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P.O. Box 247, Bridgetown, Western Australia 6255
Phone: (61 8) 9761 2829 E-mail: gca@wn.com.au
ACN 061 827 674 ABN 37 061 827 674

Testing Laboratory: Unit B, 15 Rose Street, Bridgetown, WA 6255

1815/2

COMPANY: ACH Minerals Pty Ltd

ATTENTION: Paul Bennett

FROM: Graeme Campbell

SUBJECT: Ravensthorpe Gold Project: Geochemical Testing of Slurry Samples of **Oxide-Ore-Tailings** and **Primary-Ore-Tailings** – Implications for Tailings Management

NO. PAGES (including this page): 78 DATE: 10th July 2019

Paul,

The testwork results obtained in this study are presented in **Tables 1-4**, and shown on **Figure 1**.

Photographs of the samples received for testing, and various testing procedures, are shown on **Plates 1-3**.

Details of the metallurgical testwork programme employed to generate the tailings-slurry samples tested herein, are presented in **Attachment I**.

Destruction of cyanide forms via oxidation with SO_2 was undertaken during the metallurgical study to ensure the residual cyanide forms were either below, or near, the respective analytical detection-limits.

Copies of the laboratory reports are presented in **Attachment II**.

An earlier study of tailings geochemistry for the Kundip ores forms the subject of the GCA (2005) report:

- Graeme Campbell and Associates Pty Ltd, 2005, "Phillips River Project: Geochemical Characterisation of Process-Tailings-Slurry Samples ['Static-Testwork'] – Implications for Process-Tailings Management", unpublished report prepared for Tectonic Resources NL

1.0 TESTWORK OUTCOMES

1.1 Tailings-Solids

1.1.1 Acid-Base Chemistry

The Oxide-Ore-Tailings sample is classified as Non-Acid Forming (NAF), and reflects 'negligible-sulphides' (Total-S = 0.05 %) [**Table 1**].

The Primary-Ore-Tailings sample is classified as Potentially-Acid Forming (PAF), due to 'accessory-sulphides' [Cr(II)-Reducible-S value of 1.7 %] in a gangue that is partially calcareous ("$CaCO_3$" content of *ca.* 2 %) .

In terms of the intrinsic reactivity of the sulphide-mineral suite (chiefly pyrite), determination of the Oxygen-Consumption Rate (OCR) resulted in an OCR_{30oC} value of 1.30E-10 kg O_2/kg/s. This OCR corresponds to an Acid-Generation Rate (AGR) of *ca.* 2-3 kg H_2SO_4/tonne/year at 30 ^{o}C under conditions near-optimal for sulphide-oxidation.

Given the occurrence of 'accessory-pyrite', a reaction temperature of 30 ^{o}C, and circum-neutral-pH, this OCR value indicates a moderate reactivity (i.e. pyrite not hyper-reactive).

The pH-buffering curve (**Figure 1**) indicates that the carbonate-mineral suite includes ferroan forms (e.g. ankerites).

1.1.2 Multi-Element Composition and Mineralogy

Both the Oxide-Ore-Tailings and Primary-Ore-Tailings samples were characterised by major/minor-element contents below, or close to, those typically recorded for soils, regoliths and bedrocks derived from non-mineralised terrain (**Table 2**).

Although variously enriched in As, Se, Mo, Cu, Ag, and Bi, the degree of enrichment was not marked.[1]

In terms of mineralogy, the Oxide-Ore-Tailings sample comprised mostly kaolin clays, muscovites and quartz with sub-ordinate goethites (**Table 3**). Traces of ilmenites and Ti-oxides also occurred.

The Primary-Ore-Tailings sample comprised mostly chlorites, albites and quartz with sub-ordinate pyrite, epidotes and micas. Pyrrhotites and calcites were trace components.

1.2 Tailings-Slurry-Waters

1.2.1 General Chemistry

For both the Oxide-Ore-Tailings and Primary-Ore-Tailings samples, the tailings-slurry-waters were mildly-alkaline (pH 8-9), and saline with TDS-(grav.) values of 13,000-18,000 mg/L (**Table 4**).[2]

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[1] The indicated element enrichments in **Table 3** fall within the range recorded for the tailings-solids typically produced at local gold-mines (Campbell, unpublished results since the late-1980s). The As contents (< 100 mg/kg) of the tailings-solids samples assayed in this study lie at the 'low-end-of-the-range' for tailings-solids associated with gold mineralisation within Western Australia.

[2] TDS-(grav.) = Total-Dissolved-Solids-(gravimetric).

The saline state of the tailings-slurry-waters reflects both the salinity of site-groundwaters sourced for make-up-water for processing, and the generation of SO_4 during the cyanide-detoxification treatment using SO_2.

The minor-element concentrations were typically below, or near, the respective detection-limits (10-100 µg/L range generally, reflective of reduced analytical sensitivity associated with the elevated salinity).

1.2.2 Cyanide Forms

The tailings-slurry-waters had (**Table 4**):

- Total-Cyanide ($CN_{Tot.}$) concentrations of 1.2-1.4 mg/L
- Weak-Acid-Dissociable-Cyanide (CN_{WAD}) and Free-Cyanide (CN_{Free}) concentrations well within the sub-mg/L range, and typically below detection

The above indicates near-quantitative destruction of the cyanide forms resulting from NaCN addition for Au recovery during the metallurgical investigation.

Consistent with the $CN_{Tot.}$, CN_{WAD} and CN_{Free} concentrations, the concentrations of cyanide-complexing metals (chiefly, Fe, Cu, Zn, Ni, Co, Ag, and Hg) were typically below the respective detection-limits (**Table 4**).

For the Primary-Ore-Tailings sample, the Cu concentration in the slurry-water was 0.55 mg/L, likely due to complexing by NH_3.

The NH_3-N concentrations were 14-34 mg/L (**Table 4**) reflect incomplete oxidation of CN-N to NO_3-N during the SO_2 treatment in the bench-scale metallurgical investigation.

Within the full-scale operation for cyanide detoxification, improved efficiencies of CN-N transformation to NO_3-N should appreciably reduce the residual Cu concentrations within the slurry-water of the Primary-Ore-Tailings stream.[3]

2.0 IMPLICATIONS FOR TAILINGS MANAGEMENT

Based on the testwork results obtained in this study, implications for the design of the tailings-storage facility (TSF) are outlined below.

2.1 Operational Phase of TSF

2.1.1 Sequence of Tailings Types

Over the Life-of-Mine (LOM) of *ca.* 8 years, it is anticipated that *ca.* 3.1 million tonnes of a range of ore types is to be milled.

Oxide-Ores (mostly from Kaolin Pit), corresponding to Completely-Oxidised (CO), Strongly-Oxidised (SO) and Partly-Oxidised (PO) forms should amount to *ca.* 1.2 million tonnes (i.e. *ca.* 39 % of the total).

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[3] Optimisation work for CN-detoxification in terms of decomposition efficiencies and unit costs would form part of the overall processing route for the Project.

Primary-Ores (from Kaolin Pit, and underground operations at Harbour View and Flag Deposits) should amount to *ca.* 1.9 million tonnes (i.e. *ca.* 61 % of the total).

2.1.2 Decant-Water

By subjecting the Oxide-Ore-Tailings and Primary-Ore-Tailings streams to (SO_2-based) cyanide-detoxification treatment prior to discharge to the TSF, the decant-water ponded on top of the tailings-bed poses no risk to wildlife (e.g. birds).

Ores milled at local gold-mines typically have 'NaCN-demands' that are low-to-moderate, so that the ensuing TSF-decant-waters have CN_{WAD} concentrations within the low tens-of-mg/L range, and below the industry target of 50 mg/L for wildlife protection.

For the Ravensthorpe Gold Project, the decant-water should have a CN_{WAD} concentration within the sub-mg/L range (i.e. appreciably lower than that typically recorded at sites within the WA Goldfields).

Since cyanide forms have been destroyed, the concentrations of cyanide-complexing metals (e.g. Fe, Cu, etc.) should be below, or close to, the respective detection-limits.

The risk to wildlife (e.g. birds) of the decant-water is further reduced by its salinity (e.g. TDS within 10-20 g/L range).

2.1.3 Seepage Control

Given the above chemistry of the tailings-waters, measures for controlling seepage need not be overly stringent.

The saline state of the tailings-waters is also similar to that of the site groundwaters with TDS values of 10+ g/L.

2.2 Decommissioning of TSF

When the TSF is decommissioned, the Surface-Zone (e.g. uppermost 2+ m) of the tailings-bed should comprise Primary-Ore-Tailings that are PAF.

A 'store-release-cover' system will be required to restrict infiltration into the tailings-bed which will be unsaturated above the 'tension-saturated-zone' extending upward from the phreatic-surface at depth.

Provisionally, following cessation of tailings-slurry discharge to the TSF, it should take up to a decade, approximately, for acidic conditions (e.g. pH 3-5) to develop in the weathering-zone (nominal 50-100 mm) at the top of the exposed tailings-bed. That is, 'lag-phase' weathering should occur over this period of time, due to circum-neutral buffering by the carbonate-minerals (calcites / ankerites) in the Primary-Ore-Tailings.

Investigations need to be carried out during the Project to tailor the design of the 'store-release-cover' system in light of the site's climate, biophysical setting, and final land-use. The very nature of the (main) Kaolin Deposit (i.e. chiefly an 'oxide' orebody) means that there is a voluminous supply of clay-rich / ferruginous regoliths (e.g. saprolites) well suited to the construction of a 'store-release-cover' system for the TSF.

3.0 CLOSURE

The destruction of cyanide forms greatly reduces risks arising from the chemistry of tailings-waters for the Project which in turn simplifies the measures needed for geochemical and environmental control during the active-lifetime of the TSF. Although investigations are required to optimise the engineering design and earthworks costings, the decommissioning of TSFs containing PAF-tailings in the surface-zone via 'store-release-cover' systems has been a well-understood, and relative straight forward, task for many years now within the Western Australian gold-mining industry.

I trust the above is useful to you.

Regards,

Dr GD Campbell
Director

encl. Tables 1-4
Figure 1
Plates 1-3
Attachments I-II

TABLES

Table 1: Acid-Base-Analysis and Net-Acid-Generation Results for Tailings-Solids Samples

GCA-SAMPLE NO.	TAILINGS-TYPE	TOTAL-S (%)	Cr(II)-RED.-S (%)	TOTAL-C (%)	CO3-C (%)	CARB.-ANC (calc'd)	BULK-ANC	NAG pH=4.5	NAG pH=7.0	NAG-pH	AFP CATEGORY
						kg H2SO4/tonne					
GCA11868	Oxide-Ore-Tailings	0.05	nm	0.06	<0.01	<1	3 (3)	nm	nm	nm	**NAF**
GCA11902	Primary-Ore-Tailings	3.04	1.7	0.35	0.33	27	22 (22)	17 (18)	22 (24)	2.7 (2.7)	**PAF**

Notes:
ANC = Acid-Neutralisation Capacity; NAG = Net-Acid Generation; AFP = Acid-Formation Potential; PAF = Potentially-Acid Forming;
NAF = Non-Acid Forming; nm = not measured
All values expressed on a dry-weight basis, except for NAG-pH
Values in parentheses represent duplicate determinations

Table 2: Multi-Element-Analysis Results for Tailings-Solids Samples

SAMPLE_ ID	TAILINGS- TYPE	S	Ca	Mg	K	Na	Al	Fe	Ti	Si	As	Sb	Se	Mo	B	F
		%									mg/kg					
GCA11868	Oxide-Ore-Tailings	0.05	0.1	0.14	2.06	0.24	8.24	3.43	0.32	34.0	33.7	0.40	0.73	8.2	<50	160
GCA11902	Primary-Ore-Tailings	3.04	1.2	2.4	0.86	1.1	5.7	11.0	0.22	27.5	35	0.5	0.80	38	<20	130
		Average-Crustal Abundance (Bowen 1979)									1.5	0.2	0.05	1.5	10	950

		Cu	Zn	Cd	Pb	Hg	Ni	Cr	Co	Mn	Ag	Bi	P	Sr	Ba	Sn	V	Tl	Th	U
		mg/kg																		
GCA11868	Oxide-Ore-Tailings	174	6	<0.02	8.6	<0.01	162	344	8.6	37	0.55	2.80	49	17.40	319.1	7.0	73	0.15	2.50	0.56
GCA11902	Primary-Ore-Tailings	940	230	0.9	63	0.05	350	500	190	650	2.5	2.4	380	24	160	2.2	71	0.2	3.3	1.6
Average-Crustal Abundance (Bowen 1979)		50	75	0.11	14	0.05	80	100	20	950	0.07	0.05	1,000	370	500	2.2	160	0.6	12	2.4

▨	signifies element content 10-100 times average-crustal abundance
🟦	signifies element content 100+ times average-crustal abundance

Reference: Bowen HJM, 1979, "Environmental Chemistry of the Elements", Academic Press, New York

Note: GLS (Maddington) assayed the Oxide-Ore-Tailings-Solids sample, whereas SGS (Perth Airport) assayed the Primary-Ore-Tailings-Solids sample. The analytical sensitivity for these laboratories vary slightly.

Table 3: Mineralogical Results for Tailings-Solids Samples

Oxide-Ore-Tailings (GCA11868)		**Primary-Ore-Tailings (GCA11902)**	
kaolin muscovite quartz	20-50 %	chlorite quartz	20-50 %
		albite	10-20 %
goethite	1-10 %	**pyrite** epidote mica	1-10 %
ilmenite Ti-oxide	< 1 %	**pyrrhotite** **calcite** Fe-silicate (?)	< 1 %

Notes:

- major = 20-50 %; minor = 10-20 %; accessory = 1-10 %; trace = less than 1 %

Table 4: Analysis Results for Tailings-Slurry-Water Samples

ELEMENT/ PARAMETER	Oxide-Ore-Tailings (GCA11868)	Primary-Ore-Tailings (GCA11902)	ELEMENT/ PARAMETER	Oxide-Ore-Tailings (GCA11868)	Primary-Ore-Tailings (GCA11902)
Major-Parameters			***Minor-Ions (µg/L)***		
pH	8.6	8.5	As	30	<10
pH (GCA)	8.5	8.3	Sb	<1	<10
EC (µS/cm)	17,860	27,000	Se	<50	<10
EC (GCA, µS/cm)	21,800	29,100	B	200	400
TDS-(grav.)	13,091	18,000	Mo	29	120
Major-Ions (mg/L)			Mn	<100	42
			Al	<100	<50
Na	4,113	5,300	Cd	<2	<1
K	99	120	Pb	<50	<10
Mg	250.5	62	Cr	<100	<10
Ca	230.8	720	Bi	<1	<10
Cl	5,980	6,900	P	<1,000	<250
SO4	1,944	4,800	Ba	291	49
HCO3 (as CaCO3)	325	190	Sr	465	490
CO3 (as CaCO3)	58	10	Tl	<1	<10
F	1.0	<0.1	V	<100	<10
Si	8.3	1.2	Sn	<10	<10
			U	7	<10
Nitrogen-Forms (mg/L)			Th	<1	<10
NH3-N	14	34	***Cyanide-Complexing Metals (mg/L)***		
NO3-N	0.13	0.35			
			Fe	<0.1	<0.05
Cyanide Forms (mg/L)			Cu	<0.1	0.55
			Zn	<0.1	<0.05
CNtot	1.7	1.2	Ni	<0.1	<0.01
CNwad	<0.4	0.037	Co	0.030	0.92
CNfree	<0.2	<0.004	Ag	0.082	0.019
SCN	<1	590	Hg	<0.01	<0.0005

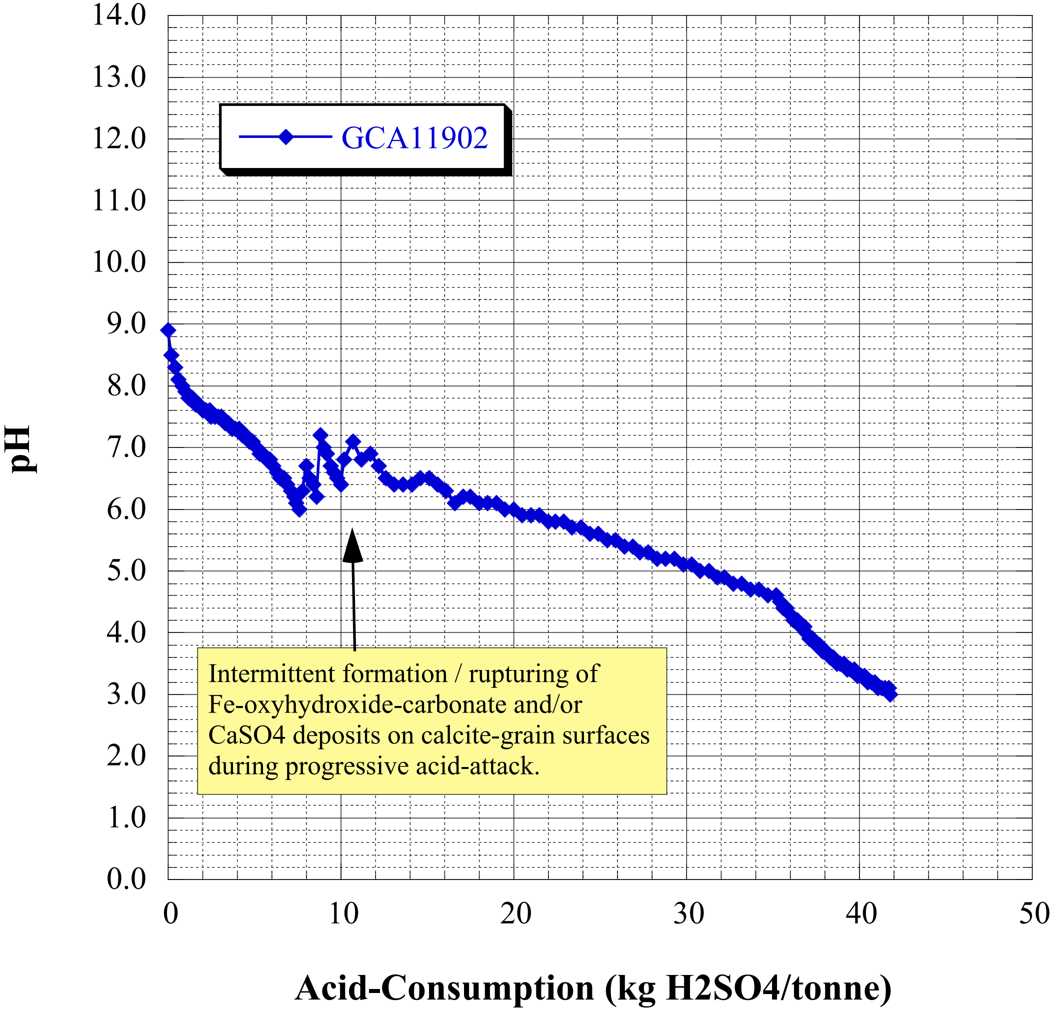
Notes:
EC = Electrical-Conductivity; TDS-(grav.) = Total-Dissolved-Solids-(gravimetric).
CNtot = Total-Cyanide; CNwad = Weak-Acid-Dissociable-Cyanide; CNfree = Free-Cyanide; SCN = thiocyanate

N.B. The Oxide-Ore-Tailings-Slurry-Water sample was assayed by GLS (Maddington), whereas the Primary-Ore-Tailings-Slurry-Water sample was assyed by SGS (Perth Airport). The analytical sensitivy for these laboratories vary slightly.

FIGURE

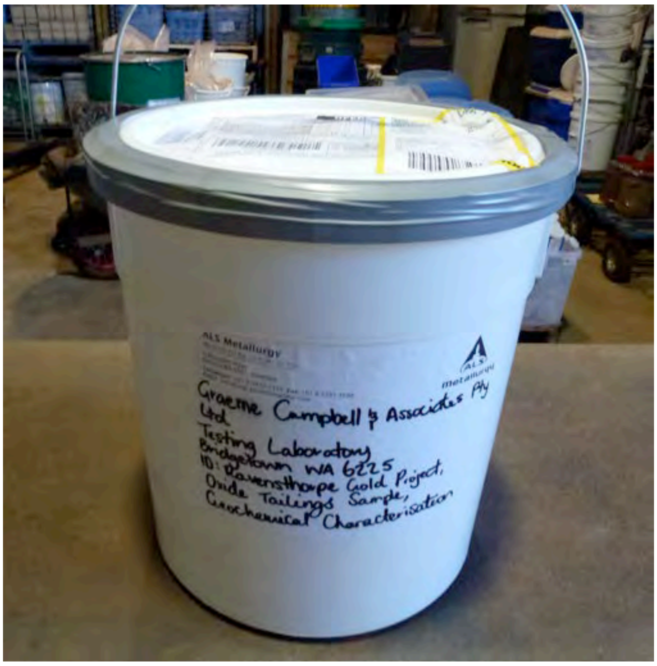
Figure 1

pH-Buffering Curve for Tailings-Solids Sample (Primary-Ore-Tailings)



PLATES

GCA11868 (Oxide-Ore-Tailings)



GCA11902 (Primary-Ore-Tailings)

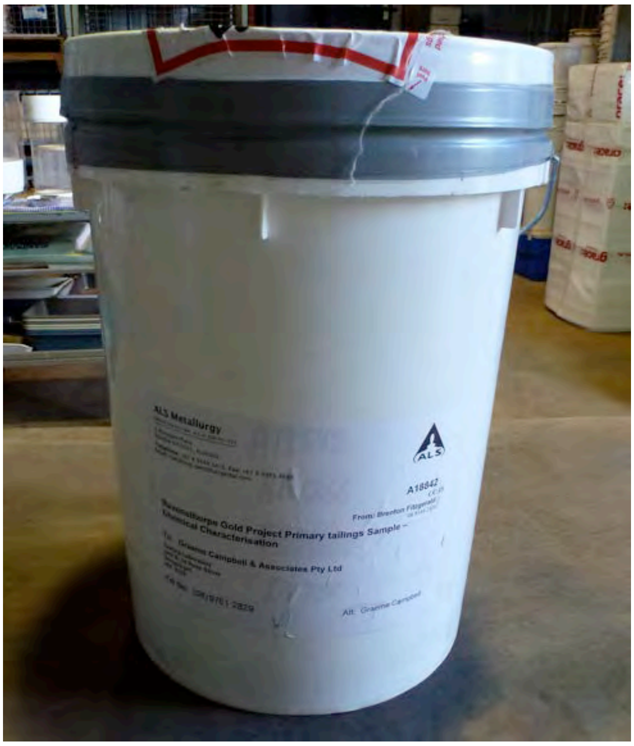


PLATE 1: Tailings-Slurry Samples Provided by ALS Metallurgy (Balcatta) 'As-Received' at GCA Testing Laboratory (Bridgetown).

PLATE 2: Acid-Neutralisation-Capacity (ANC) testing.

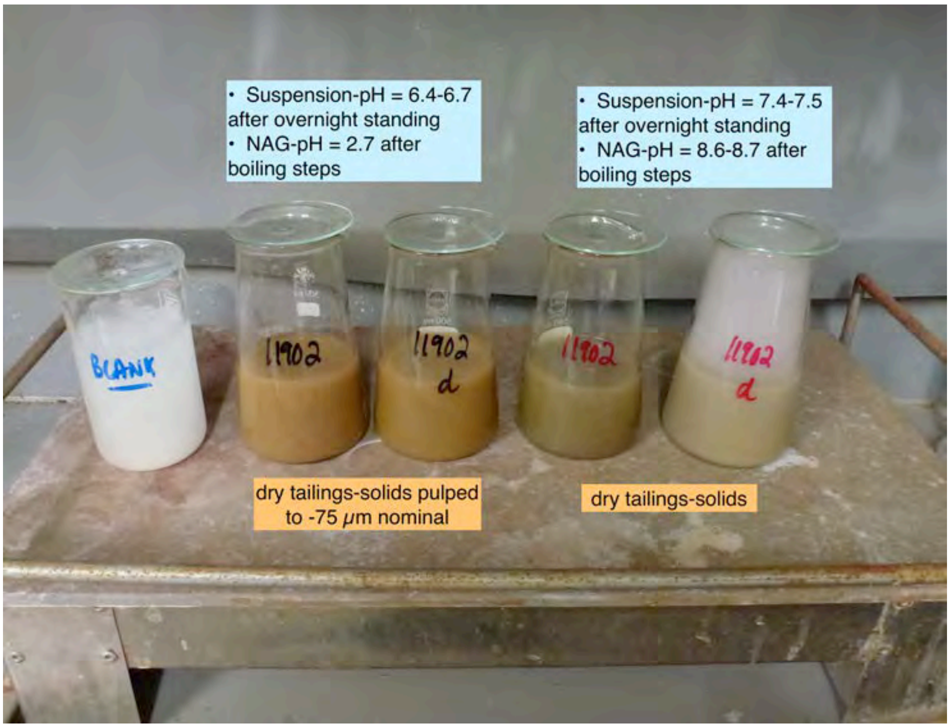


PLATE 3: Net-Acid-Generating (NAG) testing (1st boiling step prior to dosing with $CuSO_4$ solution to catalyse decomposition of residual unreacted H_2O_2 during 2nd boiling step).

ATTACHMENT I

DETAILS OF BENCH-SCALE METALLURGICAL TESTWORK STUDY

ACHMINERALS

To	Graeme Campbell & Associated Pty Ltd (GCA)
From	Paul Bennett
Subject	Origin of Oxide & Primary Ore Tailings Slurry Samples provided to GCA
Date	30 January 2018

1. Overview

This memorandum summarises the origin of the Oxide Ore Tailings Slurry Sample (Oxide Sample) and Primary Ore Tailings Sample (Primary Sample) forwarded to GCA to enable geochemical characterisation of these materials. As well as the origin, the memorandum also describes the processes these materials had been subjected to prior to dispatch to GCA.

2. Sample Origin

ACH Minerals Pty Ltd (ACH) owns 100% of the Kundip gold/copper project (Kundip & the Project) located 17km to the south east of Ravensthorpe in southern WA. ACH is conducting a feasibility study into the technical and commercial viability of Kundip. In April 2018, ACH commissioned ALS Metallurgy Pty Ltd (ALS) to undertake a program of metallurgical testwork on Kundip ores. The inventory of ores sent to ALS comprised approximately 658kg of diamond drill core from 69 individual core intervals. In addition, 435kg of oxide/fines material from an ore stockpile at the north eastern end of the Western Gem pit collected sent to ALS as feed for scrubber testwork.

2.1. Oxide Sample

The Oxide Sample was the tailings product of the testwork carried out on the Bulk Oxide Composite (BOC). BOC material was sourced from the oxide stockpile material provided as feed for scrubber testwork. When the material for the scrubber testwork had been collected, the remaining material was control crushed to P100 3.35mm, homogenised, blended and split to form charges for the BOC.

2.2. Primary Sample

The Primary Sample was the tailings product of the testwork carried out on the Bulk Sulphide Composite (BSC). The BSC was formed from 29 individual fresh core samples from Kundip. Each interval was separately crushed to minus 19mm then homogenised and split to form the BSC mass.

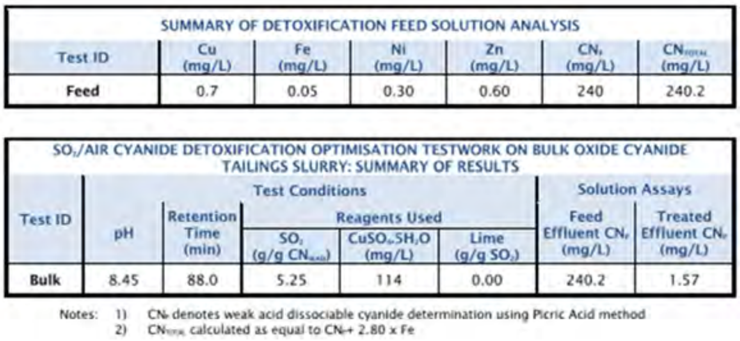
3. Sample Processes

3.1. Oxide Sample

The BOC was subjected to a series of testwork including;

- A sighter gravity amalgam, cyanidation leach (baseline bottle roll)
- A bulk gravity amalgam, cyanide leach test
- Cyanidation leach tailings treatment including;
    - Rheology testing
    - Sequential carbon loading
    - Equilibrium carbon loading
    - Cyanide detoxification testing

For the cyanide detoxification testing, an SO_2:CN ratio of 3.5:1 was selected based on 3x previous diagnostic tests. Details of the bulk discharge liquor and feed solution are summarised below;



SUMMARY OF DETOXIFICATION FEED SOLUTION ANALYSIS

Test ID	Cu (mg/L)	Fe (mg/L)	Ni (mg/L)	Zn (mg/L)	CN_W (mg/L)	CN_{TOTAL} (mg/L)
Feed	0.7	0.05	0.30	0.60	240	240.2

SO_2/AIR CYANIDE DETOXIFICATION OPTIMISATION TESTWORK ON BULK OXIDE CYANIDE TAILINGS SLURRY: SUMMARY OF RESULTS

Test ID	Test Conditions					Solution Assays	
	pH	Retention Time (min)	Reagents Used			Feed Effluent CN_W (mg/L)	Treated Effluent CN_W (mg/L)
			SO_2 (g/g CN_{WAD})	$CuSO_4.5H_2O$ (mg/L)	Lime (g/g SO_2)		
Bulk	8.45	88.0	5.25	114	0.00	240.2	1.57

Notes: 1) CN_W denotes weak acid dissociable cyanide determination using Picric Acid method
2) CN_{TOTAL} calculated as equal to CN_W+ 2.80 x Fe

At the optimal SO_2:CN ratio of 3.5:1, a CN_{WAD} level of < 5mg/L was achieved, using a single stage detoxification. The bulk test achieved a treated effluent CN_{WAD} level of 1.57mg/L.

The detoxified BOC tailings were then split and dispatched to GCA for geochemical characterisation and to Structerre for physical property testing.

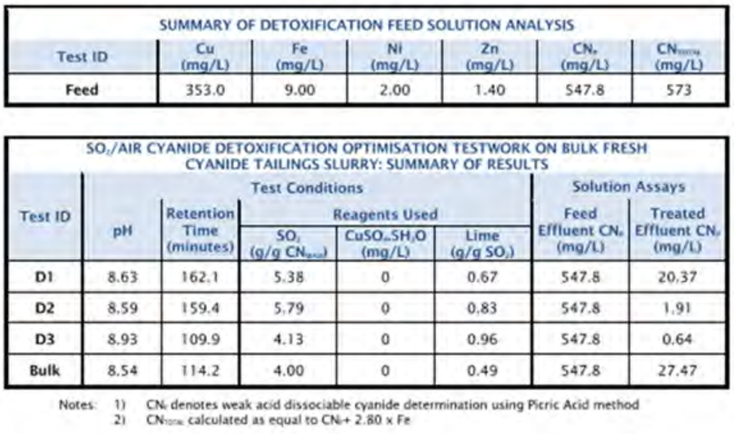
3.2. Primary Sample

A series of bulk (3 x 40L) flotation tests were undertaken on the BSC. Each flotation test was conducted on a 20kg flotation charge ground to P_{80} 75 microns.

Cyanidation leach testwork was undertaken on flotation tailings from the bulk flotation series. The 3 rougher concentrates were combined with the rougher tailings from the bulk flotation program and from this material a representative 40kg DWE charge was taken and submitted for bulk cyanidation leach.

Following the termination of the bulk leach, the leach slurry was representatively split for downstream testwork including rheology, sequential and equilibrium carbon loading and cyanide detoxification.

For the cyanide detoxification testing, an SO_2:CN ratio of 6:1 was selected based on 3x previous batch optimisation tests. Details of the batch and bulk discharge liquor and feed solution are summarised below;



SUMMARY OF DETOXIFICATION FEED SOLUTION ANALYSIS

Test ID	Cu (mg/L)	Fe (mg/L)	Ni (mg/L)	Zn (mg/L)	CN_w (mg/L)	CN_{TOTAL} (mg/L)
Feed	353.0	9.00	2.00	1.40	547.8	573

SO_2/AIR CYANIDE DETOXIFICATION OPTIMISATION TESTWORK ON BULK FRESH CYANIDE TAILINGS SLURRY: SUMMARY OF RESULTS

Test ID	Test Conditions					Solution Assays	
	pH	Retention Time (minutes)	Reagents Used			Feed Effluent CN_w (mg/L)	Treated Effluent CN_w (mg/L)
			SO_2 (g/g CN_{WAD})	$CuSO_4.5H_2O$ (mg/L)	Lime (g/g SO_2)		
D1	8.63	162.1	5.38	0	0.67	547.8	20.37
D2	8.59	159.4	5.79	0	0.83	547.8	1.91
D3	8.93	109.9	4.13	0	0.96	547.8	0.64
Bulk	8.54	114.2	4.00	0	0.49	547.8	27.47

Notes: 1) CN_w denotes weak acid dissociable cyanide determination using Picric Acid method
2) CN_{TOTAL} calculated as equal to CN_w+ 2.80 x Fe

Observations from testwork as follows;

- Target CN_{WAD} level of < 5mg/L was achieved for tests D2 & D3;
    - Test D1 and the bulk test achieved CN_{WAD} level of > 25mg/L
    - The bulk test appeared to suffer from a drop in SMBS dosage in the last 30 minutes of the test, resulting in the elevated level in the final effluent.

The detoxified BSC tailings were then split and dispatched to GCA for geochemical characterisation and to Structerre for physical property testing.

Source: Metallurgical Testwork conducted upon Samples from the Ravensthorpe Gold Project for ACH Minerals Pty Ltd/CPC Engineering, Report No. A18842, ALS Metallurgy, December 2018.

ATTACHMENT I

LABORATORY REPORTS

TOWNEND
mineralogy laboratory

Graeme Campbell and Assoc, 10-10-2018

PO Box 247

Bridgetown

WA 6255

Our reference 41317

Mineralogy (PLM/XRD) of one rock powder (GCA11868)

R Townend

ACN: 069 920 476
Unit 4, 40 Irvine Drive
Malaga. Western Australia 6090
Box 3129, Malaga D.C. WA 6945
Australia

ABN: 92 076 109 663
t +61 8 9248 1674
f +61 8 9248 1502
roger@townendmineralogy.com.au
www.townendmineralogy.com.au

RESULTS

POLISHED SECTION/XRD

	GCA11868
Quartz	Major
Kaolin	Major
Muscovite	Major
Ilmenite	Trace
Goethite	Accessory
Ti oxide	Trace

TOWNEND
mineralogy laboratory

Graeme Campbell and Assoc, 20-2-2019

Po Box 247

Bridgetown

WA 6255

Our reference 24358

Mineralogy of one pulp (SEM/XRDPLM)

R Townend

ACN: 069 920 476
Unit 4, 40 Irvine Drive
Malaga. Western Australia 6090
Box 3129, Malaga D.C. WA 6945
Australia

ABN: 92 076 109 663
t +61 8 9248 1674
f +61 8 9248 1502
roger@townendmineralogy.com.au
www.townendmineralogy.com.au

RESULTS

POLISHED SECTION/XRD/SEM

GCA	**11902**
Quartz	Major
Chlorite	Major
Albite	Minor
Mica	Accessory
Epidote	Accessory
Calcite	Trace
Fe Silicate (?)	Trace
Pyrite	Accessory
Pyrrhotite	Trace

Calcite	**SEM**
CaO	53.7%
MgO	0.3%
MnO	0.3%
FeO	1.7%

MINERALS
TEST REPORT

CLIENT

GRAEME CAMPBELL
CAMPBELL, GRAEME and ASSOCIATES
PO Box 247
BRIDGETOWN, W.A. 6255
AUSTRALIA

JOB INFORMATION

JOB CODE	:	143.0/1812884
NO. SAMPLES	:	1
NO. ELEMENTS	:	37
CLIENT ORDER NO.	:	GCA1815/2 (Job 1 of 1)
SAMPLE SUBMISSION NO.	:	
PROJECT	:	RAVENSTHORPE
SAMPLE TYPE	:	Taillings
DATE RECEIVED	:	29/08/2018
DATE REPORTED	:	28/09/2018
DATE PRINTED	:	28/09/2018

REPORT NOTES

TESTED BY

Intertek
15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100
Email: min.aus.per@intertek.com

Accredited for compliance with ISO/IEC 17025.
Company Accreditation Number 3244

NOTES

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

Analysing Laboratory: Intertek Genalysis Perth

The contents of this report have been prepared in accordance with the terms of NATA accreditation and as such should only be reproduced in full.

The analysis results reported herein have been obtained using the following methods and conditions:

Project:Ravensthorpe

The sample as listed was received as a wet tailings solid
The tailings-solids sample was oven-dried @ 80 oC as for acid-sulphate-soil testing.

Approx. 200g were pulped using the zirconia-bowl.

The results have been determined according to Genalysis methods codes :
Digestions : MPL_W002 (4A/), MPL_W005 (SE1/), ENV_W012 (FC7/SIE), MPL_W011 (FP1/) and MPL_W008 (HG1/

Analytical Finishes: ICP_W004 (/OE), ICP_W003 (/MS) and AAS_W004 (/CV)
1.Total-C and Total-S were determined using an induction furnace
The samples are ignited in oxygen ~1700C and the CO_2 and SO_2 measured by infrared detectors
Genalysis method number MPL_W043.

2.C-Acinsol (acid insoluble carbon) by a C&S analyser after removal of carbonates
and soluble organic carbon using hot hydrochloric acid
Genalysis method number MPL_W046

The results included the assay of blanks and international reference standards:
GSP-2, OREAS 45d, AMIS0342 and OREAS 24b
Genalysis in house standards:
TOC-1a , OREAS 97.01 and HgSTD-8

The results are expressed as parts per million or percent by mass in the dried and prepared material.

This report relates specifically to the sample(s) tested that were drawn and/or provided by the client or their nominated third party to Intertek. The reported result(s) provide no warranty or verification on the sample(s) representing any specific goods and/or shipment. This report was prepared solely for the use of the client named in this report. Intertek accepts no responsibility for any loss, damage or liability suffered by a third party as a result of any reliance upon or use of this report. The results provided are not intended for commercial settlement purposes.
Except where explicitly agreed in writing, all work and services performed by Intertek is subject to our standard Terms and Conditions which can be obtained at our website: intertek.com/terms/
JOB NO : 143.0/1812884
CLIENT REF : GCA1815/2
Page 3 of 9

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that figures beyond the least significant digit have significance.

For more information on the uncertainty on individual reported values, please contact the laboratory.

SAMPLE STORAGE

All solid samples (assay pulps, bulk pulps and residues will be stored for 60 days without charge. Following this samples will be stored at a daily rate until clients written advice regarding return, collection or disposal is received. If storage information is not supplied on the submission, or arranged with the laboratory in writing the default will be to store the samples with the applicable charges. Storage is charged at $4.00 per m3 per day, expenses related to the return or disposal of samples will be charged at cost. Current disposal cost is charged at $150.00 per m3.

Samples received as liquids, waters or solutions will be held for 60 days free of charge then disposed of, unless written advice fo return or collection is received.

LEGEND

X = Less than Detection Limit
SNR = Sample Not Received
* = Result Checked
DTF = Result still to come
IS = Insufficient Sample for Analysis
NA = Not Analysed
UA = Unable to Assay
> = Value beyond Limit of Method
\+ = Extra Sample Received Not Listed

ELEMENTS	Ag	Al	As	B	Ba	Bi	C	C-Acinsol	C-CO3	Ca
UNITS	ppm	%	ppm	ppm	ppm	ppm	%	%	%	%
DETECTION LIMIT	0.01	0.01	0.5	50	0.1	0.01	0.01	0.01	0.01	0.1
DIGEST	4A/	FP1/	4A/	FP1/	4A/	4A/		C71/		FP1/
ANALYTICAL FINISH	MS	OE	MS	OE	MS	MS	/CSA	CSA	/CALC	OE
SAMPLE NUMBERS										
0001 GCA11868	0.53	8.19	33.7	X	319.1	2.75	0.06	0.06	X	0.1
CHECKS										
0001 GCA11868	0.55	8.24	32.5	X	317.5	2.80	0.06	0.07		0.1
STANDARDS										
0001 OREAS 24b							0.19			
0002 TOC-1a								1.13		
0003 GSP-2	0.07		1.2		1285.0	0.04				
0004 HgSTD-8										
0005 OREAS 45d		8.19		X						0.3
0006 AMIS0342										
0007 OREAS 97.01										
BLANKS										
0001 Control Blank	X	X	X	X	X	X	X	X		X

ELEMENTS	Cd	Co	Cr	Cu	F	Fe	Hg	K	Mg	Mn
UNITS	ppm	ppm	ppm	ppm	ppm	%	ppm	%	%	ppm
DETECTION LIMIT	0.02	0.1	50	1	50	0.01	0.01	0.05	0.01	1
DIGEST	4A/	4A/	FP1/	4A/	FC7/	FP1/	HG1/	FP1/	FP1/	4A/
ANALYTICAL FINISH	MS	MS	OE	OE	SIE	OE	CV	OE	OE	OE
SAMPLE NUMBERS										
0001 GCA11868	X	8.6	344	174	156	3.40	X	2.05	0.14	36
CHECKS										
0001 GCA11868	X	8.0	342	173	160	3.43	X	2.06	0.13	37
STANDARDS										
0001 OREAS 24b										
0002 TOC-1a										
0003 GSP-2	0.05	6.5		43						303
0004 HgSTD-8							2.98			
0005 OREAS 45d			595			14.77		0.43	0.25	
0006 AMIS0342					1112					
0007 OREAS 97.01										
BLANKS										
0001 Control Blank	X	X	X	X	X	0.01	X	X	X	X

ELEMENTS	Mo	Na	Ni	P	Pb	S	S	Sb	Se	Si
UNITS	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	%
DETECTION LIMIT	0.1	20	1	10	0.5	0.01	50	0.05	0.01	0.1
DIGEST	4A/	4A/	4A/	4A/	4A/		4A/	4A/	SE1/	FP1/
ANALYTICAL FINISH	MS	OE	OE	OE	MS	/CSA	OE	MS	MS	OE
SAMPLE NUMBERS										
0001 GCA11868	8.2	2370	153	49	8.4	0.05	327	0.40	0.72	34.0
CHECKS										
0001 GCA11868	8.2	2367	162	48	8.6	0.04	339	0.32	0.73	33.9
STANDARDS										
0001 OREAS 24b						0.20				
0002 TOC-1a										
0003 GSP-2	2.0	1.94%	17	1280	32.8		486	0.32		
0004 HgSTD-8										
0005 OREAS 45d										23.8
0006 AMIS0342										
0007 OREAS 97.01									0.61	
BLANKS										
0001 Control Blank	X	X	X	X	X	X	X	X	X	X

ELEMENTS	Sn	Sr	Th	Ti	Ti	Tl	U	V	Zn
UNITS	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm
DETECTION LIMIT	0.1	0.05	0.01	0.01	5	0.02	0.01	1	1
DIGEST	4A/	4A/	4A/	FP1/	4A/	4A/	4A/	4A/	4A/
ANALYTICAL FINISH	MS	MS	MS	OE	OE	MS	MS	OE	OE
SAMPLE NUMBERS									
0001 GCA11868	7.0	17.40	2.50	0.32	1951	0.15	0.53	61	5
CHECKS									
0001 GCA11868	6.8	17.08	2.38	0.32	1886	0.15	0.56	73	6
STANDARDS									
0001 OREAS 24b									
0002 TOC-1a									
0003 GSP-2	5.3	216.19	97.92		3639	1.13	1.76	47	124
0004 HgSTD-8									
0005 OREAS 45d				0.87					
0006 AMIS0342									
0007 OREAS 97.01									
BLANKS									
0001 Control Blank	X	X	X	X	13	X	X	X	X

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
/CALC	Intertek Genalysis Perth **3244 3237** No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.	
/CSA	Intertek Genalysis Perth **3244 3237** Induction Furnace Analysed by Infrared Spectrometry	**MPL_W043, CSA : MPL_W043**
4A/MS	Intertek Genalysis Perth **3244 3237** Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Mass Spectrometry.	**4A/ : MPL_W002, MS : ICP_W003**
4A/OE	Intertek Genalysis Perth **3244 3237** Multi-acid digest including Hydrofluoric, Nitric, Perchloric and Hydrochloric acids in Teflon Tubes. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.	**4A/ : MPL_W002, OE : ICP_W004**
C71/CSA	Intertek Genalysis Perth **3244 3237** Digestion by hot acid(s) and Induction Furnace Analysed by Infrared Spectrometry	
FC7/SIE	Intertek Genalysis Perth **3244 3237** Alkaline fusion (Nickel crucible) specific for Fluorine. Analysed by Specific Ion Electrode.	**ENV_W012, SIE : ENV_W012**
FP1/OE	Intertek Genalysis Perth **3244 3237** Sodium peroxide fusion (Zirconia crucibles) and Hydrochloric acid to dissolve the melt. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.	**FP1/ : MPL_W011, OE : ICP_W004**
HG1/CV	Intertek Genalysis Perth **3244 3237** Low temperature Perchloric acid digest specific for Mercury. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.	

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
SE1/MS	Intertek Genalysis Perth **3244 3237** Aqua-Regia digest followed by Precipitation and Concentration. Specific for Selenium. Analysed by Inductively Coupled Plasma Mass Spectrometry.	

MINERALS
TEST REPORT

CLIENT

GRAEME CAMPBELL
CAMPBELL, GRAEME and ASSOCIATES
PO Box 247
BRIDGETOWN, W.A. 6255
AUSTRALIA

JOB INFORMATION

JOB CODE : 143.0/1900281
NO. SAMPLES : 1
NO. ELEMENTS : 7
CLIENT ORDER NO. : GCA1815/2 (Job 1 of 1)
SAMPLE SUBMISSION NO. :
PROJECT : RAVENSTHORPE
SAMPLE TYPE : Various
DATE RECEIVED : 08/01/2019
DATE REPORTED : 17/01/2019
DATE PRINTED : 17/01/2019

REPORT NOTES

TESTED BY

Intertek
15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100
Email: min.aus.per@intertek.com

Accredited for compliance with ISO/IEC 17025.
Company Accreditation Number 3244

NOTES
NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

Analysing Laboratory: Intertek Genalysis Perth

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The analysis results reported herein have been obtained using the following methods and conditions:

Project:Ravensthorpe
The samples as listed were received as:
oven-dried (80oC) tailings-solids sieved to -2mm
The entire sample was fine pulverised nominal -75um using a zirconia bowl.

The results have been determined according to Genalysis methods codes
Digestions : MPL_W005 (SE1/) and MPL_W008 (HG1/

Analytical Finishes: ICP_W003 (/MS) and AAS_W004 (/CV)

1.Total-C and Total-S were determined using an induction furnace
The samples are ignited in oxygen ~1700°C and the CO2 and SO2 measured by infrared detectors
Genalysis method code MPL_W043.

2.C-Acinsol (acid insoluble carbon) by a C&S analyser after removal of carbonates
and soluble organic carbon using hot hydrochloric acid
Genalysis method code MPL_W046

3. S-SO4 was determined on the pulps by precipitation of BaSO4 after digestion with Na2CO3
Genalysis method code ENV_W039, (S72/GR)

The results included the assay of blanks and international reference standards:
PD-1, GTS-2a and OREAS 45h
Genalysis in house standards:
TOC-1a and Se 0.1ppm

Intertek Genalysis signatory
Ann Patricia EVERS
Chief Chemist

Ann Evers

Date: 17-Jan-2019

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that figures beyond the least significant digit have significance.

For more information on the uncertainty on individual reported values, please contact the laboratory.

SAMPLE STORAGE

All solid samples (assay pulps, bulk pulps and residues will be stored for 60 days without charge. Following this samples will be stored at a daily rate until clients written advice regarding return, collection or disposal is received. If storage information is not supplied on the submission, or arranged with the laboratory in writing the default will be to store the samples with the applicable charges. Storage is charged at $4.00 per m3 per day, expenses related to the return or disposal of samples will be charged at cost. Current disposal cost is charged at $150.00 per m3.

Samples received as liquids, waters or solutions will be held for 60 days free of charge then disposed of, unless written advice fo return or collection is received.

LEGEND

X = Less than Detection Limit
SNR = Sample Not Received
* = Result Checked
DTF = Result still to come
IS = Insufficient Sample for Analysis
NA = Not Analysed
UA = Unable to Assay
> = Value beyond Limit of Method
\+ = Extra Sample Received Not Listed

ELEMENTS	C	C-Acinsol	C-CO3	Hg	S	S-SO4	Se
UNITS	%	%	%	ppm	%	%	ppm
DETECTION LIMIT	0.01	0.01	0.01	0.01	0.01	0.01	0.01
DIGEST		C71/		HG1/		S72/	SE1/
ANALYTICAL FINISH	/CSA	CSA	/CALC	CV	/CSA	GR	MS
SAMPLE NUMBERS							
0001 GCA11902	0.35	0.02	0.33	0.05	3.04	0.12	0.80
CHECKS							
0001 GCA11902	0.35	0.02	0.33	0.05	3.00	0.14	0.79
STANDARDS							
0001 OREAS 45h	0.48				0.02		
0002 PD-1						4.08	
0003 TOC-1a		1.20					
0004 Se 0.1ppm							0.09
0005 GTS-2a				0.25			
BLANKS							
0001 Control Blank	X	X		X	X	0.05	X

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory NATA Laboratory Accreditation	NATA Scope of Accreditation
/CALC	Intertek Genalysis Perth **3244 3237** No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.	
/CSA	Intertek Genalysis Perth **3244 3237** Induction Furnace Analysed by Infrared Spectrometry	**MPL_W043, CSA : MPL_W043**
C71/CSA	Intertek Genalysis Perth **3244 3237** Digestion by hot acid(s) and Induction Furnace Analysed by Infrared Spectrometry	
HG1/CV	Intertek Genalysis Perth **3244 3237** Low temperature Perchloric acid digest specific for Mercury. Analysed by Cold Vapour Generation Atomic Absorption Spectrometry.	
S72/GR	Intertek Genalysis Perth **3244 3237** Digestion in boiling Na_2CO_3 solution to dissolve sulphate sulphur. Analysed by Gravimetric Technique	
SE1/MS	Intertek Genalysis Perth **3244 3237** Aqua-Regia digest followed by Precipitation and Concentration. Specific for Selenium. Analysed by Inductively Coupled Plasma Mass Spectrometry.	

Accreditation No. 2562

ANALYTICAL REPORT

CLIENT DETAILS / LABORATORY DETAILS

Contact	Graeme Campbell	Manager	Ros Ma
Client	Graeme Campbell & Associates Pty Ltd	Laboratory	SGS Perth Environmental
Address	PO Box 247 Bridgetown WA 6255	Address	28 Reid Rd Perth Airport WA 6105
Telephone	0897 612 829	Telephone	(08) 9373 3500
Facsimile	0897 612 830	Facsimile	(08) 9373 3556
Email	gca@wn.com.au	Email	au.environmental.perth@sgs.com
Project	**GCA Job No. 1815/2**	SGS Reference	**PE128582 R0**
Order Number	**GCA Job No. 1815/2**	Date Received	05 Sep 2018
Samples	3	Date Reported	17 Sep 2018

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

SIGNATORIES

Mary Ann Ola-A
Inorganics Team Leader

Parameter	Units	LOR	Sample Number: PE128582.001 Sample Matrix: Solid Sample Name: GCA11868 (Solid)	Sample Number: PE128582.002 Sample Matrix: Water Sample Name: GCA11868 (Solution)

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/9/2018

Chromium Reducible Sulphur (Scr)	%	0.005	<0.005	-
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5	-
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	<0.25	-

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/9/2018

Nitrate Nitrogen, NO_3 as N	mg/L	0.05	-	0.13

Ammonia Nitrogen by FIA Method: AN261 Tested: 12/9/2018

Ammonia Nitrogen, NH_3 as N	mg/L	0.05	-	14

		Sample Number	PE128582.003
		Sample Matrix	Solid
		Sample Name	GCA11868 (Solid)_DUP
Parameter	Units	LOR	

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 12/9/2018

Chromium Reducible Sulphur (Scr)	%	0.005	<0.005
Chromium Reducible Sulphur (Scr)	moles H+/T	5	<5
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	<0.25

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 12/9/2018

Nitrate Nitrogen, NO_3 as N	mg/L	0.05	-

Ammonia Nitrogen by FIA Method: AN261 Tested: 12/9/2018

Ammonia Nitrogen, NH_3 as N	mg/L	0.05	-

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Ammonia Nitrogen by FIA **Method: ME-(AU)-[ENV]AN261**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Ammonia Nitrogen, NH_3 as N	LB150395	mg/L	0.05	<0.05	0 - 1%	101 - 105%

Chromium Reducible Sulphur (CRS) **Method: ME-(AU)-[ENV]AN217**

Parameter	QC Reference	Units	LOR	DUP %RPD	LCS %Recovery
Chromium Reducible Sulphur (Scr)	LB150476	%	0.005	0%	83 - 90%

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA **Method: ME-(AU)-[ENV]AN258**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Nitrate Nitrogen, NO_3 as N	LB150395	mg/L	0.05	<0.05	0 - 6%	NA

METHOD	METHODOLOGY SUMMARY
	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN217	Dried pulped sample is mixed with acid and chromium metal in a rapid distillation unit to produce hydrogen sulfide (H2S) which is collected and titrated with iodine (I2(aq)) to measure SCR.
AN261	Ammonia by Continuous Flow Analyser: Ammonium in a basic medium forms ammonia gas, which is separated from the sample matrix by diffusion through a polypropylene membrane. The ammonia is reacted with phenol and hypochlorite to form indophenol blue at an intensity proportional to the ammonia concentration. The blue colour is intensified with sodium nitroprusside and the absorbance measured at 630 nm. The sensitivity of the automated method is 10-20 times that of the macro method. Reference APHA 4500-NH3 H.

FOOTNOTES

IS	Insufficient sample for analysis.	LOR	Limit of Reporting
LNR	Sample listed, but not received.	↑↓	Raised or Lowered Limit of Reporting
*	NATA accreditation does not cover the performance of this service.	QFH	QC result is above the upper tolerance
**	Indicative data, theoretical holding time exceeded.	QFL	QC result is below the lower tolerance
		-	The sample was not analysed for this analyte
		NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:
a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

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ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS

Contact	Graeme Campbell
Client	Graeme Campbell & Associates Pty Ltd
Address	PO Box 247 Bridgetown WA 6255
Telephone	0897 612 829
Facsimile	0897 612 830
Email	gca@wn.com.au
Project	**GCA Job No. 1815/2**
Order Number	**GCA Job No. 1815/2**
Samples	1

LABORATORY DETAILS

Manager	Ros Ma
Laboratory	SGS Perth Environmental
Address	28 Reid Rd Perth Airport WA 6105
Telephone	(08) 9373 3500
Facsimile	(08) 9373 3556
Email	au.environmental.perth@sgs.com
SGS Reference	**PE131835 R0**
Date Received	10 Jan 2019
Date Reported	24 Jan 2019

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

Four-Acid digest subcontracted to SGS Perth Minerals, 28 Reid Rd Perth Airport WA, NATA Accreditation Number 1936, WM190471

SIGNATORIES

Michael McKay
Inorganics and ARD Supervisor

		Sample Number	PE131835.001
		Sample Matrix	Pulp
		Sample Name	GCA 11902
Parameter	Units	LOR	

Metals in soil by Four Acid digest, ICPMS Method: IMS40Q Tested: 22/1/2019

Silver, Ag*	ppm	0.1	2.5
Arsenic, As*	ppm	1	35
Barium, Ba*	ppm	1	160
Bismuth, Bi*	ppm	0.1	2.4
Cadmium, Cd*	ppm	0.1	0.9
Cobalt, Co*	ppm	0.1	190
Molybdenum, Mo*	ppm	0.1	38
Lead, Pb*	ppm	1	63
Antimony, Sb*	ppm	0.1	0.5
Selenium, Se*	ppm	2	<2
Tin, Sn*	ppm	0.3	2.2
Strontium, Sr*	ppm	0.1	24
Thorium, Th*	ppm	0.05	3.3
Thallium, Tl*	ppm	0.2	0.2
Uranium, U*	ppm	0.05	1.6

ICPAES after Four Acid Digest Digest Method: ICP40Q Tested: 22/1/2019

Aluminium, Al*	ppm	100	57000
Calcium, Ca*	ppm	40	12000
Chromium, Cr*	ppm	10	500
Copper, Cu*	ppm	5	940
Iron, Fe*	ppm	100	110000
Potassium, K*	ppm	100	8600
Magnesium, Mg*	ppm	20	24000
Manganese, Mn*	ppm	5	650
Sodium, Na*	ppm	50	11000
Nickel, Ni*	ppm	5	350
Phosphorus, P*	ppm	20	380
Sulphur, S*	ppm	20	28000
Titanium, Ti*	ppm	10	2200
Vanadium, V*	ppm	1	71
Zinc, Zn*	ppm	5	230

Rare Earth Metals in soil by ICPMS Method: IMS12S Tested: 22/1/2019

Mercury, Hg*	ppm	0.1	<0.1

		Sample Number	PE131835.001
		Sample Matrix	Pulp
		Sample Name	GCA 11902
Parameter	Units	LOR	

Metals in Soils from Alkali Fusion ICP AES Method: ICP90Q Tested: 22/1/2019

Silicon, Si*	%	0.42	27.5
Boron, B*	ppm	20	<20

Chromium Reducible Sulphur (CRS) Method: AN217 Tested: 21/1/2019

Chromium Reducible Sulphur (Scr)	%	0.005	1.7
Chromium Reducible Sulphur (Scr)	moles H+/T	5	1100
Chromium Reducible Sulphur (Scr)	kg H2SO4/T	0.25	54

Total Fluoride in Soil Method: AN142 Tested: 23/1/2019

Total Fluoride	mg/kg	50	130

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Chromium Reducible Sulphur (CRS) Method: ME-(AU)-[ENV]AN217

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Chromium Reducible Sulphur (Scr)	LB155168	%	0.005	<0.005	2%	93%
Chromium Reducible Sulphur (Scr)	LB155168	moles H+/T	5	<5		
Chromium Reducible Sulphur (Scr)	LB155168	kg H2SO4/T	0.25	<0.25		

Total Fluoride in Soil Method: ME-(AU)-[ENV]AN142

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
Total Fluoride	LB155233	mg/kg	50	<50	101%	109%

METHOD	METHODOLOGY SUMMARY
AN142	Fluoride can be measured in soil as water extractable or 'total' by Ion Selective electrode. In this method the solid sample is weighed and then fused with sodium hydroxide at 600°C. The sample is carefully neutralise with hydrochloric acid and the solution of the melt is cooled and made up to volume. The final solution is then compared to synthetic Digestion Matrix standards with analysis by ISE electrode for a total fluoride result after being calculated back to original mass.
AN217	Dried pulped sample is mixed with acid and chromium metal in a rapid distillation unit to produce hydrogen sulfide (H2S) which is collected and titrated with iodine (I2(aq)) to measure SCR.
ICP40Q	Sample solutions (from Four Acid digest) are analysed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) against matched standards.
ICP90Q	Sample solutions (from Alkali Fusion) are analysed by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) against matched standards.
IMS12S	Sample solutions are analysed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) against matched standards.
IMS40Q	Sample solutions (from Four Acid Digest) are analysed by Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) against matched standards.

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	NATA accreditation does not cover the performance of this service.
**	Indicative data, theoretical holding time exceeded.

LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	The sample was not analysed for this analyte
NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf

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ACID-NEUTRALISATION-CAPACITY (ANC) TESTWORK: BASED ON AMIRA (2002) WITH VARIATIONS TO CONSTRAIN DISSOLUTION OF NON-CARBONATE-MINERALS UNRELATED TO CIRCUM-NEUTRAL BUFFERING SAVE FOR VANISHINGLY-SMALL RATES OF PYRITE OXIDATION

SAMPLE		HCl		milli moles H+ Added	Digest-Slurry-Final-pH	NaOH		milli moles OH- Added	pH after H_2O_2 Added	BULK-ANC (kg H_2SO_4/ tonne)
ID	WT (g)	Conc. (M)	Pipette Volume (mL)			Conc. (M)	Titre Volume (mL)			
GCA11868	15.14	0.10	10	1.00	4.0	0.05	3.50	0.175	> 4.0	**3**
GCA11868	15.13	0.10	10	1.00	3.9	0.05	3.70	0.185	> 4.0	**3**
GCA11868	10.12	0.10	10	1.00	3.0	0.05	9.30	0.465	> 4.0	**3**
GCA11868	10.02	0.10	10	1.00	3.1	0.05	8.80	0.440	> 4.0	**3**
ANC Std	5.02	0.10	25	2.50	2.0	0.05	7.90	0.395	> 4.0	21
ANC Std d	5.02	0.10	25	2.50	2.1	0.05	7.80	0.390	> 4.0	21
0.1 M-HCl	-	0.10	15	1.50		0.05	30.05	1.50		100.2%
0.1 M-HCl (d)	-	0.10	15	1.50		0.05	30.10	1.51		100.3%

Notes:

1. Testing performed on **dried tailings-solids.**
2. ***ca.* 20 mL** of high-purity-deionised-water (HPDW) added to all samples (including HCl-solution 'blanks') initially.
3. HCl solution added manually via volumetric glass pipette (A Class).
4. **HCl** and **NaOH** solutions certified reagents from Merck (viz. Titripur® reagents in hermetically-sealed Titripac® casks).
5. Sample weight, and volume and strength of HCl added, based on corresponding CO_3-C value(s).
6. During acid-digestion temperature of waterbath is **80 +/- 5 oC,** and digestion performed for **1.0 hr** with beakers swirled by hand 1-2 times during this reaction period. Digestion performed using 250 mL tall-form beakers covered with watchglasses.
7. After completion of acid-digestion step, the test-slurry is boiled for *ca.* 1 min to expel any dissolved CO_2(aq).
8. Following cooling to room-T, **digest-slurry-final-pH** is measured. HPDW is then added to bring test-slurry volume to *ca.* **125 mL** for titration with NaOH solution.
9. Titration with NaOH performed manually using 50 mL glass burette with slurry stirred using magnetic stirrer-bar. Fast titration with stopcock fully open until slurry-pH rises to approximate range 4.0-4.5 when titration stops for H_2O_2 addition.
10. Three drops of **30 % H_2O_2 (v/v)** [adjusted to pH 4.5] added to slurry to oxidise **soluble-Fe(II)** forms ('latent-acidity') and precipitation of Fe(III)/Al-oxyhydroxides, etc. Minimum slurry-pH attained following H_2O_2 addition recorded.
11. Following completion of H_2O_2 addition, titration with NaOH continues to a **pH=7** end-point. Titration with NaOH undertaken so that slurry-pH at end-point is within range 6.9-7.1 (i.e. pH 7.0 +/- 0.1) for *ca.* 30 seconds. [Related pH-end-point stability criteria for manual titration (cf. autotititration) option applies in ASTM E1915-13, and AS-4969.12-09].
12. ANC Standard is pulped mixture of quartz and AR $CaCO_3$ (CO_3-C = 0.27 %; ANC = 22 kg H_2SO_4/tonne).

The main variation to the AMIRA (2002) method is initial 'applied HCl loading', as governed by CO_3-C value.

Dr GD Campbell
17th September 2018

ACID-NEUTRALISATION-CAPACITY (ANC) TESTWORK: BASED ON AMIRA (2002) WITH VARIATIONS TO CONSTRAIN DISSOLUTION OF NON-CARBONATE-MINERALS UNRELATED TO CIRCUM-NEUTRAL BUFFERING SAVE FOR VANISHINGLY-SMALL RATES OF PYRITE OXIDATION

SAMPLE		**HCl**		**milli**	**Digest-**	**NaOH**		**milli**	**pH**	**Vigour of**	**BULK-**	
ID	**WT (g)**	**Conc. (M)**	**Pipette Volume (mL)**	**moles H+ Added**	**Slurry-Final-pH**	**Conc. (M)**	**Titre Volume (mL)**	**moles OH- Added**	**after H2O2 Added**	**'Fizzing' from HCl Addition ('in-the-cold')**	**ANC (kg H2SO4/ tonne)**	
GCA11902	4.80	0.10	30	3.00	2.8	0.05	16.30	0.815	2.7	moderate-to-strong	**22**	magnetite
GCA11902 d	4.80	0.10	30	3.00	2.8	0.05	16.85	0.843	2.8		**22**	magnetite
GCA11902 *	5.00	0.10	30	3.00	3.0	0.05	15.40	0.770	2.8		**22**	magnetite
GCA11902* d	5.00	0.10	30	3.00	3.1	0.05	13.90	0.695	2.8		**23**	magnetite
ANC Std	5.00	0.10	25	2.50	1.8	0.05	7.75	0.388	> 4.0		21	
ANC Std d	5.00	0.10	25	2.50	1.8	0.05	7.75	0.388	> 4.0		21	
0.1 M-HCl	-	0.10	10	1.00		0.05	20.10	1.01			100.5%	
0.1 M-HCl (d)	-	0.10	10	1.00		0.05	20.15	1.01			100.8%	

Notes:

1. Testing performed on dried tailings-solids samples (see below). **'Fizz' testing** employed 2-3 M-HCl determined on pulps.
2. ***ca.* 20 mL** of high-purity-deionised-water (HPDW) added to all samples (including HCl-solution 'blanks') initially.
3. HCl solution added manually via volumetric glass pipette (A Class).
4. **HCl** and **NaOH** solutions certified reagents from Merck (viz. Titripur® reagents in hermetically-sealed Titripac® casks).
5. Sample weight, and volume and strength of HCl added, based on corresponding CO3-C value(s).
6. During acid-digestion temperature of waterbath is **80 +/- 5 oC,** and digestion performed for **1.0 hr** with beakers swirled by hand 1-2 times during this reaction period. Digestion performed using 250 mL tall-form beakers covered with watchglasses.
7. After completion of acid-digestion step, the test-slurries are boiled for *ca.* 1 min to expel any dissolved CO2(aq) which is important for the attainment of a stable pH7 end-point in the subsequent back-titration with NaOH solution.
8. Following cooling to room-T, **digest-slurry-final-pH** is measured. HPDW is then added to bring test-slurry volume to *ca.* **125 mL** for titration with NaOH solution.
9. Titration with NaOH performed manually using 50 mL glass burette with slurry stirred using magnetic stirrer-bar. Fast titration with stopcock fully open until slurry-pH rises to approximate range 4.0-4.5 when titration stops for H2O2 addition.
10. Three drops of **30 % H2O2 (v/v)** [adjusted to pH 4.5] added to slurry to oxidise **soluble-Fe(II)** forms ('latent-acidity') and precipitation of Fe(III)/Al-oxyhydroxides, etc. Minimum slurry-pH attained following H2O2 addition recorded.
11. Following completion of H2O2 addition, titration with NaOH continues to a **pH7** end-point. Titration with NaOH undertaken so that slurry-pH at end-point is within range 6.9-7.1 (i.e. pH 7.0 +/- 0.1) for *ca.* 30 seconds. [Related pH-end-point stability criteria for manual titration (cf. autotititration) option applies in ASTM E1915-13, and AS-4969.12-09].
12. ANC Standard is pulped mixture of quartz and AR CaCO3 (CO3-C = 0.27 %; ANC = 22 kg H2SO4/tonne).
13. Samples with 'magnetite' noted were characterised by a deposit clinging to magnetic-stirrer bar retrieved after completion of titration with NaOH solution.

For GCA11902, testing performed on **pulps** (nominal -75 µm).
For GCA11902*, testing corresponds to dried-tailings (80 oC) without pulping.

The main variation to the AMIRA (2002) method is the initial 'applied HCl loading', as governed by the CO3-C value.

Dr GD Campbell
22nd February 2019

Graeme Campbell & Associates Pty Ltd
Laboratory Report

NET-ACID-GENERATION (NAG) TESTWORK (SINGLE-ADDITION)

Sample_ ID	Sample Weight (g)	Comments	pH of Test-Suspension After O'Night Reaction [Before Boiling Steps]	Test-Suspension Values After 2nd-Boiling Step [Cu(II) Added Before Boiling]		Titre (mL) (0.1 M-NaOH)		NAG (kg H2SO4/tonne)		
				NAG-pH	NAG-EC (µS/cm)	To pH 4.5	pH 4.5 to pH 7.0	To pH 4.5	pH 4.5 to pH 7.0	To pH 7.0
GCA11902	3.00	reaction peaked overnight - 'murky-watchglass'	6.7	2.7	1,450	11.10	3.60	18	6	24
GCA11902 d	3.02	reaction peaked overnight - 'murky-watchglass'	6.4	2.7	1,720	10.50	2.80	17	5	22
GCA11902*	3.03	slight reaction overnight	7.5	8.6	626	-	-	<0.5	<0.5	<0.5
GCA11902* d	3.05	slight reaction overnight	7.4	8.7	470	-	-	<0.5	<0.5	<0.5
Blank	-	no apparent reaction overnight	4.3	5.9	52	-	0.30			

Notes: If needed, the pH of the **15 % (v/v) A.R. H2O2** solution is adjusted to **pH 4.5** using dilute NaOH solution prior to commencing the NAG Tests. **250 mL** of peroxide solution is added to sample in 500 mL conical Erlenmeyer beaker that is then covered with a watchglass. Following **reaction overnight**, the occurrence and vigour of reaction is judged according to degree of water condensation on the underside of the watchglass. The suspension-pH is measured, and the test-suspensions then boiled for *ca.* 1 hr. After allowing to cool, *ca.* 1 mL of **0.016 M-CuSO4** is added, and the 2nd-boiling step carried out for *ca.* 1 hr. The added Cu(II) catalyses the decomposition of any residual, unreacted H2O2 (AS 4969.12-2009).
(After the 1st-boiling step, and prior to addition of CuSO4, the Blank had a pH value of 7.1).
Following determination of supernatant-EC and suspension-pH, the test-suspensions are titrated manually with standardised NaOH solution to respective **pH4.5** and **pH7.0** end-points.
For GCA11902, testing performed on **pulps** (nominal -75 µm).
For GCA11902*, testing corresponds to dried-tailings (80 oC) without pulping.

'murky-watchglass' after overnight reaction indicates very sluggish reaction.

Dr GD Campbell 1st February 2019

pH-BUFFERING TESTWORK (GCA11902)

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H2SO4/tonne)	pH	Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H2SO4/tonne)	pH
0.00	0.0	8.9	20.80	10.2	6.8
0.40	0.2	8.5	21.80	10.7	7.1
0.80	0.4	8.3	22.80	11.2	6.8
1.20	0.6	8.1	23.80	11.7	6.9
1.60	0.8	8.0	24.80	12.2	6.7
2.00	1.0	7.9	25.80	12.6	6.5
2.40	1.2	7.8	26.80	13.1	6.4
2.80	1.4	7.8	27.80	13.6	6.4
3.20	1.6	7.7	28.80	14.1	6.4
3.60	1.8	7.7	29.80	14.6	6.5
4.00	2.0	7.6	30.80	15.1	6.5
4.40	2.2	7.6	31.80	15.6	6.4
4.80	2.4	7.6	32.80	16.1	6.3
5.20	2.5	7.5	33.80	16.6	6.1
5.60	2.7	7.5	34.80	17.1	6.2
6.00	2.9	7.5	35.80	17.5	6.2
6.40	3.1	7.5	36.80	18.0	6.1
6.80	3.3	7.4	37.80	18.5	6.1
7.20	3.5	7.4	38.80	19.0	6.1
7.60	3.7	7.3	39.80	19.5	6.0
8.00	3.9	7.3	40.80	20.0	6.0
8.40	4.1	7.3	41.80	20.5	5.9
8.80	4.3	7.2	42.80	21.0	5.9
9.20	4.5	7.2	43.80	21.5	5.9
9.60	4.7	7.1	44.80	22.0	5.8
10.00	4.9	7.1	45.80	22.4	5.8
10.40	5.1	7.0	46.80	22.9	5.8
10.80	5.3	6.9	47.80	23.4	5.7
11.20	5.5	6.9	48.80	23.9	5.7
11.60	5.7	6.8	49.80	24.4	5.6
12.00	5.9	6.8	50.80	24.9	5.6
12.40	6.1	6.7	51.80	25.4	5.5
12.80	6.3	6.6	52.80	25.9	5.5
13.20	6.5	6.5	53.80	26.4	5.4
13.60	6.7	6.5	54.80	26.9	5.4
14.00	6.9	6.4	55.80	27.3	5.3
14.40	7.1	6.3	56.80	27.8	5.3
14.80	7.3	6.2	57.80	28.3	5.2
15.20	7.4	6.1	58.80	28.8	5.2
15.60	7.6	6.0	59.80	29.3	5.2
16.00	7.8	6.3	60.80	29.8	5.1
16.40	8.0	6.7	61.80	30.3	5.1
16.80	8.2	6.5	62.80	30.8	5.0
17.20	8.4	6.4	63.80	31.3	5.0
17.60	8.6	6.2	64.80	31.8	4.9
18.00	8.8	7.2	65.80	32.2	4.9
18.40	9.0	7.0	66.80	32.7	4.8
18.80	9.2	6.9	67.80	33.2	4.8
19.20	9.4	6.7	68.80	33.7	4.7
19.60	9.6	6.6	69.80	34.2	4.7
20.00	9.8	6.5	70.80	34.7	4.6
20.40	10.0	6.4	71.80	35.2	4.6

Cumulative Volume of Acid Added (mL)	Cumulative Acid Consumption (kg H2SO4/tonne)	pH
72.20	35.4	4.5
72.60	35.6	4.4
73.00	35.8	4.4
73.40	36.0	4.3
73.80	36.2	4.2
74.20	36.4	4.2
74.60	36.6	4.1
75.00	36.8	4.1
75.40	36.9	4.0
75.80	37.1	3.9
76.20	37.3	3.9
76.60	37.5	3.8
77.00	37.7	3.8
77.40	37.9	3.7
77.80	38.1	3.7
78.20	38.3	3.6
78.60	38.5	3.6
79.00	38.7	3.5
79.40	38.9	3.5
79.80	39.1	3.5
80.20	39.3	3.4
80.60	39.5	3.4
81.00	39.7	3.4
81.40	39.9	3.3
81.80	40.1	3.3
82.20	40.3	3.3
82.60	40.5	3.2
83.00	40.7	3.2
83.40	40.9	3.2
83.80	41.1	3.1
84.20	41.3	3.1
84.60	41.5	3.1
85.00	41.7	3.1
85.40	41.8	3.0

Notes: Titration performed using Metrohm® 736 Titrino auto-titrator, and 0.05 M-H2SO4. Equlibration time between titrant additions is 15 minutes.
1.00 g of pulped (nominal -75 µm) sample initially dispersed in *ca.* 150 mL of deionised-water.
Test-suspension in contact with air in a CT-room @ 20 (+/1 1-2) oC, and continuously stirred.
Calibration of pH-Glass Electrode:
Immediately prior to titration: asymmetry potential = 2 mV (pH=7.00); slope-point = 174 mV (pH=4.00);
97.1 % of Nernstian response.

Dr GD Campbell 10th January 2019

Determination of Oxygen-Consumption Rate (OCR)

	GCA11902
Test Specifications and Conditions	
Moist-Solids (kg)	0.82
GWC (%)	**12.4**
Dry-Solids [DS] (kg)	0.73
Solids-SG	2.90
Dry-Solids Volume (L)	0.25
Pore-Fluid Volume (L)	0.09
Cell Volume (L)	0.61
Gas Volume [GV] (L)	0.27
GV/DS Ratio (L/kg)	0.37
Temperature (oC) [+/- 0.1]	**30.0**
Measurement with Quantek 901	
Reaction-Time (days)	**2.00**
Reaction-Time (hrs)	48.0
Measured O2-Conc. (%) [+/- 0.1]	**16.3**
O2-Consumption (%) [+/- 0.2]	4.6
O2-Consumption (mg O2)	16.4
OCR (kg O2/kg/s)	**1.30E-10**

Notes:

Testing performed on moist tailings-solids sample.

GWC = Gravimetric-Water Content; SG = Specific-Gravity.

SG value is estimated.

The relative-error for the OCR value is estimated to be *ca.* 10-20 %.

Dr GD Campbell
23rd January 2019

MINERALS
TEST REPORT

CLIENT

GRAEME CAMPBELL
CAMPBELL, GRAEME and ASSOCIATES
PO Box 247
BRIDGETOWN, W.A. 6255
AUSTRALIA

JOB INFORMATION

JOB CODE	:	143.0/1812997
NO. SAMPLES	:	3
NO. ELEMENTS	:	45
CLIENT ORDER NO.	:	GCA1815/2 (Job 1 of 1)
SAMPLE SUBMISSION NO.	:	
PROJECT	:	RAVENSTHORPE
SAMPLE TYPE	:	Solutions
DATE RECEIVED	:	29/08/2018
DATE REPORTED	:	20/09/2018
DATE PRINTED	:	20/09/2018

REPORT NOTES

TESTED BY

Intertek
15 Davison Street, Maddington 6109, Western Australia
PO Box 144, Gosnells 6990, Western Australia
Tel: +61 8 9251 8100
Email: min.aus.per@intertek.com

Accredited for compliance with ISO/IEC 17025.
Company Accreditation Number 3244

NOTES

NATA ENDORSED DOCUMENT

Company Accreditation Number 3244

Analysing Laboratory: Intertek Genalysis Perth

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The analysis results reported herein have been obtained using the following methods and conditions:

Project: Ravensthorpe

The solutions were analysed as received
The raw sample was analyzed for pH, EC, Cl, F, SCN, TDSEva and alkalinity
The HNO3 dosed sample was analyzed for the requested suite by ICPOES and ICPMS
The NaOH dosed sample was analyzed for FreeCN, CN-WAD and Total CN

Genalysis method codes: ENV_W001 (pH), ENV_W002 (EC), ENV_W011 (F)
ENV_W004 (Cl), ENV_W006 (SCN),
(ICP_W004 (OE), (ICP_W003 (MS))
ENV_040 (CN-WAD), ENV_W041 (FreeCN), ENV_042 (CN-Tot)
APHA method code: Alkalinity: 2320B, TDEva: 2540C

APHA code refers to “Standard methods for the examination of water and wastewater”,
22nd Edition 2012

Intertek Genalysis signatory
Ann Patricia EVERS
Chief Chemist

Ann Evers

Date: 20-Sep-2018

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that figures beyond the least significant digit have significance.

For more information on the uncertainty on individual reported values, please contact the laboratory.

SAMPLE STORAGE

All solid samples (assay pulps, bulk pulps and residues will be stored for 60 days without charge. Following this samples will be stored at a daily rate until clients written advice regarding return, collection or disposal is received. If storage information is not supplied on the submission, or arranged with the laboratory in writing the default will be to store the samples with the applicable charges. Storage is charged at $4.00 per m3 per day, expenses related to the return or disposal of samples will be charged at cost. Current disposal cost is charged at $150.00 per m3.

Samples received as liquids, waters or solutions will be held for 60 days free of charge then disposed of, unless written advice fo return or collection is received.

LEGEND

X = Less than Detection Limit
SNR = Sample Not Received
* = Result Checked
DTF = Result still to come
IS = Insufficient Sample for Analysis

NA = Not Analysed
UA = Unable to Assay
> = Value beyond Limit of Method
\+ = Extra Sample Received Not Listed

ELEMENTS	Ag	Al	As	B	Ba	Bi
UNITS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DETECTION LIMIT	0.001	0.1	0.01	0.1	0.005	0.001
DIGEST						
ANALYTICAL FINISH	/MS	/OE	/MS	/OE	/MS	/MS
SAMPLE NUMBERS						
0001 GCA11868 RAW						
0002 GCA11868 HNO3	0.082	X	0.03	0.2	0.291	X
0003 GCA11868 NaOH						

CHECKS						
0001 GCA11868 RAW						
0002 GCA11868 HNO3	0.082	X	0.03	0.2	0.287	X

STANDARDS						
0001 GWS-2						
0002 GWS-2						
0003 GLS-Brine1						
0004 TMDW	0.002		0.08		0.050	0.010
0005 UNI 1		25.3		5.2		

BLANKS						
0001 Control Blank						
0002 Control Blank	X	X	X	X	X	X

ELEMENTS	CO3	Ca	Cd	Cl	Co	Cr
UNITS	mgCaCO3/L	mg/l	mg/l	mg/l	mg/l	mg/l
DETECTION LIMIT	1	0.1	0.002	2	0.01	0.1
DIGEST						
ANALYTICAL FINISH	/VOL	/OE	/MS	/COL	/MS	/OE
SAMPLE NUMBERS						
0001 GCA11868 RAW	58			5980		
0002 GCA11868 HNO3		230.8	X		0.03	X
0003 GCA11868 NaOH						

CHECKS						
0001 GCA11868 RAW	53			5960		
0002 GCA11868 HNO3		230.1	X		0.03	X

STANDARDS						
0001 GWS-2	X					
0002 GWS-2						
0003 GLS-Brine1				118600		
0004 TMDW			0.009		0.02	
0005 UNI 1		25.2				24.5

BLANKS						
0001 Control Blank	X					
0002 Control Blank		X	X		X	X

ELEMENTS	Cu	EC	F	Fe-Sol	HCO3	Hg
UNITS	mg/l	mS/cm	mg/l	mg/l	mgCaCO3/L	mg/l
DETECTION LIMIT	0.1	0.01	0.1	0.1	2	0.01
DIGEST						
ANALYTICAL FINISH	/OE	/MTR	/SIE	/OE	/VOL	/MS
SAMPLE NUMBERS						
0001 GCA11868 RAW		17.86	1.0		325	
0002 GCA11868 HNO3	X			X		X
0003 GCA11868 NaOH						
CHECKS						
0001 GCA11868 RAW		17.85	1.0		322	
0002 GCA11868 HNO3	X			X		X
STANDARDS						
0001 GWS-2					99	
0002 GWS-2			0.6			
0003 GLS-Brine1						
0004 TMDW						X
0005 UNI 1	10.1			253.0		
BLANKS						
0001 Control Blank		X	X		3	
0002 Control Blank	X			X		X

ELEMENTS	K	Mg	Mn	Mo	Na	Ni
UNITS	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
DETECTION LIMIT	1	0.1	0.1	0.005	1	0.1
DIGEST						
ANALYTICAL FINISH	/OE	/OE	/OE	/MS	/OE	/OE
SAMPLE NUMBERS						
0001 GCA11868 RAW						
0002 GCA11868 HNO3	99	254.5	X	0.027	4101	X
0003 GCA11868 NaOH						

CHECKS						
0001 GCA11868 RAW						
0002 GCA11868 HNO3	98	250.5	X	0.029	4113	X

STANDARDS						
0001 GWS-2						
0002 GWS-2						
0003 GLS-Brine1						
0004 TMDW				0.102		
0005 UNI 1	24	24.8	10.0		26	10.2

BLANKS						
0001 Control Blank						
0002 Control Blank	X	X	X	X	X	X

ELEMENTS	OH	P	Pb	pH	S	Sb
UNITS	mgCaCO3/L	mg/l	mg/l	NONE	mg/l	mg/l
DETECTION LIMIT	1	1	0.05	0.1	1	0.001
DIGEST						
ANALYTICAL FINISH	/VOL	/OE	/MS	/MTR	/OE	/MS
SAMPLE NUMBERS						
0001 GCA11868 RAW	X			8.6		
0002 GCA11868 HNO3		X	X		642	X
0003 GCA11868 NaOH						
CHECKS						
0001 GCA11868 RAW	X			8.6		
0002 GCA11868 HNO3		X	X		648	X
STANDARDS						
0001 GWS-2	X					
0002 GWS-2						
0003 GLS-Brine1						
0004 TMDW			X			0.010
0005 UNI 1		24			25	
BLANKS						
0001 Control Blank	X			5.4		
0002 Control Blank		X	X		X	X

ELEMENTS	Se	Si	Sn	Sr	TDSEva	Th
UNITS	mg/l	mg/l	mg/l	mg/l	mg/Kg	mg/l
DETECTION LIMIT	0.05	0.5	0.01	0.002	20	0.001
DIGEST						
ANALYTICAL FINISH	/MS	/OE	/MS	/MS	/GR	/MS
SAMPLE NUMBERS						
0001 GCA11868 RAW					13023	
0002 GCA11868 HNO3	X	8.3	X	0.457		X
0003 GCA11868 NaOH						

CHECKS						
0001 GCA11868 RAW					13091	
0002 GCA11868 HNO3	X	7.7	X	0.465		X

STANDARDS						
0001 GWS-2						
0002 GWS-2						
0003 GLS-Brine1						
0004 TMDW	X		X	0.242		X
0005 UNI 1		50.0				

BLANKS						
0001 Control Blank					X	
0002 Control Blank	X	X	X	X		X

ELEMENTS	Tl	TotAlk	U	V	Zn	CN-Tot
UNITS	mg/l	mgCaCO3/L	mg/l	mg/l	mg/l	mg/l
DETECTION LIMIT	0.001	5	0.001	0.1	0.1	0.4
DIGEST						
ANALYTICAL FINISH	/MS	/CALC	/MS	/OE	/OE	/COL
SAMPLE NUMBERS						
0001 GCA11868 RAW		383				
0002 GCA11868 HNO3	X		0.007	X	X	
0003 GCA11868 NaOH						1.7
CHECKS						
0001 GCA11868 RAW						
0002 GCA11868 HNO3	X		0.007	X	X	
STANDARDS						
0001 GWS-2						
0002 GWS-2						
0003 GLS-Brine1						
0004 TMDW	0.010		0.010			
0005 UNI 1				9.8	9.7	
BLANKS						
0001 Control Blank						
0002 Control Blank	X		X	X	X	

ELEMENTS	CN-WAD	FreeCN	SCN
UNITS	mg/l	mg/l	mg/L
DETECTION LIMIT	0.4	0.2	1
DIGEST			
ANALYTICAL FINISH	/COL	/COL	/COL
SAMPLE NUMBERS			
0001 GCA11868 RAW			X
0002 GCA11868 HNO3			
0003 GCA11868 NaOH	X	X	
CHECKS			
0001 GCA11868 RAW			X
0002 GCA11868 HNO3			
STANDARDS			
0001 GWS-2			
0002 GWS-2			
0003 GLS-Brine1			
0004 TMDW			
0005 UNI 1			
BLANKS			
0001 Control Blank	X		X
0002 Control Blank			

METHOD CODE DESCRIPTION

Method Code	Analysing Laboratory
/CALC	Intertek Genalysis Perth No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.
/COL	Intertek Genalysis Perth No digestion or other pre-treatment undertaken. Analysed by UV-Visible Spectrometry.
/GR	Intertek Genalysis Perth Analysed by Gravimetric Technique.
/MS	Intertek Genalysis Perth No digestion or other pre-treatment undertaken. Analysed by Inductively Coupled Plasma Mass Spectrometry.
/MTR	Intertek Genalysis Perth No digestion or other pre-treatment undertaken. Analysed with Electronic Meter Measurement
/OE	Intertek Genalysis Perth Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.
/SIE	Intertek Genalysis Perth No digestion or other pre-treatment undertaken. Analysed by Specific Ion Electrode.
/VOL	Intertek Genalysis Perth No digestion or other pre-treatment undertaken. Analysed by Volumetric Technique.

SGS

ANALYTICAL REPORT

Accreditation No. 2562

CLIENT DETAILS		LABORATORY DETAILS	
Contact	Graeme Campbell	Manager	Ros Ma
Client	Graeme Campbell & Associates Pty Ltd	Laboratory	SGS Perth Environmental
Address	PO Box 247 Bridgetown WA 6255	Address	28 Reid Rd Perth Airport WA 6105
Telephone	0897 612 829	Telephone	(08) 9373 3500
Facsimile	0897 612 830	Facsimile	(08) 9373 3556
Email	gca@wn.com.au	Email	au.environmental.perth@sgs.com
Project	**GCA Job No. 1815/2**	SGS Reference	**PE131650 R1**
Order Number	**GCA Job No. 1815/2**	Date Received	08 Jan 2019
Samples	1	Date Reported	20 Feb 2019

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(898/20210).

Metals: LORs raised due to high conductivity.

Thiocyanate in Water: Matrix spike recovery failed acceptance criteria due to the presence of significant concentration of analyte (i.e. the concentration of analyte exceeds the spike level).

Discrepancies between Total-S by ICP-OES and SO4-S by discrete analyser may be due to sample matrix.

This report cancels and supersedes the report No.PE131650 R0 dated 18/1/2019 issued by SGS Environment, Health and Safety due to an amendment of report comments.

SIGNATORIES

Hue Thanh Ly
Metals Team Leader

LouiseHope

Louise Hope
Laboratory Technician

Mary Ann Ola-A
Inorganics Team Leader

Michael McKay
Inorganics and ARD Supervisor

Ohmar David
Metals Chemist

Parameter	Units	LOR	Sample Number Sample Matrix Sample Date Sample Name	PE131650.001 Solution 07 Jan 2019 GCA11902

pH in water Method: AN101 Tested: 9/1/2019

pH**	pH Units	-	8.5

Conductivity and TDS by Calculation - Water Method: AN106 Tested: 9/1/2019

Conductivity @ 25 C	µS/cm	2	27000

Total Dissolved Solids (TDS) in water Method: AN113 Tested: 11/1/2019

Total Dissolved Solids Dried at 175-185°C	mg/L	10	18000

Alkalinity Method: AN135 Tested: 9/1/2019

Total Alkalinity as CaCO3	mg/L	5	170
Carbonate Alkalinity as CO3	mg/L	1	10
Bicarbonate Alkalinity as HCO3	mg/L	5	190

Cyanide Forms in Water by CFA Method: AN296 Tested: 16/1/2019

Free Cyanide (pH 6)	mg/L	0.004	<0.004
Weak Acid Dissociable Cyanide (WADCN)	mg/L	0.004	0.037
Total Cyanide	mg/L	0.004	1.2

Fluoride by Ion Selective Electrode in Water Method: AN141 Tested: 10/1/2019

Fluoride by ISE	mg/L	0.1	<0.1

Chloride by Discrete Analyser in Water Method: AN274 Tested: 14/1/2019

Chloride, Cl	mg/L	1	6900

Sulfate in water Method: AN275 Tested: 14/1/2019

Sulfate, SO4	mg/L	1	4800

Thiocyanate in Water Method: AN156 Tested: 10/1/2019

Thiocyanate	mg/L	0.1	590

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA Method: AN258 Tested: 9/1/2019

Nitrate Nitrogen, NO_3 as N	mg/L	0.05	0.35

		Sample Number	PE131650.001
		Sample Matrix	Solution
		Sample Date	07 Jan 2019
		Sample Name	GCA11902
Parameter	Units	LOR	

Ammonia Nitrogen by FIA Method: AN261 Tested: 9/1/2019

Ammonia Nitrogen, NH_3 as N	mg/L	0.05	34

Cations in Water (Dissolved) by ICPOES Method: AN320 Tested: 14/1/2019

Calcium, Ca	µg/L	10	720000
Magnesium, Mg	µg/L	10	62000
Potassium, K	µg/L	50	120000
Sodium, Na	µg/L	50	5300000

Metals in Water (Dissolved) by ICPOES Method: AN320 Tested: 10/1/2019

Phosphorus, P	µg/L	50	<250↑
Silicon, Si	µg/L	20	1200
Sulfur, S	µg/L	100	2100000

Trace Metals (Dissolved) in Water by ICPMS Method: AN318 Tested: 10/1/2019

Aluminium, Al	µg/L	5	<50↑
Antimony, Sb	µg/L	1	<10↑
Arsenic, As	µg/L	1	<10↑
Barium, Ba	µg/L	0.2	49
Bismuth, Bi	µg/L	1	<10↑
Boron, B	µg/L	5	400
Cadmium, Cd	µg/L	0.1	<1.0↑
Chromium, Cr	µg/L	1	<10↑
Cobalt, Co	µg/L	1	920
Copper, Cu	µg/L	1	550
Iron, Fe	µg/L	5	<50↑
Lead, Pb	µg/L	1	<10↑
Manganese, Mn	µg/L	1	42
Molybdenum, Mo	µg/L	0.5	120
Nickel, Ni	µg/L	1	<10↑
Selenium, Se	µg/L	1	<10↑
Silver, Ag	µg/L	1	19
Strontium, Sr	µg/L	1	490
Thallium, Tl	µg/L	1	<10↑
Thorium, Th	µg/L	1	<10↑
Tin, Sn	µg/L	1	<10↑
Uranium, U	µg/L	1	<10↑
Vanadium, V	µg/L	1	<10↑
Zinc, Zn	µg/L	5	<50↑

Parameter	Units	LOR	Sample Number: PE131650.001 Sample Matrix: Solution Sample Date: 07 Jan 2019 Sample Name: GCA11902
Mercury (dissolved) in Water Method: AN311(Perth)/AN312 Tested: 14/1/2019			
Mercury	μg/L	0.05	<0.05

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Alkalinity **Method: ME-(AU)-[ENV]AN135**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Total Alkalinity as CaCO3	LB154871	mg/L	5	<5	6%	100%
Carbonate Alkalinity as CO3	LB154871	mg/L	1	<1		
Bicarbonate Alkalinity as HCO3	LB154871	mg/L	5	<5		

Ammonia Nitrogen by FIA **Method: ME-(AU)-[ENV]AN261**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Ammonia Nitrogen, NH_3 as N	LB154830	mg/L	0.05	<0.05	3 - 4%	107%

Cations in Water (Dissolved) by ICPOES **Method: ME-(AU)-[ENV]AN320**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Calcium, Ca	LB154947	µg/L	10	<0	0%	NA
Magnesium, Mg	LB154947	µg/L	10	<0	0%	NA
Potassium, K	LB154947	µg/L	50	<0	0%	NA
Sodium, Na	LB154947	µg/L	50	<0	0%	NA

Chloride by Discrete Analyser in Water **Method: ME-(AU)-[ENV]AN274**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Chloride, Cl	LB154935	mg/L	1	<1	0 - 1%	103 - 104%	96 - 100%

Conductivity and TDS by Calculation - Water **Method: ME-(AU)-[ENV]AN106**

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Conductivity @ 25 C	LB154916	µS/cm	2	<2	0 - 1%	100%

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Cyanide Forms in Water by CFA   Method: ME-(AU)-[ENV]AN296

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Free Cyanide (pH 6)	LB155017	mg/L	0.004	<0.004	8%	99%	
Weak Acid Dissociable Cyanide (WADCN)	LB155017	mg/L	0.004	<0.004	0 - 18%	104 - 106%	
Total Cyanide	LB155017	mg/L	0.004	<0.004	0 - 3%	95 - 99%	96%

Fluoride by Ion Selective Electrode in Water   Method: ME-(AU)-[ENV]AN141

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Fluoride by ISE	LB154852	mg/L	0.1	<0.1	0%	101%	90%

Mercury (dissolved) in Water   Method: ME-(AU)-[ENV]AN311(Perth)/AN312

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Mercury	LB154952	μg/L	0.05	<0.05	0 - 7%	90 - 104%	95 - 100%

Metals in Water (Dissolved) by ICPOES   Method: ME-(AU)-[ENV]AN320

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Phosphorus, P	LB154856	μg/L	50	<0	0%	99%
Silicon, Si	LB154856	μg/L	20	<0	195%	102%
Sulfur, S	LB154856	μg/L	100	<100	0%	102%

Nitrate Nitrogen and Nitrite Nitrogen (NOx) by FIA   Method: ME-(AU)-[ENV]AN258

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Nitrate Nitrogen, NO_3 as N	LB154830	mg/L	0.05	<0.05	1 - 12%	NA

pH in water   Method: ME-(AU)-[ENV]AN101

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery
pH**	LB154916	pH Units	-	6.0	100%

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage.* Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

Sulfate in water Method: ME-(AU)-[ENV]AN275

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Sulfate, SO4	LB154935	mg/L	1	<1	0 - 1%	105%	99 - 103%

Thiocyanate in Water Method: ME-(AU)-[ENV]AN156

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Thiocyanate	LB154774	mg/L	0.1	<0.1	0 - 4%	90%	33%

Total Dissolved Solids (TDS) in water Method: ME-(AU)-[ENV]AN113

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery	MSD %RPD
Total Dissolved Solids Dried at 175-185°C	LB154921	mg/L	10	<10	0 - 4%	93%	102%	2%

Trace Metals (Dissolved) in Water by ICPMS Method: ME-(AU)-[ENV]AN318

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery	MS %Recovery
Aluminium, Al	LB154841	µg/L	5	<5	0%	99%	
Antimony, Sb	LB154841	µg/L	1	<1		108%	
Arsenic, As	LB154841	µg/L	1	<1	4%	109%	103%
Barium, Ba	LB154841	µg/L	0.2	<1.0	2%	103%	
Bismuth, Bi	LB154841	µg/L	1	<1		103%	
Boron, B	LB154841	µg/L	5	<5	1%	109%	
Cadmium, Cd	LB154841	µg/L	0.1	<0.1	0%	108%	100%
Chromium, Cr	LB154841	µg/L	1	<1	0%	102%	104%
Cobalt, Co	LB154841	µg/L	1	<1	0%	101%	
Copper, Cu	LB154841	µg/L	1	<1	0%	106%	100%
Iron, Fe	LB154841	µg/L	5	<5	0%	98%	
Lead, Pb	LB154841	µg/L	1	<1	0%	104%	
Manganese, Mn	LB154841	µg/L	1	<1	3%	102%	117%
Molybdenum, Mo	LB154841	µg/L	0.5	<1.0	0%	101%	
Nickel, Ni	LB154841	µg/L	1	<1	0%	102%	100%
Selenium, Se	LB154841	µg/L	1	<1	0%	109%	
Silver, Ag	LB154841	µg/L	1	<1		87%	
Strontium, Sr	LB154841	µg/L	1	<1	1%	108%	
Thallium, Tl	LB154841	µg/L	1	<1	0%	106%	
Thorium, Th	LB154841	µg/L	1	<1		92%	
Tin, Sn	LB154841	µg/L	1	<1		99%	
Uranium, U	LB154841	µg/L	1	<1		103%	107%
Vanadium, V	LB154841	µg/L	1	<1	0%	97%	
Zinc, Zn	LB154841	µg/L	5	<5	0%	101%	

METHOD	METHODOLOGY SUMMARY
	Nitrate and Nitrite by FIA: In an acidic medium, nitrate is reduced quantitatively to nitrite by cadmium metal. This nitrite plus any original nitrite is determined as an intense red-pink azo dye at 540 nm following diazotisation with sulphanilamide and subsequent coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. Without the cadmium reduction only the original nitrite is determined. Reference APHA 4500-NO3- F.
AN101	pH in Soil Sludge Sediment and Water: pH is measured electrometrically using a combination electrode (glass plus reference electrode) and is calibrated against 3 buffers purchased commercially. For soils, an extract with water is made at a ratio of 1:5 and the pH determined and reported on the extract. Reference APHA 4500-H+.
AN106	Conductivity and TDS by Calculation: Conductivity is measured by meter with temperature compensation and is calibrated against a standard solution of potassium chloride. Conductivity is generally reported as µmhos/cm or µS/cm @ 25°C. For soils, an extract with water is made at a ratio of 1:5 and the EC determined and reported on the extract, or calculated back to the as-received sample. Total Dissolved Salts can be estimated from conductivity using a conversion factor, which for natural waters, is in the range 0.55 to 0.75. SGS use 0.6. Reference APHA 2510 B.
AN106	Salinity may be calculated in terms of NaCl from the sample conductivity. This assumes all soluble salts present, measured by the conductivity, are present as NaCl.
AN113	Total Dissolved Solids: A well-mixed filtered sample of known volume is evaporated to dryness at 180°C and the residue weighed. Approximate methods for correlating chemical analysis with dissolved solids are available. Reference APHA 2540 C.
AN113	The Total Dissolved Solids residue may also be ignited at 550 C and volatile TDS (Organic TDS) and non-volatile TDS (Inorganic) can be determined.
AN135	Alkalinity (and forms of) by Titration: The sample is titrated with standard acid to pH 8.3 (P titre) and pH 4.5 (T titre) and permanent and/or total alkalinity calculated. The results are expressed as equivalents of calcium carbonate or recalculated as bicarbonate, carbonate and hydroxide. Reference APHA 2320. Internal Reference AN135
AN141	Determination of Fluoride by ISE: A fluoride ion selective electrode and reference electrode combination, in the presence of a pH/complexation buffer, is used to determine the fluoride concentration. The electrode millivolt response is measured logarithmically against fluoride concentration. Reference APHA F- C.
AN156	At an acidic pH, ferric ion (Fe3+) forms an intense red colour with SCN- which is suitable for colorimetric determination. Referenced to APHA 4500CNM.
AN261	Ammonia by Continuous Flow Analyser: Ammonium in a basic medium forms ammonia gas, which is separated from the sample matrix by diffusion through a polypropylene membrane. The ammonia is reacted with phenol and hypochlorite to form indophenol blue at an intensity proportional to the ammonia concentration. The blue colour is intensified with sodium nitroprusside and the absorbance measured at 630 nm. The sensitivity of the automated method is 10-20 times that of the macro method. Reference APHA 4500-NH3 H.
AN274	Chloride by Aquakem DA: Chloride reacts with mercuric thiocyanate forming a mercuric chloride complex. In the presence of ferric iron, highly coloured ferric thiocyanate is formed which is proportional to the chloride concentration. Reference APHA 4500Cl-
AN275	sulfate by Aquakem DA: sulfate is precipitated in an acidic medium with barium chloride. The resulting turbidity is measured photometrically at 405nm and compared with standard calibration solutions to determine the sulfate concentration in the sample. Reference APHA 4500-SO42-. Internal reference AN275.
AN296	This method is applicable to the determination of free, total and weak acid dissociable cyanide in drinking water, soil and domestic and industrial waste of a variety of matrices by using San++ continuous flow analysis

METHOD SUMMARY

METHOD	METHODOLOGY SUMMARY
AN311(Perth)/AN312	Mercury by Cold Vapour AAS in Waters: Mercury ions are reduced by stannous chloride reagent in acidic solution to elemental mercury. This mercury vapour is purged by nitrogen into a cold cell in an atomic absorption spectrometer or mercury analyser. Quantification is made by comparing absorbances to those of the calibration standards. Reference APHA 3112/3500.
AN318	Determination of elements at trace level in waters by ICP-MS technique, in accordance with USEPA 6020A.
AN320	Metals by ICP-OES: Samples are preserved with 10% nitric acid for a wide range of metals and some non-metals. This solution is measured by Inductively Coupled Plasma. Solutions are aspirated into an argon plasma at 8000-10000K and emit characteristic energy or light as a result of electron transitions through unique energy levels. The emitted light is focused onto a diffraction grating where it is separated into components .
AN320	Photomultipliers or CCDs are used to measure the light intensity at specific wavelengths. This intensity is directly proportional to concentration. Corrections are required to compensate for spectral overlap between elements. Reference APHA 3120 B.
AN320 LL	Cations Low LOR by ICP-OES: Method is as per routine ICP OES method reporting a variation to the method being lower limit of reporting (LOR) for selected cations as validated by the site. Referenced to APHA 3120B.
Calculation	Free and Total Carbon Dioxide may be calculated using alkalinity forms only when the samples TDS is <500mg/L. If TDS is >500mg/L free or total carbon dioxide cannot be reported . APHA4500CO2 D.

FOOTNOTES

IS	Insufficient sample for analysis.
LNR	Sample listed, but not received.
*	NATA accreditation does not cover the performance of this service.
**	Indicative data, theoretical holding time exceeded.

LOR	Limit of Reporting
↑↓	Raised or Lowered Limit of Reporting
QFH	QC result is above the upper tolerance
QFL	QC result is below the lower tolerance
-	The sample was not analysed for this analyte
NVL	Not Validated

Samples analysed as received.
Solid samples expressed on a dry weight basis.

Where "Total" analyte groups are reported (for example, Total PAHs, Total OC Pesticides) the total will be calculated as the sum of the individual analytes, with those analytes that are reported as <LOR being assumed to be zero. The summed (Total) limit of reporting is calcuated by summing the individual analyte LORs and dividing by two. For example, where 16 individual analytes are being summed and each has an LOR of 0.1 mg/kg, the "Totals" LOR will be 1.6 / 2 (0.8 mg/kg). Where only 2 analytes are being summed, the " Total" LOR will be the sum of those two LORs.

Some totals may not appear to add up because the total is rounded after adding up the raw values.

If reported, measurement uncertainty follow the ± sign after the analytical result and is expressed as the expanded uncertainty calculated using a coverage factor of 2, providing a level of confidence of approximately 95%, unless stated otherwise in the comments section of this report.

Results reported for samples tested under test methods with codes starting with ARS-SOP, radionuclide or gross radioactivity concentrations are expressed in becquerel (Bq) per unit of mass or volume or per wipe as stated on the report. Becquerel is the SI unit for activity and equals one nuclear transformation per second.
Note that in terms of units of radioactivity:

a. 1 Bq is equivalent to 27 pCi
b. 37 MBq is equivalent to 1 mCi

For results reported for samples tested under test methods with codes starting with ARS-SOP, less than (<) values indicate the detection limit for each radionuclide or parameter for the measurement system used. The respective detection limits have been calculated in accordance with ISO 11929.

The QC criteria are subject to internal review according to the SGS QAQC plan and may be provided on request or alternatively can be found here : http://www.sgs.com.au/~/media/Local/Australia/Documents/Technical%20Documents/MP-AU-ENV-QU-022%20QA%20QC%20Plan.pdf