created for dewatering purposes **[10]**. This indicates unconsolidated alluvial deposits (alluvial aquifers) to the north-east of the ore body, a weathered zone of basement rock (potential fractured aquifer) and a south west - north east trending fault (another potential source of groundwater).

Map 3.6
Hydrogeology of The North Star Mine Area [10]



AECOM **[15]** indicated that ground water within the TSF 1 valley was approximately 25 m below existing ground level with a groundwater gradient of approximately 1.2% down the valley (i.e. northerly direction).
Based on recent geotechnical investigations (outlined in **Section 3.7)**, the inferred groundwater elevation ranges from RL 241.7 m to RL 270.4 m in the TSF 2A site area, with an inferred hydraulic gradient of approximately 1:100 towards the north west.

At the location of the RWP embankments, groundwater is close to the creek bed level and seasonally daylights in small ephemeral pools on the outer bends of the creek channel.

3.7 Geotechnical Investigations

3.7.1 Overview

Geotechnical investigations within the proposed TSF Site 2A have been conducted in a number of phases (by ATCW unless noted otherwise), as follows:

(i) 2011 Investigation (by Golder Associates) – Test pit excavation and borehole drilling in the general vicinity of Site 2A. Most of the test pits are located in the currently proposed RWP impoundment area. Two of the monitoring bore sites (BH11 A/B and BH17) coincide with the west and east abutments of the proposed TSF main embankment and the remainder are in the vicinity of the proposed RWP embankments;

(ii) 2015 Site Walkover – Geological reconnaissance to broadly identify the geological conditions at the TSF embankment sites, identify potential sources of borrow material for construction of the embankments, and assess potential geological constraints;

(iii) Phase 1 Investigation – carried out between 11 December and 17 December 2017 including excavation of 40 test pits using a 25t excavator to depths between 0.5 m and 2.6 m. Samples were also obtained from the existing TSF 1 tailings beach, Stage 1 coarse rejects stockpile and waste rock dump. Sixteen topsoil samples were recovered from the TSF impoundment for material characterisation;

(iv) Phase 2 Investigation – conducted in January and February 2018 including the drilling of six HQ diamond core boreholes to depths between 6 m and 19.5 m in the TSF and RWP embankment footprint areas. Two in-situ falling head permeability tests and four down-hole packer tests were conducted in three of the boreholes. Three boreholes were completed as standpipe piezometers.

(v) Phase 3 Investigation – conducted in August and September 2018 including the excavation of 52 tests pits using a 20t excavator (to depths between 0.45 m and 4.8 m) and the drilling of eight PQ diamond core boreholes (to depths between 9.0 m and 26 m) within the TSF and RWP areas. In-situ permeability testing was conducted in the area of the RWP embankments and central abutment hill, comprising four falling head tests in two boreholes and 28 straddle packer tests in six boreholes. Geological mapping of the RWP embankment area was also completed.

3.7.2 Field Work

Field investigations have included borehole drilling, in-situ permeability testing, installation of ground water monitoring wells, test pit excavations and bulk sampling for laboratory characterisation of potential construction materials. The aims of the investigations were to:

(i) Investigate the nature and condition of foundation materials beneath the TSF and RWP embankment footprints;

(ii) Estimate the permeability of the alluvial and residual soils, and underlying rock-mass foundations of the TSF and RWP embankments;

(iii) Assess topsoil and foundation stripping requirements, and detailed excavation conditions in associated civil works areas such as spillways;

(iv) Locate suitable quarry areas for embankment rockfill materials; and

(v) Identify the potential borrow areas for embankment low-permeability and granular filter materials, and collect bulk samples for subsequent laboratory testing.

Details of the geotechnical investigations, together with the location of the boreholes and test pits are presented in **Appendix B**.

Note that the **Appendix B** report expands and updates the Geotechnical Investigation draft document issued by ATCW in February 2018 **[7]**.

3.7.3 General Geological Profile

The TSF and RWP impoundments are situated in an east west trending, broad valley area confined by a narrow, banded iron formation (BIF) and silicified chert mesa landform approximately 90 m high on the northern side and a broad dissected ridge of sandstone of similar height on the southern side. Several sandstone hills generally between 10 m and 70 m high are also present within the overall valley area in the western part of the TSF impoundment.

The eastern part of the valley area is split into two sub-valleys by an elongated mesa ridge extending approximately 2 km in a north westerly direction from the eastern side of the TSF impoundment.

The rock units which are of Proterozoic age, have an overall east -west strike and generally dip at about 70° to the North. They have been subject to low grade metamorphism by compression in an east – west direction and contacts between sandstone and interbedded shale units are frequently sinuous. Small scale, tight isoclinal folding is frequently observed in the relatively deformable shale units.

The sandstone outcrops are blocky in nature with typical block dimensions of a few hundred millimetres. The rock mass is discoloured red brown on the surface; however, this is superficial in nature, being a few millimetres thick. Breaking of blocks with sturdy blows of a geological hammer reveals grey, relatively fresh rock material of moderate to high strength beneath.

The shales are thinly bedded, typically with alternating purple grey and pale-yellow grey bands. Contacts between individual beds are tight. The rock is typically of low and medium strength.

Superficial deposits are restricted in depth and lateral extent, generally being confined to the valley floor area and the drainage channels that meander westwards between the sandstone hills.

3.7.4 RWP Embankment Foundation Conditions

The investigations and observations at the RWP embankment location have revealed that moderately weathered fine to coarse grained sandstones of high strength are the dominant rock type in the south and central abutment areas. This rock type forms the low hills throughout the RWP and TSF impoundment areas. Moderately weathered shales and siltstones of medium strength are prevalent at the north embankment and abutment and in most of the valley floor areas in the impoundments.

The rock mass types are considered satisfactory foundation materials for the RWP embankments.

In creek and valley floor areas, sandy topsoil of up to 0.4 m thickness overlies alluvial deposits, which extended to a typical depth of less than 2 m in the creek bed through the RWP South embankment. Alluvial deposits in this area consisted of dense silty sandy gravels with cobbles.

Colluvial deposits are present on the lower slopes of the embankment abutments, with a maximum thickness of approximately 2 m at the base of the valley sides. The colluvium overlies the weathered rock profile, and is typically composed of clayey gravels and sandy gravels.

It is considered that foundation stripping to a depth of 0.5 m will generally reveal a competent foundation profile at the embankment locations. In the elevated areas outside of creeks and valley floors, where superficial deposits are thin or absent, it is expected that a nominal stripping depth of 0.2 m will reveal competent foundation materials.

3.7.5 TSF Embankment Foundation Conditions

Beneath discontinuous superficial cover, highly to moderately weathered sandstone or interbedded siltstones and shales were identified at the main TSF embankment. Slightly weathered to fresh sandstone was typically intersected in boreholes at depths of around 17 m.

The weathered rock mass is considered a satisfactory foundation for the TSF Embankment.

At the main and intermediate hill abutments, a thin (0.1 m) horizon of topsoil overlies up to 2 m of colluvium, which in turn overlies the weathered rock profile. Colluvial deposits typically consist of dense clayey gravels and sandy gravels, with frequent cobbles and boulders.

It is considered that foundation stripping to a typical depth of 0.5 m will generally reveal a competent foundation profile. In elevated areas outside of creeks and valley floors, where superficial deposits are thin or absent, it is expected that a stripping depth of 0.2 m will reveal competent foundation materials.

3.7.6 Rock Mass Permeability

Based on the insitu testing, the near surface and exposed sandstone rock mass is considered highly permeable whereas the shale and siltstone units are of low to moderate permeability.

At the RWP embankments, highly permeable sandstone was identified to approximately 20 m depth in the vicinity of the south embankment and the central sandstone hill, with a maximum estimated permeability of 2×10^{-5} m/s, reducing to 3×10^{-6} m/s from between 15 and 20 m. Below 20 m at a relatively uniform elevation of approximately 230 m AHD, permeability was up to two orders of magnitude lower at 2×10^{-7} m/s.

Permeability results in the shales and siltstones toward the north abutment and within the proposed RWP Spillway area were also low, in the order of 10^{-7} m/s.

Falling head tests in the superficial creek channel deposits at the South embankment returned high permeability results in the order of 10^{-3} m/s.

Permeability tests in the TSF Embankment footprint area indicted lower permeabilities overall in both sandstone and shale units, typically ranging from 10^{-6} to 10^{-7} m/s.

Details of the permeability testing are presented in **Appendix B**.

3.7.7 Groundwater

Groundwater was encountered in all the boreholes in the valley floor area at depths ranging of 2.3 m to 6.6 m. The inferred groundwater elevation ranges from RL 241.7 m to RL 270.4 m at the TSF location, within an inferred hydraulic gradient of 1:100 towards the north west.

At the RWP south embankment location, the groundwater table daylights seasonally, pooling in small shallow depressions at the northern edge of the creek. Comparison of groundwater monitoring bore water levels in Golder Borehole 5A between July 2018 (when a pool was visible) and October 2018 indicated a fall in elevation of 600 mm during this period.

The groundwater levels recorded during the geotechnical investigations are presented in the **Appendix B**.

4 RETAINING STRUCTURE MATERIAL CHARACTERISATION

4.1 Retaining Structure Overview

As described in **Section 2.1**, it is proposed that the TSF embankments will be constructed in seven stages over the 20-year LOM using the "downstream" method of raise construction. Ultimately the TSF retaining structures will comprise:

- A main embankment at the north-western end of the TSF, ultimately 68 m high;
- Two western embankments; and
- Two eastern saddle embankments.

The facility includes a downstream Return Water Pond (RWP) which will have two small adjacent embankments of 16 m and 9 m height, one each side of a central sandstone hill abutment.

Bulk embankment construction materials for the earlier construction stages will comprise quarried sandstone rock fill sourced from the TSF and RWP impoundments, as well as waste materials from the ore processing operations. The proportion of waste rock material will increase over time as access to the TSF impoundment becomes restricted due to tailings beach development.

Due to the scarcity of suitable clayey materials, bituminous geomembrane (BGM) liners will be applied to the upstream faces of the retaining embankments. Detailed descriptions of the adopted embankment construction materials, together with the engineering analyses undertaken to produce the embankment zoning designs, are provided in **Sections 0**, **11** and **0** of this Report.

4.2 Potential Borrow Sources

4.2.1 Low Permeability (Clayey) Materials

Clayey soils suitable for use as low permeability zones within the TSF and RWP embankments are in limited supply in the areas investigated.

Possible sources of low permeability clayey materials exist along the alluvial channel alignments and on the colluvial lower hillslopes; however, sources are limited in terms of exploitable areas and depths are generally limited to between 0.5 m and 1.0 m. Based on the geotechnical investigations undertaken at the site, the identified clayey soil deposits will not provide sufficient quantities of material for the required size of the TSF and RWP embankments.

4.2.2 Granular and Tailings Filter Materials

Some of the laboratory testing conducted on alluvial creek bed materials indicated potentially suitable tailings filter zone materials, however the quantities are not sufficient to warrant developing these sources.

Testing also showed that the existing process plant coarse rejects material could be a source of tailings filter zones construction materials. The advantage with these materials is that they have reasonably homogeneous characteristics, and exist in large stockpiles from Stage 1 processing operations. Some of the coarser materials tested during the geotechnical investigation will likely be subject to screening to remove oversize particles, but are otherwise suitable.

Significant quantities of Stage 2 coarse rejects will be available for construction stages beyond the initial starter embankments.

4.2.3 Rockfill Material

The shale units identified in the vicinity of the embankments are generally of moderate strength and are not susceptible to slaking when wet. Their thinly banded fabric and steep dip orientation should render them suitable to directional ripping with appropriate equipment. These materials are considered suitable for use as embankment fill, generally in the downstream zones.

The sandstone rock mass found in the numerous hills within the western part of the TSF impoundment is generally of medium to high strength and durable. Its blocky fabric renders it suitable to blasting and ripping to produce a rock fill product suitable for embankment construction. Relatively minor interbeds of folded shale units are present within the hills, so the available product is likely to comprise minor shale material.

The siltstone rock mass identified at the RWP spillway location is considered suitable for embankment rock fill and should supply most of the material required to construct the RWP embankments.

In addition to impoundment rockfill quarries, mine waste rock could be acquired from stripping of the proposed mine pits or from existing waste rock stockpiles near the Stage 1 plant area. There is currently insufficient Stage 1 waste rock available to construct the initial TSF embankments.

4.3 Liquefaction Potential

4.3.1 Overview

The TSF embankments are proposed to be founded on natural weathered rock and dense alluvial and colluvial granular materials.

The TSF embankments are proposed to be largely constructed of granular materials with a relatively high permeability of 1×10^{-5} m/sec and are proposed to be placed to a high standard of compaction.

Such foundation and rockfill material characteristics do not meet any of the recognised criteria for being susceptible to cyclic (seismic) or static liquefaction triggers, which require:

- Materials must be saturated;
- Materials must be sufficiently loose such that during rapid loading, they will contract to failure. Materials with contractive tendencies will show volumetric densification and generate excess pore pressures under undrained conditions, which can induce failure.

4.3.2 Zone 2A

Liquefaction is a recognised safety issue in TSFs, particularly those comprising embankment materials (typically gravels, sands and silts) which are relatively loose (e.g. hydraulically placed or end-dumped without compaction), saturated and of low cohesion. Although the Zone 2A embankment materials are effectively cohesionless and hence potentially liquefiable if saturated and placed loosely, it is proposed that the compaction standards applied during construction will prevent the possibility of liquefaction, as described below.

The mechanism of liquefaction is best understood by analysis of the critical state model, which presents the Critical State Line (CSL), usefully defined in terms of effective stress versus void ratio. The CSL can be identified as the point at which the void ratio of a soil element remains constant while shearing continues, and defines the point at which failure of a soil element will occur. Failure may be either contractive or dilative, depending on the initial state of the material. Materials which fail contractively will show volumetric densification and generate excess pore pressures under undrained conditions, which can induce failure by liquefaction. Conversely, materials which dilate towards failure are not considered subject to liquefaction.

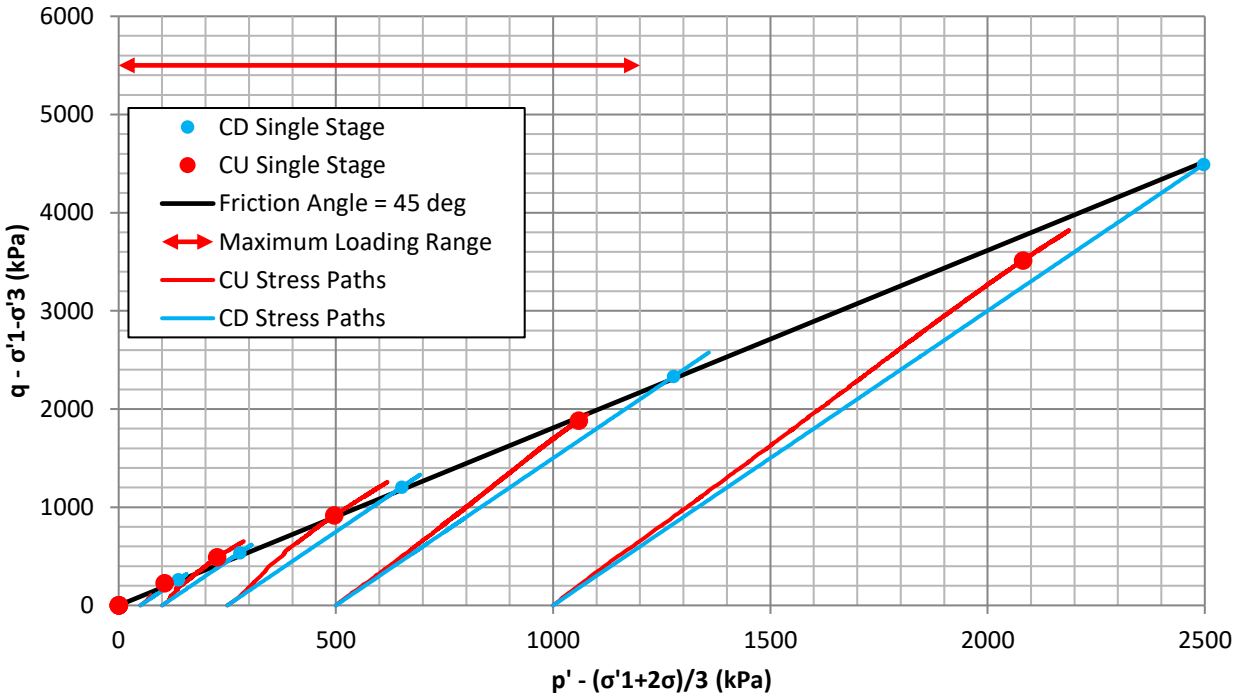
As stated above, contractive or dilative failure can be dependent on the initial state of the material, hence placement and compaction methods can be used to manipulate how a material fails. For example, if a material is compacted to a state which has a higher density than the CSL, it will behave as a dilative material and hence will not liquefy. Therefore, the compaction specification for Zone 2A material can be used to create a dilative material.

Single stage Consolidated Drained (CD) and Consolidated Undrained (CU) triaxial tests were completed on proposed Stage 2 coarse rejects samples by E-Precision Laboratory in December 2018 for stockpile design purposes. Results of these tests were provided to ATCW by IBO in January 2019. The tests were performed at effective pressures ranging from approximately 150 kPa to 2,500 kPa, although the maximum effective pressure that Zone 2A materials will be subjected to is in the order of 1,200 kPa.

The samples were remoulded to minimum dry density and at 3% moisture content, with initial dry densities in the range of 1.87 t/m^3. Although no densities were recorded at the end of the tests, stress paths indicate that even at low pressures the samples do not exhibit any sign of contraction, implying that the materials are not liquefiable. The stress paths are presented **Chart 4.1,** using Cambridge effective stress paths.

Chart 4.1

Design Coarse Rejects Triaxial Results - Cambridge Effective Stress Paths



If the materials were contractive, the effective stress would reduce in response to excess pore pressure generation, resulting in the stress paths presented in **Chart 4.1** failing toward the left hand side. The stress paths presented fail toward the right, indicating dilative tendencies, even at such low densities.

It is also important to note that Zone 2A materials will be compacted in the field, meaning the actual density of the material will be significantly higher than that tested in the triaxial apparatus (which was approximately 1.87 t/m^3). Compaction tests were carried out on the same samples, indicating a maximum dry density of 2.15 t/m^3 at 9% moisture content, which is much higher than that tested in the triaxial.

Nonetheless it is recommended that maximum and minimum dry densities for the material be determined in the laboratory to assist with compaction specifications in terms of relative densities. The compaction specification would likely adopt a minimum 65 to 70 % relative density. Subsequent field trials (refer to **Section 11.5.2**) would be undertaken at the commencement of construction to develop relevant method compaction specifications (i.e. layer thickness, roller type and number of passes).

5 TAILINGS CHARACTERISATION

5.1 Physical Properties

5.1.1 General

As documented in **Section 1.3**, the current IBO Stage 2 design tailings particle size distribution is finer than what was used for the draft design **[1]**, with a P_{80} reducing from 75 µm to approximately 40 µm.

Previous laboratory characterisation testing was conducted by ATCW in 2015 **[4]** (i.e. the "Fig 5" and "Fig 6" wet tailings samples). Testing included basic characterisation tests (particle density, plasticity) and specialised tailings testing (initial settled density and rheology). Unfortunately, other important specialised tests (shrinkage limit density and segregation threshold) were not conducted on the 2015 samples.

Updated tailings testwork was completed in 2019 to provide data for consolidation modelling analyses. Testing including basic characterisation tests (e.g. particle density, plasticity) and specialised tailings testing (initial settled density, shrinkage limit density and Rowe Cell consolidation testing).

A combined laboratory testing report (including the relevant 2015 and 2016 tailings samples) is provided as **Appendix C1**, whilst the updated 2019 tailings testwork and consolidation modelling are provided as **Appendix C2** and **Appendix C3**, respectively. A summary of the tailings physical properties is presented in the following sections.

5.1.2 Tailings Classification

Table 5.1 presents the results of the tailings characterisation laboratory testing from 2015, 2016 and 2019. The results indicate that apart from the particle size, the tailings characteristics are generally very similar.

Table 5.1
Summary Of Tailings Geotechnical Testing

Test		2015 "Fig 5"	2015 "Fig 6"	2016 "PP25 & PP32"	2019 Sample
Particle size distribution (P_{80}):		45 µm	42 µm	75 µm	35 µm
Atterberg Limits -	Liquid Limit:	25	19	18	29
	Plasticity Index:	4	2	2	9
Particle Density (t/m^3):		2.97	2.97	3.04	2.92
Segregation Threshold:		*Not tested - estimated to be 52% - 55%*		58%	Not tested
Unified Soil Classification:		Low plasticity Silt		Low plasticity Silt	Low Plasticity Clay

5.1.3 Tailings Density and Bleed Water Rate

The tailings densities resulting from the laboratory testing are presented in **Table 5.2**.

Table 5.2
Tailings Density Parameters

Year	Sample	Initial Settled Density		Shrinkage Limit Density (t/m^3)	Bleed Water Rate (m^3/t)
		Solids Content (%)	Density (t/m^3)		
2015	Fig 5	65	1.45	*Not tested - estimated to be 1.75 - 1.80*	0.19
	Fig 6	65	1.43		
2016	PP25 & PP32	65	1.52	1.87	0.21
2019	Consolidation	65	1.43	1.66	0.18

These parameters can be defined as follows:

Initial Settled Density (ISD): This is the density that the tailings reach as they settle soon after discharge. During the sedimentation phase bleed water is released. For the design tailings discharge solids content of 65% and an average tailings beach layer thickness of 50 mm, an ISD of 1.45 t/m^3 has been adopted.

Shrinkage Limit Density (SLD): This is the limiting density that tailings will achieve at the surface when subject to solar desiccation. Desiccation occurs when the rate of evaporation exceeds the rate at which consolidation water is expelled from the tailings surface. The process of desiccation is actually consolidation, however, the forces causing it are due to a process known as suction and are considerably greater than those caused by self-weight consolidation at shallow depths.

Bleed Water Rate: This is defined as the water released from the tailings slurry upon deposition due to sedimentation, or alternatively as the tailings settle from the discharged slurry density to the ISD. A rate of 0.2 m^3 per tonne of solids has been adopted, which equates to just under 40% of the water contained in the slurry being released to flow to the decant pond at discharge.

5.2 Design Density

5.2.1 Background

In general, the density of the overall tailings deposit increases with time. The increase in density is a result of three processes: sedimentation, desiccation and consolidation. The densities achievable through sedimentation and desiccation can be estimated from the laboratory testing described above.

Consolidation is a time dependent process whereby water is “squeezed” from the pore spaces in the tailings due to their self-weight. Consolidation is accepted to commence when sedimentation is complete. Tailings density increases with depth; however, the rate of density increase is affected by the permeability of the tailings and rate of discharge. As deposition continues, the addition of tailings will eventually lead to further consolidation and resultant increase in density.

For design purposes, the Overall Insitu Density (OID) is used to estimate the required storage capacity of the TSF. In a well-designed and operated TSF, the OID will approach the SLD (refer to **Section 5.1.3**), as its surface area and resultant rate of rise have been configured to enhance evaporative drying of the deposited tailings.

5.2.2 Assessment and Adopted OID

The adopted OID has been based on the estimates made by one-dimensional tailings consolidation modelling, which was based on the results of Rowe Cell consolidation testing, presented in **Appendix C3** and **Appendix C2**, respectively.

A Model was created using the 2019 laboratory test results completed on a representative tailings sample. The model included incompressible layers of foundation materials with permeability values based on geotechnical data presented in **Appendix B**.

Results of the consolidation modelling presented in **Appendix C3** indicate that the OID during the first year of deposition increases from approximately 1.43 t/m^3 to 1.64 t/m^3, thereafter increasing to approximately 1.7 t/m^3.

Based on these results, an average OID of 1.5 t/m^3 for the initial TSF stage (Stage 1A) has been adopted, increasing to an OID of 1.7 t/m^3 by Stage 3 (refer to the TSF staging schedule in **Chart 8.5** for further details).

5.3 Tailings Beach Slope

5.3.1 Background

This is the slope formed by the tailings after deposition, and impacts upon embankment requirements and thus cost and construction programming. The slope depends primarily upon the tailings discharge solids concentration, segregation threshold and rheology. If the segregation limit is well below the expected discharge solids content, there will be little or no segregation or sorting on the beach.

Tailings beach slopes are related to the sheared yield stress and viscosity, as well as the total flow in the tailings stream. Increases in sheared yield stress and viscosity result in an increase in the beach slope of the tailings surface. Also, reducing the flow in a tailings stream increases the beach slope, thus the number of tailings discharge points is an important consideration.

Experience shows that, in practice, the solids concentration from the thickeners will vary from day to day. The variation depends on many factors such as fluctuations in feed rate, flocculant behaviour, ore type, and operational decisions. The outcome is invariably a slightly concave beach profile as the lower density tailings will beach at the toe of the slope at the flattest angle and the highest density tailings will beach at the head of the beach at the steepest angle.

5.3.2 Assessment and Adopted Beach Slopes

Rheology test work was completed for representative samples during the 2015 **[4]** and 2016 **[5]** test programs. The rheological data from relevant samples has been summarised and presented with the relevant test report certificates in **Appendix C**.

The laboratory data suggests that segregation of fine and coarse tailings is unlikely during deposition, as the segregation limit is well below the expected discharge solids content.

The evaluation of beach slopes for the TSF has been based on various input parameters in addition to a unique set of Herschel-Bulkley rheological parameters derived from the rheology data that was measured in the ATCW laboratory.

The beach slopes have been calculated in accordance with the methodology set out in a technical paper by Pirouz et al. **[18]**.

To determine the beach slope concavity, the slopes are divided into four parts: Upper section, middle section, lower section and a run-out section. The beach slope prediction of the upper, middle and lower parts is determined using the mean plus 1 x standard deviation slurry concentration, mean slurry concentration and mean minus 1 x standard deviation slurry concentration values.

Table 5.3 summarises the findings of the beach slope prediction calculations for a variety of spigot numbers.

The slopes are expressed as percentages; with each one equal to the height of the beach divided by the length of the beach (i.e. the 0.44% slope is equal to 0.44 m of vertical fall over a 100 m horizontal length of the tailings beach).

Table 5.3
Beach Profile Determination By Number Of Spigots

Number of Spigots Operating	Predicted Beach Slope (%)			
	Upper	Middle	Lower	Run out
1	0.30	0.23	0.17	0.13
2	**0.40**	**0.30**	**0.23**	**0.17**
3	0.50	0.38	0.28	0.21
4	0.60	0.45	0.34	0.25
5	0.70	0.50	0.38	0.28

The variables that are of most relevance to the beach slope are the discharge flow and the rheology (which is affected by the slurry solids concentration). An increase in the discharge flow will flatten the beach slope. An increase in solids concentration will steepen the slope.

For modelling purposes, the 2 spigot beach profiles have been adopted.

5.4 Beach Slope Stability

5.4.1 Liquefaction Potential

Soils (including tailings) can be susceptible to liquefaction during an earthquake event of sufficient strength if they meet some or all of the following criteria:

- Are predominantly silty or sandy, with fines of low or no plasticity;
- Are saturated; and
- Have low density and strength.

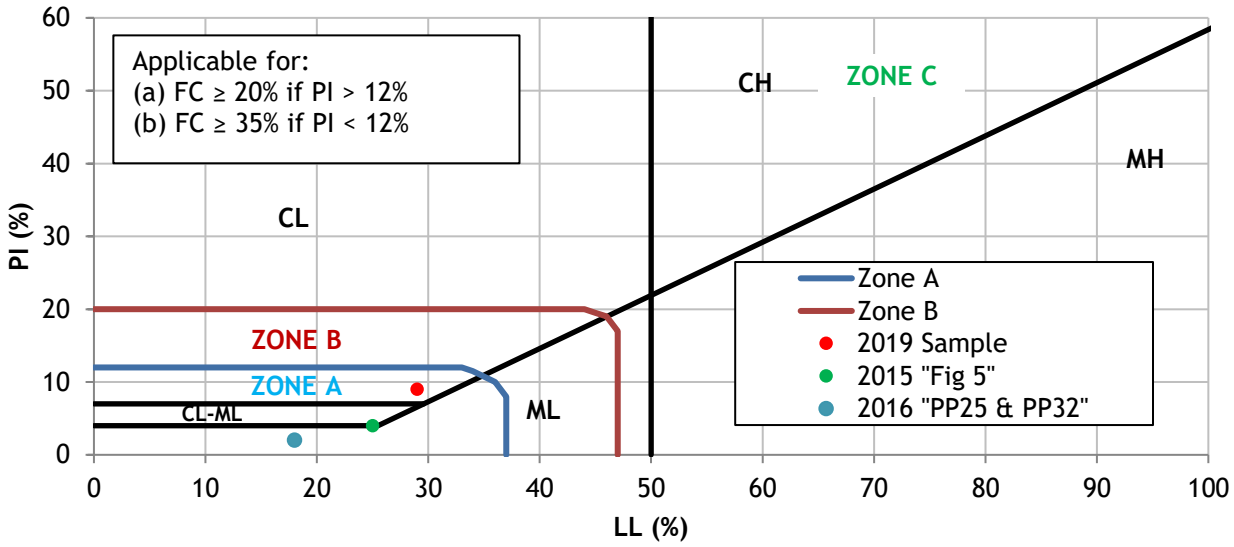
The ANCOLD guidelines for Design of Dams & Appurtenant Structures for Earthquake **[19]** set out a process for initial screening of soils to assess whether they could potentially liquefy. If so,

further analyses may be required to determine the ability of a dam to resist the motion caused by an earthquake and to assess the effect of potential loss of shear strength on dam stability.

The Seed et al. **[20]** criteria is based on a database of field liquefaction performance and data from laboratory plasticity characterisation tests. The method is applicable for materials with Fines Content (FC) greater than 20%, and splits materials into three Zones based on plasticity, as shown **Chart 5.1.**

Chart 5.1

Method for Assessment of Liquefiable Soil Types - Seed et al [20]



The three Zones are defined as:

- Zone A - Materials susceptible to “classic” cyclic liquefaction;
- Zone B - Materials may be liquefiable; and
- Zone C - Materials not generally susceptible to “classic” cyclic liquefaction.

Screening indicates that the low plasticity silt/clay tailings fall in Zone A, and would potentially be susceptible to liquefaction. However, liquefaction can only occur under a particular set of conditions. For earthquake-induced liquefaction, the two key conditions are as follows:

(i) The degree of saturation of the tailings (i.e. the tailings need to be saturated or at least have a moisture content greater than 85% of the liquid limit); and

(ii) The Factor of Safety (FS) against liquefaction must be less than unity for the given earthquake. This can be calculated by comparing -

a. The Cyclic Stress Ratio (CSR), which is a measure of the cyclic load applied to the tailings material by the earthquake (i.e. the magnitude of the design earthquake and the ground acceleration), with

b. The Cycle Resistance Ratio (CRR), which is the capacity of the tailings material to resist liquefaction. (i.e. the density, in-situ stress conditions and the strength of the potentially liquefiable tailings).

If the CSR is greater than the CRR, then the FS < 1.0, and liquefaction is likely to occur.

Due to the excess of evaporation over rainfall at the site, it is expected that the tailings beach will not be in a fully saturated condition, and hence not susceptible to liquefaction processes.

However, since the liquid limit of the tailings is low (20%), much of the tailings will have a moisture content in excess of 0.85 x LL and given the large catchment and potential for periods of flood water inundation, it is assumed that during operations the tailings may be sufficiently saturated to satisfy condition (i) above.

5.4.2 Post-Liquefaction Beach Stability

Experience indicates that for tailings deposits with a saturated tailings beach, a degree of deformation may occur during seismic events (cyclic mobility), depending on the angle of the beach, the strength of the tailings, and the intensity and duration of shaking. Continuing deformations (liquefaction flow sliding) after the end of shaking are not anticipated.

However, for verification purposes, a post-liquefaction stability analysis **[21]** has been carried out for the upper and lower slopes of the final Stage 7 tailings beach using infinite-slope theory.

For the post-liquefaction stability analysis, it has been assumed that the tailings have been deposited and dried to the OID defined in **Section 5.2** (1.7 t/m^3).

A saturated bulk density, γ = 2.10 t/m^3 is assumed, given the density of water, γ_w = 1.0 t/m^3 and zero air voids moisture content = 29%.

The post-liquefaction steady-state (residual) shear strength is not constant, but is dependent on the vertical effective stress distribution within the tailings deposit. On the basis of previous ATCW test results obtained for testing of tailings samples with similar characteristics to those described in **Section 5.1**, the post-liquefaction shear strength of normally consolidated tailings can be expressed as:

S_{us} = k x σ_{vo}' , where

S_{us} = (steady-state) undrained, post liquefaction shear strength,

k = constant

σ_{vo}' = vertical effective stress

The results of laboratory shear vane testing indicate that a value of k = 0.07 is appropriate. Results from triaxial testing suggest higher values of k, but for this analysis, we have conservatively taken the lower value.

The equations derived from the stability of long, shallow slopes ("infinite slope theory") may be used to analyse this situation. The concave beach slope profile described in **Section 5.3** has been adopted. Two cases may be considered:

1. Upper Slope

For the upper, steepest portion of the beach:

Slope angle β = 0.4% (sin β = 0.004)

It is conservatively assumed that the slope is saturated, but does not have a phreatic surface. For this condition, the stability equation for the Factor of Safety (FS) reduces to:

$$FS = \frac{k}{\sin\beta} = \frac{0.07}{0.004} = 17.5$$ i.e. the slope will remain stable.

2. Lower Slope

For the lower, flatter portion of the tailings beach:

Slope angle β = 0.23% ($\sin\beta$ = 0.0023)

In this case it is assumed that the slope is fully saturated, and has a phreatic surface at the top of the tailings (i.e. has applied hydrostatic pore pressures). This situation would occur below the decant pond. For this condition, the equation for stability is:

$$FS = \frac{k}{\sin\beta}\left(1 - \frac{\gamma_w}{\gamma}\right) = \frac{0.07}{0.0023}\left(1 - \frac{1}{2.1}\right) = 15.9$$ i.e. the slope will remain stable.

5.4.3 Conclusion

Whilst the tailings physical characteristics suggest they are potentially liquefiable, the post liquefaction stability analyses have shown that the adopted tailings beach slopes will remain stable, even when hydrostatic pore pressure conditions are assumed after seismic-induced liquefaction.

Following capping and closure, the design conditions anticipate the tailings beach to become desaturated below the capping layer, and cyclic mobility will not occur.

5.5 Tailings Geochemistry

To manage issues of Acid Metalliferous Drainage (AMD) it is necessary to assess the geochemical properties of the tailings and the materials proposed to be used for construction of all of the embankments in the TSF 2A and RWP facilities.

Hence the geochemical properties of the tailings are important, and since it is proposed to construct part of the embankments out of coarse rejects (generated at Stage 1 and proposed Stage 2 plant) and mine waste rock, the geochemical properties of these materials are also important.

GHD conducted long term (12 months) kinetic leachate tests on two types of tailings samples **[22]**. The samples were from two streams, referred to as “dry” tailings (3% moisture content) from magnetic separation maximum size of 3 mm, and “fine” tailings (30% moisture content) from wet separation. GHD indicated that the tailings materials are acid consuming.

Golder in 2015 conduced geochemical characterisation of waste rock and tailings, and prepared a an Acid Metalliferous Drainage (AMD) assessment **[23]**. The objective of their study was static (short-term) testing to characterise the materials and to assess the GHD conclusion following changes in the iron recovery process at the time of the study. Samples from four process streams referred to as wet fresh, wet oxide, dry fresh and dry oxide were tested (total 44 samples).

Golder classified all tailings samples as Non-Acid Forming (NAF) following the AMIRA classification method **[24]**. However, according to an internal North Star classification, some of the tailings samples were classified as Potentially Acid Forming (PAF), because of a very small positive Net