ASH CLASSIFICATION STUDY

SASOL SIGMA COLLIERY

14 JANUARY 2014

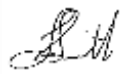
Digby Wells and Associates (South Africa) (Pty) Ltd (Subsidiary of Digby Wells & Associates (Pty) Ltd). Co. Reg. No. 2010/008577/07. Fern Isle, Section 10, 359 Pretoria Ave Randburg Private Bag X10046, Randburg, 2125, South Africa
Tel: +27 11 789 9495, Fax: +27 11 789 9498, info@digbywells.com, www.digbywells.com

Directors: A Sing*, AR Wilke, LF Koeslag, PD Tanner (British)*, AJ Reynolds (Chairman) (British)*, J Leaver*, GE Trusler (C.E.O)
*Non-Executive

This document has been prepared by **Digby Wells Environmental**.

Report Title: **Ash Classification Study**

Project Number: **SAS1691**

Name	Responsibility	Signature	Date
André van Coller (M.Sc.)	Geochemistry and reporting		13 January 2014
Lucas Smith (M.Sc.)	Review		18 November 2013

LIST OF ABBREVIATIONS

Abbreviation	Description
ABA	Acid-Base Accounting
Alk	Alkalinity
AMD	Acid Mine Drainage
AP	Acid Potential
ARL	Acceptable Risk Level
DEA	Department of Environmental Affairs
DW	Distilled Water
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
LC	Leachable Concentration
LCT	Leachable Concentrations Threshold
mg/kg	milligram per kilogram
mg/l	milligram per litre
NAG	Nett Acid Generation
NNP	Nett Neutralising Potential
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
ppb	parts per billion
ppm	parts per million
SANS	South African National Standards
SPLP	Synthetic Precipitation Leachate Procedure
TCLP	Toxicity Characteristic Leachate Procedure
TCT	Total Concentrations Threshold
TDS	Total Dissolved Solids
WHO	World Health Organisation
XRD	X-Ray Diffraction
XRF	X-Ray Florescence

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed by Sasol Sigma Colliery (hereafter Sasol) to conduct various specialist studies and investigation to form part of an Environmental Impact Study (EIA) for the licencing and feasibility of backfilling the Sigma underground colliery with ash produced from the processing of coal.

This report and the various components of it forms part of the geochemical and waste classification study to evaluate the impacts of the backfilling may have on the regional water quality as well as to class the waste to motivate for the alternative waste management activity.

For the purpose of characterising the waste material both in a geochemical and waste classification criteria samples were taken over a period of 1 week. Both wet and dry ash samples were taken with the following methodology:

- Three (3) samples per day (1 kg each) of dry ash just after the burning process for a period of 5 days (15 kg in total);
- One (1) sample per day (2 Litre sample – 20% ash/80% water) from the ash slurry stream just before it enters the pump house over a period of 5 days

The sampling run ensures that all the samples were taken at locations and periods to ensure that the data received from the test results are representative of the ash material.

The samples were sent to the Water Lab (Pty) Ltd were accredited methods were used to prepare and analyses the samples. The samples were prepared as follows:

- The dry ash samples were:
  - The 3 samples from each day were combined to form 5 batches of 3 kg samples representative of each day;
  - The sample for each day was then split into 5 smaller batches for the various tests; and
  - The dry samples from each day labelled A, B, C, D, and E was then sent for Acid-Base Accounting (ABA), Nett Acid Generation (NAG), X-ray diffraction (XRD), X-ray florescence (XRF), Toxicity Characteristic Leachate Procedures (TCLP) and Distilled water (DW) leachate tests.
- The wet ash sample was:
  - The 5 samples were combined and allowed to settle after which the solid and liquid phases were separated;
  - The liquid phase was tested for macro and micro elements to determine the characteristics of the ash water; and
  - The solid phase was labelled AWS and sent for Distilled Water (DW) leachate tests to serve as input into the waste classification.

The purpose of this environmental geochemical evaluation and waste classification is to determine the environmental risks associated with using ash as backfill material. The preferred waste management activity proposed and currently being investigated by Sasol Sigma is the use the waste material (ash) as backfill material to fill old mine voids currently labelled with a high risk of subsidence.

The ash material will be pumped in the form of slurry (consisting of 20% ash and 80% water) into areas at risk of subsidence via purposely drilled boreholes after which excess water will be removed through dewatering boreholes and reused. The ash material will then be left to settle and solidify.

Ash material has a very low permeability and hydraulic conductivity and will act as an aquitard once it has settled and compacted; leading to little or no groundwater movement through the newly formed layers. The aquitard/aquiclude nature of the ash material will be favourable as it will not allow leachate to travel down or sideways into the receiving groundwater or surface water systems. In theory any leachable elements will be in small quantities and be easily diluted under natural conditions. The feasibility and potential risk of the ash backfilling methodology proposed will thus be determined in this study through various geochemical tests and evaluations.

Furthermore, the waste classification of the ash material will feed into the licencing and motivation from Sasol to use and licence the backfilling of the ash into the old mine voids as a feasible alternative waste management activity.

Waste Classification

Based on the classification of the Distilled/Reagent water leachate test results against the relevant TCT and LCT limits as given in the legislative guidelines for waste classification (DEA 2013a), the ash to be used as backfill can be classified as follows:

- For boron (B) the results show that LCT0<LC<LCT1 and TC<TCT0;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste;

The following recommendations are made by Digby Wells based on the outcome of the study reported in this document:

The following recommendations are made by Digby Wells based on the outcome of this study:

- In the DW tests the main elements of concern leaching out are B, Ba, Ca, Se, Al and Cr. These elements should be monitored in all phases of the project on a monthly basis;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste; however
    - Based on the low concentrations of the leachable ions (although they are above TCT0 and LCT0 in certain cases), the low NAG and the high NNP (section 3.2.3) it is concluded that the alternative waste management activity

of using the ash material for backfilling of the mine voids at Sigma Colliery is feasible and a motivation to the authorities for this activity to be licenced is recommended.

- The low permeability and hydraulic conductivity of ash will allow little to no seepage through the newly formed ash layers once allowed to settle and thus the environmental concentration of contaminants entering the receiving environment will be low and easily diluted through natural processes.

- If the waste management activity of backfilling the mine voids is not pursued the waste should be disposed of at a Class C Landfill.
- Previous limits and target water quality conditions in the water licence granted for the ash backfilling in Licence #20021165 was well set and achievable. It is recommended that these conditions are kept and monitoring should ensure that the target water quality standards are achieved.

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1 INTRODUCTION

Digby Wells Environmental (hereafter Digby Wells) was appointed by Sasol Sigma Colliery (hereafter Sigma) to conduct various specialist studies as part of an Environmental Impact Assessment (EIA) for the licencing and feasibility of backfilling the Sigma underground colliery with ash produced from the processing of coal at Infrachem. Ash is currently produced from the coal through burning processes at Infrachem and is then fed into the ash slurry stream after mixing with water to produce the slurry.

Sasol Infrachem (the ash supplier) is currently undertaking a process to reassess its various waste and by-product streams, including ash. It views the ash as a by-product and is currently engaging with the DEA for verification of this. Should the DEA share this view, a waste management licence will not be required and the application will be withdrawn. If, on the other hand, the DEA disagrees with Sasol Infrachem and a waste management licence is required the process will continue as per the EIA regulations. Sasol Infrachem will however still apply for authorisation as per the other legislation as listed above and ensure that the backfilling is conducted in accordance with its statutory duties, including the duty of care.

The ash backfilling process being studied and proposed as an environmental management option is of importance due to its effective management of the subsidence currently taking place in certain mined out areas and can potentially occur in the areas where backfilling has not yet been done. The ash backfilling process is thus an important step in managing and addressing the risk of surface subsidence in the Sigma Colliery project area.

Previously under the Water Licence (Licence # 20021165) granted to Sasol Sigma, ash backfilling was attempted with continuous and frequent monitoring of both surface water and groundwater qualities and levels. These results have shown that the overall water quality in the project has improved since the start of the backfilling and has met all licence conditions set for water quality. Based on this historical data backfilling is feasible and thus a new licence is being applied for.

This report forms part of the geochemical and waste classification study to evaluate the potential impacts that the backfilling may have on the regional water quality, as well as to classify the ash as part of the motivation for this environmental management activity.

This report only refers waste classification and no in depth discussions of tests, monitoring data, models and outcomes of studies referring to the groundwater study is made.

1.1 Study Purpose

The purpose of the study is to determine the classification of the material for the licencing for this proposed ash management activity.

1.2 Deliverables

The following deliverables form part of this study:

- Technical report that includes:
  - Classification of the ash material as per the relevant classification procedures; and
  - Recommendations relating to possible mitigation measures and water management.

1.3 Scope of Work and Methodology

1.3.1 Sampling of Ash Material

For the purpose of characterising the ash material according to geochemical and relevant classification criteria, samples were taken over a period of one week. Both wet and dry ash samples were taken according to the following methodology:

- Three dry ash samples per day (1 kg each); sampled just after the burning process for a period of 5 days (15 kg in total); and
- One sample per day (2 litre samples – 20% ash / 80% water) from the ash slurry stream just before it enters the pump house over a period of 5 days.

This sampling protocol ensures that all the samples were taken at locations and time frames in line with authority requirements and to ensure that the data received from the test results are representative of the ash material.

1.3.2 Laboratory tests

All samples were sent to Waterlab (Pty) Ltd where accredited methods were used to prepare and analyse the samples. The samples were prepared as follows:

- The dry ash samples:
  - The three samples from each day's sampling run were combined to form 5 batches of 3 kg samples, representative of each day;
  - The sample for each day was then split into 5 smaller batches for the various tests; and
  - The dry samples from each day labelled A, B, C, D, and E was then sent for Acid-Base Accounting (ABA), Nett Acid Generation (NAG), X-ray diffraction (XRD), X-ray florescence (XRF), and Toxicity Characteristic Leachate Procedures (TCLP) and Distilled Water (DW) leachate tests.
- The wet ash sample:
  - The 5 samples were combined and allowed to settle after which the solid and liquid phases were separated;
  - The liquid phase was tested for macro and micro elements to determine the characteristics of the ash water; and

- The solid phase was labelled AWS and sent for Distilled Water (DW) leachate tests to serve as input into the classification.

1.3.3 Result interpretations

The results of the laboratory tests were assessed against various guidelines from the US EPA, WHO, SANS Drinking water standards and the guidelines as set out in the National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008) to determine the potential environmental and human risks, as well as to determine the classification of the ash material.

1.3.4 Technical reporting

A technical report was compiled summarising all results and interpretations, as well as listing recommendations and possible mitigation measures. The classification report also serves as input into a motivation for the licencing of the ash to be used for backfilling of mine voids.

2 PREFERED ASH MANAGEMENT ACTIVITY AND OBJECTIVES

The purpose of this environmental geochemical evaluation and classification is to determine the environmental risks associated with using ash as backfill material. The preferred ash management activity proposed and currently being investigated by Sasol Sigma is the use the ash material as backfill material to fill old mine voids currently labelled with a high risk of subsidence.

The ash material will be pumped in the form of slurry (consisting of 20% ash and 80% water) into areas at risk of subsidence via purposely drilled boreholes after which excess water will be removed through dewatering boreholes and reused. The ash material will then be left to settle and solidify.

Ash material has a very low permeability and hydraulic conductivity and will act as an aquitard once it has settled and compacted; leading to little or no groundwater movement through the newly formed layers. The aquitard/aquiclude nature of the ash material will be favourable as it will not allow leachate to travel down or sideways into the receiving groundwater or surface water systems. In theory any leachable elements will be in small quantities and be easily diluted under natural conditions. The feasibility and potential risk of the ash backfilling methodology proposed will thus be determined in this study through various geochemical tests and evaluations.

Furthermore, the classification of the ash material will feed into the licencing and motivation from Sasol to use and licence the backfilling of the ash into the old mine voids as a feasible ash management activity.

Previously ash backfilling has been done under the a water licence (Licence 20021165) with certain water quality objectives set that should be adhered to. Since the start of the project the water quality of the monitoring network and project area has improved and all objectives have been reached. Thus based on past processes and monitoring the backfilling of mine voids at Sasol Sigma Colliery is feasible.

3 ASH CLASSIFICATION

3.1 Introduction

The backfilling option proposed for the Sigma Colliery is an ash management activity that will be a mono-disposal process. Due to the mono-disposal nature of the backfilling option the ash slurry was sent for Distilled/Reagent water leachate tests as well as a complete analysis of the fluid phase. The results of these tests were then classed and compared against the Total Concentration Threshold (TCT) and Leachable Concentration Threshold (LCT) limits to determine the waste type as per legislative guidelines given in the National Environmental Management Waste Act, 2008 (Act No. 59 of 2008).

The results of the water analysis and ash analysis were combined in a weighted average calculation of 80% water and 20% ash for the total concentrations. This procedure was followed as the current and planned water to ash ratio in the slurry will be 80% water and 20% ash. The sum of these weighted average calculations thus gives an accurate indication of the concentrations that can be expected to enter the mine voids. The leachable concentrations however represent an accurate indication of what can leach from the solid phase into the environment and was used as such. Where values were below the limit of detection they were indicated as such.

The water phase of the slurry was submitted for a full organic analysis as well. Due to the volatile nature of most of the organic compounds and there high mobility, if any organic compounds were found in the ash material itself it would either have combusted or dissolved into the liquid.

3.2 Legislative Guidelines

The following legislative guidelines were instated in August 2013 and give the background and guidelines for classification in South Africa:

- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Waste Information Regulations, 2012 (DEA 2012);
- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Norms and Standards for the Assessment of Waste for Landfill Disposal (DEA 2013a);
- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Norms and Standards for the Disposal of Waste to Landfill (DEA 2013b); and
- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Waste Classification and Management Regulations (DEA 2013c).

The above four documents were used as the classification guidelines for this project.

3.3 Data Evaluation and Comparisons

3.3.1 Total Concentration Threshold

From the classification of the ash slurry material according to the TCT limits (Table 1) the following can be concluded:

- All TCT values from the ash slurry material is below the TCT0 threshold limits;

3.3.2 Leachable Concentration Threshold

From the classification of the ash material according to the LCT limits (Table 2) the following can be concluded:

- The ash slurry sample shows boron (B = 1.4 mg/kg) levels above the recommended LCT0 limits but are still well below the LCT1 limits;
- All other concentrations of the ions tested for and present in the samples are within the LCT0 limits.

3.4 Classification

Based on the classification of the Distilled/Reagent water leachate test results against the relevant TCT and LCT limits as given in the legislative guidelines for classification (DEA 2013a), the ash to be used as backfill can be classified as follows:

- For boron (B) the results show that LCT0<LC<LCT1 and TC<TCT0;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste;
- A Type 3 waste may only be disposed of at a Class C (GLB+) landfill; however
    - Based on the low concentrations of the leachable ions (although they are above TCT0 and LCT0 in certain cases), the low NAG and high NNP (section 3.2.3) it is concluded that the alternative ash management activity of backfilling the mine voids at Sigma colliery with the ash material is feasible and a motivation to the authorities for this activity to be licenced is recommended; furthermore
    - The low permeability and hydraulic conductivity of ash will allow little to no seepage through the newly formed ash layers once it has settled and thus the environmental concentration of contaminants entering the receiving environment will be low and easily diluted through natural processes.

Table 1: TCT classification table

Parameter	Unit	TCT0	TCT1	TCT2	AWS
As	mg/kg	**5.8**	**500**	**2000**	0.01
B	mg/kg	**150**	**15000**	**60000**	5.71
Ba	mg/kg	**62.5**	**6250**	**25000**	8.15
Cd	mg/kg	**7.5**	**260**	**1040**	0.0004
Co	mg/kg	**50**	**5000**	**20000**	<0.02
Cr	mg/kg	**46000**	**800000**	**N/A**	0.49
Cu	mg/kg	**16**	**19500**	**78000**	<0.02
Hg	mg/kg	**0.93**	**160**	**640**	0.0012
Mn	mg/kg	**1000**	**25000**	**100000**	0.04
Mo	mg/kg	**40**	**1000**	**4000**	0.223456
Ni	mg/kg	**91**	**10600**	**42400**	<0.02
Pb	mg/kg	**20**	**1900**	**7600**	<0.02
Sb	mg/kg	**10**	**75**	**300**	0.016
Se	mg/kg	**10**	**50**	**200**	0.06
V	mg/kg	**150**	**2680**	**10720**	0.55
Zn	mg/kg	**240**	**160000**	**640000**	<0.02
Fluoride as F	mg/kg	**100**	**10000**	**40000**	4

Table 2: LCT classification table

Parameter	Unit	LCT0	LCT1	LCT2	LCT3	AWS
As	mg/l	**0.01**	**0.5**	**1**	**4**	0.003
B	mg/l	**0.5**	**25**	**50**	**200**	1.4
Ba	mg/l	**0.7**	**35**	**70**	**280**	0.4
Cd	mg/l	**0.003**	**0.15**	**0.3**	**1.2**	0.0001
Co	mg/l	**0.5**	**25**	**50**	**200**	<0.001
Cr	mg/l	**0.1**	**5**	**10**	**40**	0.09
Cu	mg/l	**2**	**100**	**200**	**800**	<0.001
Hg	mg/l	**0.006**	**0.3**	**0.6**	**2.4**	0.0003
Mn	mg/l	**0.5**	**25**	**50**	**200**	0.01
Mo	mg/l	**0.07**	**3.5**	**7**	**28**	0.03
Ni	mg/l	**0.07**	**3.5**	**7**	**28**	<0.001
Pb	mg/l	**0.01**	**0.5**	**1**	**4**	<0.001
Sb	mg/l	**0.02**	**1**	**2**	**8**	0.004
Se	mg/l	**0.01**	**0.5**	**1**	**4**	0.01
V	mg/l	**0.2**	**10**	**20**	**80**	0.14
Zn	mg/l	**5**	**250**	**500**	**2000**	<0.001
Chloride as Cl	mg/l	**300**	**15000**	**30000**	**120000**	8
Sulphate as SO_4	mg/l	**250**	**12500**	**25000**	**100000**	22
Nitrate as N	mg/l	**11**	**550**	**1100**	**4400**	<0.2
Fluoride as F	mg/l	**1.5**	**75**	**150**	**600**	0.6

4 CONCLUSIONS

Based on the geochemical study results and classification the following can be concluded:

Based on the classification of the Distilled/Reagent water leachate test results against the relevant TCT and LCT limits (as given in the legislative guidelines for classification (DEA 2013a), the ash to be used as backfill can be classified as follows:

- For boron (B) the results show that LCT0<LC<LCT1 and TC<TCT0;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste;

5 RECOMMENDATIONS

The following recommendations are made by Digby Wells based on the outcome of this study:

- In the DW tests the main elements of concern leaching out are B, Ba, Ca, Se, Al and Cr. These elements should be monitored in all phases of the project on a monthly basis;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste; however
    - Based on the low concentrations of the leachable ions (although they are above TCT0 and LCT0 in certain cases), the low NAG and the high NNP (section 3.2.3) it is concluded that the alternative ash management activity of using the ash material for backfilling of the mine voids at Sigma Colliery is feasible and a motivation to the authorities for this activity to be licenced is recommended.
    - The low permeability and hydraulic conductivity of ash will allow little to no seepage through the newly formed ash layers once allowed to settle and thus the environmental concentration of contaminants entering the receiving environment will be low and easily diluted through natural processes.
- If the ash management activity of backfilling the mine voids is not pursued the ash should be disposed of at a Class C Landfill.
- Previous limits and target water quality conditions in the water licence granted for the ash backfilling in Licence #20021165 was well set and achievable. It is recommended that these conditions are kept and monitoring should ensure that the target water quality standards are achieved.

6 REFERENCES

DEA, 2013a. *National Norms and Standards for the Assessment of Waste for Landfill Disposal*, Department of Environmental Affairs.

DEA, 2013b. *National Norms and Standards for the Disposal of Waste to Landfill*,

DEA, 2013c. *National Waste Classification and Management Regulations*, Department of Environmental Affairs.

DEA, 2012. *National Waste Information Regulations, 2012*, Department of Environmental Affairs.

Appendix A: Laboratory certificates

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

Building D
The Woods
41 De Havilland Cresent
Persequor Techno Park
Meiring Naudé Drive
Pretoria

P.O. Box 283
Persequor Park, 0020
Tel: +2712 – 349 – 1066
Fax: +2712 – 349 – 2064
e-mail: admin@waterlab.co.za

SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2013 - 09 - 26 **Date completed:** 2013 - 10 – 14

Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmental **Contact person: Mr. A. van Coller**

Address: Private Bag X10046 Randburg 2125 **e-mail: andre.van.coller@digbywells.com**

Telephone: 011 789 9495 **Facsimile: 011 789 9498** **Mobile: -**

Analyses in mg/ℓ (Unless specified otherwise)	Method Identification	Sample Identification
		Composite
Sample Number		18946
pH – Value at 25°C	WLAB001	12.3
Electrical Conductivity in mS/m at 25°C	WLAB002	523
Total Dissolved Solids at 180°C *	WLAB003	1 412
Total Acidity as $CaCO_3$*	WLAB022	<5
Total Alkalinity as $CaCO_3$	WLAB007	1 248
P-Alkalinity as $CaCO_3$ *	WLAB023	880
Bicarbonate Alkalinity as $CaCO_3$ *	WLAB023	<5
Carbonate Alkalinity as $CaCO_3$ *	WLAB023	736
Total Hardness as $CaCO_3$ *	WLAB051	1 102
Chloride as Cl	WLAB046	163
Sulphate as SO_4	WLAB046	60
Fluoride as F	WLAB014	1.7
Nitrate as N	WLAB046	<0.2
Nitrite as N	WLAB046	0.3
Ortho Phosphate as P	WLAB046	<0.2
Dissolved Oxygen as O_2 *	WLAB040	6.0
Free & Saline Ammonia as N	WLAB046	3.8
Ammonium as NH_4 *	---	<0.2
Sodium as Na	WLAB015	168
Potassium as K	WLAB015	15.6
Calcium as Ca	WLAB015	442
Magnesium as Mg	WLAB015	<2

Analyses continued on next page

A. van de Wetering

Technical Signatory

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

Building D
The Woods
41 De Havilland Cresent
Persequor Techno Park
Meiring Naudé Drive
Pretoria

P.O. Box 283
Persequor Park, 0020
Tel: +2712 – 349 – 1066
Fax: +2712 – 349 – 2064
e-mail: admin@waterlab.co.za

SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2013 - 09 - 26 **Date completed:** 2013 - 10 – 14

Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmental **Contact person: Mr. A. van Coller**

Address: Private Bag X10046 Randburg 2125 **e-mail: andre.van.coller@digbywells.com**

Telephone: 011 789 9495 **Facsimile: 011 789 9498** **Mobile: -**

Analyses in mg/ℓ (Unless specified otherwise)	**Method Identification**	**Sample Identification**
		Composite
Sample Number		18946
Aluminium as Al	WLAB015	3.78
Arsenic as As *	WLAB015	<0.010
Boron as B *	WLAB015	0.696
Cadmium as Cd	WLAB015	<0.005
Chromium as Cr	WLAB015	0.167
Hexavalent Chromium as Cr^{6+} *	WLAB032	0.160
Cobalt as Co	WLAB015	<0.025
Copper as Cu	WLAB015	<0.025
Iron as Fe	WLAB015	0.559
Lead as Pb	WLAB015	<0.020
Manganese as Mn	WLAB015	<0.025
Mercury as Hg *	WLAB047	<0.001
Nickel as Ni	WLAB015	<0.025
Selenium as Se *	WLAB015	0.032
Uranium as U *	WLAB015	<0.010
Zinc as Zn	WLAB015	<0.025
% Balancing	---	98.9

*** = Not SANAS Accredited**

Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

A. van de Wetering

_____

Technical Signatory

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY FLUORESCENCE

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Major Elements	Major Element Concentration (wt %)[s]				
	A	B	C	D	E
	18940	18941	18942	18943	18944
SiO_2	49.12	48.3	46.87	61.01	48.49
TiO_2	2.54	2.56	2.54	1.68	2.36
Al_2O_3	32.53	32.47	33.21	24.65	31.15
Fe_2O_3	3.23	3.18	3.3	2.62	3.06
MnO	0.04	0.05	0.05	0.04	0.05
MgO	0.59	0.67	0.75	0.52	0.73
CaO	6.16	6.35	6.65	0.65	5.78
Na_2O	0.63	0.78	0.87	0.3	0.79
K_2O	0.67	0.69	0.72	1.81	0.7
P_2O_5	0.14	0.15	0.15	0.08	0.15
Cr_2O_3	0.05	0.05	0.05	0.04	0.05
SO_3	0.1	0.26	0.14	0.11	0.36
LOI	3.72	4.06	4.18	6.22	5.86
Total	99.52	99.57	99.48	99.73	99.53
H_2O-	0.04	0.08	0.2	0.47	0.13

[s] =Results obtained from sub-contracted laboratory

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY FLUORESCENCE

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Trace Elements	Trace Element Concentration (ppm) [s]				
	A	B	C	D	E
	18940	18941	18942	18943	18944
As	23.5	21.8	25.9	<1.00	20.6
Ba	812	846	897	479	828
Bi	<1.00	<1.00	<1.00	<5.00	<1.00
Br	1.32	1.16	1.21	<1.00	1.25
Cd	1.84	<5.00	<5.00	<5.00	<5.00
Ce	<5.00	<5.00	<5.00	<5.00	<5.00
Cl	1129	881	1041	802	956
Co	12.7	32.5	53.9	<5.00	42.7
Cs	<1.00	<1.00	1.49	<1.00	<1.00
Cu	84.7	71	78	23.7	72.8
Ga	72	74.4	76.4	21	64.5
Ge	15.8	14	18.5	4.09	13.2
Hf	8.68	8.88	9.02	14.9	8.71
Hg	1.6	1.65	1.73	<5.00	1.37
La	103	66.2	92.2	15.1	69.7
Lu	<1.00	<1.00	<1.00	<1.00	<1.00
Mo	13.9	11.3	13.1	10.8	12.2
Nb	53.7	54.1	53.1	19.1	49
Nd	80.3	83.5	70.9	65.2	62.5
Ni	75.5	74.2	80.7	52.9	74
Pb	111	133	128	20.1	103
Rb	32.9	35.8	36.2	59.9	33.9
Sb	<5.00	3.39	<1.00	3.12	3.66
Sc	18.6	16.6	21	12.6	18.8
Se	<1.00	<5.00	<1.00	<5.00	<1.00
Sm	17.9	16.4	17.1	12.6	17.2
Sn	1.76	2.89	1.56	4.78	2.49
Sr	905	887	1128	161	1063
Ta	3.27	3.57	5.17	3.27	2.66
Te	27.5	30.4	25.7	2.7	29.7
Th	56	60.9	58.7	29.9	53.4
Tl	2.21	1.95	1.26	<1.00	1.74

Results continued on next page

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY FLUORESCENCE

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Trace Elements	Trace Element Concentration (ppm) [s]				
	A	B	C	D	E
	18940	18941	18942	18943	18944
U	15	16.2	17.2	4.63	16.6
V	281	290	304	74.9	282
W	5.16	5.12	4.93	4.93	4.95
Y	107	112	110	26.5	104
Yb	26.7	25	25.9	18.8	24.3
Zn	95.6	94.4	115	111	63.5
Zr	733	739	718	967	673

[s] =Results obtained from sub-contracted laboratory

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2013-09-26 **Date completed: 2013-10-23**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Composition (%) [s]

A			B			C		
18940			18941			18942		
Mineral	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error
Amorphous	53.55	1.26	Amorphous	58.08	1.2	Amorphous	55.83	1.29
Lime	0.83	0.13	Lime	0.67	0.13	Lime	0.52	0.14
Calcite	0.12	0.11	Calcite	0.04	0.1	Calcite	0	0
Mullite	38.51	1.11	Mullite	36.07	1.05	Mullite	38.06	1.17
Quartz	6.98	0.57	Quartz	5.14	0.51	Quartz	5.6	0.54

Composition (%) [s]

D			E		
18943			18944		
Mineral	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error
Amorphous	75.55	0.87	Amorphous	55.43	1.23
Lime	0.36	0.09	Lime	1.08	0.15
Calcite	0.1	0.17	Calcite	0	0
Mullite	6.28	0.42	Mullite	35.65	1.05
Quartz	17.7	0.57	Quartz	7.84	0.57

[s] Results obtained from sub-contracted laboratory

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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X-RAY DIFFRACTION

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Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Note:

The material submitted was scanned after addition of 20 % Si for quantitative determination of amorphous content and micronizing in a McCrone micronizing mill.

The material was prepared for XRD analysis using a backloading preparation method.

It was analysed with a PANalytical Empyrean diffractometer with PIXcel detector and fixed slits with Fe filtered Co-K_ radiation. The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight%) were estimated using the Rietveld method.

Errors are on the 3 sigma level in the column to the right of the amount (in weight per cent).

Comment:

• In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.

• Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group .

• Errors reported for phases occurring in minor amounts are sometimes larger than that of the quantity reported, indicating the possible absence of those phases.

Ideal Mineral compositions:
Calcite CaCO3
Lime CaO
Mullite 3Al2O3 2SiO2
Quartz SiO2

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification					
	A	B	C	D	E	E
Sample Number	**18940**	**18941**	**18942**	**18943**	**18944**	**18944D**
Paste pH	11.7	11.8	12.1	12.2	12.2	12.2
Total Sulphur (%) (LECO)	0.05	0.06	0.07	0.05	<0.01	<0.01
Acid Potential (AP) (kg/t)	1.56	1.88	2.19	1.56	0.31	0.31
Neutralization Potential (NP)	43.50	27.00	36.25	39.25	24.75	25.50
Nett Neutralization Potential (NNP)	41.94	25.13	34.06	37.69	24.44	25.19
Neutralising Potential Ratio (NPR) (NP : AP)	27.84	14.40	16.57	25.12	79.20	81.60
Rock Type	III	III	III	III	III	III

*** Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.**

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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ACID – BASE ACCOUNTING
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Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

APPENDIX : TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

- Acid Potential (AP) ; *Synonyms*: Maximum Potential Acidity (MPA)
  Method: Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn*: Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)
  Method: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)
  Calculation: NNP = NP – AP ; NAPP = ANC – MPA
- Neutralising Potential Ratio (NPR)
  Calculation: NPR = NP : AP

CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

If NNP (NP – AP) < 0, the sample has the potential to generate acid
If NNP (NP – AP) > 0, the sample has the potential to neutralise acid produced

Any sample with NNP < 20 is potentiall acid-generating, and any sample with NNP > -20 might not generate acid (Usher *et al.*, 2003)

ROCK CLASSIFICATION

TYPE I	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
TYPE III	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

Guidelines for screening criteria based on ABA (Price *et al*., 1997 ; Usher *et al*., 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	**< 1:1**	Likely AMD generating
Possibly	**1:1 – 2:1**	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	**2:1 – 4:1**	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	**>4:1**	No further AMD testing required unless materials are to be used as a source of alkalinity

CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
3) NPR ratios of 3:1 to 1:1 are consider inconclusive.
4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al*., 2003)

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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EPA-600 MODIFIED SOBEK METHOD

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Project number: 1000 **Report number: 42135** **Order number: SAS1691**

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Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

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E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
NETT ACID GENERATION

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Nett Acid Generation	Sample Identification: pH 4.5 & 7					
	A	**B**	**C**	**D**	**E**	**E**
Sample Number	**18940**	**18941**	**18942**	**18943**	**18944**	**18944D**
NAG pH: (H_2O_2)	10.2	10.3	10.3	10.5	10.2	10.2
NAG (kg H_2SO_4 / t)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-30**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	A		B	
Sample number	**18940**		**18941**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	12.2		12.1	
Electrical Conductivity in mS/m at 25˚C	279		206	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	790	1 580	612	12 240
Chloride as Cl	<5	<100	<5	<100
Sulphate as SO_4	22	440	31	620
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.6	12	0.5	10
Phosphorus as P	<0.025	<0.500	<0.025	<0.500
ICP-MS Quant [s]	See attached report 42135 ICP DW		See attached report 42135 ICP DW	
Acid Base Accounting	See attached report 42135 ABA		See attached report 42135 ABA	
Net Acid Generation	See attached report 42135 NAG		See attached report 42135 NAG	
X-Ray Diffraction [s]	See attached report 42135 XRD		See attached report 42135 XRD	
X-Ray Fluorescence [s]	See attached report 42135 XRF		See attached report 42135 XRF	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-30**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	C		D	
Sample number	**18942**		**18943**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	12.3		12.4	
Electrical Conductivity in mS/m at 25˚C	392		527	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	1 020	20 400	1 368	27 360
Chloride as Cl	<5	<100	<5	<100
Sulphate as SO_4	9	180	<5	<100
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	1.0	20	0.7	14
Phosphorus as P	<0.025	<0.500	<0.025	<0.500
ICP-MS Quant [s]	See attached report 42135 ICP DW		See attached report 42135 ICP DW	
Acid Base Accounting	See attached report 42135 ABA		See attached report 42135 ABA	
Net Acid Generation	See attached report 42135 NAG		See attached report 42135 NAG	
X-Ray Diffraction [s]	See attached report 42135 XRD		See attached report 42135 XRD	
X-Ray Fluorescence [s]	See attached report 42135 XRF		See attached report 42135 XRF	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-30**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	E		AWS	
Sample number	**18944**		**18945**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	12.2		11.4	
Electrical Conductivity in mS/m at 25˚C	281		461	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	732	14 640	136	2 720
Chloride as Cl	<5	<100	8	160
Sulphate as SO_4	23	460	22	440
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.8	16	0.6	12
Phosphorus as P	<0.025	<0.500	<0.025	<0.500
ICP-MS Quant [s]	See attached report 42135 ICP DW		See attached report 42135 ICP DW	
Acid Base Accounting	See attached report 42135 ABA		See attached report 42135 ABA	
Net Acid Generation	See attached report 42135 NAG		See attached report 42135 NAG	
X-Ray Diffraction [s]	See attached report 42135 XRD		See attached report 42135 XRD	
X-Ray Fluorescence [s]	See attached report 42135 XRF		See attached report 42135 XRF	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-MS QUANTITATIVE ANALYSIS [s]

Date received: 26/09/2013 **Date Completed:** 30/10/2013
Project number: 1000 **Report number:** 42135

Client name: Digby Wells Environmental **Contact person:** Andre van Coller
Adress: Private Bag X10046, Randburg, 2125 **Email:** andre.van.coller@digbywells.com
Telephone: 011 789 9495

Extract	Sample Dry Mass (g)	Volume (ml)	Factor
Distilled Water	50	1000	20

[s]= Results obtained form subcontracted laboratory

Sample Id	Sample Number	Ag	Ag	Al	Al	As	As
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	3.01	60	0.001	0.020
B	18941	<0.001	<0.020	4.52	90	0.001	0.020
C	18942	<0.001	<0.020	0.708	14	0.002	0.040
D	18943	0.001	0.020	0.486	10	0.001	0.020
E	18944	<0.001	<0.020	2.13	43	0.001	0.020
AWS	19845	<0.001	<0.020	3.65	73	0.003	0.060

Sample Id	Sample Number	Au	Au	B	B	Ba	Ba
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	2.63	53	3.01	60
B	18941	<0.001	<0.020	2.57	51	2.17	43
C	18942	<0.001	<0.020	0.366	7.32	4.03	81
D	18943	<0.001	<0.020	0.063	1.25	11	220
E	18944	<0.001	<0.020	2.01	40	3.93	79
AWS	19845	<0.001	<0.020	1.37	27	0.382	7.63

Sample Id	Sample Number	Be	Be	Bi	Bi	Ca	Ca
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.01	<0.20
A	18940	<0.001	<0.020	<0.001	<0.020	322	6440
B	18941	<0.001	<0.020	<0.001	<0.020	282	5640
C	18942	<0.001	<0.020	<0.001	<0.020	440	8800
D	18943	<0.001	<0.020	<0.001	<0.020	560	11200
E	18944	<0.001	<0.020	<0.001	<0.020	327	6540
AWS	19845	<0.001	<0.020	<0.001	<0.020	65	1300

Sample Id	Sample Number	Cd	Cd	Ce	Ce	Co	Co
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.0001	<0.0020	<0.001	<0.020	<0.001	<0.020
A	18940	0.0002	0.004	<0.001	<0.020	<0.001	<0.020
B	18941	0.0002	0.004	<0.001	<0.020	<0.001	<0.020
C	18942	0.0002	0.004	<0.001	<0.020	<0.001	<0.020
D	18943	0.0001	0.002	<0.001	<0.020	<0.001	<0.020
E	18944	0.0001	0.002	<0.001	<0.020	<0.001	<0.020
AWS	19845	0.0001	0.002	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample Number	Cr	Cr	Cs	Cs	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.255	5.09	0.001	0.020	<0.001	<0.020
B	18941	0.362	7.24	0.001	0.020	<0.001	<0.020
C	18942	0.177	3.54	0.001	0.020	<0.001	<0.020
D	18943	0.061	1.21	0.001	0.020	<0.001	<0.020
E	18944	0.114	2.28	0.001	0.020	<0.001	<0.020
AWS	19845	0.086	1.72	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample Number	Fe	Fe	Ga	Ga	Ge	Ge
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.01	<0.20	<0.001	<0.020	<0.001	<0.020
A	18940	<0.01	<0.20	0.078	1.55	0.001	0.020
B	18941	<0.01	<0.20	0.103	2.06	<0.001	<0.020
C	18942	<0.01	<0.20	0.056	1.12	<0.001	<0.020
D	18943	<0.01	<0.20	0.042	0.832	<0.001	<0.020
E	18944	<0.01	<0.20	0.082	1.64	<0.001	<0.020
AWS	19845	<0.01	<0.20	0.028	0.563	<0.001	<0.020

Sample Id	Sample Number	Hf	Hf	Hg	Hg	Ho	Ho
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.200	<0.0001	<0.0020	<0.001	<0.200
A	18940	<0.001	<0.200	0.0006	0.0120	<0.001	<0.200
B	18941	<0.001	<0.200	0.0007	0.0140	<0.001	<0.200
C	18942	<0.001	<0.200	0.0005	0.0100	<0.001	<0.200
D	18943	<0.001	<0.200	0.0002	0.0040	<0.001	<0.200
E	18944	<0.001	<0.200	0.0006	0.0120	<0.001	<0.200
AWS	19845	<0.001	<0.200	0.0003	0.0060	<0.001	<0.200

Sample Id	Sample Number	Ir	Ir	K	K	La	La
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.01	<0.20	<0.001	<0.020
A	18940	<0.001	<0.020	0.154	3.1	<0.001	<0.020
B	18941	<0.001	<0.020	0.166	3.3	<0.001	<0.020
C	18942	<0.001	<0.020	0.164	3.3	<0.001	<0.020
D	18943	<0.001	<0.020	0.103	2.1	<0.001	<0.020
E	18944	<0.001	<0.020	0.041	0.814	<0.001	<0.020
AWS	19845	<0.001	<0.020	0.435	8.7	<0.001	<0.020

Sample Id	Sample Number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg

Det Limit		<0.001	<0.020	<0.01	<0.200	<0.001	<0.020
A	18940	0.300	<0.020	<0.01	<0.200	<0.001	<0.020
B	18941	0.370	<0.020	<0.01	<0.200	<0.001	<0.020
C	18942	0.330	<0.020	<0.01	<0.200	0.010	0.200
D	18943	0.260	<0.020	<0.01	<0.200	<0.001	<0.020
E	18944	0.370	7.40	<0.01	<0.200	<0.001	<0.020
AWS	19845	0.070	<0.020	<0.01	<0.200	0.010	0.200

Sample Id	Sample Number	Mo	Mo	Na	Na	Nb	Nb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.058	1.17	1.27	25	<0.001	<0.020
B	18941	0.069	1.37	1.47	29	<0.001	<0.020
C	18942	0.050	1.01	1.61	32	<0.001	<0.020
D	18943	0.033	0.656	1.54	31	<0.001	<0.020
E	18944	0.053	1.05	2.04	41	<0.001	<0.020
AWS	19845	0.030	0.601	6.12	122	<0.001	<0.020

Sample Id	Sample Number	Nd	Nd	Ni	Ni	Pb	Pb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	0.024	0.485	<0.001	<0.020
B	18941	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
C	18942	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
D	18943	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
E	18944	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
AWS	19845	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample Number	Pt	Pt	Rb	Rb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	0.002	0.040	0.002	0.040
B	18941	<0.001	<0.020	0.002	0.040	0.002	0.040
C	18942	<0.001	<0.020	0.002	0.040	0.001	0.020
D	18943	<0.001	<0.020	0.002	0.040	0.001	0.020
E	18944	<0.001	<0.020	0.002	0.040	0.002	0.040
AWS	19845	<0.001	<0.020	0.002	0.040	0.004	0.080

Sample Id	Sample Number	Sc	Sc	Se	Se	Si	Si
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.05	<1.00
A	18940	0.001	0.020	0.042	0.845	1.5	31
B	18941	0.001	0.020	0.072	1.43	2.0	41
C	18942	<0.001	<0.020	0.014	0.288	0.950	19
D	18943	<0.001	<0.020	0.025	0.492	0.540	11
E	18944	<0.001	<0.020	0.045	0.900	1.7	35
AWS	19845	0.005	0.100	0.009	0.180	7.1	142

Sample Id	Sample Number	Sn	Sn	Sr	Sr	Ta	Ta
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	3.53	71	<0.001	<0.020
B	18941	<0.001	<0.020	2.83	57	<0.001	<0.020
C	18942	<0.001	<0.020	4.43	89	<0.001	<0.020
D	18943	<0.001	<0.020	5.49	110	<0.001	<0.020
E	18944	<0.001	<0.020	3.69	74	<0.001	<0.020
AWS	19845	<0.001	<0.020	0.819	16	<0.001	<0.020

Sample Id	Sample Number	Te	Te	Th	Th	Ti	Ti
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
A	18940	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
B	18941	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
C	18942	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
D	18943	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
E	18944	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
AWS	19845	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00

Sample Id	Sample Number	Tl	Tl	U	U	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.001	<0.020
A	18940	<0.001	<0.020	<0.0001	<0.0020	0.011	0.221
B	18941	<0.001	<0.020	<0.0001	<0.0020	0.022	0.449
C	18942	<0.001	<0.020	<0.0001	<0.0020	0.009	0.180
D	18943	<0.001	<0.020	<0.0001	<0.0020	0.004	0.085
E	18944	<0.001	<0.020	<0.0001	<0.0020	0.012	0.239
AWS	19845	<0.001	<0.020	0.0003	0.006	0.137	2.75

Sample Id	Sample Number	W	W	Y	Y
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	0.043	0.856	<0.001	<0.020
B	18941	0.052	1.05	<0.001	<0.020
C	18942	0.034	0.672	<0.001	<0.020
D	18943	0.017	0.341	<0.001	<0.020
E	18944	0.041	0.813	<0.001	<0.020
AWS	19845	0.023	0.468	<0.001	<0.020

Sample Id	Sample Number	Zn	Zn	Zr	Zr
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	<0.001	<0.020
B	18941	<0.001	<0.020	<0.001	<0.020
C	18942	<0.001	<0.020	<0.001	<0.020
D	18943	<0.001	<0.020	<0.001	<0.020
E	18944	<0.001	<0.020	<0.001	<0.020
AWS	19845	<0.001	<0.020	<0.001	<0.020

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-31**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	A		B	
Sample number	**18940**		**18941**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**TCLP 2**		**TCLP 2**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	4.7		4.7	
Electrical Conductivity in mS/m at 25˚C	368		364	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	600	12 000	564	11 280
Chloride as Cl	<5	<100	<5	<100
Sulphate as SO_4	94	1 880	109	2 180
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.4	8.0	0.3	6.0
Phosphorus as P	0.3	6.0	0.4	8.0
ICP-MS Quant [s]	See attached report 42135 ICP TCLP		See attached report 42135 ICP TCLP	

[s] Subcontracted

TCLP 2 = pH2.9

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-31**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	C		D	
Sample number	**18942**		**18943**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**TCLP 2**		**TCLP 2**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	4.8		5.1	
Electrical Conductivity in mS/m at 25˚C	402		496	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	1000	20 000	1776	35 520
Chloride as Cl	5	100	7	140
Sulphate as SO_4	118	2 360	81	1 620
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.4	8.0	0.8	16
Phosphorus as P	0.3	6.0	0.2	4.0
ICP-MS Quant [s]	See attached report 42135 ICP TCLP		See attached report 42135 ICP TCLP	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-31**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification	
	E	
Sample number	**18944**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**TCLP 2**	
Dry Mass Used (g)	**50**	
Volume Used (mℓ)	**1000**	
pH Value at 25˚C	4.7	
Electrical Conductivity in mS/m at 25˚C	366	
Units	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	720	14 400
Chloride as Cl	<5	<100
Sulphate as SO_4	95	1 900
Nitrate as N	<0.2	<4.0
Fluoride as F	0.4	8.0
Phosphorus as P	0.3	6.0
ICP-MS Quant [s]	See attached report 42135 ICP TCLP	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-MS QUANTITATIVE ANALYSIS [s]

Date received: 26/09/2013
Project number: 1000

Date Completed: 31/10/2013
Report number: 42135

Client name: Digby Wells Environmental
Adress: Private Bag X10046, Randburg, 2125
Telephone: 011 789 9495

Contact person: Andre van Coller
Email: andre.van.coller@digbywells.com

Extract	Sample Dry Mass (g)	Volume (ml)	Factor
TCLP	50	1000	20

[s]= Results obtained form subcontracted laboratory

Sample Id	Sample Number	Ag	Ag	Al	Al	As	As
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	17.7	354	0.023	0.455
B	18941	<0.001	<0.020	25.2	504	0.027	0.538
C	18942	<0.001	<0.020	15.3	306	0.022	0.437
D	18943	<0.001	<0.020	8.36	167	0.010	0.193
E	18944	<0.001	<0.020	12.3	246	0.026	0.513

Sample Id	Sample Number	Au	Au	B	B	Ba	Ba
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	7.2	143	1.60	32
B	18941	<0.001	<0.020	8.9	178	1.49	30
C	18942	<0.001	<0.020	8.9	178	1.34	27
D	18943	<0.001	<0.020	6.2	124	1.76	35
E	18944	<0.001	<0.020	6.7	135	1.70	34

Sample Id	Sample Number	Be	Be	Bi	Bi	Ca	Ca
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.01	<0.20
A	18940	0.006	0.120	<0.001	<0.020	998	19960
B	18941	0.008	0.160	<0.001	<0.020	1000	20000
C	18942	0.006	0.120	<0.001	<0.020	1140	22800
D	18943	0.004	0.080	<0.001	<0.020	1400	28000
E	18944	0.005	0.100	<0.001	<0.020	1010	20200

Sample Id	Sample Number	Cd	Cd	Ce	Ce	Co	Co
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.0001	<0.0020	<0.001	<0.020	<0.001	<0.020
A	18940	0.0019	0.038	0.082	1.64	0.012	0.241
B	18941	0.0027	0.053	0.105	2.09	0.013	0.255
C	18942	0.0025	0.051	0.073	1.45	0.014	0.281
D	18943	0.0021	0.042	0.060	1.20	0.013	0.259
E	18944	0.0037	0.074	0.078	1.56	0.011	0.220

Sample Id	Sample Number	Cr	Cr	Cs	Cs	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.501	10	0.001	0.020	0.043	0.859
B	18941	0.591	12	0.001	0.020	0.031	0.624
C	18942	0.484	9.68	0.001	0.020	0.022	0.436
D	18943	0.229	4.59	0.001	0.020	<0.001	<0.020
E	18944	0.281	5.62	0.001	0.020	0.020	0.392

Sample Id	Sample Number	Fe	Fe	Ga	Ga	Ge	Ge
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.01	<0.20	<0.001	<0.020	<0.001	<0.020
A	18940	0.573	11	0.006	0.120	0.206	4.11
B	18941	0.818	16	0.010	0.200	0.250	5.01
C	18942	0.390	7.79	0.005	0.100	0.230	4.60
D	18943	0.207	4.14	0.003	0.060	0.149	2.97
E	18944	0.266	5.31	0.003	0.060	0.214	4.27

Sample Id	Sample Number	Hf	Hf	Hg	Hg	Ho	Ho
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.200	<0.0001	<0.0020	<0.001	<0.200
A	18940	<0.001	<0.200	0.0002	0.004	0.007	0.140
B	18941	<0.001	<0.200	0.0002	0.004	0.008	0.160
C	18942	<0.001	<0.200	0.0001	0.002	0.006	0.120
D	18943	<0.001	<0.200	0.0001	0.002	0.005	0.100
E	18944	<0.001	<0.200	0.0001	0.002	0.006	0.120

Sample Id	Sample Number	Ir	Ir	K	K	La	La
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.01	<0.20	<0.001	<0.020
A	18940	<0.001	<0.020	0.454	9.1	0.082	1.63
B	18941	<0.001	<0.020	0.524	10.5	0.098	1.96
C	18942	<0.001	<0.020	0.602	12.0	0.079	1.58
D	18943	<0.001	<0.020	0.457	9.1	0.064	1.29
E	18944	<0.001	<0.020	0.653	13.1	0.069	1.38

Sample Id	Sample Number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg

Det Limit		<0.001	<0.020	<0.01	<0.200	<0.001	<0.020
A	18940	0.400	862	43.1	862	1.18	24
B	18941	0.510	750	37.5	750	1.26	25
C	18942	0.530	1074	53.7	1074	1.38	28
D	18943	0.410	1206	60.3	1206	1.58	32
E	18944	0.490	1064	53.2	1064	1.56	31

Sample Id	Sample Number	Mo	Mo	Na	Na	Nb	Nb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.020	0.397	1.98	40	<0.001	<0.020
B	18941	0.019	0.388	2.56	51	<0.001	<0.020
C	18942	0.029	0.588	2.84	57	<0.001	<0.020
D	18943	0.027	0.546	2.74	55	<0.001	<0.020
E	18944	0.014	0.286	2.98	60	<0.001	<0.020

Sample Id	Sample Number	Nd	Nd	Ni	Ni	Pb	Pb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.095	1.91	0.028	0.563	<0.001	<0.020
B	18941	0.109	2.17	0.023	0.454	0.002	0.040
C	18942	0.096	1.91	0.025	0.510	<0.001	<0.020
D	18943	0.083	1.66	0.016	0.323	<0.001	<0.020
E	18944	0.081	1.62	0.012	0.241	0.004	0.080

Sample Id	Sample Number	Pt	Pt	Rb	Rb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	0.004	0.080	0.015	0.300
B	18941	<0.001	<0.020	0.005	0.100	0.016	0.320
C	18942	<0.001	<0.020	0.005	0.100	0.016	0.320
D	18943	<0.001	<0.020	0.004	0.080	0.010	0.200
E	18944	<0.001	<0.020	0.005	0.100	0.016	0.320

Sample Id	Sample Number	Sc	Sc	Se	Se	Si	Si
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.05	<1.00
A	18940	0.080	1.59	0.029	0.572	92.4	1848
B	18941	0.088	1.75	0.035	0.697	103.9	2078
C	18942	0.078	1.55	0.018	0.354	93.5	1870
D	18943	0.059	1.18	0.021	0.421	75.6	1512
E	18944	0.075	1.50	0.060	1.21	91.7	1834

Sample Id	Sample Number	Sn	Sn	Sr	Sr	Ta	Ta
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	7.59	152	<0.001	<0.020
B	18941	<0.001	<0.020	7.18	144	<0.001	<0.020
C	18942	<0.001	<0.020	9.59	192	<0.001	<0.020
D	18943	<0.001	<0.020	13.00	260	<0.001	<0.020
E	18944	<0.001	<0.020	8.30	166	<0.001	<0.020

Sample Id	Sample Number	Te	Te	Th	Th	Ti	Ti
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
A	18940	0.007	0.140	0.0002	0.004	0.029	0.584
B	18941	0.008	0.160	0.0003	0.006	0.042	0.831
C	18942	0.007	0.140	0.0002	0.004	0.022	0.436
D	18943	0.003	0.060	0.0001	0.002	0.014	0.277
E	18944	0.007	0.140	0.0001	0.002	0.015	0.307

Sample Id	Sample Number	Tl	Tl	U	U	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.001	<0.020
A	18940	<0.001	<0.020	0.0181	0.362	0.298	5.97
B	18941	<0.001	<0.020	0.0219	0.437	0.320	6.40
C	18942	<0.001	<0.020	0.0177	0.353	0.390	7.79
D	18943	<0.001	<0.020	0.0089	0.178	0.131	2.63
E	18944	<0.001	<0.020	0.0073	0.146	0.309	6.18

Sample Id	Sample Number	W	W	Y	Y
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	0.001	0.020	0.209	4.18
B	18941	0.002	0.040	0.230	4.60
C	18942	0.002	0.040	0.201	4.02
D	18943	0.002	0.040	0.175	3.50
E	18944	0.001	0.020	0.179	3.59

Sample Id	Sample Number	Zn	Zn	Zr	Zr
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	0.158	3.15	0.001	0.020
B	18941	0.219	4.38	0.001	0.020
C	18942	0.199	3.98	0.001	0.020
D	18943	0.146	2.92	<0.001	<0.020
E	18944	0.293	5.86	<0.001	<0.020

Appendix B: Leachate result classification

Distilled water leach results compared to Drinking water guidelines

Results for chemicals that are of health significance in drinking-water																													
Parameter	**pH**	**Total Alk**	**F**	**Cl**	**NO3 as N**	**SO4**	**Al**	**As**	**B***	**Ba***	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**K**	**Mg**	**Mn**	**Mo***	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**V**	**Zn**	**U***
Unit	**-**	**mg/l CaCO3**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Class 1 (recommended limit)	5 - 9.5	N/A	1	200	10	400	0.3	0.01			150	0.0050	0.5	0.1	1	0.2	0.001	50	70	0.1		200	0.15	0.02	0.01	0.02	0.2	5	
Class 2 (max allowed for limited duration)	4 - 5 / 9.5 - 10	N/A	1.5	600	20	600	0.5	0.05			300	0.0100	1	0.5	2	2	0.005	100	100	1		400	0.35	0.05	0.05	0.05	0.5	10	
Class 3 (not recommended for consumtion)	<4 / >10	N/A	>1.5	>600	>20	>600	>0.5	>0.05	0.5	0.7	>300	>0.01	>1	>0.5	>2	>2	>0.005	>100	>100	>1	0.07	>400	>0.35	>0.05	>0.05	>0.05	>0.5	>10	0.015
A	12.2	790	0.6	<5	<0.2	22	3.0	0.001	2.6	3.0	322	0.0002	<0.001	0.25	<0.001	<0.01	0.0006	0.15	<0.01	<0.001	0.06	1.27	0.024	<0.001	0.002	0.042	0.01	<0.001	<0.0001
B	12.1	612	0.5	<5	<0.2	31	4.5	0.001	2.6	2.2	282	0.0002	<0.001	0.36	<0.001	<0.01	0.0007	0.17	<0.01	<0.001	0.07	1.47	<0.001	<0.001	0.002	0.072	0.02	<0.001	<0.0001
C	12.3	1020	1	<5	<0.2	9	0.7	0.002	0.4	4.0	440	0.0002	<0.001	0.18	<0.001	<0.01	0.0005	0.16	<0.01	0.01	0.05	1.61	<0.001	<0.001	0.001	0.014	0.01	<0.001	<0.0001
D	12.4	1368	0.7	<5	<0.2	<5	0.5	0.001	0.1	11.0	560	0.0001	<0.001	0.06	<0.001	<0.01	0.0002	0.10	<0.01	<0.001	0.03	1.54	<0.001	<0.001	0.001	0.025	0.004	<0.001	<0.0001
E	12.2	732	0.8	<5	<0.2	23	2.1	0.001	2.0	3.9	327	0.0001	<0.001	0.11	<0.001	<0.01	0.0006	0.04	<0.01	<0.001	0.05	2.04	<0.001	<0.001	0.002	0.045	0.01	<0.001	<0.0001
AWS	11.4	136	0.6	8	<0.2	22	3.6	0.003	1.4	0.4	65	0.0001	<0.001	0.09	<0.001	<0.01	0.0003	0.43	<0.01	0.01	0.03	6.12	<0.001	<0.001	0.004	0.009	0.14	<0.001	0.0003
Average	**12.1**	**776**	**1**	**8**	**<0.2**	**21**	**2.4**	**0.002**	**1.5**	**4.1**	**333**	**0.0002**	**<0.001**	**0.18**	**<0.001**	**<0.01**	**0.0005**	**0.18**	**<0.01**	**0.01**	**0.05**	**2**	**0.024**	**<0.001**	**0.002**	**0.035**	**0.03**	**<0.001**	**0.0003**

Results for chemicals that are not of health significance in drinking-water																													
Parameter	**Ag**	**Au**	**Be**	**Bi**	**Ce**	**Cs**	**Ga**	**Ge**	**Hf**	**Ho**	**Ir**	**La**	**Li**	**Nb**	**Nd**	**Pt**	**Rb**	**Sc**	**Si**	**Sn**	**Sr**	**Ta**	**Te**	**Th**	**Ti**	**Tl**	**W**	**Y**	**Zr**	**P**
Unit	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
A	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.07761	0.001	<0.001	<0.001	<0.001	<0.001	0.3	<0.001	<0.001	<0.001	0.002	0.001	1.54	<0.001	3.52844	<0.001	<0.001	<0.0001	<0.05	<0.001	0.04282	<0.001	<0.001	<0.025
B	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.10324	<0.001	<0.001	<0.001	<0.001	<0.001	0.37	<0.001	<0.001	<0.001	0.002	0.001	2.04	<0.001	2.83379	<0.001	<0.001	<0.0001	<0.05	<0.001	0.0523	<0.001	<0.001	<0.025
C	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.05611	<0.001	<0.001	<0.001	<0.001	<0.001	0.33	<0.001	<0.001	<0.001	0.002	<0.001	0.95	<0.001	4.42868	<0.001	<0.001	<0.0001	<0.05	<0.001	0.03361	<0.001	<0.001	<0.025
D	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.04159	<0.001	<0.001	<0.001	<0.001	<0.001	0.26	<0.001	<0.001	<0.001	0.002	<0.001	0.54	<0.001	5.48622	<0.001	<0.001	<0.0001	<0.05	<0.001	0.01705	<0.001	<0.001	<0.025
E	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.08177	<0.001	<0.001	<0.001	<0.001	<0.001	0.37	<0.001	<0.001	<0.001	0.002	<0.001	1.73	<0.001	3.69389	<0.001	<0.001	<0.0001	<0.05	<0.001	0.04066	<0.001	<0.001	<0.025
AWS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02814	<0.001	<0.001	<0.001	<0.001	<0.001	0.07	<0.001	<0.001	<0.001	0.002	0.005	7.09	<0.001	0.81868	<0.001	<0.001	<0.0001	<0.05	<0.001	0.02342	<0.001	<0.001	<0.025

TCLP results compared to Drinking water guidelines

Results for chemicals that are of health significance in drinking-water																													
Parameter	**pH**	**Total Alk**	**F**	**Cl**	**NO3 as N**	**SO4**	**Al**	**As**	**B***	**Ba***	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**K**	**Mg**	**Mn**	**Mo***	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**V**	**Zn**	**U***
Unit	**-**	**mg/l CaCO3**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Class 1 (recommended limit)	5 - 9.5	N/A	1	200	10	400	0.3	0.01			150	0.0050	0.5	0.1	1	0.2	0.001	50	70	0.1		200	0.15	0.02	0.01	0.02	0.2	5	
Class 2 (max allowed for limited duration)	4 - 5 / 9.5 - 10	N/A	1.5	600	20	600	0.5	0.05			300	0.0100	1	0.5	2	2	0.005	100	100	1		400	0.35	0.05	0.05	0.05	0.5	10	
Class 3 (not recommended for consumtion)	<4 / >10	N/A	>1.5	>600	>20	>600	>0.5	>0.05	0.5	0.7	>300	>0.01	>1	>0.5	>2	>2	>0.005	>100	>100	>1	0.07	>400	>0.35	>0.05	>0.05	>0.05	>0.5	>10	0.015
A	4.7	600	0.4	<5	<0.2	94	18	0.023	7.2	1.6	998	0.002	0.012	0.50	0.043	0.6	0.0002	0.45	43.1	1.18	0.020	1.98	0.028	<0.001	0.015	0.029	0.30	0.2	0.018
B	4.7	564	0.3	<5	<0.2	109	25	0.027	8.9	1.5	1000	0.003	0.013	0.59	0.031	0.8	0.0002	0.52	37.5	1.26	0.019	2.56	0.023	0.002	0.016	0.035	0.32	0.2	0.022
C	4.8	1000	0.4	5	<0.2	118	15	0.022	8.9	1.3	1140	0.003	0.014	0.48	0.022	0.4	0.0001	0.60	53.7	1.38	0.029	2.84	0.025	<0.001	0.016	0.018	0.39	0.2	0.018
D	5.1	1776	0.8	7	<0.2	81	8	0.010	6.2	1.8	1400	0.002	0.013	0.23	<0.001	0.2	0.0001	0.46	60.3	1.58	0.027	2.74	0.016	<0.001	0.010	0.021	0.13	0.1	0.009
E	4.7	720	0.4	<5	<0.2	95	12	0.026	6.7	1.7	1010	0.004	0.011	0.28	0.020	0.3	0.0001	0.65	53.2	1.56	0.014	2.98	0.012	0.004	0.016	0.060	0.31	0.3	0.007
Average	**4.8**	**932**	**0.46**	**6**	**<0.2**	**99.4**	**16**	**0.021**	**7.6**	**1.6**	**1109.6**	**0.003**	**0.013**	**0.42**	**0.029**	**0.5**	**0.0001**	**0.54**	**49.56**	**1.39**	**0.022**	**2.62**	**0.021**	**0.003**	**0.015**	**0.03**	**0.29**	**0.2**	**0.015**

Results for chemicals that are not of health significance in drinking-water																													
Parameter	**Ag**	**Au**	**Be**	**Bi**	**Ce**	**Cs**	**Ga**	**Ge**	**Hf**	**Ho**	**Ir**	**La**	**Li**	**Nb**	**Nd**	**Pt**	**Rb**	**Sc**	**Si**	**Sn**	**Sr**	**Ta**	**Te**	**Th**	**Ti**	**Tl**	**W**	**Y**	**Zr**	**P**
Unit	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
A	<0.001	<0.001	0.006	<0.001	0.082215	0.001	0.006	0.2056	<0.001	0.007	<0.001	0.08163	0.4	<0.001	0.09544	<0.001	0.004	0.07957	92.39	<0.001	7.591487	<0.001	0.007	0.0002	0.0292	<0.001	0.001	0.20917	0.001	0.3
B	<0.001	<0.001	0.008	<0.001	0.10458	0.001	0.01	0.25041	<0.001	0.008	<0.001	0.09816	0.51	<0.001	0.10871	<0.001	0.005	0.08756	103.89	<0.001	7.176271	<0.001	0.008	0.0003	0.04156	<0.001	0.002	0.22996	0.001	0.4
C	<0.001	<0.001	0.006	<0.001	0.072592	0.001	0.005	0.22994	<0.001	0.006	<0.001	0.07905	0.53	<0.001	0.09574	<0.001	0.005	0.07751	93.49	<0.001	9.586995	<0.001	0.007	0.0002	0.02182	<0.001	0.002	0.20108	0.001	0.3
D	<0.001	<0.001	0.004	<0.001	0.060197	0.001	0.003	0.14865	<0.001	0.005	<0.001	0.06432	0.41	<0.001	0.08297	<0.001	0.004	0.05888	75.59	<0.001	13.0024	<0.001	0.003	0.0001	0.01383	<0.001	0.002	0.17511	<0.001	0.2
E	<0.001	<0.001	0.005	<0.001	0.078231	0.001	0.003	0.21363	<0.001	0.006	<0.001	0.06878	0.49	<0.001	0.08124	<0.001	0.005	0.07525	91.69	<0.001	8.301456	<0.001	0.007	0.0001	0.01534	<0.001	0.001	0.17942	<0.001	0.3

GEOCHEMICAL ASH BACKFILL AND WASTE CLASSIFICATION STUDY

SASOL SIGMA COLLIERY

14 JANUARY 2014

Digby Wells and Associates (South Africa) (Pty) Ltd (Subsidiary of Digby Wells & Associates (Pty) Ltd). Co. Reg. No. 2010/008577/07. Fern Isle, Section 10, 359 Pretoria Ave Randburg Private Bag X10046, Randburg, 2125, South Africa
Tel: +27 11 789 9495, Fax: +27 11 789 9498, info@digbywells.com, www.digbywells.com

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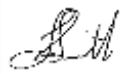
Report Title: **Geochemical Ash Backfill and Waste Classification Study**

Project Number: **SAS1691**

Name	Responsibility	Signature	Date
André van Coller (M.Sc.)	Geochemistry and reporting		13 January 2014
Lucas Smith (M.Sc.)	Review		18 November 2013

LIST OF ABBREVIATIONS

Abbreviation	Description
ABA	Acid-Base Accounting
Alk	Alkalinity
AMD	Acid Mine Drainage
AP	Acid Potential
ARL	Acceptable Risk Level
DEA	Department of Environmental Affairs
DW	Distilled Water
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
LC	Leachable Concentration
LCT	Leachable Concentrations Threshold
mg/kg	milligram per kilogram
mg/l	milligram per litre
NAG	Nett Acid Generation
NNP	Nett Neutralising Potential
NP	Neutralising Potential
NPR	Neutralising Potential Ratio
ppb	parts per billion
ppm	parts per million
SANS	South African National Standards
SPLP	Synthetic Precipitation Leachate Procedure
TCLP	Toxicity Characteristic Leachate Procedure
TCT	Total Concentrations Threshold
TDS	Total Dissolved Solids
WHO	World Health Organisation
XRD	X-Ray Diffraction
XRF	X-Ray Florescence

EXECUTIVE SUMMARY

Digby Wells Environmental (hereafter Digby Wells) has been appointed by Sasol Sigma Colliery (hereafter Sasol) to conduct various specialist studies and investigation to form part of an Environmental Impact Study (EIA) for the licencing and feasibility of backfilling the Sigma underground colliery with ash produced from the processing of coal.

This report and the various components of it forms part of the geochemical and waste classification study to evaluate the impacts of the backfilling may have on the regional water quality as well as to class the waste to motivate for the alternative ash management activity.

For the purpose of characterising the ash material both in a geochemical and waste classification criteria samples were taken over a period of 1 week. Both wet and dry ash samples were taken with the following methodology:

- Three (3) samples per day (1 kg each) of dry ash just after the burning process for a period of 5 days (15 kg in total);
- One (1) sample per day (2 Litre sample – 20% ash/80% water) from the ash slurry stream just before it enters the pump house over a period of 5 days

The sampling run ensures that all the samples were taken at locations and periods to ensure that the data received from the test results are representative of the ash material.

The samples were sent to the Water Lab (Pty) Ltd were accredited methods were used to prepare and analyses the samples. The samples were prepared as follows:

- The dry ash samples were:
    - The 3 samples from each day were combined to form 5 batches of 3 kg samples representative of each day;
    - The sample for each day was then split into 5 smaller batches for the various tests; and
    - The dry samples from each day labelled A, B, C, D, and E was then sent for Acid-Base Accounting (ABA), Nett Acid Generation (NAG), X-ray diffraction (XRD), X-ray florescence (XRF), Toxicity Characteristic Leachate Procedures (TCLP) and Distilled water (DW) leachate tests.
- The wet ash sample was:
    - The 5 samples were combined and allowed to settle after which the solid and liquid phases were separated;
    - The liquid phase was tested for macro and micro elements to determine the characteristics of the ash water; and
    - The solid phase was labelled AWS and sent for Distilled Water (DW) leachate tests to serve as input into the waste classification.

The purpose of this environmental geochemical evaluation and waste classification is to determine the environmental risks associated with using ash as backfill material. The

preferred waste management activity proposed and currently being investigated by Sasol Sigma is to use the waste material (ash) as backfill material to fill old mine voids currently labelled with a high risk of subsidence.

The ash material will be pumped in the form of slurry (consisting of 20% ash and 80% water) into areas at risk of subsidence via purposely drilled boreholes after which excess water will be removed through dewatering boreholes and reused. The ash material will then be left to settle and solidify.

Ash material has a very low permeability and hydraulic conductivity and will act as an aquitard once it has settled and compacted; leading to little or no groundwater movement through the newly formed layers. The aquitard/aquiclude nature of the ash material will be favourable as it will not allow leachate to travel down or sideways into the receiving groundwater or surface water systems. In theory any leachable elements will be in small quantities and be easily diluted under natural conditions. The feasibility and potential risk of the ash backfilling methodology proposed will thus be determined in this study through various geochemical tests and evaluations.

Furthermore, the waste classification of the ash material will feed into the licencing and motivation from Sasol to use and licence the backfilling of the ash into the old mine voids as a feasible alternative management activity.

The following conclusions have been reached through the study explained above:

Geochemical evaluation

- The ash mineralogy is dominated by quartz and mullite with large percentages of amorphous material and trace element inclusions;
- The ash material has a high NNP and will allow for the buffering of any acidic environments;
- In the DW tests the main elements of concern leaching out is B, Ba, Ca, Se, Al and Cr. These elements should be monitored in all phases of the project on a monthly basis;
- The ash water sampled showed that the mixing of the slurry water and ash allows for the solution of Al, B, Se, Cr and Ca into the ash water and removing some of the elements of concern before it reaches the pump house; and
- Although some elements do leach out in significant concentrations in the DW tests and can pose an environmental health risk, the low permeability and hydraulic conductivity of the ash material will result in a small amount of seepage through the system once it has been deposited in the mine voids. It can be assumed that any small amount of leachable ions from the ash will be diluted to acceptable levels once it comes into contact with groundwater or surface water at the decant positions.

Waste Classification

Based on the classification of the Distilled/Reagent water leachate test results against the relevant TCT and LCT limits as given in the legislative guidelines for waste classification (DEA 2013a), the ash to be used as backfill can be classified as follows:

- For boron (B) the results show that LCT0<LC<LCT1 and TC<TCT0;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste;

The following recommendations are made by Digby Wells based on the outcome of the study reported in this document:

The following recommendations are made by Digby Wells based on the outcome of this study:

- In the DW tests the main elements of concern leaching out are B, Ba, Ca, Se, Al and Cr. These elements should be monitored in all phases of the project on a monthly basis;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste; however
    - Based on the low concentrations of the leachable ions (although they are above TCT0 and LCT0 in certain cases), the low NAG and the high NNP (section 3.2.3) it is concluded that the alternative waste management activity of using the ash material for backfilling of the mine voids at Sigma Colliery is feasible and a motivation to the authorities for this activity to be licenced is recommended.
    - The low permeability and hydraulic conductivity of ash will allow little to no seepage through the newly formed ash layers once allowed to settle and thus the environmental concentration of contaminants entering the receiving environment will be low and easily diluted through natural processes.
- If the waste management activity of backfilling the mine voids is not pursued the waste should be disposed of at a Class C Landfill.
- Previous limits and target water quality conditions in the water licence granted for the ash backfilling in Licence #20021165 was well set and achievable. It is recommended that these conditions are kept and monitoring should ensure that the target water quality standards are achieved.

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1 INTRODUCTION

Digby Wells Environmental (hereafter Digby Wells) was appointed by Sasol Sigma Colliery (hereafter Sigma) to conduct various specialist studies as part of an Environmental Impact Assessment (EIA) for the licencing and feasibility of backfilling the Sigma underground colliery with ash produced from the processing of coal at Infrachem. Ash is currently produced from the coal through burning processes at Infrachem and is then fed into the ash slurry stream after mixing with water to produce the slurry. Currently Sasol labels the ash produced from the coal burning process as a by-product and not a waste.

The ash backfilling process being studied and proposed as an environmental management option is of importance due to its effective management of the subsidence currently taking place in certain mined out areas and can potentially occur in the areas where backfilling has not yet been done. The ash backfilling process is thus an important step in managing and addressing the risk of surface subsidence in the Sigma Colliery project area.

Previously under the Water Licence (Licence # 20021165) granted to Sasol Sigma, ash backfilling was attempted with continuous and frequent monitoring of both surface water and groundwater qualities and levels. These results have shown that the overall water quality in the project has improved since the start of the backfilling and has met all licence conditions set for water quality. Based on this historical data backfilling is feasible and thus a new licence is being applied for.

This report forms part of the geochemical and waste classification study to evaluate the potential impacts that the backfilling may have on the regional water quality, as well as to classify the ash as part of the motivation for this environmental management activity.

This report only refers to geochemistry and waste classification and no in depth discussions of tests, monitoring data, models and outcomes of studies referring to the groundwater study is made and will form part of the Geohydrological Assessment report as an appendix.

1.1 Study Purpose

The purpose of the study is to determine the environmental geochemical risks associated with backfilling underground mine voids with ash produced from Sasol processes at Infrachem and to determine the waste type and classification of the material for the licencing for this proposed ash management activity.

1.2 Deliverables

The following deliverables form part of this study:

- Technical report that includes:
  - Geochemical laboratory results and interpretations;
  - Geochemical evaluation and identification of potential environmental impacts of the backfilling activity;

- Classification of the ash material as per waste classification procedures; and
- Recommendations relating to possible mitigation measures and water management.

1.3 Scope of Work and Methodology

1.3.1 Sampling of Ash Material

For the purpose of characterising the waste material according to geochemical and waste classification criteria samples were taken over a period of one week. Both wet and dry ash samples were taken according to the following methodology:

- Three dry ash samples per day (1 kg each); sampled just after the burning process for a period of 5 days (15 kg in total); and
- One sample per day (2 litre samples – 20% ash / 80% water) from the ash slurry stream just before it enters the pump house over a period of 5 days.

This sampling protocol ensures that all the samples were taken at locations and time frames in line with authority requirements and to ensure that the data received from the test results are representative of the ash material.

1.3.2 Laboratory tests

All samples were sent to Waterlab (Pty) Ltd where accredited methods were used to prepare and analyse the samples. The samples were prepared as follows:

- The dry ash samples:
  - The three samples from each day's sampling run were combined to form 5 batches of 3 kg samples, representative of each day;
  - The sample for each day was then split into 5 smaller batches for the various tests; and
  - The dry samples from each day labelled A, B, C, D, and E was then sent for Acid-Base Accounting (ABA), Nett Acid Generation (NAG), X-ray diffraction (XRD), X-ray florescence (XRF), and Toxicity Characteristic Leachate Procedures (TCLP) and Distilled Water (DW) leachate tests.
- The wet ash sample:
  - The 5 samples were combined and allowed to settle after which the solid and liquid phases were separated;
  - The liquid phase was tested for macro and micro elements to determine the characteristics of the ash water; and
  - The solid phase was labelled AWS and sent for Distilled Water (DW) leachate tests to serve as input into the waste classification.

1.3.3 Result interpretations

The results of the laboratory tests were assessed against various guidelines from the US EPA, WHO, SANS Drinking water standards and the guidelines as set out in the National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008) to determine the potential environmental and human risks, as well as to determine the waste type and classification of the ash material.

Along with the evaluation of the results against various standards, the mineralogy and chemical composition of the ash was interpreted to understand where any possible contamination can originate from.

1.3.4 Technical reporting

A technical report was compiled summarising all results and interpretations, as well as listing recommendations and possible mitigation measures. The waste classification report also serves as input into a motivation for the licencing of the ash, as well as the ash management activity of backfilling the mine voids.

2 SITE DESCRIPTION

Sigma Colliery is situated in the Free State Province, adjacent to the town of Sasolburg. In the north, it borders on the Vaal River, just above the barrage. It comprises of the main Sigma Underground Colliery, and the Wonderwater Strip Mine and Mohlolo Underground Colliery next to the Vaal River.

2.1 Climate

The area has a temperate climate characterised by warm summers and cold winters. Average annual rainfall is 658 mm and occurs mainly during summer months. Average daily temperatures vary between 8.9°C in June to 21.7°C in January. The climate is typically a cool temperate Highveld climate characterised by a cool to warm summers and cold winters. Rainfall is recorded at the Sasol Infrachem rainfall station, which indicates that the rainfall occurs in summer months (October to March).

2.2 Topography and Drainage

Sigma Colliery lies in the quaternary catchment C22K. The general topography of can be described as undulating and sloping towards the Vaal River. The DEM and slope model indicated that mining activities have significantly altered the topography and surface water flow in the north and east.

Four rivers and stream drain the area. The main system is the Vaal River to the north. The Taaibospruit drains the area to the east of Sasolburg and has no influence on the Colliery. Two gradual valleys, carrying the Leeuspruit and Rietspruit, run parallel to each other in a south-east north-west direction towards Vaal River. The Leeuspruit and the Rietspruit overly the Colliery, and have an influence on the mine, especially in areas of subsidence.

Elevation within these river valleys varies from around 1430 m at the valley bottoms to 1490 m at the valley tops. Slopes are mostly flat across the landscape except for isolated pockets of steeper slopes along the banks of the Vaal River and where mining activities have taken place. Years of underground Mining at the Sigma Colliery has resulted in large subsided areas with the potential of further subsidence occurring in the future. Ash backfilling along the R59 near Sasolburg has yielded positive results in stabilising the topography.

2.3 Geology of the Study Area

Sigma Colliery lies in the Sasolburg-Vereeniging Coalfield. The stratigraphy of the coalfield is typical of the coal-bearing margins of the Karoo Sequence. The succession consists of pre-Karoo rocks (dolomites of the Chuniespoort Group of the Transvaal Sequence) overlain by the Dwyka Formation (2-15 m thickness), followed by the Ecca Group sediments, of which the Vryheid Formation is the coal-bearing horizon. Mainly the lava of the Ventersdorp and Hekpoort Groups underlie the coal.

The Vryheid Formation contains four major coal seams. These seams are named from 1 at the base, 2A and 2B in the centre, and 3 being the topmost seam. The seams mined at Sigma Colliery are the No 3-seam, and the No 2 A and B seams, which for the purpose of this report, will be treated as one seam. The coal seam dips from north to south. The depth of the coal seam ranges from 150 m deep in the south, to 55 m at Wonderwater

Dolerite intrusions in the form of dykes and sills are present over the entire coalfield and are responsible for structural complications. At Sigma Colliery the central and southern sections are intruded by dolerite sills

3 PREFERED ASH MANAGEMENT ACTIVITY AND OBJECTIVES

The purpose of this environmental geochemical evaluation and waste classification is to determine the environmental risks associated with using ash as backfill material. The preferred waste management activity proposed and currently being investigated by Sasol Sigma is the use the ash material as backfill material to fill old mine voids currently labelled with a high risk of subsidence.

The ash material will be pumped in the form of slurry (consisting of 20% ash and 80% water) into areas at risk of subsidence via purposely drilled boreholes after which excess water will be removed through dewatering boreholes and reused. The ash material will then be left to settle and solidify.

Ash material has a very low permeability and hydraulic conductivity and will act as an aquitard once it has settled and compacted; leading to little or no groundwater movement through the newly formed layers. The aquitard/aquiclude nature of the ash material will be favourable as it will not allow leachate to travel down or sideways into the receiving groundwater or surface water systems. In theory any leachable elements will be in small quantities and be easily diluted under natural conditions. The feasibility and potential risk of the ash backfilling methodology proposed will thus be determined in this study through various geochemical tests and evaluations.

Furthermore, the waste classification of the ash material will feed into the licencing and motivation from Sasol to use and licence the backfilling of the ash into the old mine voids as a feasible alternative waste management activity.

Previously ash backfilling has been done under the a water licence (Licence 20021165) with certain water quality objectives set that should be adhered to. Since the start of the project the water quality of the monitoring network and project area has improved and all objectives have been reached. Thus based on past processes and monitoring the backfilling of mine voids at Sasol Sigma Colliery is feasible.

4 GEOCHEMICAL EVALUATION

4.1 Laboratory Test Descriptions and Purpose

4.1.1 XRD and XRF

XRF is an X-ray method used to determine the elemental composition of a material that allows for the evaluation of a materials chemical compound distribution, as well as the various trace element concentrations. XRD allows for the measurement of the crystal structures within a sample to determine the mineralogical composition of the material that allows the specialist to determine whether any reactive solids will lead to environmental risks through the study of the various minerals.

4.1.2 ABA and NAG

The Acid-Base Accounting (ABA) procedure measures the acid- and alkaline-producing potential of the ash in order to determine if, after disturbance, the waste material will produce acid and subsequently leach metals. This procedure includes NAG tests that evaluate the Net Acid Generation and neutralising potential of the material to also evaluate the potential of the material to counter acid production.

4.1.3 Leachate Tests and Total Element Analysis

The Distilled/Reagent water leachate (DW) tests are done to simulate the heavy metal and anion leachate potential of soils, waste material and waste water left in-situ under normal conditions with only neutral water allowing leaching to occur. These tests will simulate and evaluate the potential of any heavy metal or ion contamination from the waste material that will be produced by the plant and used in the backfilling of the mine voids. The distilled/reagent water tests are used to evaluate the leachability of material that will be mono-disposed.

Furthermore, Toxicity Characteristic Leachate Procedure (TCLP) tests were done to evaluate a worst case scenario where the ash material will come into contact with acidic conditions. The TCLP test results were only used in simulating worst case scenario concentrations in the numerical groundwater model and mass transport models (see Geohydrological Specialist Report for the results and use thereof)

4.1.4 Water analysis

The ash slurry that will be used in the backfilling process is a mixture of 20% ash and 80% water. The solid (ash) and liquid (water) phases separates completely within an hour and this water was separated from the slurry sample before leachate tests were conducted on the ash to determine the hydrochemical characteristics of the water used in the pumping process. This water analysed will enter the mine voids with the ash after which it will then again be abstracted from the system to allow the ash to settle and compact into the solid phase that is needed to fill the voids.

The water analysis was thus done to evaluate how much of the contaminants can potentially be separated by the backfilling process and thus allowing the elimination of hazardous compounds from the system in the planned processes. The water analysis also gives an indication of any organic contaminants that can be expected to form part of the backfilling material.

The water phase was later again combined with the total concentrations and leachate concentrations of the ash slurries solid phase.

4.2 Test Results and Interpretations

All laboratory results and certificates are shown in Appendix A.

4.2.1 XRF Results of Dry Ash Material

The major oxides accounting for the make-up of the dry ash material, as observed in the mineralogy of the XRD results, are shown in the XRF summary in Table 1. During the ignition of the XRF tests there was an average loss of 4.8% of the material.

From the XRF results it is observed that the distribution of metals and ions in various bonds with oxide is typical of the amorphous and inert nature of ash. The major compounds in the material are SiO_2, Al_2O_3 with smaller amounts of TiO_2, Fe_2O_3 and CaO. The source of CaO is the lime dosage of the coal before burning with calcite; also a mineral associated with the coal formations. TiO_2 and Fe_2O_3 are two metal oxides also associated with the mineralogy of the coal material burned to produce the ash. The metal distribution in the ash material is most probably included in the amorphous crystals in traces and various other combinations, with the Fe and Ti concentrations associated with the coal mineralogy for example pyrite and pyrrhotite.

SiO_2 and Al_2O_3, as observed in the mineralogy of the ash, are associated with the silicate minerals of the coal material which is burned to form new secondary silicate and aluminium silicate minerals. The ions most likely to leach from the distribution observed in the XRF results are Ca, Al and Fe.

From the XRF results trace element distributions were also determined for the ash material. These results are shown in Table 2 and also compared to average continental crust distributions. Although this is not a true comparison it does indicate the higher concentration of certain elements that observed in the crust of the earth due to the combustion of some elements and thus the enrichment of others. It should be noted that this is however no reflection or classification of the quality of the ash material. In most cases the trace element concentrations in the ash is higher than crustal averages. This is most probably due to the concentrated nature of the material after burning, allowing the increase (proportional) of some elements and the decrease of others.

The alkaline nature of the ash is however helpful in allowing any acid that can potentially form to be neutralised and this in turn allows for metal dissolution and leachability decreasing. However some elements that can potentially leach out based on the trace element distributions are As, Ba and Sr.

The potential risk of metals leaching from the ash is dependent on the acid producing potential of the ash, which in theory should be very low. This will however be determined by the ABA and NAG results to be discussed in section 3.2.3.

Table 1: Dry sample XRF results

Compound	Major Element Concentration (wt %)					
	A	B	C	D	E	AWS
SiO2	49.12	48.3	46.87	61.01	48.49	45.96
TiO2	2.54	2.56	2.54	1.68	2.36	2.46
Al2O3	32.53	32.47	33.21	24.65	31.15	31.43
Fe2O3	3.23	3.18	3.3	2.62	3.06	3.23
MnO	0.04	0.05	0.05	0.04	0.05	0.05
MgO	0.59	0.67	0.75	0.52	0.73	0.92
CaO	6.16	6.35	6.65	0.65	5.78	6.32
Na2O	0.63	0.78	0.87	0.3	0.79	1.05
K2O	0.67	0.69	0.72	1.81	0.7	0.88
P2O5	0.14	0.15	0.15	0.08	0.15	0.14
Cr2O3	0.05	0.05	0.05	0.04	0.05	0.04
SO3	0.1	0.26	0.14	0.11	0.36	0.12
LOI	3.72	4.06	4.18	6.22	5.86	6.9
Total	99.52	99.57	99.48	99.73	99.53	99.5
H2O-	0.04	0.08	0.2	0.47	0.13	0.55

Table 2: Distribution of selected trace elements

Element	Upper continental crust	Sample ID with elemental distribution in ppm					
		A	B	C	D	E	AWS
As	**1.5**	23.5	21.8	25.9	<1.00	20.6	16.9
Ba	**550**	812	846	897	479	828	873
Bi	**1.27**	<1.00	<1.00	<1.00	<1.00	<1.00	1.32
Cd	**98**	1.84	<5.00	<5.00	<5.00	<5.00	<5.00
Ce	**64**	<5.00	<5.00	<5.00	<5.00	<5.00	<5.00
Co	**17**	12.7	32.5	53.9	<5.00	42.7	66.3
Cs	**4.8**	<1.00	<1.00	1.49	<1.00	<1.00	2.18
Cu	**25**	84.7	71	78	23.7	72.8	73.4
Ga	**17**	72	74.4	76.4	21	64.5	67.7
Ge	**1.6**	15.8	14	18.5	4.09	13.2	15.2
Hf	**5.8**	8.68	8.88	9.02	14.9	8.71	8.52
Hg	**9**	1.6	1.65	1.73	<5.00	1.37	1.48
La	**30**	103	66.2	92.2	15.1	69.7	70.5
Lu	**0.32**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
Mo	**1.5**	13.9	11.3	13.1	10.8	12.2	10.9
Nb	**12.5**	53.7	54.1	53.1	19.1	49	53.2
Nd	**26**	80.3	83.5	70.9	65.2	62.5	82.1
Ni	**50**	75.5	74.2	80.7	52.9	74	70
Pb	**16**	111	133	128	20.1	103	85.3
Rb	**112**	32.9	35.8	36.2	59.9	33.9	38.8
Sb	**0.2**	<5.00	3.39	<1.00	3.12	3.66	<5.00
Sc	**13**	18.6	16.6	21	12.6	18.8	20.3
Se	**50**	<1.00	<5.00	<1.00	<5.00	<1.00	<1.00

Element	Upper continental crust	Sample ID with elemental distribution in ppm					
		A	B	C	D	E	AWS
Sm	**4.5**	17.9	16.4	17.1	12.6	17.2	17.4
Sn	**5.5**	1.76	2.89	1.56	4.78	2.49	8.15
Sr	**350**	905	887	1128	161	1063	1409
Ta	**1.1**	3.27	3.57	5.17	3.27	2.66	3.9
Th	**10.7**	56	60.9	58.7	29.9	53.4	57.1
Tl	**0.75**	2.21	1.95	1.26	<1.00	1.74	2.59
U	**2.8**	15	16.2	17.2	4.63	16.6	18.6
V	**110**	281	290	304	74.9	282	250
W	**2**	5.16	5.12	4.93	4.93	4.95	5.31
Y	**22**	107	112	110	26.5	104	120
Yb	**2.2**	26.7	25	25.9	18.8	24.3	26.6
Zn	**71**	95.6	94.4	115	111	63.5	47.2
Zr	**190**	733	739	718	967	673	743

4.2.2 XRF Results of Ash Slurry

The wet ash sample or ash slurry sample was separated from the water phase and also sent for all tests to evaluate and compare the results and to determine whether the water/ash mixture does significantly change or alter the quality of the ash. The slurry solids (sample AWS) is also shown in Table 1 and Table 2.

The comparison with the dry ash XRF results and trace element distribution indicates the mixture of the ash does not have a significant effect on the main mineralogy and elemental content of the ash that will be deposited. The proportional distribution of most of the elements and compounds remain the same. In some cases the trace element and major compound content is lower due to some elements going into solution and in other cases the concentrations where slightly higher due to possible precipitation of elements enriched in the water used to produce the slurry.

The source of the trace elements and compounds remain the same as discussed in section 4.2.1. The main parameters that can potentially leach out from the ash material are Ca, Al, Fe, As, Br and Sr. However as also mentioned in the previous section the mobility and potential release of these elements into solution is highly dependent on the acid producing potential of the ash.

4.2.3 XRD Results of Dry Ash Material

The XRF and trace element results discussed in section 4.2.1 and 4.2.2 (in combination) forms the ash mineralogy as shown in the XRD results (Table 3). The dry ash mineralogy is dominated by amorphous material, mullite and quartz. The amorphous material is glass like crystals with no definite crystal structure and will mostly be made up of SiO_2 in combination with various other trace elements. The trace elements within the unstructured mineralogy of the amorphous material will be reactive based on the pH trends of the system it is introduced to. However, due to the unstructured bonds reactive metals like B, Ba, Mn, Mg and other

metals like As can easily be released into a system as various aqueous species dependent on the physical chemical characteristics of the receiving environment.

The high Al_2O_3 and SiO_2 content observed in the XRF results combine to form the quartz and mullite mineralogy. The high CaO content is from the calcite and lime mineralogy.

The mullite, lime and calcite content of the ash will result in high concentrations of Al and Ca leaching out and will be confirmed with the leachate tests. Furthermore Mn, Mg, B, Ba, nickel (Ni) and arsenic (As) can be expected to leach out in acidic environments, but will have to be confirmed with the leachate results.

Table 3: XRD analysis results summary

Mineral	A	B	C	D	E	AWS
	(weight %)					
Amorphous	53.55	58.08	55.83	75.55	55.43	-
Lime	0.83	0.67	0.52	0.36	1.08	-
Calcite	0.12	0.04	-	0.1	-	5.33
Mullite	38.51	36.07	38.06	6.28	35.65	81.81
Quartz	6.98	5.14	5.6	17.7	7.84	12.85
Total	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**

4.2.4 XRD Results of Ash Slurry

The XRD results of the solid ash phase from the slurry sample AWS also shown in Table 3 is compared to the dry ash samples. Sample AWS is dominated by mullite with calcite and quartz making up the rest of the sample. No amorphous material and lime was picked up in the slurry analysis. This could be due to the solution of these minerals into the transport water that is mixed with the dry ash. Although some minerals have fallen away the main mineralogy stays intact.

The main elements that can potentially leach out into solution from the slurry sample however remains Ni, As, Mn, Mg, B and Ba. Metal leachability can potentially be lower due to the absence of the amorphous material.

4.2.5 ABA and NAG Results – Dry Ash

From the ABA and NAG results in Table 4 and Table 5 the following can be concluded:

- The paste pH of the ash material is highly alkaline with all total sulphur % below the acid producing limit of 0.25 %S proposed by the US EPA;
- For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity, but it is likely to be only of short-term significance;
- The low sulphur content and alkaline nature of the ash allows for a big difference between the Acid Potential (AP) and Neutralising Potential (NP), resulting in a Nett Neutralising Potential (NNP) of well above 0 for all samples;

- The high NNP and NAG of the samples allow for the ash to be classified as a type III rock/material – non-acid forming; and
- Based on the non-acid forming nature of the ash the potential metal contamination and leachability is low.

Table 4: ABA results summary for dry ash

Acid – Base Accounting	Sample Identification				
Modified Sobek (EPA-600)	A	B	C	D	E
Paste pH	11.7	11.8	12.1	12.2	12.2
Total Sulphur (%) (LECO)	0.05	0.06	0.07	0.05	<0.01
Acid Potential (AP) (kg/t)	1.56	1.88	2.19	1.56	0.31
Neutralization Potential (NP)	43.5	27	36.25	39.25	24.75
Nett Neutralization Potential (NNP)	41.94	25.13	34.06	37.69	24.44
Neutralising Potential Ratio (NPR) (NP : AP)	27.84	14.4	16.57	25.12	79.2
Rock Type	III	III	III	III	III

Table 5: NAG results summary for dry ash

Nett Acid Generation	Sample Identification: pH 4.5 & 7				
	A	B	C	D	E
NAG pH: (H2O2)	10.2	10.3	10.3	10.5	10.2
NAG (kg H2SO4 / t)	<0.01	<0.01	<0.01	<0.01	<0.01

4.2.6 ABA and NAG Results – Ash Slurry

The solid ash phase of the ash slurry was also sent for ABA and NAG analysis to determine whether the dissolution and mixture with the slurry water has any significant effect on the acid producing potential of the ash. The results are shown in Table 6 and Table 7.

The following can be concluded from the ash slurry sample analysis:

- The paste pH of the ash material is highly alkaline with all total sulphur % below the acid producing limit of 0.25 %S proposed by the US EPA;
- For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity, but it is likely to be only of short-term significance;
- The low sulphur content and alkaline nature of the ash allows for a big difference between the Acid Potential (AP) and Neutralising Potential (NP), resulting in a Nett Neutralising Potential (NNP) of well above 0 for all samples;
- The high NNP and NAG of the samples allow for the ash to be classified as a type III rock/material – non-acid forming; and
- Based on the non-acid forming nature of the ash the potential metal contamination and leachability is low.

Table 6: ABA results summary for ash slurry sample

Acid – Base Accounting	AWS
Modified Sobek (EPA-600)	
Paste pH	11.7
Total Sulphur (%) (LECO)	0.11
Acid Potential (AP) (kg/t)	3.44
Neutralization Potential (NP)	44
Nett Neutralization Potential (NNP)	40
Neutralising Potential Ratio (NPR) (NP : AP)	13
Rock Type	III

Table 7: NAG results summary for ash slurry sample

Nett Acid Generation	Sample Identification: pH 4.5 & 7.0
	AWS
NAG pH: (H_2O_2)	9.5
NAG (kg H_2SO_4 / t)	<0.01

4.2.7 Leachate Tests

Two leachate tests were done to evaluate the leachability of elements and contaminants, both for the waste classification, as well as to determine the risk under a conservative approach in acidic conditions. The normal distilled/reagent water tests were done to evaluate the potential for contaminants to leach out under normal conditions with a pH of the water being close to neutral and just enough salts to allow reactions to proceed. Along with the distilled water leach procedure the TCLP tests were conducted using fluid 2 with a reagent pH of 2.9 and thus simulating the conservative scenario in which the ash comes into contact with an acidic environment as in the case of Acid Mine Drainage (AMD) development. The TCLP results are however discussed briefly and used in the geohydrological report.

In the next sub-section the leachate tests are compared against SANS drinking water standards and WHO guidelines (where no SANS guidelines exist) to determine the effect that a potential release of the leachate into a water supply environment can have on human health as per standard practice in environmental impact assessments. These comparisons are shown in Appendix B. In Section 5 of this report the Distilled water leachate results will be compared against threshold limits and guidelines as per waste classification legislation.

4.2.7.1 Distilled/Reagent Water Leach Results

The distilled water (DW) leachate results were compared against drinking water guidelines as shown in Appendix B. The ions were divided into two groups namely those elements posing a health risk if consumed by humans and those that do not show a risk. The dry ash

sample leachate results (samples A to E) and the ash slurry results (sample AWS) were discussed separately.

From the data comparison against drinking water guidelines the following can be observed:

- **Dry ash sample leachable concentrations (LC)**
  - All 5 samples are not suitable for human consumption due to pH values and the concentrations of aluminium (Al), boron (B), barium (Ba), chrome (Cr) and selenium (Se) being above the recommended limits for drinking water;
- **Ash slurry leachable concentrations (LC)**
  - Sample AWS that was taken from the ash slurry stream has the best quality of all samples, with the lowest leachable concentrations. This is due to the removal of some of the dissolved ions from the system as soon as the water (used to mix with ash so that it can be pumped) is removed.
  - The leachate from the ash slurry is however also not suitable for human consumption die to levels of pH, Al, B and Cr being above the recommended drinking water guidelines.
- The pH levels of all the fluids from the leachate procedure are highly alkaline due to the high alkalinity of the ash; with the NNP of the samples also high. This alkalinity will be helpful in neutralising acid in an acidic environment, but under normal conditions will allow the water produced from the ash to be not suitable for consumption;
- From the other metals and ions that is not of any health risk to humans the only metals leaching in detectible concentrations are lithium (Li), tungsten (W) and silicon (Si);
- The high Si content is from the quartz and mullite mineralogy observed in the XRD results;
- The Ca concentrations are high in all samples and this is due to the lime and calcium mineralogy associated with the production of the ash;
- Although some elements do leach out in significant concentrations and can pose an environmental health risk, the low permeability and hydraulic conductivity of the ash material will allow for only a small amount of seepage through the system once it has been deposited in the mine voids. It can therefore be assumed that any small amount of leachable ions from the ash will be diluted to acceptable levels once it comes into contact with groundwater or surface water ; and
- It is however recommended that this be confirmed through geochemical modelling and continuous monitoring.

4.2.8 Ash Water Analysis

As mentioned in the DW test results the ash slurry sample submitted for testing showed the best quality leachate product. This could be due to the solution of the most reactive ions into

the slurry water that will later be removed (large portions of it) through abstraction in the backfilling process.

The analysis and comparison of the ash water sample against the same standards as those used for the DW tests confirms this as shown in Table 8. The main conclusions after assessment of the hydrochemistry of the slurry water are:

- The sample is deemed unsuitable for human consumption due to pH, TDS, EC, F, Cr and Se levels above the recommended drinking water limits
- The high concentrations of Cr, Ca and Se correlate with the elements leaching out in significant quantities from the ash as observed in the DW tests and this is due to the ash mineralogy; and
- The high F concentrations in the water is most probably naturally occurring and not from the ash mineralogy and geochemistry.

It should be kept in mind that the contents of the ash slurry water are highly dependent on the quality of the water used to produce the slurry. Concentrations of elements can vary significantly and from day to day depending on the water used.

Table 8: Ash water analysis results

Parameter	Unit	Drinking water limits	Ash water
pH	-	5 - 9.7	12.4
TDS	mg/l	1200	1492
EC	mS/m	170	596
HCO3	mg/l	N/A	<5
CO3	mg/l	N/A	72
Total Alk	mg/l CaCO3	N/A	1320
F	mg/l	1.5	2
Cl	mg/l	300	178
NO3 as N	mg/l	11	<0.2
SO4	mg/l	500	41
As	mg/l	0.01	<0.010
B*	mg/l	0.5	0.276
Cd	mg/l	0.003	<0.005
Co	mg/l	0.5	<0.025
Cr	mg/l	0.05	0.187
Cu	mg/l	2	<0.025
Fe	mg/l	2	0.3
Hg	mg/l	0.006	<0.001
Mn	mg/l	0.5	<0.025
Ni	mg/l	0.07	<0.025
Pb	mg/l	0.01	<0.020
Se	mg/l	0.01	0.031
Zn	mg/l	5	<0.025
*WHO guidelines used			

4.3 Geochemistry Conclusions

Based on the geochemical tests and mineralogical data of both the ash and the slurry water the following can be concluded:

- The ash mineralogy is dominated by quartz and mullite with large percentages of amorphous material and trace element inclusions;
- The ash material has a high NNP and will allow for the buffering of any acidic environments;
- In the DW tests the main elements of concern leaching out is B, Ba, Ca, Se, Al and Cr. These elements should be monitored in all phases of the project on a monthly basis;
- The ash water sampled showed that the mixing of the slurry water and ash allows for the solution of Al, B, Se, Cr and Ca into the ash water and removing some of the elements of concern before it reaches the pump house;
- Although some elements do leach out in significant concentrations in both the TCLP and DW tests and can pose an environmental health risk, the low permeability and hydraulic conductivity of the ash material will result in a small amount of seepage through the system once it has been deposited in the mine voids. It can be assumed that any small amount of leachable ions from the ash will be diluted to acceptable levels once it comes into contact with groundwater or surface water at the decant positions; and
- It is recommended that this be confirmed through continuous monitoring.

5 WASTE CLASSIFICATION

5.1 Introduction

The backfilling option proposed for the Sigma Colliery is an ash management activity that will be a mono-disposal process. Due to the mono-disposal nature of the backfilling option the ash slurry was sent for Distilled/Reagent water leachate tests as well as a complete analysis of the fluid phase. The results of these tests were then classed and compared against the Total Concentration Threshold (TCT) and Leachable Concentration Threshold (LCT) limits to determine the waste type as per legislative guidelines given in the National Environmental Management Waste Act, 2008 (Act No. 59 of 2008).

The results of the water analysis and ash analysis were combined in a weighted average calculation of 80% water and 20% ash for the total concentrations. This procedure was followed as the current and planned water to ash ratio in the slurry will be 80% water and 20% ash. The sum of these weighted average calculations thus gives an accurate indication of the concentrations that can be expected to enter the mine voids. The leachable concentrations however represent an accurate indication of what can leach from the solid phase into the environment and was used as such. Where values were below the limit of detection they were indicated as such.

The water phase of the slurry was submitted for a full organic analysis as well. Due to the volatile nature of most of the organic compounds and there high mobility, if any organic compounds were found in the ash material itself it would either have combusted or dissolved into the liquid.

5.2 Legislative Guidelines

The following legislative guidelines were instated in August 2013 and give the background and guidelines for waste classification in South Africa:

- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Waste Information Regulations, 2012 (DEA 2012);
- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Norms and Standards for the Assessment of Waste for Landfill Disposal (DEA 2013a);
- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Norms and Standards for the Disposal of Waste to Landfill (DEA 2013b); and
- National Environmental Management Waste Act, 2008 (ACT No. 59 of 2008). National Waste Classification and Management Regulations (DEA 2013c).

The above four documents are presented in Appendix C and were used as the waste classification guidelines for this project.

5.3 Data Evaluation and Comparisons

5.3.1 Total Concentration Threshold

From the classification of the ash slurry material according to the TCT limits (Table 9) the following can be concluded:

- All TCT values from the ash slurry material is below the TCT0 threshold limits;

5.3.2 Leachable Concentration Threshold

From the classification of the ash material according to the LCT limits (Table 10) the following can be concluded:

- The ash slurry sample shows boron (B = 1.4 mg/kg) levels above the recommended LCT0 limits but are still well below the LCT1 limits;
- All other concentrations of the ions tested for and present in the samples are within the LCT0 limits.

5.4 Classification

Based on the classification of the Distilled/Reagent water leachate test results against the relevant TCT and LCT limits as given in the legislative guidelines for waste classification (DEA 2013a), the ash to be used as backfill can be classified as follows:

- For boron (B) the results show that LCT0<LC<LCT1 and TC<TCT0;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste;
- A Type 3 waste may only be disposed of at a Class C (GLB+) landfill; however
    - Based on the low concentrations of the leachable ions (although they are above TCT0 and LCT0 in certain cases), the low NAG and high NNP (section 3.2.3) it is concluded that the alternative waste management activity of backfilling the mine voids at Sigma colliery with the ash material is feasible and a motivation to the authorities for this activity to be licenced is recommended; furthermore
    - The low permeability and hydraulic conductivity of ash will allow little to no seepage through the newly formed ash layers once it has settled and thus the environmental concentration of contaminants entering the receiving environment will be low and easily diluted through natural processes.
    - Previous monitoring of the water quality in the area where backfilling has been done indicates that the water quality has improved since backfilling with subsidence also stopped and thus based on this is also deemed feasible.

Table 9: TCT classification table

Parameter	Unit	TCT0	TCT1	TCT2	AWS
As	mg/kg	**5.8**	**500**	**2000**	0.01
B	mg/kg	**150**	**15000**	**60000**	5.71
Ba	mg/kg	**62.5**	**6250**	**25000**	8.15
Cd	mg/kg	**7.5**	**260**	**1040**	0.0004
Co	mg/kg	**50**	**5000**	**20000**	<0.02
Cr	mg/kg	**46000**	**800000**	**N/A**	0.49
Cu	mg/kg	**16**	**19500**	**78000**	<0.02
Hg	mg/kg	**0.93**	**160**	**640**	0.0012
Mn	mg/kg	**1000**	**25000**	**100000**	0.04
Mo	mg/kg	**40**	**1000**	**4000**	0.223456
Ni	mg/kg	**91**	**10600**	**42400**	<0.02
Pb	mg/kg	**20**	**1900**	**7600**	<0.02
Sb	mg/kg	**10**	**75**	**300**	0.016
Se	mg/kg	**10**	**50**	**200**	0.06
V	mg/kg	**150**	**2680**	**10720**	0.55
Zn	mg/kg	**240**	**160000**	**640000**	<0.02
Fluoride as F	mg/kg	**100**	**10000**	**40000**	4

Table 10: LCT classification table

Parameter	Unit	LCT0	LCT1	LCT2	LCT3	AWS
As	mg/l	**0.01**	**0.5**	**1**	**4**	0.003
B	mg/l	**0.5**	**25**	**50**	**200**	1.4
Ba	mg/l	**0.7**	**35**	**70**	**280**	0.4
Cd	mg/l	**0.003**	**0.15**	**0.3**	**1.2**	0.0001
Co	mg/l	**0.5**	**25**	**50**	**200**	<0.001
Cr	mg/l	**0.1**	**5**	**10**	**40**	0.09
Cu	mg/l	**2**	**100**	**200**	**800**	<0.001
Hg	mg/l	**0.006**	**0.3**	**0.6**	**2.4**	0.0003
Mn	mg/l	**0.5**	**25**	**50**	**200**	0.01
Mo	mg/l	**0.07**	**3.5**	**7**	**28**	0.03
Ni	mg/l	**0.07**	**3.5**	**7**	**28**	<0.001
Pb	mg/l	**0.01**	**0.5**	**1**	**4**	<0.001
Sb	mg/l	**0.02**	**1**	**2**	**8**	0.004
Se	mg/l	**0.01**	**0.5**	**1**	**4**	0.01
V	mg/l	**0.2**	**10**	**20**	**80**	0.14
Zn	mg/l	**5**	**250**	**500**	**2000**	<0.001
Chloride as Cl	mg/l	**300**	**15000**	**30000**	**120000**	8
Sulphate as SO_4	mg/l	**250**	**12500**	**25000**	**100000**	22
Nitrate as N	mg/l	**11**	**550**	**1100**	**4400**	<0.2
Fluoride as F	mg/l	**1.5**	**75**	**150**	**600**	0.6

6 IMPACT ASSESSMENT

The potential impacts and risks identified through the geochemical evaluation of the ash material has been assessed and rated as part of the geohydrological study and is included in the geohydrological specialist report.

7 CONCLUSIONS

Based on the geochemical study results and waste classification the following can be concluded:

7.1 Geochemical study

- The ash mineralogy is dominated by quartz and mullite with large percentages of amorphous material and trace element inclusions;
- The ash material has a high NNP and will allow for the buffering of any acidic environments;
- In the DW tests the main elements of concern leaching out are B, Ba, Ca, Se, Al and Cr. These elements should be monitored in all phases of the project on a monthly basis;
- The ash water sampled showed that the mixing of the slurry water and ash allows for the dissolution of Al, B, Se, Cr and Ca into the ash water and removing some of the elements of concern before it reaches the pump house; and
- Although some elements do leach out in significant concentrations in both the DW tests and can pose an environmental health risk, the low permeability and hydraulic conductivity of the ash material will result in a small amount of seepage through the system once it has been deposited in the mine voids. It can be assumed that any small amount of leachable ions from the ash will be diluted to acceptable levels once it comes into contact with groundwater or surface water at the decant positions.

7.2 Waste Classification

Based on the classification of the Distilled/Reagent water leachate test results against the relevant TCT and LCT limits (as given in the legislative guidelines for waste classification (DEA 2013a), the ash to be used as backfill can be classified as follows:

- For boron (B) the results show that LCT0<LC<LCT1 and TC<TCT0;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste;

8 RECOMMENDATIONS

The following recommendations are made by Digby Wells based on the outcome of this study:

- In the DW tests the main elements of concern leaching out are B, Ba, Ca, Se, Al and Cr. These elements should be monitored in all phases of the project on a monthly basis;
- The ash to be used for the backfilling of the underground voids can be classed as a Type 3 waste; however
  - Based on the low concentrations of the leachable ions (although they are above TCT0 and LCT0 in certain cases), the low NAG and the high NNP (section 3.2.3) it is concluded that the alternative waste management activity of using the ash material for backfilling of the mine voids at Sigma Colliery is feasible and a motivation to the authorities for this activity to be licenced is recommended.
  - The low permeability and hydraulic conductivity of ash will allow little to no seepage through the newly formed ash layers once allowed to settle and thus the environmental concentration of contaminants entering the receiving environment will be low and easily diluted through natural processes.
- If the waste management activity of backfilling the mine voids is not pursued the waste should be disposed of at a Class C Landfill.
- Previous limits and target water quality conditions in the water licence granted for the ash backfilling in Licence #20021165 was well set and achievable. It is recommended that these conditions are kept and monitoring should ensure that the target water quality standards are achieved.

9 REFERENCES

DEA, 2013a. *National Norms and Standards for the Assessment of Waste for Landfill Disposal*, Department of Environmental Affairs.

DEA, 2013b. *National Norms and Standards for the Disposal of Waste to Landfill*,

DEA, 2013c. *National Waste Classification and Management Regulations*, Department of Environmental Affairs.

DEA, 2012. *National Waste Information Regulations, 2012*, Department of Environmental Affairs.

Appendix A: Laboratory certificates

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

Building D
The Woods
41 De Havilland Cresent
Persequor Techno Park
Meiring Naudé Drive
Pretoria

P.O. Box 283
Persequor Park, 0020
Tel: +2712 – 349 – 1066
Fax: +2712 – 349 – 2064
e-mail: admin@waterlab.co.za

SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2013 - 09 - 26 **Date completed:** 2013 - 10 – 14

Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmental **Contact person: Mr. A. van Coller**

Address: Private Bag X10046 Randburg 2125 **e-mail: andre.van.coller@digbywells.com**

Telephone: 011 789 9495 **Facsimile: 011 789 9498** **Mobile: -**

Analyses in mg/ℓ (Unless specified otherwise)	Method Identification	Sample Identification
		Composite
Sample Number		18946
pH – Value at 25°C	WLAB001	12.3
Electrical Conductivity in mS/m at 25°C	WLAB002	523
Total Dissolved Solids at 180°C *	WLAB003	1 412
Total Acidity as $CaCO_3$*	WLAB022	<5
Total Alkalinity as $CaCO_3$	WLAB007	1 248
P-Alkalinity as $CaCO_3$ *	WLAB023	880
Bicarbonate Alkalinity as $CaCO_3$ *	WLAB023	<5
Carbonate Alkalinity as $CaCO_3$ *	WLAB023	736
Total Hardness as $CaCO_3$ *	WLAB051	1 102
Chloride as Cl	WLAB046	163
Sulphate as SO_4	WLAB046	60
Fluoride as F	WLAB014	1.7
Nitrate as N	WLAB046	<0.2
Nitrite as N	WLAB046	0.3
Ortho Phosphate as P	WLAB046	<0.2
Dissolved Oxygen as O_2 *	WLAB040	6.0
Free & Saline Ammonia as N	WLAB046	3.8
Ammonium as NH_4 *	---	<0.2
Sodium as Na	WLAB015	168
Potassium as K	WLAB015	15.6
Calcium as Ca	WLAB015	442
Magnesium as Mg	WLAB015	<2

Analyses continued on next page

A. van de Wetering

Technical Signatory

WATERLAB (Pty) Ltd

Reg. No.: 1983/009165/07 V.A.T. No.: 4130107891

Building D
The Woods
41 De Havilland Cresent
Persequor Techno Park
Meiring Naudé Drive
Pretoria

P.O. Box 283
Persequor Park, 0020
Tel: +2712 – 349 – 1066
Fax: +2712 – 349 – 2064
e-mail: admin@waterlab.co.za

SANAS Accredited Testing Laboratory
No. T0391

CERTIFICATE OF ANALYSES
GENERAL WATER QUALITY PARAMETERS

Date received: 2013 - 09 - 26 **Date completed:** 2013 - 10 – 14

Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmental **Contact person: Mr. A. van Coller**

Address: Private Bag X10046 Randburg 2125 **e-mail: andre.van.coller@digbywells.com**

Telephone: 011 789 9495 **Facsimile: 011 789 9498** **Mobile: -**

Analyses in mg/ℓ (Unless specified otherwise)	**Method Identification**	**Sample Identification**
		Composite
Sample Number		18946
Aluminium as Al	WLAB015	3.78
Arsenic as As *	WLAB015	<0.010
Boron as B *	WLAB015	0.696
Cadmium as Cd	WLAB015	<0.005
Chromium as Cr	WLAB015	0.167
Hexavalent Chromium as Cr^{6+} *	WLAB032	0.160
Cobalt as Co	WLAB015	<0.025
Copper as Cu	WLAB015	<0.025
Iron as Fe	WLAB015	0.559
Lead as Pb	WLAB015	<0.020
Manganese as Mn	WLAB015	<0.025
Mercury as Hg *	WLAB047	<0.001
Nickel as Ni	WLAB015	<0.025
Selenium as Se *	WLAB015	0.032
Uranium as U *	WLAB015	<0.010
Zinc as Zn	WLAB015	<0.025
% Balancing	---	98.9

*** = Not SANAS Accredited**

Tests marked "Not SANAS Accredited" in this report are not included in the SANAS Schedule of Accreditation for this Laboratory.

A. van de Wetering

_____

Technical Signatory

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY FLUORESCENCE

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Major Elements	Major Element Concentration (wt %)[s]				
	A	B	C	D	E
	18940	18941	18942	18943	18944
SiO_2	49.12	48.3	46.87	61.01	48.49
TiO_2	2.54	2.56	2.54	1.68	2.36
Al_2O_3	32.53	32.47	33.21	24.65	31.15
Fe_2O_3	3.23	3.18	3.3	2.62	3.06
MnO	0.04	0.05	0.05	0.04	0.05
MgO	0.59	0.67	0.75	0.52	0.73
CaO	6.16	6.35	6.65	0.65	5.78
Na_2O	0.63	0.78	0.87	0.3	0.79
K_2O	0.67	0.69	0.72	1.81	0.7
P_2O_5	0.14	0.15	0.15	0.08	0.15
Cr_2O_3	0.05	0.05	0.05	0.04	0.05
SO_3	0.1	0.26	0.14	0.11	0.36
LOI	3.72	4.06	4.18	6.22	5.86
Total	99.52	99.57	99.48	99.73	99.53
H_2O-	0.04	0.08	0.2	0.47	0.13

[s] =Results obtained from sub-contracted laboratory

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY FLUORESCENCE

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Trace Elements	Trace Element Concentration (ppm) [s]				
	A	B	C	D	E
	18940	18941	18942	18943	18944
As	23.5	21.8	25.9	<1.00	20.6
Ba	812	846	897	479	828
Bi	<1.00	<1.00	<1.00	<5.00	<1.00
Br	1.32	1.16	1.21	<1.00	1.25
Cd	1.84	<5.00	<5.00	<5.00	<5.00
Ce	<5.00	<5.00	<5.00	<5.00	<5.00
Cl	1129	881	1041	802	956
Co	12.7	32.5	53.9	<5.00	42.7
Cs	<1.00	<1.00	1.49	<1.00	<1.00
Cu	84.7	71	78	23.7	72.8
Ga	72	74.4	76.4	21	64.5
Ge	15.8	14	18.5	4.09	13.2
Hf	8.68	8.88	9.02	14.9	8.71
Hg	1.6	1.65	1.73	<5.00	1.37
La	103	66.2	92.2	15.1	69.7
Lu	<1.00	<1.00	<1.00	<1.00	<1.00
Mo	13.9	11.3	13.1	10.8	12.2
Nb	53.7	54.1	53.1	19.1	49
Nd	80.3	83.5	70.9	65.2	62.5
Ni	75.5	74.2	80.7	52.9	74
Pb	111	133	128	20.1	103
Rb	32.9	35.8	36.2	59.9	33.9
Sb	<5.00	3.39	<1.00	3.12	3.66
Sc	18.6	16.6	21	12.6	18.8
Se	<1.00	<5.00	<1.00	<5.00	<1.00
Sm	17.9	16.4	17.1	12.6	17.2
Sn	1.76	2.89	1.56	4.78	2.49
Sr	905	887	1128	161	1063
Ta	3.27	3.57	5.17	3.27	2.66
Te	27.5	30.4	25.7	2.7	29.7
Th	56	60.9	58.7	29.9	53.4
Tl	2.21	1.95	1.26	<1.00	1.74

Results continued on next page

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY FLUORESCENCE

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

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Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Trace Elements	Trace Element Concentration (ppm) [s]				
	A	B	C	D	E
	18940	18941	18942	18943	18944
U	15	16.2	17.2	4.63	16.6
V	281	290	304	74.9	282
W	5.16	5.12	4.93	4.93	4.95
Y	107	112	110	26.5	104
Yb	26.7	25	25.9	18.8	24.3
Zn	95.6	94.4	115	111	63.5
Zr	733	739	718	967	673

[s] =Results obtained from sub-contracted laboratory

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2013-09-26 **Date completed: 2013-10-23**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Composition (%) [s]

A			B			C		
18940			18941			18942		
Mineral	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error
Amorphous	53.55	1.26	Amorphous	58.08	1.2	Amorphous	55.83	1.29
Lime	0.83	0.13	Lime	0.67	0.13	Lime	0.52	0.14
Calcite	0.12	0.11	Calcite	0.04	0.1	Calcite	0	0
Mullite	38.51	1.11	Mullite	36.07	1.05	Mullite	38.06	1.17
Quartz	6.98	0.57	Quartz	5.14	0.51	Quartz	5.6	0.54

Composition (%) [s]

D			E		
18943			18944		
Mineral	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error
Amorphous	75.55	0.87	Amorphous	55.43	1.23
Lime	0.36	0.09	Lime	1.08	0.15
Calcite	0.1	0.17	Calcite	0	0
Mullite	6.28	0.42	Mullite	35.65	1.05
Quartz	17.7	0.57	Quartz	7.84	0.57

[s] Results obtained from sub-contracted laboratory

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

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Project number: 1000 **Report number: 42135** **Order number: SAS1691**

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Note:

The material submitted was scanned after addition of 20 % Si for quantitative determination of amorphous content and micronizing in a McCrone micronizing mill.

The material was prepared for XRD analysis using a backloading preparation method.

It was analysed with a PANalytical Empyrean diffractometer with PIXcel detector and fixed slits with Fe filtered Co-K_ radiation. The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight%) were estimated using the Rietveld method.

Errors are on the 3 sigma level in the column to the right of the amount (in weight per cent).

Comment:

• In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.

• Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group .

• Errors reported for phases occurring in minor amounts are sometimes larger than that of the quantity reported, indicating the possible absence of those phases.

Ideal Mineral compositions:
Calcite CaCO3
Lime CaO
Mullite 3Al2O3 2SiO2
Quartz SiO2

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification					
	A	B	C	D	E	E
Sample Number	**18940**	**18941**	**18942**	**18943**	**18944**	**18944D**
Paste pH	11.7	11.8	12.1	12.2	12.2	12.2
Total Sulphur (%) (LECO)	0.05	0.06	0.07	0.05	<0.01	<0.01
Acid Potential (AP) (kg/t)	1.56	1.88	2.19	1.56	0.31	0.31
Neutralization Potential (NP)	43.50	27.00	36.25	39.25	24.75	25.50
Nett Neutralization Potential (NNP)	41.94	25.13	34.06	37.69	24.44	25.19
Neutralising Potential Ratio (NPR) (NP : AP)	27.84	14.40	16.57	25.12	79.20	81.60
Rock Type	III	III	III	III	III	III

*** Negative NP values are obtained when the volume of NaOH (0.1N) titrated (pH: 8.3) is greater than the volume of HCl (1N) to reduce the pH of the sample to 2.0 – 2.5 Any negative NP values are corrected to 0.00.**

Please refer to Appendix (p.2) for a Terminology of terms and guidelines for rock classification

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

APPENDIX : TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

- Acid Potential (AP) ; *Synonyms*: Maximum Potential Acidity (MPA)
  Method: Total S(%) (Leco Analyzer) x 31.25
- Neutralization Potential (NP) ; *Synonyms:* Gross Neutralization Potential (GNP) ; *Syn*: Acid Neutralization Capacity (ANC) (The capacity of a sample to consume acid)
  Method: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)
- Nett Neutralization Potential (NNP) ; *Synonyms:* Nett Acid Production Potential (NAPP)
  Calculation: NNP = NP – AP ; NAPP = ANC – MPA
- Neutralising Potential Ratio (NPR)
  Calculation: NPR = NP : AP

CLASSIFICATION ACCORDING TO NETT NEUTRALISING POTENTIAL (NNP)

If NNP (NP – AP) < 0, the sample has the potential to generate acid
If NNP (NP – AP) > 0, the sample has the potential to neutralise acid produced

Any sample with NNP < 20 is potentiall acid-generating, and any sample with NNP > -20 might not generate acid (Usher *et al.*, 2003)

ROCK CLASSIFICATION

TYPE I	Potentially Acid Forming	Total S(%) > 0.25% and NP:AP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and NP:AP ratio 1:3 or less
TYPE III	Non-Acid Forming	Total S(%) < 0.25% and NP:AP ratio 1:3 or greater

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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CLASSIFICATION ACCORDING TO NEUTRALISING POTENTIAL RATIO (NPR)

Guidelines for screening criteria based on ABA (Price *et al*., 1997 ; Usher *et al*., 2003)

Potential for ARD	Initial NPR Screening Criteria	Comments
Likely	**< 1:1**	Likely AMD generating
Possibly	**1:1 – 2:1**	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides
Low	**2:1 – 4:1**	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficiently reactive NP
None	**>4:1**	No further AMD testing required unless materials are to be used as a source of alkalinity

CLASSIFICATION ACCORDING TO SULPHUR CONTENT (%S) AND NEUTRALISING POTENTIAL RATIO (NPR)

For sustainable long-term acid generation, at least 0.3% Sulphide-S is needed. Values below this can yield acidity but it is likely to be only of short-term significance. From these facts, and using the NPR values, a number of rules can be derived:

1) Samples with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation.
2) NPR ratios of >4:1 are considered to have enough neutralising capacity.
3) NPR ratios of 3:1 to 1:1 are consider inconclusive.
4) NPR ratios below 1:1 with Sulphide-S above 3% are potentially acid-generating. (Soregaroli & Lawrence, 1998 ; Usher *et al*., 2003)

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

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EPA-600 MODIFIED SOBEK METHOD

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Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

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E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
NETT ACID GENERATION

Date received: 2013-09-26 **Date completed: 2013-10-22**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Nett Acid Generation	Sample Identification: pH 4.5 & 7					
	A	**B**	**C**	**D**	**E**	**E**
Sample Number	**18940**	**18941**	**18942**	**18943**	**18944**	**18944D**
NAG pH: (H_2O_2)	10.2	10.3	10.3	10.5	10.2	10.2
NAG (kg H_2SO_4 / t)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-30**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	A		B	
Sample number	**18940**		**18941**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	12.2		12.1	
Electrical Conductivity in mS/m at 25˚C	279		206	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	790	1 580	612	12 240
Chloride as Cl	<5	<100	<5	<100
Sulphate as SO_4	22	440	31	620
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.6	12	0.5	10
Phosphorus as P	<0.025	<0.500	<0.025	<0.500
ICP-MS Quant [s]	See attached report 42135 ICP DW		See attached report 42135 ICP DW	
Acid Base Accounting	See attached report 42135 ABA		See attached report 42135 ABA	
Net Acid Generation	See attached report 42135 NAG		See attached report 42135 NAG	
X-Ray Diffraction [s]	See attached report 42135 XRD		See attached report 42135 XRD	
X-Ray Fluorescence [s]	See attached report 42135 XRF		See attached report 42135 XRF	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-30**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	C		D	
Sample number	**18942**		**18943**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	12.3		12.4	
Electrical Conductivity in mS/m at 25˚C	392		527	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	1 020	20 400	1 368	27 360
Chloride as Cl	<5	<100	<5	<100
Sulphate as SO_4	9	180	<5	<100
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	1.0	20	0.7	14
Phosphorus as P	<0.025	<0.500	<0.025	<0.500
ICP-MS Quant [s]	See attached report 42135 ICP DW		See attached report 42135 ICP DW	
Acid Base Accounting	See attached report 42135 ABA		See attached report 42135 ABA	
Net Acid Generation	See attached report 42135 NAG		See attached report 42135 NAG	
X-Ray Diffraction [s]	See attached report 42135 XRD		See attached report 42135 XRD	
X-Ray Fluorescence [s]	See attached report 42135 XRF		See attached report 42135 XRF	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
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TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-30**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	E		AWS	
Sample number	**18944**		**18945**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**Distilled Water**		**Distilled Water**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	12.2		11.4	
Electrical Conductivity in mS/m at 25˚C	281		461	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	732	14 640	136	2 720
Chloride as Cl	<5	<100	8	160
Sulphate as SO_4	23	460	22	440
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.8	16	0.6	12
Phosphorus as P	<0.025	<0.500	<0.025	<0.500
ICP-MS Quant [s]	See attached report 42135 ICP DW		See attached report 42135 ICP DW	
Acid Base Accounting	See attached report 42135 ABA		See attached report 42135 ABA	
Net Acid Generation	See attached report 42135 NAG		See attached report 42135 NAG	
X-Ray Diffraction [s]	See attached report 42135 XRD		See attached report 42135 XRD	
X-Ray Fluorescence [s]	See attached report 42135 XRF		See attached report 42135 XRF	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-MS QUANTITATIVE ANALYSIS [s]

Date received: 26/09/2013 **Date Completed:** 30/10/2013
Project number: 1000 **Report number:** 42135

Client name: Digby Wells Environmental **Contact person:** Andre van Coller
Adress: Private Bag X10046, Randburg, 2125 **Email:** andre.van.coller@digbywells.com
Telephone: 011 789 9495

Extract	Sample Dry Mass (g)	Volume (ml)	Factor
Distilled Water	50	1000	20

[s]= Results obtained form subcontracted laboratory

Sample Id	Sample Number	Ag	Ag	Al	Al	As	As
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	3.01	60	0.001	0.020
B	18941	<0.001	<0.020	4.52	90	0.001	0.020
C	18942	<0.001	<0.020	0.708	14	0.002	0.040
D	18943	0.001	0.020	0.486	10	0.001	0.020
E	18944	<0.001	<0.020	2.13	43	0.001	0.020
AWS	19845	<0.001	<0.020	3.65	73	0.003	0.060

Sample Id	Sample Number	Au	Au	B	B	Ba	Ba
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	2.63	53	3.01	60
B	18941	<0.001	<0.020	2.57	51	2.17	43
C	18942	<0.001	<0.020	0.366	7.32	4.03	81
D	18943	<0.001	<0.020	0.063	1.25	11	220
E	18944	<0.001	<0.020	2.01	40	3.93	79
AWS	19845	<0.001	<0.020	1.37	27	0.382	7.63

Sample Id	Sample Number	Be	Be	Bi	Bi	Ca	Ca
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.01	<0.20
A	18940	<0.001	<0.020	<0.001	<0.020	322	6440
B	18941	<0.001	<0.020	<0.001	<0.020	282	5640
C	18942	<0.001	<0.020	<0.001	<0.020	440	8800
D	18943	<0.001	<0.020	<0.001	<0.020	560	11200
E	18944	<0.001	<0.020	<0.001	<0.020	327	6540
AWS	19845	<0.001	<0.020	<0.001	<0.020	65	1300

Sample Id	Sample Number	Cd	Cd	Ce	Ce	Co	Co
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.0001	<0.0020	<0.001	<0.020	<0.001	<0.020
A	18940	0.0002	0.004	<0.001	<0.020	<0.001	<0.020
B	18941	0.0002	0.004	<0.001	<0.020	<0.001	<0.020
C	18942	0.0002	0.004	<0.001	<0.020	<0.001	<0.020
D	18943	0.0001	0.002	<0.001	<0.020	<0.001	<0.020
E	18944	0.0001	0.002	<0.001	<0.020	<0.001	<0.020
AWS	19845	0.0001	0.002	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample Number	Cr	Cr	Cs	Cs	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.255	5.09	0.001	0.020	<0.001	<0.020
B	18941	0.362	7.24	0.001	0.020	<0.001	<0.020
C	18942	0.177	3.54	0.001	0.020	<0.001	<0.020
D	18943	0.061	1.21	0.001	0.020	<0.001	<0.020
E	18944	0.114	2.28	0.001	0.020	<0.001	<0.020
AWS	19845	0.086	1.72	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample Number	Fe	Fe	Ga	Ga	Ge	Ge
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.01	<0.20	<0.001	<0.020	<0.001	<0.020
A	18940	<0.01	<0.20	0.078	1.55	0.001	0.020
B	18941	<0.01	<0.20	0.103	2.06	<0.001	<0.020
C	18942	<0.01	<0.20	0.056	1.12	<0.001	<0.020
D	18943	<0.01	<0.20	0.042	0.832	<0.001	<0.020
E	18944	<0.01	<0.20	0.082	1.64	<0.001	<0.020
AWS	19845	<0.01	<0.20	0.028	0.563	<0.001	<0.020

Sample Id	Sample Number	Hf	Hf	Hg	Hg	Ho	Ho
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.200	<0.0001	<0.0020	<0.001	<0.200
A	18940	<0.001	<0.200	0.0006	0.0120	<0.001	<0.200
B	18941	<0.001	<0.200	0.0007	0.0140	<0.001	<0.200
C	18942	<0.001	<0.200	0.0005	0.0100	<0.001	<0.200
D	18943	<0.001	<0.200	0.0002	0.0040	<0.001	<0.200
E	18944	<0.001	<0.200	0.0006	0.0120	<0.001	<0.200
AWS	19845	<0.001	<0.200	0.0003	0.0060	<0.001	<0.200

Sample Id	Sample Number	Ir	Ir	K	K	La	La
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.01	<0.20	<0.001	<0.020
A	18940	<0.001	<0.020	0.154	3.1	<0.001	<0.020
B	18941	<0.001	<0.020	0.166	3.3	<0.001	<0.020
C	18942	<0.001	<0.020	0.164	3.3	<0.001	<0.020
D	18943	<0.001	<0.020	0.103	2.1	<0.001	<0.020
E	18944	<0.001	<0.020	0.041	0.814	<0.001	<0.020
AWS	19845	<0.001	<0.020	0.435	8.7	<0.001	<0.020

Sample Id	Sample Number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg

Det Limit		<0.001	<0.020	<0.01	<0.200	<0.001	<0.020
A	18940	0.300	<0.020	<0.01	<0.200	<0.001	<0.020
B	18941	0.370	<0.020	<0.01	<0.200	<0.001	<0.020
C	18942	0.330	<0.020	<0.01	<0.200	0.010	0.200
D	18943	0.260	<0.020	<0.01	<0.200	<0.001	<0.020
E	18944	0.370	7.40	<0.01	<0.200	<0.001	<0.020
AWS	19845	0.070	<0.020	<0.01	<0.200	0.010	0.200

Sample Id	Sample Number	Mo	Mo	Na	Na	Nb	Nb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.058	1.17	1.27	25	<0.001	<0.020
B	18941	0.069	1.37	1.47	29	<0.001	<0.020
C	18942	0.050	1.01	1.61	32	<0.001	<0.020
D	18943	0.033	0.656	1.54	31	<0.001	<0.020
E	18944	0.053	1.05	2.04	41	<0.001	<0.020
AWS	19845	0.030	0.601	6.12	122	<0.001	<0.020

Sample Id	Sample Number	Nd	Nd	Ni	Ni	Pb	Pb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	0.024	0.485	<0.001	<0.020
B	18941	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
C	18942	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
D	18943	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
E	18944	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
AWS	19845	<0.001	<0.020	<0.001	<0.020	<0.001	<0.020

Sample Id	Sample Number	Pt	Pt	Rb	Rb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	0.002	0.040	0.002	0.040
B	18941	<0.001	<0.020	0.002	0.040	0.002	0.040
C	18942	<0.001	<0.020	0.002	0.040	0.001	0.020
D	18943	<0.001	<0.020	0.002	0.040	0.001	0.020
E	18944	<0.001	<0.020	0.002	0.040	0.002	0.040
AWS	19845	<0.001	<0.020	0.002	0.040	0.004	0.080

Sample Id	Sample Number	Sc	Sc	Se	Se	Si	Si
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.05	<1.00
A	18940	0.001	0.020	0.042	0.845	1.5	31
B	18941	0.001	0.020	0.072	1.43	2.0	41
C	18942	<0.001	<0.020	0.014	0.288	0.950	19
D	18943	<0.001	<0.020	0.025	0.492	0.540	11
E	18944	<0.001	<0.020	0.045	0.900	1.7	35
AWS	19845	0.005	0.100	0.009	0.180	7.1	142

Sample Id	Sample Number	Sn	Sn	Sr	Sr	Ta	Ta
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	3.53	71	<0.001	<0.020
B	18941	<0.001	<0.020	2.83	57	<0.001	<0.020
C	18942	<0.001	<0.020	4.43	89	<0.001	<0.020
D	18943	<0.001	<0.020	5.49	110	<0.001	<0.020
E	18944	<0.001	<0.020	3.69	74	<0.001	<0.020
AWS	19845	<0.001	<0.020	0.819	16	<0.001	<0.020

Sample Id	Sample Number	Te	Te	Th	Th	Ti	Ti
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
A	18940	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
B	18941	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
C	18942	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
D	18943	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
E	18944	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
AWS	19845	<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00

Sample Id	Sample Number	Tl	Tl	U	U	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.001	<0.020
A	18940	<0.001	<0.020	<0.0001	<0.0020	0.011	0.221
B	18941	<0.001	<0.020	<0.0001	<0.0020	0.022	0.449
C	18942	<0.001	<0.020	<0.0001	<0.0020	0.009	0.180
D	18943	<0.001	<0.020	<0.0001	<0.0020	0.004	0.085
E	18944	<0.001	<0.020	<0.0001	<0.0020	0.012	0.239
AWS	19845	<0.001	<0.020	0.0003	0.006	0.137	2.75

Sample Id	Sample Number	W	W	Y	Y
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	0.043	0.856	<0.001	<0.020
B	18941	0.052	1.05	<0.001	<0.020
C	18942	0.034	0.672	<0.001	<0.020
D	18943	0.017	0.341	<0.001	<0.020
E	18944	0.041	0.813	<0.001	<0.020
AWS	19845	0.023	0.468	<0.001	<0.020

Sample Id	Sample Number	Zn	Zn	Zr	Zr
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	<0.001	<0.020
B	18941	<0.001	<0.020	<0.001	<0.020
C	18942	<0.001	<0.020	<0.001	<0.020
D	18943	<0.001	<0.020	<0.001	<0.020
E	18944	<0.001	<0.020	<0.001	<0.020
AWS	19845	<0.001	<0.020	<0.001	<0.020

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-31**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	A		B	
Sample number	**18940**		**18941**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**TCLP 2**		**TCLP 2**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	4.7		4.7	
Electrical Conductivity in mS/m at 25˚C	368		364	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	600	12 000	564	11 280
Chloride as Cl	<5	<100	<5	<100
Sulphate as SO_4	94	1 880	109	2 180
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.4	8.0	0.3	6.0
Phosphorus as P	0.3	6.0	0.4	8.0
ICP-MS Quant [s]	See attached report 42135 ICP TCLP		See attached report 42135 ICP TCLP	

[s] Subcontracted

TCLP 2 = pH2.9

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-31**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification			
	C		D	
Sample number	**18942**		**18943**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**TCLP 2**		**TCLP 2**	
Dry Mass Used (g)	**50**		**50**	
Volume Used (mℓ)	**1000**		**1000**	
pH Value at 25˚C	4.8		5.1	
Electrical Conductivity in mS/m at 25˚C	402		496	
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	1000	20 000	1776	35 520
Chloride as Cl	5	100	7	140
Sulphate as SO_4	118	2 360	81	1 620
Nitrate as N	<0.2	<4.0	<0.2	<4.0
Fluoride as F	0.4	8.0	0.8	16
Phosphorus as P	0.3	6.0	0.2	4.0
ICP-MS Quant [s]	See attached report 42135 ICP TCLP		See attached report 42135 ICP TCLP	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

Building D, The Woods,
Persequor Techno Park,
Meiring Naudé Road, Pretoria
P.O. Box 283, 0020

Telephone: +2712 – 349 – 1066
Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
TCLP / ACID RAIN / DISTILLED WATER EXTRACTIONS

Date received: 2013-09-26 **Date completed: 2013-10-31**
Project number: 1000 **Report number: 42135** **Order number: SAS1691**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
Facsimile: 011 789 9498 **Telephone: 011 789 9495** **Cell: 076 076 9443**

Analyses	Sample Identification	
	E	
Sample number	**18944**	
TCLP / Acid Rain / Distilled Water / H_2O_2	**TCLP 2**	
Dry Mass Used (g)	**50**	
Volume Used (mℓ)	**1000**	
pH Value at 25˚C	4.7	
Electrical Conductivity in mS/m at 25˚C	366	
Units	**mg/ℓ**	**mg/kg**
Alkalinity as $CaCO_3$	720	14 400
Chloride as Cl	<5	<100
Sulphate as SO_4	95	1 900
Nitrate as N	<0.2	<4.0
Fluoride as F	0.4	8.0
Phosphorus as P	0.3	6.0
ICP-MS Quant [s]	See attached report 42135 ICP TCLP	

[s] Subcontracted

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

CERTIFICATE OF ANALYSES

ICP-MS QUANTITATIVE ANALYSIS [s]

Date received: 26/09/2013
Project number: 1000

Date Completed: 31/10/2013
Report number: 42135

Client name: Digby Wells Environmental
Adress: Private Bag X10046, Randburg, 2125
Telephone: 011 789 9495

Contact person: Andre van Coller
Email: andre.van.coller@digbywells.com

Extract	Sample Dry Mass (g)	Volume (ml)	Factor
TCLP	50	1000	20

[s]= Results obtained form subcontracted laboratory

Sample Id	Sample Number	Ag	Ag	Al	Al	As	As
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	17.7	354	0.023	0.455
B	18941	<0.001	<0.020	25.2	504	0.027	0.538
C	18942	<0.001	<0.020	15.3	306	0.022	0.437
D	18943	<0.001	<0.020	8.36	167	0.010	0.193
E	18944	<0.001	<0.020	12.3	246	0.026	0.513

Sample Id	Sample Number	Au	Au	B	B	Ba	Ba
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	7.2	143	1.60	32
B	18941	<0.001	<0.020	8.9	178	1.49	30
C	18942	<0.001	<0.020	8.9	178	1.34	27
D	18943	<0.001	<0.020	6.2	124	1.76	35
E	18944	<0.001	<0.020	6.7	135	1.70	34

Sample Id	Sample Number	Be	Be	Bi	Bi	Ca	Ca
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.01	<0.20
A	18940	0.006	0.120	<0.001	<0.020	998	19960
B	18941	0.008	0.160	<0.001	<0.020	1000	20000
C	18942	0.006	0.120	<0.001	<0.020	1140	22800
D	18943	0.004	0.080	<0.001	<0.020	1400	28000
E	18944	0.005	0.100	<0.001	<0.020	1010	20200

Sample Id	Sample Number	Cd	Cd	Ce	Ce	Co	Co
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.0001	<0.0020	<0.001	<0.020	<0.001	<0.020
A	18940	0.0019	0.038	0.082	1.64	0.012	0.241
B	18941	0.0027	0.053	0.105	2.09	0.013	0.255
C	18942	0.0025	0.051	0.073	1.45	0.014	0.281
D	18943	0.0021	0.042	0.060	1.20	0.013	0.259
E	18944	0.0037	0.074	0.078	1.56	0.011	0.220

Sample Id	Sample Number	Cr	Cr	Cs	Cs	Cu	Cu
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.501	10	0.001	0.020	0.043	0.859
B	18941	0.591	12	0.001	0.020	0.031	0.624
C	18942	0.484	9.68	0.001	0.020	0.022	0.436
D	18943	0.229	4.59	0.001	0.020	<0.001	<0.020
E	18944	0.281	5.62	0.001	0.020	0.020	0.392

Sample Id	Sample Number	Fe	Fe	Ga	Ga	Ge	Ge
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.01	<0.20	<0.001	<0.020	<0.001	<0.020
A	18940	0.573	11	0.006	0.120	0.206	4.11
B	18941	0.818	16	0.010	0.200	0.250	5.01
C	18942	0.390	7.79	0.005	0.100	0.230	4.60
D	18943	0.207	4.14	0.003	0.060	0.149	2.97
E	18944	0.266	5.31	0.003	0.060	0.214	4.27

Sample Id	Sample Number	Hf	Hf	Hg	Hg	Ho	Ho
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.200	<0.0001	<0.0020	<0.001	<0.200
A	18940	<0.001	<0.200	0.0002	0.004	0.007	0.140
B	18941	<0.001	<0.200	0.0002	0.004	0.008	0.160
C	18942	<0.001	<0.200	0.0001	0.002	0.006	0.120
D	18943	<0.001	<0.200	0.0001	0.002	0.005	0.100
E	18944	<0.001	<0.200	0.0001	0.002	0.006	0.120

Sample Id	Sample Number	Ir	Ir	K	K	La	La
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.01	<0.20	<0.001	<0.020
A	18940	<0.001	<0.020	0.454	9.1	0.082	1.63
B	18941	<0.001	<0.020	0.524	10.5	0.098	1.96
C	18942	<0.001	<0.020	0.602	12.0	0.079	1.58
D	18943	<0.001	<0.020	0.457	9.1	0.064	1.29
E	18944	<0.001	<0.020	0.653	13.1	0.069	1.38

Sample Id	Sample Number	Li	Li	Mg	Mg	Mn	Mn
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg

Det Limit		<0.001	<0.020	<0.01	<0.200	<0.001	<0.020
A	18940	0.400	862	43.1	862	1.18	24
B	18941	0.510	750	37.5	750	1.26	25
C	18942	0.530	1074	53.7	1074	1.38	28
D	18943	0.410	1206	60.3	1206	1.58	32
E	18944	0.490	1064	53.2	1064	1.56	31

Sample Id	Sample Number	Mo	Mo	Na	Na	Nb	Nb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.020	0.397	1.98	40	<0.001	<0.020
B	18941	0.019	0.388	2.56	51	<0.001	<0.020
C	18942	0.029	0.588	2.84	57	<0.001	<0.020
D	18943	0.027	0.546	2.74	55	<0.001	<0.020
E	18944	0.014	0.286	2.98	60	<0.001	<0.020

Sample Id	Sample Number	Nd	Nd	Ni	Ni	Pb	Pb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	0.095	1.91	0.028	0.563	<0.001	<0.020
B	18941	0.109	2.17	0.023	0.454	0.002	0.040
C	18942	0.096	1.91	0.025	0.510	<0.001	<0.020
D	18943	0.083	1.66	0.016	0.323	<0.001	<0.020
E	18944	0.081	1.62	0.012	0.241	0.004	0.080

Sample Id	Sample Number	Pt	Pt	Rb	Rb	Sb	Sb
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	0.004	0.080	0.015	0.300
B	18941	<0.001	<0.020	0.005	0.100	0.016	0.320
C	18942	<0.001	<0.020	0.005	0.100	0.016	0.320
D	18943	<0.001	<0.020	0.004	0.080	0.010	0.200
E	18944	<0.001	<0.020	0.005	0.100	0.016	0.320

Sample Id	Sample Number	Sc	Sc	Se	Se	Si	Si
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.05	<1.00
A	18940	0.080	1.59	0.029	0.572	92.4	1848
B	18941	0.088	1.75	0.035	0.697	103.9	2078
C	18942	0.078	1.55	0.018	0.354	93.5	1870
D	18943	0.059	1.18	0.021	0.421	75.6	1512
E	18944	0.075	1.50	0.060	1.21	91.7	1834

Sample Id	Sample Number	Sn	Sn	Sr	Sr	Ta	Ta
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020	<0.001	<0.020
A	18940	<0.001	<0.020	7.59	152	<0.001	<0.020
B	18941	<0.001	<0.020	7.18	144	<0.001	<0.020
C	18942	<0.001	<0.020	9.59	192	<0.001	<0.020
D	18943	<0.001	<0.020	13.00	260	<0.001	<0.020
E	18944	<0.001	<0.020	8.30	166	<0.001	<0.020

Sample Id	Sample Number	Te	Te	Th	Th	Ti	Ti
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.05	<1.00
A	18940	0.007	0.140	0.0002	0.004	0.029	0.584
B	18941	0.008	0.160	0.0003	0.006	0.042	0.831
C	18942	0.007	0.140	0.0002	0.004	0.022	0.436
D	18943	0.003	0.060	0.0001	0.002	0.014	0.277
E	18944	0.007	0.140	0.0001	0.002	0.015	0.307

Sample Id	Sample Number	Tl	Tl	U	U	V	V
		mg/l	mg/kg	mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.0001	<0.0020	<0.001	<0.020
A	18940	<0.001	<0.020	0.0181	0.362	0.298	5.97
B	18941	<0.001	<0.020	0.0219	0.437	0.320	6.40
C	18942	<0.001	<0.020	0.0177	0.353	0.390	7.79
D	18943	<0.001	<0.020	0.0089	0.178	0.131	2.63
E	18944	<0.001	<0.020	0.0073	0.146	0.309	6.18

Sample Id	Sample Number	W	W	Y	Y
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	0.001	0.020	0.209	4.18
B	18941	0.002	0.040	0.230	4.60
C	18942	0.002	0.040	0.201	4.02
D	18943	0.002	0.040	0.175	3.50
E	18944	0.001	0.020	0.179	3.59

Sample Id	Sample Number	Zn	Zn	Zr	Zr
		mg/l	mg/kg	mg/l	mg/kg
Det Limit		<0.001	<0.020	<0.001	<0.020
A	18940	0.158	3.15	0.001	0.020
B	18941	0.219	4.38	0.001	0.020
C	18942	0.199	3.98	0.001	0.020
D	18943	0.146	2.92	<0.001	<0.020
E	18944	0.293	5.86	<0.001	<0.020

Appendix B: Leachate result classification

Distilled water leach results compared to Drinking water guidelines

Results for chemicals that are of health significance in drinking-water																													
Parameter	**pH**	**Total Alk**	**F**	**Cl**	**NO3 as N**	**SO4**	**Al**	**As**	**B***	**Ba***	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**K**	**Mg**	**Mn**	**Mo***	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**V**	**Zn**	**U***
Unit	**-**	**mg/l CaCO3**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Class 1 (recommended limit)	5 - 9.5	N/A	1	200	10	400	0.3	0.01			150	0.0050	0.5	0.1	1	0.2	0.001	50	70	0.1		200	0.15	0.02	0.01	0.02	0.2	5	
Class 2 (max allowed for limited duration)	4 - 5 / 9.5 - 10	N/A	1.5	600	20	600	0.5	0.05			300	0.0100	1	0.5	2	2	0.005	100	100	1		400	0.35	0.05	0.05	0.05	0.5	10	
Class 3 (not recommended for consumtion)	<4 / >10	N/A	>1.5	>600	>20	>600	>0.5	>0.05	0.5	0.7	>300	>0.01	>1	>0.5	>2	>2	>0.005	>100	>100	>1	0.07	>400	>0.35	>0.05	>0.05	>0.05	>0.5	>10	0.015
A	12.2	790	0.6	<5	<0.2	22	3.0	0.001	2.6	3.0	322	0.0002	<0.001	0.25	<0.001	<0.01	0.0006	0.15	<0.01	<0.001	0.06	1.27	0.024	<0.001	0.002	0.042	0.01	<0.001	<0.0001
B	12.1	612	0.5	<5	<0.2	31	4.5	0.001	2.6	2.2	282	0.0002	<0.001	0.36	<0.001	<0.01	0.0007	0.17	<0.01	<0.001	0.07	1.47	<0.001	<0.001	0.002	0.072	0.02	<0.001	<0.0001
C	12.3	1020	1	<5	<0.2	9	0.7	0.002	0.4	4.0	440	0.0002	<0.001	0.18	<0.001	<0.01	0.0005	0.16	<0.01	0.01	0.05	1.61	<0.001	<0.001	0.001	0.014	0.01	<0.001	<0.0001
D	12.4	1368	0.7	<5	<0.2	<5	0.5	0.001	0.1	11.0	560	0.0001	<0.001	0.06	<0.001	<0.01	0.0002	0.10	<0.01	<0.001	0.03	1.54	<0.001	<0.001	0.001	0.025	0.004	<0.001	<0.0001
E	12.2	732	0.8	<5	<0.2	23	2.1	0.001	2.0	3.9	327	0.0001	<0.001	0.11	<0.001	<0.01	0.0006	0.04	<0.01	<0.001	0.05	2.04	<0.001	<0.001	0.002	0.045	0.01	<0.001	<0.0001
AWS	11.4	136	0.6	8	<0.2	22	3.6	0.003	1.4	0.4	65	0.0001	<0.001	0.09	<0.001	<0.01	0.0003	0.43	<0.01	0.01	0.03	6.12	<0.001	<0.001	0.004	0.009	0.14	<0.001	0.0003
Average	**12.1**	**776**	**1**	**8**	**<0.2**	**21**	**2.4**	**0.002**	**1.5**	**4.1**	**333**	**0.0002**	**<0.001**	**0.18**	**<0.001**	**<0.01**	**0.0005**	**0.18**	**<0.01**	**0.01**	**0.05**	**2**	**0.024**	**<0.001**	**0.002**	**0.035**	**0.03**	**<0.001**	**0.0003**

Results for chemicals that are not of health significance in drinking-water																													
Parameter	**Ag**	**Au**	**Be**	**Bi**	**Ce**	**Cs**	**Ga**	**Ge**	**Hf**	**Ho**	**Ir**	**La**	**Li**	**Nb**	**Nd**	**Pt**	**Rb**	**Sc**	**Si**	**Sn**	**Sr**	**Ta**	**Te**	**Th**	**Ti**	**Tl**	**W**	**Y**	**Zr**	**P**
Unit	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
A	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.07761	0.001	<0.001	<0.001	<0.001	<0.001	0.3	<0.001	<0.001	<0.001	0.002	0.001	1.54	<0.001	3.52844	<0.001	<0.001	<0.0001	<0.05	<0.001	0.04282	<0.001	<0.001	<0.025
B	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.10324	<0.001	<0.001	<0.001	<0.001	<0.001	0.37	<0.001	<0.001	<0.001	0.002	0.001	2.04	<0.001	2.83379	<0.001	<0.001	<0.0001	<0.05	<0.001	0.0523	<0.001	<0.001	<0.025
C	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.05611	<0.001	<0.001	<0.001	<0.001	<0.001	0.33	<0.001	<0.001	<0.001	0.002	<0.001	0.95	<0.001	4.42868	<0.001	<0.001	<0.0001	<0.05	<0.001	0.03361	<0.001	<0.001	<0.025
D	0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.04159	<0.001	<0.001	<0.001	<0.001	<0.001	0.26	<0.001	<0.001	<0.001	0.002	<0.001	0.54	<0.001	5.48622	<0.001	<0.001	<0.0001	<0.05	<0.001	0.01705	<0.001	<0.001	<0.025
E	<0.001	<0.001	<0.001	<0.001	<0.001	0.001	0.08177	<0.001	<0.001	<0.001	<0.001	<0.001	0.37	<0.001	<0.001	<0.001	0.002	<0.001	1.73	<0.001	3.69389	<0.001	<0.001	<0.0001	<0.05	<0.001	0.04066	<0.001	<0.001	<0.025
AWS	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.02814	<0.001	<0.001	<0.001	<0.001	<0.001	0.07	<0.001	<0.001	<0.001	0.002	0.005	7.09	<0.001	0.81868	<0.001	<0.001	<0.0001	<0.05	<0.001	0.02342	<0.001	<0.001	<0.025

TCLP results compared to Drinking water guidelines

Results for chemicals that are of health significance in drinking-water																													
Parameter	**pH**	**Total Alk**	**F**	**Cl**	**NO3 as N**	**SO4**	**Al**	**As**	**B***	**Ba***	**Ca**	**Cd**	**Co**	**Cr**	**Cu**	**Fe**	**Hg**	**K**	**Mg**	**Mn**	**Mo***	**Na**	**Ni**	**Pb**	**Sb**	**Se**	**V**	**Zn**	**U***
Unit	**-**	**mg/l CaCO3**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
Class 1 (recommended limit)	5 - 9.5	N/A	1	200	10	400	0.3	0.01			150	0.0050	0.5	0.1	1	0.2	0.001	50	70	0.1		200	0.15	0.02	0.01	0.02	0.2	5	
Class 2 (max allowed for limited duration)	4 - 5 / 9.5 - 10	N/A	1.5	600	20	600	0.5	0.05			300	0.0100	1	0.5	2	2	0.005	100	100	1		400	0.35	0.05	0.05	0.05	0.5	10	
Class 3 (not recommended for consumtion)	<4 / >10	N/A	>1.5	>600	>20	>600	>0.5	>0.05	0.5	0.7	>300	>0.01	>1	>0.5	>2	>2	>0.005	>100	>100	>1	0.07	>400	>0.35	>0.05	>0.05	>0.05	>0.5	>10	0.015
A	4.7	600	0.4	<5	<0.2	94	18	0.023	7.2	1.6	998	0.002	0.012	0.50	0.043	0.6	0.0002	0.45	43.1	1.18	0.020	1.98	0.028	<0.001	0.015	0.029	0.30	0.2	0.018
B	4.7	564	0.3	<5	<0.2	109	25	0.027	8.9	1.5	1000	0.003	0.013	0.59	0.031	0.8	0.0002	0.52	37.5	1.26	0.019	2.56	0.023	0.002	0.016	0.035	0.32	0.2	0.022
C	4.8	1000	0.4	5	<0.2	118	15	0.022	8.9	1.3	1140	0.003	0.014	0.48	0.022	0.4	0.0001	0.60	53.7	1.38	0.029	2.84	0.025	<0.001	0.016	0.018	0.39	0.2	0.018
D	5.1	1776	0.8	7	<0.2	81	8	0.010	6.2	1.8	1400	0.002	0.013	0.23	<0.001	0.2	0.0001	0.46	60.3	1.58	0.027	2.74	0.016	<0.001	0.010	0.021	0.13	0.1	0.009
E	4.7	720	0.4	<5	<0.2	95	12	0.026	6.7	1.7	1010	0.004	0.011	0.28	0.020	0.3	0.0001	0.65	53.2	1.56	0.014	2.98	0.012	0.004	0.016	0.060	0.31	0.3	0.007
Average	**4.8**	**932**	**0.46**	**6**	**<0.2**	**99.4**	**16**	**0.021**	**7.6**	**1.6**	**1109.6**	**0.003**	**0.013**	**0.42**	**0.029**	**0.5**	**0.0001**	**0.54**	**49.56**	**1.39**	**0.022**	**2.62**	**0.021**	**0.003**	**0.015**	**0.03**	**0.29**	**0.2**	**0.015**

Results for chemicals that are not of health significance in drinking-water																													
Parameter	**Ag**	**Au**	**Be**	**Bi**	**Ce**	**Cs**	**Ga**	**Ge**	**Hf**	**Ho**	**Ir**	**La**	**Li**	**Nb**	**Nd**	**Pt**	**Rb**	**Sc**	**Si**	**Sn**	**Sr**	**Ta**	**Te**	**Th**	**Ti**	**Tl**	**W**	**Y**	**Zr**	**P**
Unit	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
A	<0.001	<0.001	0.006	<0.001	0.082215	0.001	0.006	0.2056	<0.001	0.007	<0.001	0.08163	0.4	<0.001	0.09544	<0.001	0.004	0.07957	92.39	<0.001	7.591487	<0.001	0.007	0.0002	0.0292	<0.001	0.001	0.20917	0.001	0.3
B	<0.001	<0.001	0.008	<0.001	0.10458	0.001	0.01	0.25041	<0.001	0.008	<0.001	0.09816	0.51	<0.001	0.10871	<0.001	0.005	0.08756	103.89	<0.001	7.176271	<0.001	0.008	0.0003	0.04156	<0.001	0.002	0.22996	0.001	0.4
C	<0.001	<0.001	0.006	<0.001	0.072592	0.001	0.005	0.22994	<0.001	0.006	<0.001	0.07905	0.53	<0.001	0.09574	<0.001	0.005	0.07751	93.49	<0.001	9.586995	<0.001	0.007	0.0002	0.02182	<0.001	0.002	0.20108	0.001	0.3
D	<0.001	<0.001	0.004	<0.001	0.060197	0.001	0.003	0.14865	<0.001	0.005	<0.001	0.06432	0.41	<0.001	0.08297	<0.001	0.004	0.05888	75.59	<0.001	13.0024	<0.001	0.003	0.0001	0.01383	<0.001	0.002	0.17511	<0.001	0.2
E	<0.001	<0.001	0.005	<0.001	0.078231	0.001	0.003	0.21363	<0.001	0.006	<0.001	0.06878	0.49	<0.001	0.08124	<0.001	0.005	0.07525	91.69	<0.001	8.301456	<0.001	0.007	0.0001	0.01534	<0.001	0.001	0.17942	<0.001	0.3