21 October 2022

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Dear Piyush Shah (I/C General Manager – Geo),

The purpose of this testwork was to represent the best possible silica sand product using conventional mineral processing techniques and to develop a silica sand characterisation showing the product purity of each sequential method. The silica sand characterisation was completed at a bench scale using approximately 5kg of feed material.

The feed preparation and silica characterisation consisted of several stages; these stages are listed below:

1. Trash screening at 1mm to remove any large foreign material
2. Wet screening at 45µm to remove slimes
3. Dry screening of the +45µm fraction to prepare the -600+106µm fraction for further processing
4. Densiometric separation of the -600+106µm fraction at a specific gravity of 2.70 to remove heavy minerals
5. Attritioning to clean the mineral surfaces followed by desliming at 106µm
6. Magnetic separation at 3 and 8 amps to remove magnetic minerals
7. Hot Acid Leach (HAL) to dissolve surface impurities,

A table of the Fe content by each sequential fraction can be seen below.

Table 1 – Progressive characterisation Fe_2O_3 grades

Fraction	Fe_2O_3 content (ppm)
As-received Feed	5,417
Deslimed Feed (-1.0+0.45mm)	3,605
Sized Ore (-0.6+0.106mm)	3,300
Gravity Product (2.7sg float)	1,500
Attritioned Product	1,200
Non-magnetic Product#	920
Acid Leach Product#	180

 # samples analysed by ICP-AES method

As indicated, note that high purity silica assay ICP methods were used for non-magnetic product and the acid leach product fraction compared to XRF for the previous fractions.

The characterisation shows the best possible product that can be produced using conventional mineral processing techniques. The Fe_2O_3 content was reduced from 5417ppm in the as received feed to 3,300ppm in the size ore (-600+106µm) to 180ppm in the acid leach product giving an overall Fe_2O_3 reduction of 96.7% by weight. Each processing stage reduced the Fe_2O_3 content. With the most significant reductions seen after desliming (5417ppm to 3605ppm), HLS separation (simulating gravity process), from 3300ppm to 1500ppm and the acid leach stage from 920 to 180ppm Fe_2O_3.

The feed preparation and characterisation testwork are outlined in Figure 1 below and results are discussed in subsequent sections of this document.

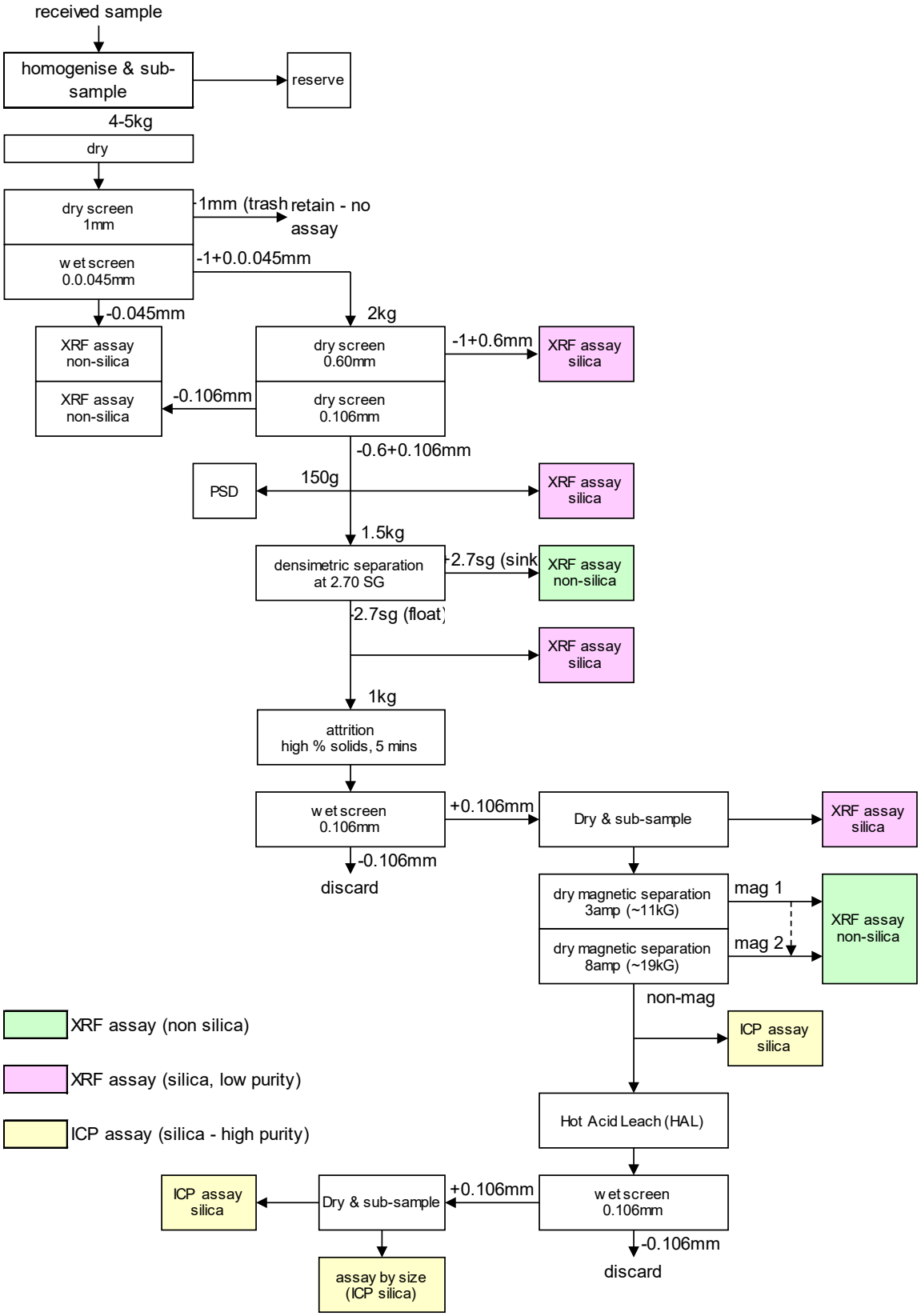


Figure 1: Process flowchart of silica characterisation

1. Sample Screening (simulates Feed Preparation Circuit)

Approximately 19kg of material was sent to Mineral Technologies, which was dried and homogenised upon receival, and then split to obtain a ~5kg representative sub-sample for characterisation. The sub-sample was firstly dry screened at 1mm to remove any larger foreign material (trash) followed by desliming at 45µm. The -1mm+45µm fraction from the desliming was then dry screened at 600µm and 106µm.

The results from the screening and associated images (Figure 2) can be seen below.

Table 2 – Trash Screening and De-sliming

Fraction	% Mass		Assay (%, unless specified)									
	to stage	to feed	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3 (ppm)	CaO	K_2O	MgO	SO_3	TiO_2	LOI_{1000}
+1mm*	9.4	9.4	97.5	0.360	0.43	5	0.010	0.010	0.030	0.010	0.37	0.25
-1mm+0.045mm	88.9	88.9	97.5	0.360	0.43	5	0.010	0.010	0.030	0.010	0.37	0.25
-45µm	1.7	1.7	56.5	10.90	20.1	250	0.170	0.080	0.140	0.090	2.44	9.28
Total	100.0	100.0	96.8	0.542	0.77	10	0.013	0.011	0.032	0.012	0.41	0.41

* +1mm assay assumed to be the same as -1.0+0.045mm size range

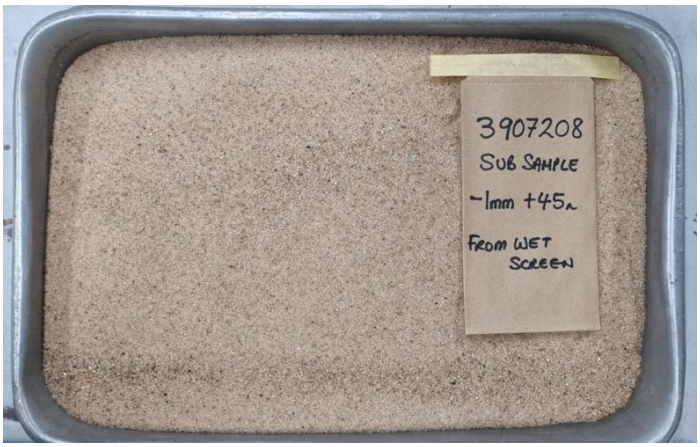


Figure 2: -1mm+45µm fraction after desliming at 45µm

From the original sample 88.9% of the feed reported to the -1mm+45µm size fraction with 9.4% removed through trash screening and a further 1.7% removed through desliming. The slimes fraction contains several impurities, including Fe_2O_3 (10.9%), TiO_2 (2.44%), and Al_2O_3 (20.1%) while the SiO_2 grade of the slimes fraction was 56.5%.

The -1mm+45µm fraction was then dry screened over 600µm and 106µm sieves. The mass splits and assays from the dry screening can be seen in Table 3. Images of the size fractions has also been included in Figure 3:

Table 3 – Dry sieving mass and assay

Fraction	% Mass		Assay (%, unless specified)									
	to stage	to feed	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3 (ppm)	CaO	K_2O	MgO	SO_3	TiO_2	LOI_{1000}
-1000+600µm	11.6	10.4	98.1	0.280	0.29	<100	0.010	0.010	0.020	0.010	0.11	0.24
-600+106µm	86.4	76.8	97.6	0.330	0.43	<100	0.010	0.010	0.030	0.010	0.32	0.24
-106+45µm	2.0	1.8	90.7	2.150	1.21	270	0.020	0.010	0.070	0.030	4.19	0.79
Total	100.0	88.9	97.5	0.360	0.43	5	0.010	0.010	0.030	0.010	0.37	0.25
Feed (direct)		88.9	97.5	0.360	0.43	5	0.010	0.010	0.030	0.010	0.37	0.25

Figure 3: size fractions after dry screening

The bulk of the material (86.4% of the -1.0+0.045mm and 76.8% of the total feed) reported to the -600+106µm fraction, 11.6% reported to the -1mm+600µm fraction and the remaining mass (2.0%) reported to the -106+45µm fraction.

The -1mm+600µm fraction assayed 98.11% SiO_2 with 0.28% Fe_2O_3, 0.29% Al_2O_3 and 0.11 TiO_2 as the main contaminants. The -600+106µm fraction assayed 97.6% SiO_2 and higher levels of contaminants, 0.33% Fe_2O_3, 0.32% TiO_2, and 0.43% Al_2O_3. The -106+45µm fraction had higher levels of impurities and a reduction in SiO_2 content compared to the other fractions. Approximately 20% of the iron bearing particles were contained in the +600µm or the -106µm size fractions.

2. Density Separation (simulates Gravity Separation Circuit)

Heavy liquid separation (HLS) was performed on the -600+106µm fraction at an SG of 2.70. Both the float (-2.7 SG) and the sink (+2.7 SG) fractions were assayed. The mass splits, assay results and an image of each fraction can be seen in Table 4 and Figure 4:

Table 4 – Density separation of --600+106µm fraction

Fraction	% Mass		Assay (%, unless specified)									
	to stage	to feed	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3 (ppm)	CaO	K_2O	MgO	SO_3	TiO_2	LOI_{1000}
-2.7sg (float)	99.1	76.1	98.6	0.150	0.34	<100	0.010	0.010	0.010	0.010	0.04	0.20
+2.7sg (sink)	0.9	0.7	34.0	19.00	9.34	2220	0.100	0.010	0.730	0.120	31.2	2.51
Total	100.0	76.8	98.0	0.328	0.43	21	0.011	0.010	0.017	0.011	0.33	0.22
Feed (direct)		76.8	97.6	0.330	0.43	<100	0.010	0.010	0.030	0.010	0.32	0.24

Figure 4: -600+106µm float and sink products

Of the -600+106µm fraction 99.1% (76.1% of the initial feed) by mass reported to the float fraction. A significant drop in Fe_2O_3, TiO_2, and Al_2O_3 impurity content and upgrade of silica was seen.

The float fraction saw an improvement in Fe_2O_3 content from 0.33% to 0.15% and an increase of 1% in silica content. Approximately 55% of the iron bearing particles were removed by density (gravity) separation.

3. Attrition (simulates Mechanical Surface Cleaning)

The float faction from the HLS was processed in a high energy attritioning cell to clean the surfaces and remove impurities from the sand particles. The residence time was 5 minutes with an operating solids density of ~75% w/w. The attrition discharge sample was then wet screened at 106µm to remove any liberated slimes. The slimes fraction was discarded while a sub-sample of the +106µm attritioned fraction was sent for assay.

The mass splits and assay results for the attritioned product can be seen below (Table 5):

Table 5 – Mass fraction and assay results for the +106µm attritioned fraction

Fraction	% Mass		Assay (%, unless specified)									
	to stage	to feed	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3 (ppm)	CaO	K_2O	MgO	SO_3	TiO_2	LOI_{1000}
Attritioned (+106µm)	98.8	75.2	98.6	0.120	0.28	<100	0.010	0.010	0.010	0.010	0.04	0.17
Attritioned (-106µm)	1.2	0.9	*Not Assayed*									
Total	100.0	76.1										
Feed (direct)		76.1	98.6	0.150	0.34	<100	0.010	0.010	0.010	0.010	0.04	0.20

The attritioning process rejected 1.2% of the gravity float fraction to the -106µm attritioned fraction. A reduction in Fe_2O_3, and Al_2O_3 content was observed while SiO_2 content remained the same. The Fe_2O_3 content reduced from 0.15% to 0.12%. Approximately 20% of the iron bearing particles were removed by attritioning and de-slime.

Figure 5: +106µm attrition product

4. Magnetic Fractionation (simulates Wet & Dry Magnetic Separation)

The attritioned sample was fractionated using an Induced Reading Roll Magnetic Separator (IRMS) to remove magnetic impurities from the sample. The IRMS was processed at 3.0 amps (simulating the maximum field strength that may be achieved in wet magnetic separation) followed by 8.0 amps (maximum field strength for dry magnetic separation). The individual weights of the 3.0 and 8.0 amp magnetic products were recorded separately, then combined to provide enough mass for assay.

The mass splits, assay results and an image of each fraction can be seen in Table 6 and Figure 6.

Table 6 – Mass fraction and assay results for the magnetic fractionation

Fraction	% Mass		Assay (%, unless specified)									
	to stage	to feed	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3 (ppm)	CaO	K_2O	MgO	SO_3	TiO_2	LOI_{1000}
Non-mag (8 amps)	99.2	74.6	99.4	0.092	0.26	3	0.006	0.006	0.002	n/a	0.03	0.20
Mag 2 (3-8 amps)	0.7	0.5	93.9	1.390	2.46	4	0.030	0.010	0.030	0.040	0.60	1.43
Mag 1 (3 amps)	0.1	0.1	93.9	1.390	2.46	4	0.030	0.010	0.030	0.040	0.60	1.43
Total	100.0	75.2	99.4	0.102	0.27	3	0.006	0.006	0.002	0.000	0.04	0.21
Feed (direct)		75.2	98.6	0.120	0.28	<100	0.010	0.010	0.010	0.010	n/a	0.17

Figure 6: +106µm attrition product

The 'mag 1' fraction accounted for 0.1% of the initial feed, this portion was completed at 3.0Amps, which generates a magnetic field strength of approximately 13,500 Gauss. Another 0.5% of the feed mass was removed in 'mag 2' (3-8 amps) while 74.6% of the feed mass was retained in the 'non-mag' fraction.

A reduction in Fe_2O_3, TiO_2 and Al_2O_3 content was observed while SiO_2 content increased to 99.4%. The Fe_2O_3 content reduced from 0.15% to 0.12%. Approximately 20% of the iron bearing particles were removed by attritioning and de-slime.

5. Hot Acid Leach (simulates Hepworth Process Circuit)

A sub-sample of the 'non-mag' fraction was then subject to a Hot Acid Leach (HAL) which simulates the Hepworth acid leach process and aims to remove surface iron oxides staining the silica (quartz) particles. The sample was heated to 150°C for 90 minutes with 70g/kg of 35% sulphuric acid. The acid bake discharge was then carefully neutralised by successive washing, and wet screened at 106µm to remove any leached slimes. Sub-samples of the neutralised product were extracted and sent for assay while the effluent was discarded.

The mass splits, assay results and images of the leach feed (non-magnetic product) and leached product can be seen in.

Table 7 – Mass fraction and assay results for the HAL

Fraction	% Mass		Assay (%, unless specified)									
	to stage	to feed	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3 (ppm)	CaO	K_2O	MgO	SO_3	TiO_2	LOI_{1000}
Leached solids (+106µm)	99.0	73.8	99.7	0.018	0.10	1	0.006	0.005	0.002	n/a	0.03	0.12
Leach effluent	1.0	0.8		n/a								
Total	100.0	74.6										
Feed (direct)		74.6	99.4	0.092	0.26	3	0.006	0.006	0.002	n/a	0.03	0.20

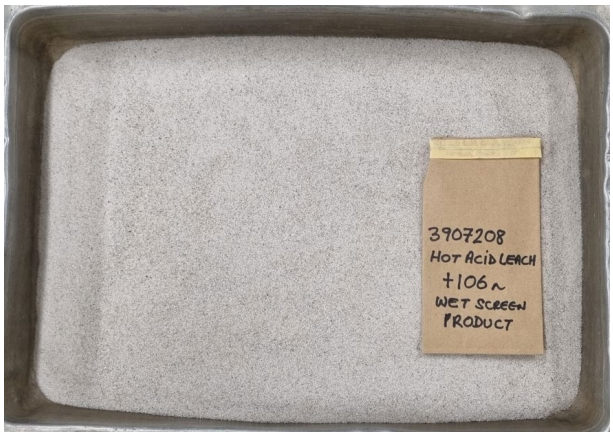


Figure 7: +106µm attrition product

A small portion of mass was removed during the HAL process, 0.8% of the initial feed.

As a result of HAL, the TiO_2 content showed a minor reduction (down to 0.03%), while the Al_2O_3 content also dropped by 0.16% to 0.1%. A significant reduction in the Fe_2O_3 content was realised reducing from 0.092% to 0.018%. It is estimated that the HAL removed 81% of the iron contaminants. The SiO_2 content increased slightly to 99.7%.

6. Final Product Characterisation

A particle size distribution and assay by size was completed on the HAL product, with results shown graphically in and in Table 8:

Table 8 – Assay bby size of leached product

Fraction	% Mass		Assay (%, unless specified)									
	to stage	to feed	SiO_2	Fe_2O_3	Al_2O_3	Cr_2O_3 (ppm)	CaO	K_2O	MgO	SO_3	TiO_2	LOI_{1000}
-600+425µm	13.7	10.2	99.7	0.021	0.08	3	0.005	0.005	0.002	n/a	0.03	0.11
-425+300µm	24.4	18.0	99.7	0.018	0.09	3	0.006	0.005	0.002	n/a	0.03	0.14
-300+212µm	28.7	21.2	99.7	0.017	0.10	2	0.005	0.005	0.002	n/a	0.03	0.09
-212+150µm	21.7	16.0	99.7	0.017	0.12	2	0.006	0.005	0.002	n/a	0.03	0.15
-150+106µm	11.5	8.5	99.7	0.019	0.14	3	0.006	0.007	0.002	n/a	0.03	0.13
Total	100.0	73.8	99.7	0.018	0.10	2	0.006	0.005	0.002	0.000	0.03	0.12
Feed (direct)		73.8	99.7	0.018	0.10	1	0.006	0.005	0.002	n/a	0.03	0.12

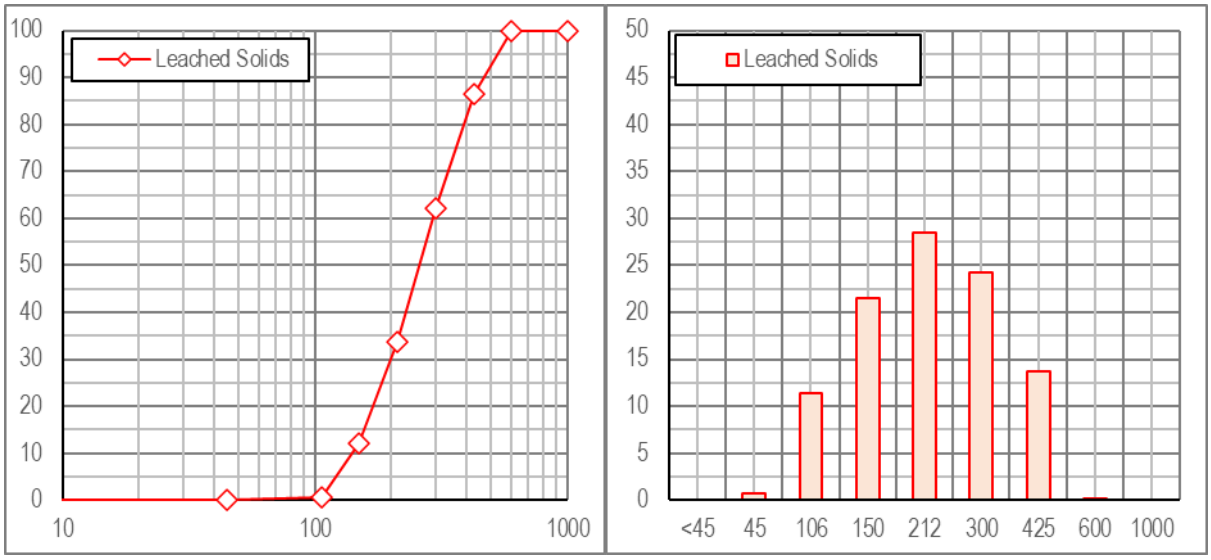


Figure 8: Particle size distribution of HAL product

Higher impurity levels are measured in the -150+106µm or +425µm size fractions and the lowest iron grade is shown to be in the -300+150µm with a grade of 170ppm Fe_2O_3. This size range represents only 37.2% by mass of the initial feed sample.

7. Summary of Metallurgical Characterisation

A summary of the mass distribution and assays for each sequential separation stage simulating standard silica sand beneficiation techniques is shown in Table 9.

Table 9: Metallurgical Characterisation Summary

Product Description	% wt	Assay (%)								
	to feed	SiO_2	Fe_2O_3	Al_2O_3	CaO	K_2O	MgO	Na_2O	TiO_2	LOI_{1000}
As-received Feed	100	96.8	0.542	0.77	0.013	0.011	0.032	0.00	0.408	0.41
De-slimed Feed (-1.0+0.45mm)	88.9	97.5	0.360	0.43	0.010	0.010	0.030	<0.01	0.373	0.25
Sized Ore (-0.6+0.106mm)	76.8	97.6	0.330	0.43	0.010	0.010	0.030	<0.01	0.320	0.24
Gravity Product (2.7sg float)	76.1	98.6	0.150	0.34	0.010	0.010	0.010	<0.01	0.040	0.20
Attrition Product	75.2	98.6	0.120	0.28	0.010	0.010	0.010	<0.01	0.040	0.17
Non-magnetic Product	74.6	99.4	0.092	0.26	0.006	0.006	0.002	0.003	0.033	0.20
Acid Leach Product	73.8	99.7	0.018	0.10	0.006	0.005	0.002	0.003	0.029	0.12

Salient observations are:

- Over 25% of the feed mass was rejected during the sample preparation stages through trash screening (>1mm) and desliming (<45µm) and the initial -600+106µm fraction had an Fe_2O_3 content of 0.33%.
- Over the remaining separation stages, only 3% of the feed mass was further rejected.
- Major impurity levels Fe_2O_3, TiO_2, and Al_2O_3, progressively decrease as the sample moved through the processing stages.
- The largest proportional drop in terms of Fe_2O_3 was a result of the feed preparation, with approximately 60% of the iron rejected while the gravity separation stage contributed to >18% rejection of the iron.
- Most of the TiO_2 is shown to be rejected through gravity separation
- Significant Al_2O_3 is contained in the slimes / fines and is also successfully removed by the leach process.

A full suite of the assays and a sequential flow diagram with mass distributions, Fe_2O_3 content and operating conditions has been included in the appendices.

The interpretations and conclusions contained within this report pertain to the sample as received, and any variations in feed type or specification are beyond the scope of this report.

Sincerely,

Wendy Nutt

Metallurgist

Appendices

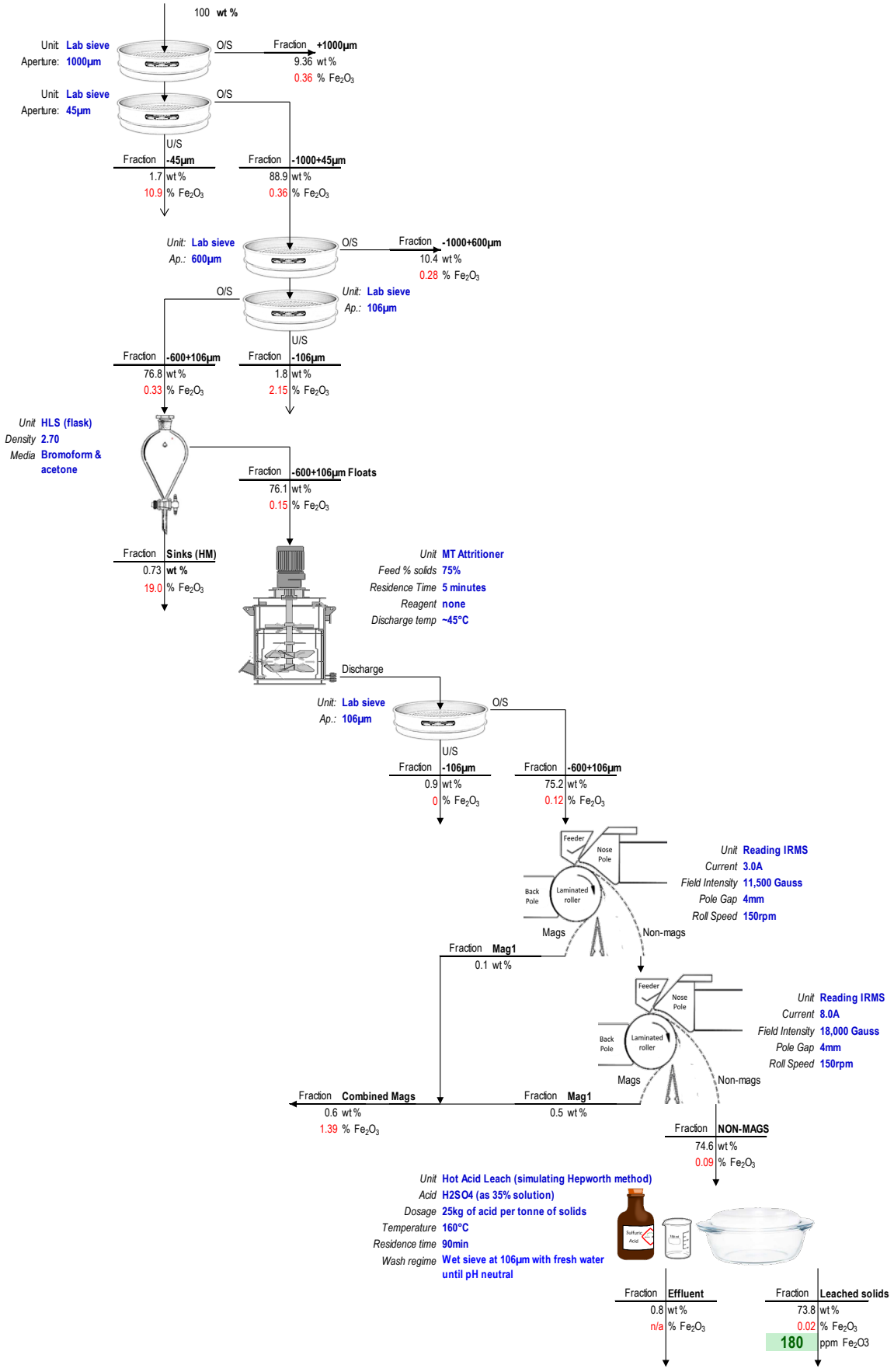
Appendix A: Assay Report

		TiO2	Fe2O3	SiO2	Al2O3	Cr2O3	MgO	MnO	ZrO2	P2O5	U	Th	V2O5	Nb2O5	SO3	CaO	K2O	CeO2	La2O3	LOI1000
UNITS		%	%	%	%	%	%	%	%	%	ppm	ppm	%	%	%	%	%	%	%	%
DETECTION		0.01	0.01	0.01	0.01	0.001	0.01	0.01	0.01	0.001	10	10	0.01	0.001	0.01	0.01	0.01	0.002	0.001	0.01
METHOD		XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	XRF202	TG001
A/6910	-45 from wet screen	2.44	10.9	56.5	20.1	0.025	0.14	0.01	0.08	0.034	-10	13	0.06	0.006	0.09	0.17	0.08	0.006	0.005	9.28
A/6911	-106 +45um	4.19	2.15	90.7	1.21	0.027	0.07	0.02	0.57	0.029	13	61	0.03	0.009	0.03	0.02	0.01	0.016	0.002	0.79
A/6911 Rpt	-106 +45um	4.22	2.16	90.8	1.19	0.028	0.07	0.02	0.56	0.03	15	58	0.03	0.01	0.03	0.02	0.01	0.018	0.004	0.72
A/6912	-600 +106um 2.7sg	31.2	19	34	9.34	0.222	0.73	0.29	1.51	0.101	-10	138	0.16	0.069	0.12	0.1	0.01	0.036	0.014	2.51
A/6913	Mag 1 + Mag 2 Combined	0.6	1.39	93.9	2.46	0.004	0.03	-0.01	0.07	0.015	-10	13	0.01	0.004	0.04	0.03	0.01	0.002	0.001	1.43
A/6913 Rpt	Mag 1 + Mag 2 Combined	0.59	1.39	93.8	2.45	0.006	0.03	-0.01	0.07	0.014	-10	15	0.01	0.006	0.04	0.03	0.01	0.002	-0.001	1.45

		OA-GRA05x	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26	ME-XRF26
SAMPLE		LOI 1000	Al2O3	BaO	CaO	Cr2O3	Fe2O3	K2O	MgO	MnO	Na2O	P2O5	SO3	SiO2	SrO	TiO2	Total
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
A/6914	-1mm +600um	0.24	0.29	<0.01	0.01	<0.01	0.28	0.01	0.02	<0.01	<0.01	<0.01	0.01	98.06	<0.01	0.11	99.15
A/6915	-600 +106um	0.24	0.43	<0.01	0.01	<0.01	0.33	0.01	0.03	<0.01	<0.01	<0.01	0.01	97.59	<0.01	0.32	99.1
A/6916	-2.7sg float	0.2	0.34	<0.01	0.01	<0.01	0.15	0.01	0.01	<0.01	<0.01	<0.01	0.01	98.6	<0.01	0.04	99.45
A/6917	+106um attrition wet screen	0.17	0.28	<0.01	0.01	<0.01	0.12	0.01	0.01	<0.01	<0.01	<0.01	0.01	98.59	<0.01	0.04	99.34

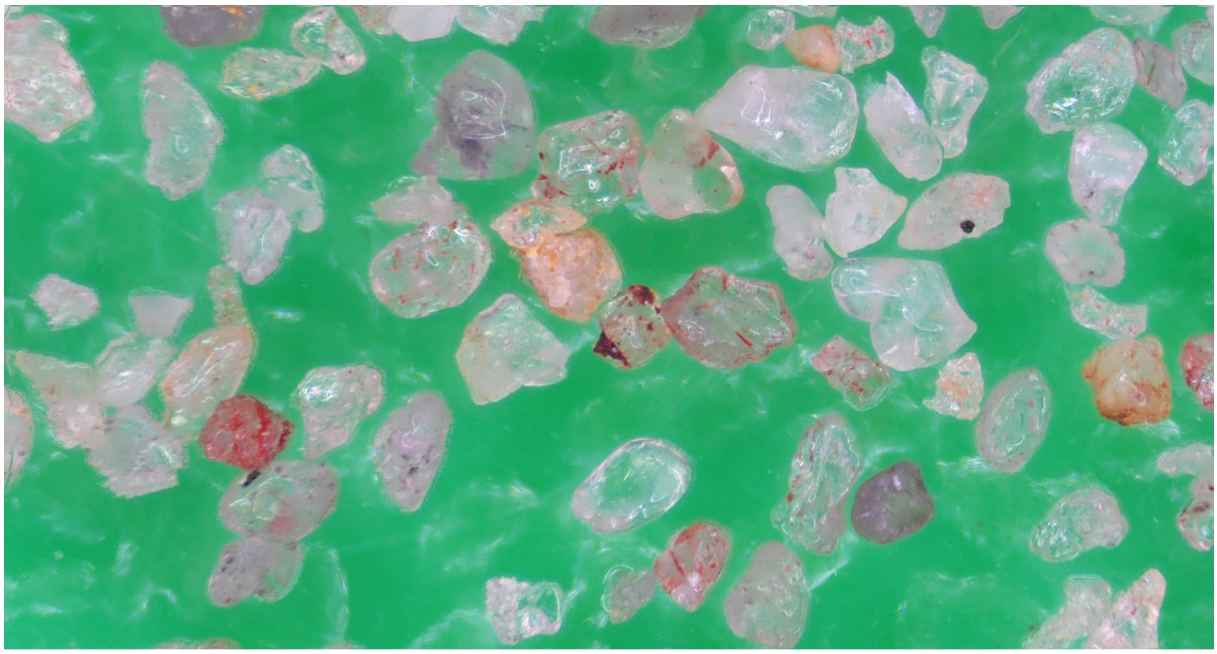
		ME-PKG85	ME-PKG85	ME-PKG85	ME-PKG85	ME-PKG85	ME-PKG85	ME-PKG85	ME-PKG85	ME-PKG85	ME-PKG85	OA-GRA05x
SAMPLE		SiO2	Al2O3	Fe2O3	TiO2	Cr2O3	CaO	Cu	K2O	MgO	Na2O	LOI 1000
		%	%	%	%	ppm	%	%	%	%	%	%
A/6918	8 AMP NM	99.4	0.257	0.092	0.033	3	0.006	<0.001	0.006	0.002	0.003	0.2
A/6919	+106 HAL wet Screen	99.7	0.104	0.018	0.029	1	0.006	<0.001	0.005	0.002	0.003	0.12
A/6920	+425 PSD	99.7	0.079	0.021	0.032	3	0.005	<0.001	0.005	0.002	0.003	0.11
A/6921	-425 +300 PSD	99.7	0.087	0.018	0.028	3	0.006	<0.001	0.005	0.002	0.003	0.14
A/6922	-300 +212 PSD	99.7	0.1	0.017	0.026	2	0.005	<0.001	0.005	0.002	0.003	0.09
A/6923	-212 +150 PSD	99.7	0.118	0.017	0.027	2	0.006	<0.001	0.005	0.002	0.004	0.15
A/6924	-150 PSD	99.7	0.137	0.019	0.034	3	0.006	<0.001	0.007	0.002	0.004	0.13

Appendix B: Laboratory Process Flow Diagram



Appendix C: Microscopic Photos of Leach Feed and Leached Product

Leach Feed (De-slimed Attrition Discharge Non-mags)



Leached Product