Kriel Power Station Ash Dump Extension

Geochemistry and Waste Classification Assessment

Project Number:

ESK2840

Prepared for:

Eskom Holdings SOC Limited

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Lucas Smith	Review		December 2014

EXECUTIVE SUMMARY

Digby Wells Environmental (Digby Wells) was tasked to perform a geochemistry and waste classification assessment for the proposed Kriel power station dump extension project. Kriel Power Station is located approximately 6 km northeast of Matla Coal Mine in the Mpumalanga Province (Appendix A, Plan 1). The existing ash dam at the Kriel Power Station is reaching full capacity and Eskom therefore requires the construction of a new ash dam in order to continue operations. If required, and during ongoing construction of the new ash dam, Eskom plans to transfer ash to the neighbouring Matla Power Station and/or increase the height of the existing facility at Kriel Power Station.

The objectives of the study are as follow:

- Geochemically assess the existing ash dam material, as well as fresh ash material to assist with waste classification of the material; and
- Waste classification and liner requirements.

The geochemistry and waste classification project forms part of the bigger hydrogeological investigation. Throughout the process the source term – pathway –receptor methodology was applied to have a holistic understanding of the study area and potential risks to the environment and their significance. The geochemistry and waste classification part of the project serves the sole purpose of characterising the source of potential contamination with the geohydrological study investigating the pathways and receptors.

The following paragraphs summarises the findings of the study:

Geochemistry

The ABA and NAG tests performed on the ash samples allowed for an evaluation of any potential for acid generation from the material analysed or alternatively whetehr the material is neutralising or not.. The test ABA and NAG results (given in Appendix B) can be summarised as follows:

- All samples have a paste pH of above 11 which is well above the acid producing margin of pH 5. This shows that the material is highly alkaline with a buffering potential. The high pH can however lead to dissolution and higher aqueous activity of metals like Al and B;
- Although pyrite content was observed the total sulphur concentrations in all samples are below the recommended 0.3% and no oxidation of sulphide minerals should lead to acid formation;
- The Neutralising Potential Ratio (AP:NP) is well above 4:1 indicating that the nett neutralising capacity of the material is much higher than any potential for acid production;

- Along with the high NPR, all samples show no NAG potential (all values are less than 0.01) and thus all the ash samples can be classified as non-acid generating; and
- Although no acid generation is predicted there is still a potential for certain elements to leach at high pH levels.

Distilled water tests were performed on two fresh ash slurry samples (ASS3 and ASS2), three ash samples from the existing ash dumps (AEDS1, AEDS2 and AEDS3) and one fly ash sample (FAS1), before being mixed with process water to produce slurry.

The tests on the existing ash dump samples and fly ash samples were to assess and compare the potential changes in material behaviour under normal neutral leaching conditions. The following conclusions have been reached from the results presented in Table 4-5:

- The two fresh samples submitted for testing according to NEM:WA guidelines showed the best leachate quality results with all parameters of concern below the SANS drinking water guideline values, with the exception of pH;
- Both samples showed leachable pH levels above 10 indicating, as mentioned in the mineralogical and ABA interpretations, a high buffering capacity;
- The fly ash and existing ash dump samples however showed leachable concentrations of B, Ba, Cr, Mo and TDS above the recommended limits for drinking water but within the limits of the LCT for waste classification;
- The higher leachability in these samples can be due to the fresh ash slurry samples (that has been mixed with water) allowing for a lower leachability of elements in the aqueous state; and
- The fly ash samples showed the highest concentration of metal leachate due to no water being mixed with the sample, allowing for a higher available total element concentration.

Synthetic Precipitation Leachate Procedures (SPLP) was performed on each sample type (results listed and compared against drinking water standards in Table 4-5) to evaluate a worst case scenario under slightly acidic conditions (pH 4.8). This provided input into the environmental impact assessments and contaminant transport modelling.

The following conclusions based on the results compared against SANS drinking water standards can be reached:

- The ash slurry sample produced the cleanest leachate with only an alkaline pH again being above recommended values;
- The ash dump and fly ash samples had leachable concentrations of B, Ba, Cr, Mo and TDS, above the recommended guideline values; and
- The cleaner results in both test types on the ash slurry indicate that the potential impact from the new ash dump will be much less than previous dumps.

Although drinking water standards were used for comparison. These values are not a true reflection of what will reach the receptors and the drinking water standards were only used as a reference value. The waste classification discussed below is the relevant classification to guide the liner requirements.

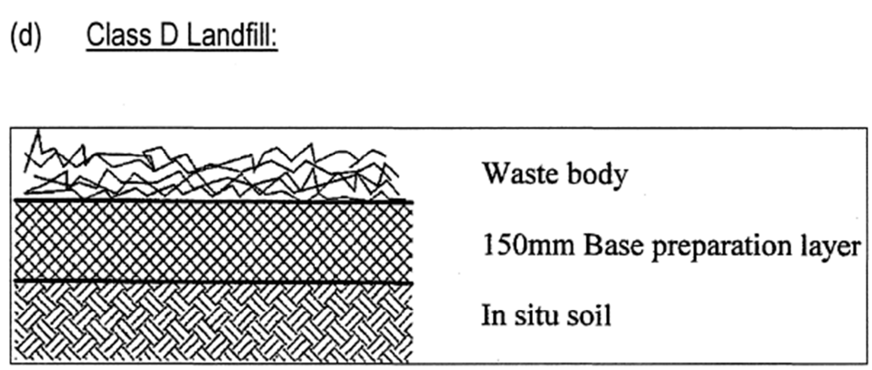
Waste Classification

Based on the leachate tests results for waste classification of the ash the following classification of the material according to the NEM: WA guidelines can be made:

- The material has a TC classification of TCT0 < TC ≤ TCT1;
- The material has a LC classification of LC ≤ LCT0; and
- The waste can be classified as a Type 3 waste with the waste disposal facility to be designed in accordance to the guidelines for a Class C landfill site shown in Figure 5-1.

However, following the above conclusions from the interpretation of the results based on the NEM: WA guidelines it should be noted that only the TC values renders this material a Type 3 waste that requires a Class C liner. The leachate (which is the pollution that will be released by the source) is well within the LCT0 guideline ranges.

If a risk based approach is implemented and only the LC values are used this material will be classed as a Type 4 waste which requires a Class D liner, or similar, as shown



below.

Liner requirements

Based on the above study taking into accounts both geochemical and hydrogeological conclusions from the groundwater study and the current groundwater resource state, DWE concluded the following on the need for the ash dumps to be lined based on a risk based approach followed:

- From the geochemical assessment and geohydrological models it has been shown that the potential contamination and environmental impacts from seepage from the ash dumps is a very low risk and not likely based on a conservative approach and simulations. All material was characterised and modelling considered conservative simulations; and
- DWE thus finds that the need for a Class C liner, as stipulated by the waste classification is not necessary as the potential impact for contamination from the dumps is very low and the probability or likelihood of a high volume of contaminants being released is also negligible. Thus, the recommendation based on a risk based approach is for the motivation for a Class D liner or similar design instead.

Recommendations

- Based on the outcome of the groundwater and geochemical investigations, In order to assess the groundwater level drop and potential impact on groundwater users due to ash dam construction and to assess groundwater deterioration (if any) due to the operation of the ash dam a monitoring programme is required.
- It is recommended that the groundwater monitoring be supplemented with the proposed new boreholes listed in the table below. The exact location of the new boreholes can be altered following a geophysical assessment (Plan 5).

BOREHOLE ID	COORDINATES	
	Latitude	Longitude
BH1A	-26.288147°	29.206993°
BH1B	-26.274230°	29.222923°
BH1C	-26.263444°	29.219698°
BH1D	-26.251490°	29.211249°
BH1E	-26.261808°	29.196200°
BH1F	-26.270432°	29.175587°
BH1G	-26.279813°	29.188151°

- Quarterly monitoring of groundwater quality and levels as per the monitoring program;
- Based on all data considered and a risk based approach implementing the source term-pathway-methodology, it is recommended that a Class D or similar is appropriate

for the ash dump as long as good management processes are in place with monitoring data acquired regularly; and

- Integrated water management plan needs to be designed to include storm water management.

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1 Introduction

1.1 Project Description

Digby Wells Environmental (Digby Wells) was tasked to perform a geochemical and waste classification assessment for the proposed Kriel power station dump extension project. Kriel Power Station is located approximately 6 km northeast of Matla Coal Mine in the Mpumalanga Province (Appendix A, Plan 1). The existing ash dam at the Kriel Power Station is reaching full capacity and Eskom therefore requires the construction of a new ash dam in order to continue operations. If required, and during ongoing construction of the new ash dam, Eskom plans to transfer ash to the neighbouring Matla Power Station and/or increase the height of the existing facility at Kriel Power Station.

The proposed site for the new ash dam is situated at an old mined-out area, opposite the old ash dam that is in operation; partially filled with ash and spoils material (Appendix A, Plan 1). Although the site selection process recommended this as the preferred site for ash disposal, detailed geotechnical studies will be conducted to quantify the extent of differential settlements. The findings will then be used to finalise the designs of the proposed ash dam extension.

In order to comply with pollution prevention measures, as per the Department of Water and Sanitation's (DWS) Best Practice Guidelines and Eskom's policy of zero harm to the environment, Eskom committed to obtain applicable water use authorisations for the following activities:

- The proposed ash facility;
- Ash transfer link;
- "Step-in and go higher" of the existing facilities; and
- Waste Classification of the ash material.

1.2 Study Objectives

The objectives of the geochemical study are as follow:

- Geochemically assess the existing ash dam material, as well as fresh ash material to assist with waste classification of the material;
- Waste classification and liner requirements.

1.3 Deliverables

The following deliverables form part of this study:

- Geochemistry assessment;
- Waste classification; and
- Technical report with recommendations.

1.4 Report Structure

The remainder of the report is structured as follows:

- Section 2: Methodology
- Section 3: Project Area Description
- Section 4: Geochemistry
- Section 5: Waste Classification
- Section 6: Conclusions
- Section 7: Recommendations

2 Methodology

2.1 Desktop Study

During this task, available documentation and information related to the project and surrounding areas was sourced from the client and the public domain. Most of the data used in this report is a combination of existing data from previous geohydrological studies (Aurecon, 2011) and data collected during the 2014 hydrocensus and geochemical sampling associated with this study. All data feeds into the impact assessment and groundwater reserve determination.

2.2 Geochemistry

Ten (10) samples of ash and spoil material were submitted for geochemical characterisation. The following characterisation tests were conducted:

- The Synthetic Precipitation Leachate Procedure (SPLP) and Distilled water leachate tests (DWLT) are done to simulate the heavy metal and anion leachate potential of the material and water left in-situ under normal conditions with only rain water allowing leaching to occur. These tests will simulate and evaluate the potential of any heavy metal or ion contamination from the ash and spoil material.
- The Acid Base Accounting (ABA) procedure measures the acid- and alkaline-producing potential of the undisturbed material in order to determine if, after disturbance, the ash material will produce acid and subsequently leach metals leading to contamination risks. This procedure includes Net Acid Generation (NAG) tests that evaluate the acid generation and neutralising potential of the material.
- The X-Ray Diffraction (XRD) tests allows for the measurement of the crystal structures within a sample to determine the mineralogical composition of the material. The XRD test is an X-ray method used to determine the elemental composition of a material.

2.2.1 Sample Distribution and Locations

During the site visit on 3 July 2014, ash dump sites 2 and 3 were visited, as well as the mixing plant where fly ash is received and then slurried for deposition onto the ash dumps.

The following sample distribution and locations were used:

- Two (2) dry fly ash samples from the conveyor line before being mixed with water, to represent the geochemistry of the ash before water can allow reactions to take place;
- Four (4) ash slurry samples from the ash stream after the fly ash have been mixed with water to produce the slurry, to represent the fresh material as it will be deposited onto the new facility; and

- Four (4) ash samples from 4 locations on the existing ash dump, to allow for an evaluation of the ash chemistry after leaching and reactions have taken place. The exact positions of these locations were chosen by the samplers based on the accessibility to the points listed in Table 2-1.

Table 2-1: Geochemical sample locations

Site ID	Latitude	Longitude
EADS1	-26.265471°	29.202271°
EADS2	-26.268865°	29.202039°
EADS3	-26.266287°	29.196309°
EADS4	-26.270421°	29.192601°

2.2.2 Sampling Methodology and Preservation

2.2.2.1 Fly Ash

The dry fly ash samples (1 kg in weight) were taken directly from the conveyor line and collected in plastic sampling bags (provided by Digby Wells). The bags were sealed with cable ties and labelled FAS1 and FAS2 with the date of sampling.

2.2.2.2 Ash Slurry

The ash slurry samples (2 litres per sample) were collected in glass bottles (provided by Digby Wells). The bottles were sealed and labelled ASS1, ASS2, ASS3 and ASS4 with the date of sampling.

2.2.2.3 Ash Dump Material

Samples were taken from the existing ash dump (Table 1) with a soil sampling auger (provided by Digby Wells) up to a depth of approximately 1 m below surface. The samples were collected in plastic sampling bags (provided by Digby Wells). The bags were sealed with cable ties and labelled EADS1, EADS2, EADS3 and EADS4 with the date of sampling.

2.2.2.4 Sample Preservation

All samples were sealed and labelled in the supplied containers/bags and stored in a cool dry place out of direct sunlight.

2.3 Reporting

A technical report summarising the laboratory results with a completed waste classification and recommendations on the liner requirements.

3 Project Area Description

3.1 Topography and Drainage

The Kriel Power Station has been constructed in an undulating area, on the crest of a southwest-northeast trending ridge. Springs in the vicinity of Kriel Power Station feed the seasonal Onverwacht, Pampoen and Vaal Pan Spruits (which drain to the east, north and west respectively). Ultimately, all surface water from this area drains into the Olifants River via the Riet (water draining north and west of the ridge) and Steenkool (water draining east) spruits (Aurecon 2011).

The topography of the area is variable due to the nature of mining activities and the subsequent rehabilitation that has taken place. The entire area to the east and south of the complex has been disturbed, either by mining and rehabilitation activities, or by the construction of existing dams. Where the pit has been rehabilitated, the topography is gently undulating, however, there are areas where the dragline tips still form steep cones of spoil. The western final cut void has been filled with ash from the power station and rehabilitated. The eastern final cut void is still open and is partially filled with water. The ground generally slopes towards the southwest.

Two cross sections across the proposed site and study area, one from north to south (Figure 3-1) and the other from east to west (Figure 3-2) show the topography of the area with ash dumps mostly located on the high points.

The proposed site for the new ash dump extension lies within the watersheds of the B11D quaternary catchment, forming part of the Olifants Water Management Area (WMA). The main drainage or stream of the area is the Dwars-in-die-weg spruit which drains into the Olifants River to the north (Appendix A, Plan 2). The topographical changes due to mining and ash dump activities have however developed open pit areas as discussed previously to the east of the proposed extension site. These pits are flooded and act as a drain to which most of the groundwater and surface water is currently flowing.

Figure 3-1: Topographical cross-section from north to south (Google Earth)

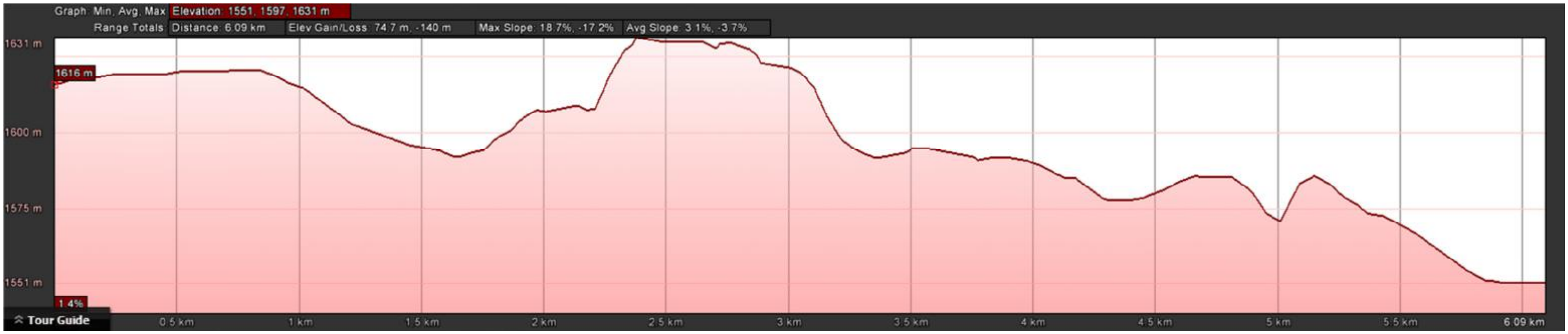


Figure 3-2: Topographical cross-section from east to west (Google Earth)

3.2 Climate, Rainfall and Groundwater recharge

The climate is typically Highveld conditions, with warm summers (12 to 29 degrees Celsius (°C)) and cold winters (-3 to 20 °C). Frost is usually experienced between May and August (Aurecon, 2011).

According to the *FAOClim 2.0* database the project area receives an average of 693 mm rain per annum (mm/a). The mean annual evapotranspiration for the area is 1 418 mm/a (Aurecon, 2011). This correlates well with the GRDM database giving MAP as 672 mm/a.

The estimated groundwater recharge of the area is 39.06 mm/a or 5.6% of the Mean Annual Precipitation (MAP). This is based on the available GRDM data.

3.3 Geology

According to the published 1:250 000 geological map (2628 East Rand), the area under investigation comprises the Ecca Group, and Dwyka and Vryheid Formations (Appendix A, Plan 3). The sediments of the Vryheid Formation overlie an uneven Dwyka floor, which is controlled by the topography of the pre-Karoo platform upon which the Karoo sediments were deposited. The Vryheid Formation, which is present throughout the Highveld Coal Field, attains 140 meters at the thickest point and contains a number of coal seams, of which four (No. 1, 2, 4 and 5 Seams) are considered to have economic potential (Aurecon, 2011).

The deposition of the Vryheid Formation sediments is largely controlled by the irregular pre-Karoo platform on which they were deposited. The pre-Karoo rocks, consisting mainly of felsites of the Bushveld Igneous Complex, have been glacially sculptured to give rise to uneven basement topography. The thin veneer sediments of the Dwyka Formation, which overlies the pre-Karoo, are generally not thick enough to ameliorate the irregularities in the placated surface, which therefore affected the deposition of the younger Vryheid Formation sediments.

The Ecca sediments consist predominantly of sandstone, siltstone, shale and coal. Combinations of these rock types are found in the form of inter-bedded siltstone, mudstone and coarse grained sandstone. Coarse-grained sandstone is a characteristic of the sediments in the Highveld Area. The overburden thickness and preservation of the coal seams is dependent on the surface geomorphology and the subsurface pre-Karoo basement floor (Aurecon, 2011).

Dolerite intrusions in the form of dykes and sills are present within the Ecca Group. The sills usually precede the dykes, with the latter being emplaced during a later period of tensional forces within the earth's crust. Tectonically, the Karoo sediments are practically undisturbed. Faults are rare. However, fractures are common in competent rocks such as sandstone and coal (Aurecon, 2011).

4 Geochemistry

The sole purpose of the geochemistry and waste classification tasks is to supplement and advise the geohydrological study and models. Throughout the study the recommended source term-pathway-receptor methodology was applied to allow a risk based approach. The geochemistry work characterises the sources and feeds into the decision on a proposed liner system.

The samples listed in Table 4-1 were collected as described in section 2.2.2 and submitted for the tests indicated.

Table 4-1: Sample ID's and laboratory tests

Sample ID	Material type	Tests done
ASS1	Ash - slurry	XRD, XRF, ABA, NAG and Distilled water leachate test
ASS2	Ash - slurry	XRD, XRF, ABA, NAG and Distilled water leachate test
ASS3	Ash - slurry	XRD, XRF, ABA, NAG and Distilled water leachate test
ASS4	Ash - slurry	XRD, XRF, ABA, NAG and SPLP test
AEDS1	Ash - Dry ash slurry sample from ash dump	XRD, XRF, ABA, NAG and Distilled water leachate test
AEDS2	Ash - Dry ash slurry sample from ash dump	XRD, XRF, ABA, NAG and Distilled water leachate test
AEDS3	Ash - Dry ash slurry sample from ash dump	XRD, XRF, ABA, NAG and Distilled water leachate test
AEDS4	Ash - Dry ash slurry sample from ash dump	XRD, XRF, ABA, NAG and SPLP test
FAS1	Fly ash	XRD, XRF, ABA, NAG and Distilled water leachate test
FAS2	Fly ash	XRD, XRF, ABA, NAG and SPLP test

The current National Environmental Management: Waste Act, 2008 (Act No. 59 of 2008) (NEM:WA) guidelines proposes distilled water (DW)/ reagent water leachate tests according to the Australian Standard Leachate Procedures (ASLP) for waste classification of material to be mono-disposed. As the ash dumps will only receive ash the distilled water tests were performed for the waste classification purposes. To assess a worst case scenario as per standard practice in environmental management projects the SPLP tests were also performed on each sample to allow an evaluation of the bio-available elements that can potentially leach into solution under slightly acidic or acid rain conditions.

Sections 4.1 to 4.5 describe and evaluates the ash dump and fresh ash material, to feed into the environmental impact assessment. The DW test results will also be used in Section 5for the waste classification of the ash material. Only organic parameters were analysed for in the leachate procedures on ASS4. This was done to evaluate whether any organics do exist and to save costs on duplicating tests.

4.1 XRF Results

The XRF results summarised in Table 4-2 and Table 4-3 indicate the oxide and trace element distributions for the various samples.

The standard deviation across all samples, for the various oxide distributions is never more than 2.2%. This indicates that possible dissolution and removal of some elements from the reactions with the slurry water and natural leaching of elements on the existing dumps are not a major factor and doesn't affect the mineralogical nature of the ash material. The high SiO_2 content (which is mostly in the form of amorphous material formed due to the high temperatures during burning) lowers the solubility of the material with the low hydraulic conductivity of ash material also aiding in not allowing any elements that does dissolve to leave the system.

The major oxides present in the ash material are SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO. The sulphur content is low with a high lime content (CaO) indicating a low potential for acid generation with a high buffering capacity. On ignition of the test there was a low loss of material as the ash already went through a high temperature procedure with a low moisture content.

The trace element distribution was compared to average crustal values and in most cases is higher than normal. This is however no indication of any potential impacts or leachability. All heavy metals expected in the amorphous ash in small quantities are present with As, B, Ba, Al and Mn mostly prone to dissolve and be removed from the solid system.

Table 4-2: XRF results summary

Major Elements	Major Element Concentration (wt %)[s]											
	ASS 3	ASS 2	ASS 1	AEDS 1	AEDS 2	AEDS 3	AEDS 4	FAS 1	FAS 2	Min	Max	St Dev
SiO_2	49.28	48.99	51.81	47.95	50.34	47.48	48.16	51.38	50.53	**47.48**	**51.81**	**1.5**
TiO_2	1.51	1.5	1.52	1.68	1.6	1.61	1.61	1.73	1.7	**1.5**	**1.73**	**0.1**
Al_2O_3	27.97	28.39	28.58	30.34	29.99	30.54	29.3	30.82	30.66	**27.97**	**30.82**	**1.0**
Fe_2O_3	4.06	3.66	3.92	2.49	2.34	2.43	2.67	2.85	2.65	**2.34**	**4.06**	**0.6**
MnO	0.04	0.04	0.05	0.03	0.03	0.03	0.04	0.03	0.03	**0.03**	**0.05**	**0.0**
MgO	1.27	1.24	1.34	1.4	1.3	1.44	1.35	0.94	0.89	**0.89**	**1.44**	**0.2**
CaO	9.47	9.06	9.57	6.82	6.16	6.99	7.69	7.09	6.82	**6.16**	**9.57**	**1.2**
Na_2O	0.07	0.05	0.03	0.21	0.18	0.34	0.19	0.12	0.15	**0.03**	**0.34**	**0.1**
K_2O	0.72	0.73	0.72	0.86	0.87	0.81	0.93	0.68	0.66	**0.66**	**0.93**	**0.1**
P_2O_5	0.4	0.39	0.43	0.72	0.59	0.69	0.64	0.56	0.54	**0.39**	**0.72**	**0.1**
Cr_2O_3	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02	**0.02**	**0.04**	**0.0**
SO_3	0.85	0.77	0.6	0.6	0.82	0.83	0.99	0.83	0.83	**0.6**	**0.99**	**0.1**
LOI	2.28	2.52	2.04	7.26	6.11	5.11	6.32	1.7	1.17	**1.17**	**7.26**	**2.2**
H_2O	0.49	0.53	0.31	1.07	2.07	0.76	1.64	0.1	0.16	**0.1**	**2.07**	**0.6**

Table 4-3: Trace elements compared to crustal averages

Trace Elements	Upper continental crust	Trace Element Concentration (ppm) [s]								
		ASS 3	ASS 2	ASS 1	AEDS 1	AEDS 2	AEDS 3	AEDS 4	FAS 1	FAS 2
As	**1.5**	1.55	4.33	2.47	15.2	16.3	16.4	15.9	11.3	11.7
Ba	**550**	814	798	745	954	932	966	1021	710	729
Bi	**1.27**	1.3	1.43	0.9	1.56	1.68	1.84	1.36	1.23	1.4
Cd	**98**	4.42	5.03	4.78	4.94	3.55	6.85	5.87	4.98	4.62
Ce	**64**	187	127	73.9	108	129	101	101	131	117
Co	**17**	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.5	<0.5
Cs	**4.8**	2.18	3.8	3.85	4.69	1.85	4.21	7.78	3.2	3.55
Cu	**25**	44.8	44	38.2	59.4	58.9	62	57.7	52.6	54
Ga	**17**	24.5	24	21.4	45.6	39.8	40.4	40.1	35.3	36
Ge	**1.6**	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.5	<0.5
Hf	**5.8**	7.37	11.1	3.37	1.92	1.71	6.39	2.95	2.36	6.46
Hg	**9**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.0	<1.0
La	**30**	23.1	61.1	42.9	34	44.8	39.9	37.6	62	33.4
Lu	**0.32**	2.58	2.47	2.37	2.17	2.15	2.25	2.22	2.29	2.27
Mo	**1.5**	2.35	2.31	2.35	2.28	2.23	2.3	2.27	2.26	2.25
Nb	**12.5**	32.9	36.4	31.5	41.3	39.2	40.2	40.8	37.8	37.3
Nd	**26**	<2.39	<2.39	<2.39	35.6	44	58	46.4	<2.3	<2.3
Ni	**50**	39.1	34.8	34.2	51	45.5	53.2	39.4	54.2	46.2
Pb	**16**	<2.03	<2.03	<2.03	100	101	111	91	68.6	71.4
Rb	**112**	32.7	35.7	29.9	55.5	53	50.8	57.7	38.4	39.1
Sb	**0.2**	4.63	<1.48	<1.48	4.4	4.64	2.66	<1.48	<1.48	2.79
Sc	**13**	35	43.2	38.3	33.5	31.4	33.3	35.8	31.2	34
Se	**50**	3.02	2.24	2.87	8.99	7.36	8.58	6.86	5.51	6.07
Sm	**4.5**	14.5	14.9	14.1	3.37	7.26	4.38	6.11	8.18	10.5

Trace Elements	Upper continental crust	Trace Element Concentration (ppm) [s]								
		ASS 3	ASS 2	ASS 1	AEDS 1	AEDS 2	AEDS 3	AEDS 4	FAS 1	FAS 2
Sn	**5.5**	18.5	14.5	12.5	18.5	18.4	17.5	19.5	15.5	14.5
Sr	**350**	1908	1893	1723	2569	1928	2388	2340	1595	1607
Ta	**1.1**	1.21	1.54	1.82	1.43	1.35	1.61	1.62	2.19	1.76
Th	**10.7**	25.6	24.7	25.6	33.3	29	30.3	32.3	32.3	30.9
Tl	**0.75**	0.71	0.65	0.37	1.06	0.78	0.95	1.25	0.87	0.84
U	**2.8**	14.9	13.6	13.2	23.1	15.3	20.3	18.2	13.8	13.9
V	**110**	<7.60	<7.60	<7.60	<7.60	<7.60	<7.60	<7.60	<7.6	<7.6
W	**2**	1.33	1.32	1.26	1.18	1.16	1.16	1.3	1.13	1.22
Y	**22**	67.3	68.2	61.5	80.6	74.4	76.4	79.5	70.3	71.2
Yb	**2.2**	10.1	10.1	7.34	5.81	4.84	6.8	7.28	3.77	8.88
Zn	**71**	32	30.8	30.9	55.3	52.3	50.8	47.5	46.6	43.5
Zr	**190**	479	483	444	535	478	518	521	473	479

4.2 XRD Results

The XRD results summarised in Table 4-4 shows that minerals formed through the combination of the trace elements and oxides discussed in section 4.1. The high silica content was distributed mainly between the amorphous (glass) and quartz minerals. The high iron content observed in the XRF results was distributed between hematite, magnetite and pyrite, with mullite and lime completing the mineral content distribution.

The process in which the ash is produced at high temperatures lead to high aluminium silicate content with iron and calcium based minerals left. The pyrite content can potentially lead to acid formation. However, a high calcite and lime content with high buffering capacity and the low reactivity of silica will counter any acid production with neutralising reactions.

The following are the ideal chemical formulas for each mineral:

Quartz: SiO_2

Plagioclase: $(Na, Ca)Al_2Si_3O_8$

Lime: CaO

Magnetite: Fe_{34}

Pyrite: $Fe S_2$

Calcite: $CaCO_3$

Mullite: $Al_{4.5}Si_{1.5}O_{9.75}$

Hematite: Fe_2O_3

Table 4-4: XRD results summary

Mineral	Mineral weight %								
	ASS3	**ASS2**	**ASS1**	**AEDS1**	**AEDS2**	**AEDS3**	**AEDS4**	**FAS1**	**FAS2**
Amorphous	39.33	34.54	39.75	36.51	38.06	35.57	37.9	37.14	39.86
Calcite	0.99	1.5	2.53	5.94	2.45	4.3	3.95	0.63	0
Hematite	2.02	2.05	1.6	0.14	0.42	0.38	0.45	0.92	0.92
Magnetite	3.77	3.79	3.1	2.87	2.55	2.59	2.62	3.55	3.48
Mullite	19.97	22.47	19.05	35.48	34.49	36.13	32.64	34.05	35.4
Plagioclase	18.08	18.2	19.29	2.7	1.45	3.79	3.17	1.78	0
Pyrite	0.25	0.41	0.47	0.32	0.76	0.6	0.57	0.54	0.41
Quartz	15.6	17.03	14.22	16.04	19.83	16.65	18.7	19.22	17.97
Lime	-	-	-	-	-	-	-	2.18	1.96
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

4.3 ABA and NAG Results

The Acid Base Accounting (ABA) and Net Acid Generation (NAG) tests performed on the ash samples allow for an evaluation of any potential for acid generation from the material analysed. The ABA and NAG results given in Appendix B can be summarised as follows:

- All samples have a paste pH of above 11 which is well above the acid producing margin of pH 5. This shows that the material is highly alkaline with a buffering potential. The high pH can however lead to dissolution and higher aqueous activity of metals like Al and B;
- The total sulphur concentrations in all samples are below the recommended 0.3%. Above the 0.3% value material will have an acid generating potential;
- The Neutralising Potential Ratio (AP:NP) is well above 4:1 indicating that the nett neutralising capacity of the material is much higher than any potential for acid production;
- Along with the high NPR, all samples show no NAG potential (all values are lower than 0.01) and thus all the ash samples can be classified as non-acid generating; and
- Although no acid generation is predicted there is still a potential for certain elements to leach at high pH levels.

4.4 Distilled Water Leachate Tests

Distilled water tests were performed on two fresh ash slurry samples (ASS3 and ASS2), three ash samples from the existing ash dumps (AEDS1, AEDS2 and AEDS3) and one fly ash sample (FAS1) before being mixed with process water to produce slurry.

The tests on the existing ash dump and fly ash samples were to assess and compare the potential changes in material behaviour under normal, neutral leaching conditions. The following conclusions have been reached from the results presented in Table 4-5:

- The two fresh samples submitted for testing according to NEM:WA guidelines showed the best leachate quality results with all parameters of concern below the SANS drinking water guideline values with the exception of pH;
- Both samples showed leachable pH levels above 10 indicating (as mentioned in the mineralogical and ABA interpretations) a high buffering capacity;
- The fly ash and existing ash dump samples however showed leachable concentrations of B, Ba, Cr, Mo and TDS; above the recommended limits for drinking water;
- The higher leachability in these samples can be due to the fresh ash slurry samples (that has been mixed with water) allowing for a lower leachability of elements in the aqueous state; and
- The fly ash samples showed the highest concentration of metal leach due to no water being mixed with the sample allowing for a higher available total element concentration.

4.5 SPLP Tests

Synthetic Precipitation Leachate Procedures (SPLP) were performed on each sample (results listed and compared against drinking water standards in Table 4-5) to evaluate a worst case scenario under slightly acidic conditions (pH 4.8); to provide input into the environmental impact assessments and contaminant transport modelling.

The following conclusions, for results compared against SANS drinking water standards can be reached:

- The ash slurry sample produced the best quality leachate, with only an alkaline pH being above recommended values;
- The ash dump and fly ash samples had leachable concentrations of B, Ba, Cr, Mo and TDS; above the recommended guidelines; and
- The better quality results in both ash slurry tests indicate that the potential impact from the new ash dump will be much less than previous dumps.

Although drinking water standards were used for comparison in this section of the report. These values are not a true reflection of what will reach the receptors and the drinking water standards were only used as a reference value. The waste classification discussed below is the relevant classification to guide the liner requirements. The drinking water standards are more stringent than the LCT values.

Table 4-5: Distilled water and SPLP leachate results

Sample ID	SANS 241:2011 Drinking water guidelines	ASS3	ASS2	AEDS1	AEDS2	AEDS3	FAS1	ASS1	AEDS4	FAS2
Test method		**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**SPLP**	**SPLP**	**SPLP**
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
As, Arsenic	**0.01**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
B, Boron	**0.5**	0.167	0.104	1.27	0.801	0.997	0.848	0.232	0.518	0.868
Ba, Barium	**0.7**	0.174	0.195	<0.025	0.028	0.033	2.18	0.126	0.048	2.05
Cd, Cadmium	**0.003**	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Co, Cobalt	**0.5**	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Cr_{Total}, Chromium Total	**0.05**	<0.025	0.036	0.142	0.220	0.141	0.238	<0.025	0.240	0.138
Cu, Copper	**2**	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Hg, Mercury	**0.006**	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mn, Manganese	**0.5**	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Mo, Molybdenum	**0.07**	<0.025	<0.025	0.052	0.107	0.027	0.107	<0.025	0.026	0.106
Ni, Nickel	**0.07**	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Pb, Lead	**0.01**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sb, Antimony	**0.02**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Se, Selenium	**0.01**	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
V, Vanadium	**0.2**	<0.025	<0.025	0.136	0.075	0.070	<0.025	<0.025	0.037	<0.025
Zn, Zinc	**5**	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Total Dissolved Solids*	**1200**	222	192	152	150	170	1650	178	192	1692
Chloride as Cl	**300**	<5	<5	<5	<5	<5	<5	<5	<5	<5
Sulphate as SO_4	**500**	63	50	61	69	74	143	81	72	98
Nitrate as N	**11**	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2

Sample ID	SANS 241:2011 Drinking water guidelines	ASS3	ASS2	AEDS1	AEDS2	AEDS3	FAS1	ASS1	AEDS4	FAS2
Test method		Distilled Water	Distilled Water	Distilled Water	Distilled Water	Distilled Water	Distilled Water	SPLP	SPLP	SPLP
Units	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Fluoride as F	**1.5**	<0.2	<0.2	<0.2	<0.2	<0.2	0.8	<0.2	<0.2	0.9
Total Cyanide as CN	**0.07**	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
pH	**5 -9.7**	11.2	11.4	10.6	10.8	10.9	12.2	10.8	11.0	12.3

5 Waste Classification

5.1 Legislative Guidelines

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

- NEM:WA National Waste Information Regulations, 2012 (DEA 2012);
- NEM:WA National Norms and Standards for the Assessment of Waste for Landfill Disposal (DEA 2013a);
- NEM:WA National Norms and Standards for the Disposal of Waste to Landfill (DEA 2013b); and
- NEM:WA National Waste Classification and Management Regulations (DEA 2013c).

5.2 Data Evaluation and Comparisons

The distilled water tests performed on samples ASS1, ASS2, ASS3 and ASS4 (all samples taken from the ash slurry that will be dumped on the new dump site); in accordance with the classification guidelines for mono-disposal sites, were classed against the various thresholds for total concentrations (TC) and leachable concentrations (LC). ASS4's fluid phase was submitted for organic analysis to confirm that no organic material is present. TC analysis was done on all samples, with distilled/reagent water tests done for LC analysis only on ASS3 and ASS2 with ASS submitted for SPLP analysis as discussed in section 4.5.

5.2.1 Total Concentration Threshold

The following classification, also shown in Table 5-1 was made based on the total concentrations threshold (TCT) classes for ASS1, ASS2 and ASS3:

- Barium (Ba), selenium (Se) and fluoride (F) exceed the TCT0 guideline values and fall within the limits of TCT1; and
- All other elements are below the TCT0 guideline values.

Table 5-1: Total Concentration Threshold (TCT)

Sample ID	NEM:WA Total Concentration Thresholds					
	TCT0	TCT1	TCT2	ASS3	ASS2	ASS1
Units	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
As, Arsenic	**5.8**	**500**	**2000**	<4.00	<4.00	<4.00
B, Boron	**150**	**15000**	**60000**	32.4	32	34.4
Ba, Barium	**62.5**	**6250**	**25000**	656	684	708
Cd, Cadmium	**7.5**	**260**	**1040**	3.6	3.6	3.6
Co, Cobalt	**50**	**5000**	**20000**	<10	<10	<10
Cr_{Total}, Chromium Total [s]	**46000**	**800000**	**N/A**	60.8	47.2	54.4
Cu, Copper	**16**	**19500**	**78000**	<10	<10	<10
Hg, Mercury	**0.93**	**160**	**640**	<0.4	<0.4	<0.4
Mn, Manganese	**1000**	**25000**	**100000**	305.2	320	335.6
Mo, Molybdenum	**40**	**1000**	**4000**	<10	<10	<10
Ni, Nickel	**91**	**10600**	**42400**	25.6	24.8	27.2
Pb, Lead	**20**	**1900**	**7600**	<8.00	<8.00	<8.00
Sb, Antimony	**10**	**75**	**300**	<4.00	<4.00	4.8
Se, Selenium	**10**	**50**	**200**	10.4	20	8.8
V, Vanadium	**150**	**2680**	**10720**	<10	<10	<10
Zn, Zinc	**240**	**160000**	**640000**	<10	<10	<10
Total Fluoride [s] mg/kg	**100**	**10000**	**40000**	185	253	263
Total Cyanide as CN mg/kg	**14**	**10500**	**42000**	<0.01	<0.01	<0.01

5.2.2 Leachable Concentration Threshold

The following classification also shown in Table 5-2 was made based on the leachable concentrations threshold (LCT) classes in ASS3 and ASS2:

- All samples fall within the limits of LCT0.

Table 5-2: Leachable Concentration Threshold (LCT)

	NEM:WA Leachable Concentration Thresholds				Distilled water test samples	
Parameters	**LCT0**	**LCT1**	**LCT2**	**LCT3**	**ASS3**	**ASS2**
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
As, Arsenic	**0.01**	**0.5**	**1**	**4**	<0.010	<0.010
B, Boron	**0.5**	**25**	**50**	**200**	0.167	0.104
Ba, Barium	**0.7**	**35**	**70**	**280**	0.174	0.195
Cd, Cadmium	**0.003**	**0.15**	**0.3**	**1.2**	<0.003	<0.003
Co, Cobalt	**0.5**	**25**	**50**	**200**	<0.025	<0.025
Cr_{Total}, Chromium Total	**0.1**	**5**	**10**	**40**	<0.025	0.036
Cr(VI), Chromium (VI)	**0.05**	**2.5**	**5**	**20**	<0.010	0.029
Cu, Copper	**2**	**100**	**200**	**800**	<0.025	<0.025

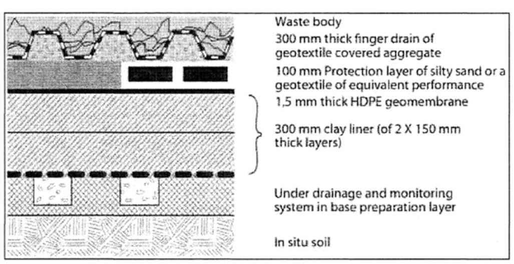
	NEM:WA Leachable Concentration Thresholds				Distilled water test samples	
Parameters	**LCT0**	**LCT1**	**LCT2**	**LCT3**	**ASS3**	**ASS2**
Units	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Hg, Mercury	**0.006**	**0.3**	**0.6**	**2.4**	<0.001	<0.001
Mn, Manganese	**0.5**	**25**	**50**	**200**	<0.025	<0.025
Mo, Molybdenum	**0.07**	**3.5**	**7**	**28**	<0.025	<0.025
Ni, Nickel	**0.07**	**3.5**	**7**	**28**	<0.025	<0.025
Pb, Lead	**0.01**	**0.5**	**1**	**4**	<0.010	<0.010
Sb, Antimony	**0.02**	**1**	**2**	**8**	<0.010	<0.010
Se, Selenium	**0.01**	**0.5**	**1**	**4**	<0.010	<0.010
V, Vanadium	**0.2**	**10**	**20**	**80**	<0.025	<0.025
Zn, Zinc	**5**	**250**	**500**	**2000**	<0.025	<0.025
Total Dissolved Solids*	**1000**	**12500**	**25000**	**100000**	222	192
Chloride as Cl	**300**	**15000**	**30000**	**120000**	<5	<5
Sulphate as SO_4	**250**	**12500**	**25000**	**100000**	63	50
Nitrate as N	**11**	**550**	**1100**	**4400**	<0.2	<0.2
Fluoride as F	**1.5**	**75**	**150**	**600**	<0.2	<0.2
Total Cyanide as CN	**0.07**	**3.5**	**7**	**28**	<0.05	<0.05

5.3 Classification

Based on the leachate tests the following classification of the material (according to the NEM: WA guidelines) can be made:

- The material has a TC classification of TCT0 < TC ≤ TCT1;
- The material has a LC classification of LC ≤ LCT0; and
- The waste can be classified as a Type 3 waste, with the waste disposal facility to be designed in accordance to the guidelines for a Class C landfill site shown in Figure 5-1.

Figure 5-1: Type C landfill design



However, following the above conclusions from the interpretation of the results based on the NEM: WA guidelines it should be noted that only the TC values renders this material a Type

3 waste that requires a Class C liner. The leachate (which is the pollution that will be released by the source) is well within the LCT0 guideline ranges.

If a risk based approach is implemented and only the LC values are used this material will be classed as a Type 4 waste which requires a Class D liner, or similar, as shown below in Figure 5-2.

(d) Class D Landfill:

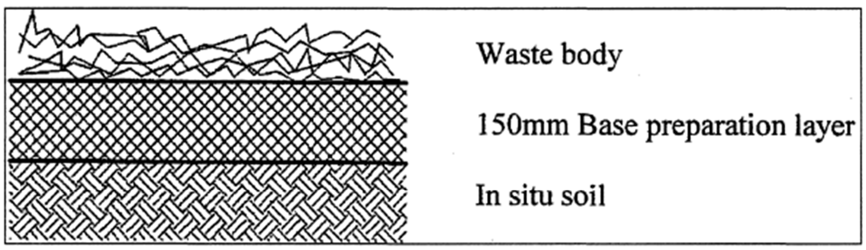


Figure 5-2: Type D liner design

6 Conclusions

6.1 Geochemistry

The ABA and NAG tests performed on the ash samples allowed for an evaluation of any potential for acid generation from the material analysed. The test ABA and NAG results (given in Appendix B) can be summarised as follows:

- All samples have a paste pH of above 11 which is well above the acid producing margin of pH 5. This shows that the material is highly alkaline with a buffering potential. The high pH can however lead to dissolution and higher aqueous activity of metals like Al and B;
- The total sulphur concentrations in all samples are below the recommended 0.3%;
- The Neutralising Potential Ratio (AP:NP) is well above 4:1 indicating that the nett neutralising capacity of the material is much higher than any potential for acid production;
- Along with the high NPR, all samples show no NAG potential (all values are less than 0.01) and thus all the ash samples can be classified as non-acid generating; and
- Although no acid generation is predicted there is still a potential for certain elements to leach at high pH levels.

Distilled water tests were performed on two fresh ash slurry samples (ASS3 and ASS2), three ash samples from the existing ash dumps (AEDS1, AEDS2 and AEDS3) and one fly ash sample (FAS1), before being mixed with process water to produce slurry.

The tests on the existing ash dump samples and fly ash samples were to assess and compare the potential changes in material behaviour under normal neutral leaching conditions. The following conclusions have been reached from the results presented in Table 4-5:

- The two fresh samples submitted for testing according to NEM:WA guidelines showed the best leachate quality results with all parameters of concern below the SANS drinking water guideline values, with the exception of pH;
- Both samples showed leachable pH levels above 10 indicating, as mentioned in the mineralogical and ABA interpretations, a high buffering capacity;
- The fly ash and existing ash dump samples however showed leachable concentrations of B, Ba, Cr, Mo and TDS above the recommended limits for drinking water;
- The higher leachability in these samples can be due to the fresh ash slurry samples (that has been mixed with water) allowing for a lower leachability of elements in the aqueous state; and

- The fly ash samples showed the highest concentration of metal leachate due to no water being mixed with the sample, allowing for a higher available total element concentration.

Synthetic Precipitation Leachate Procedures (SPLP) were performed on each sample type (results listed and compared against drinking water standards in Table 4-5) to evaluate a worst case scenario under slightly acidic conditions (pH 4.8). This provided input into the environmental impact assessments and contaminant transport modelling.

The following conclusions based on the results compared against SANS drinking water standards can be reached:

- The ash slurry sample produced the cleanest leachate with only an alkaline pH again being above recommended values;
- The ash dump and fly ash samples had leachable concentrations of B, Ba, Cr, Mo and TDS, above the recommended guideline values; and
- The cleaner results in both test types on the ash slurry indicate that the potential impact from the new ash dump will be much less than previous dumps.

6.2 Waste Classification

Based on the leachate tests results for waste classification of the ash the following classification of the material according to the NEM: WA guidelines can be made:

- The waste can be classified as a Type 3 waste, with the waste disposal facility to be designed in accordance to the guidelines for a Class C landfill site shown in Figure 5-1.
- However, following the above conclusions from the interpretation of the results based on the NEM: WA guidelines it should be noted that only the TC values renders this material a Type 3 waste that requires a Class C liner. The leachate (which is the pollution that will be released by the source) is well within the LCT0 guideline ranges.
- If a risk based approach is implemented and only the LC values are used this material will be classed as a Type 4 waste which requires a Class D liner, or similar as shown in Figure 5-2.

6.3 Liner requirements:

Based on the above study taking into account both geochemical and hydrogeological conclusions and the current groundwater resource state DWE concluded the following on the need for the ash dumps to be lined:

- From the geochemical assessment and geohydrological models it has been shown that the potential contamination and environmental impacts from seepage from the ash dumps is a very low risk and not likely based on a conservative approach and simulations. All material was characterised and modelling considered conservative simulations; and

- DWE thus finds that the need for a Class C liner, as stipulated by the waste classification is not necessary as the potential impact for contamination from the dumps is very low and the probability or likelihood of a high volume of contaminants being released is also negligible. Thus, the recommendation based on a risk based approach is for the motivation for a Class D liner or similar design instead.

7 Recommendations

Based on the outcome of the groundwater and geochemical investigations, In order to assess the groundwater level drop and potential impact on groundwater users due to ash dam construction and to assess groundwater deterioration (if any) due to the operation of the ash dam a monitoring programme is required.

- It is recommended that the groundwater monitoring be supplemented with the proposed new boreholes listed in. The exact location of the new boreholes can be altered following a geophysical assessment (plan 5).

Table 7-1: Recommended monitoring boreholes

BOREHOLE ID	COORDINATES	
	Latitude	Longitude
BH1A	-26.288147°	29.206993°
BH1B	-26.274230°	29.222923°
BH1C	-26.263444°	29.219698°
BH1D	-26.251490°	29.211249°
BH1E	-26.261808°	29.196200°
BH1F	-26.270432°	29.175587°
BH1G	-26.279813°	29.188151°

- Quarterly monitoring of groundwater quality and levels as per the monitoring program;
- Based on all data considered and a risk based approach implementing the source term-pathway-methodology, it is recommended that a Class D or similar is appropriate

for the ash dump as long as good management processes are in place with monitoring data acquired regularly; and

- Integrated water management plan needs to be designed to include storm water management.

8 References

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Hodgson F.D.I, Krantz R.M, 1995, Investigation into Groundwater Quality Deterioration in the Olifants River Catchment Above the Loskop Dam with Specialised Investigation in the Witbank Dam Sub-Catchment, Bloemfontein.

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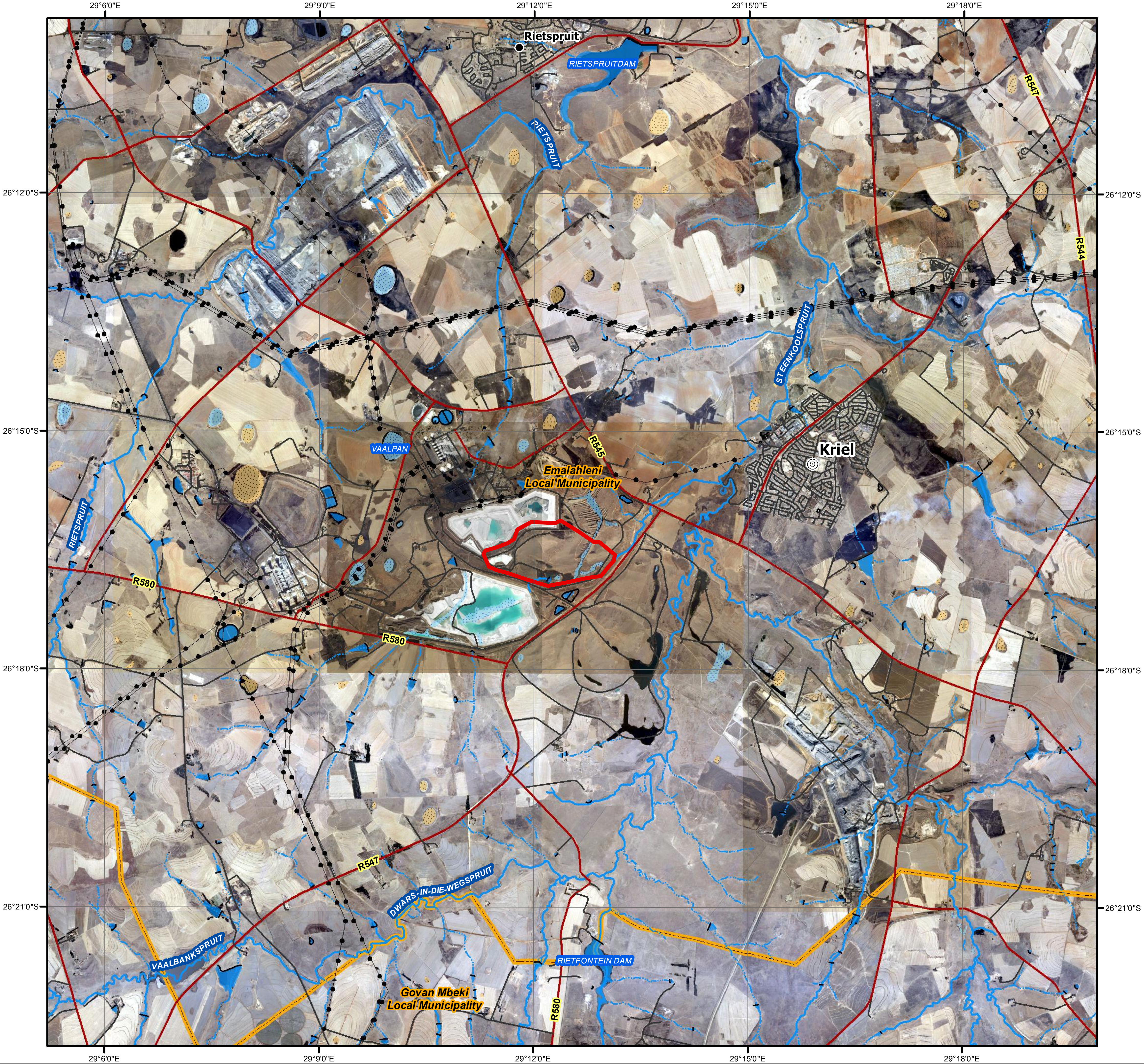
Appendix A: Plans

Plan 1

Kriel Power Station IWULA

Local Setting



Legend

- Project Area
- Secondary Town
- Settlement
- Power Line
- Main Road
- Minor Road
- Dam Wall
- Non-Perennial Stream
- Perennial Stream
- Dam / Lake
- Non-Perennial Pan
- Perennial Pan
- Local Municipal Boundary

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Date: 31/10/2014

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1:90 000

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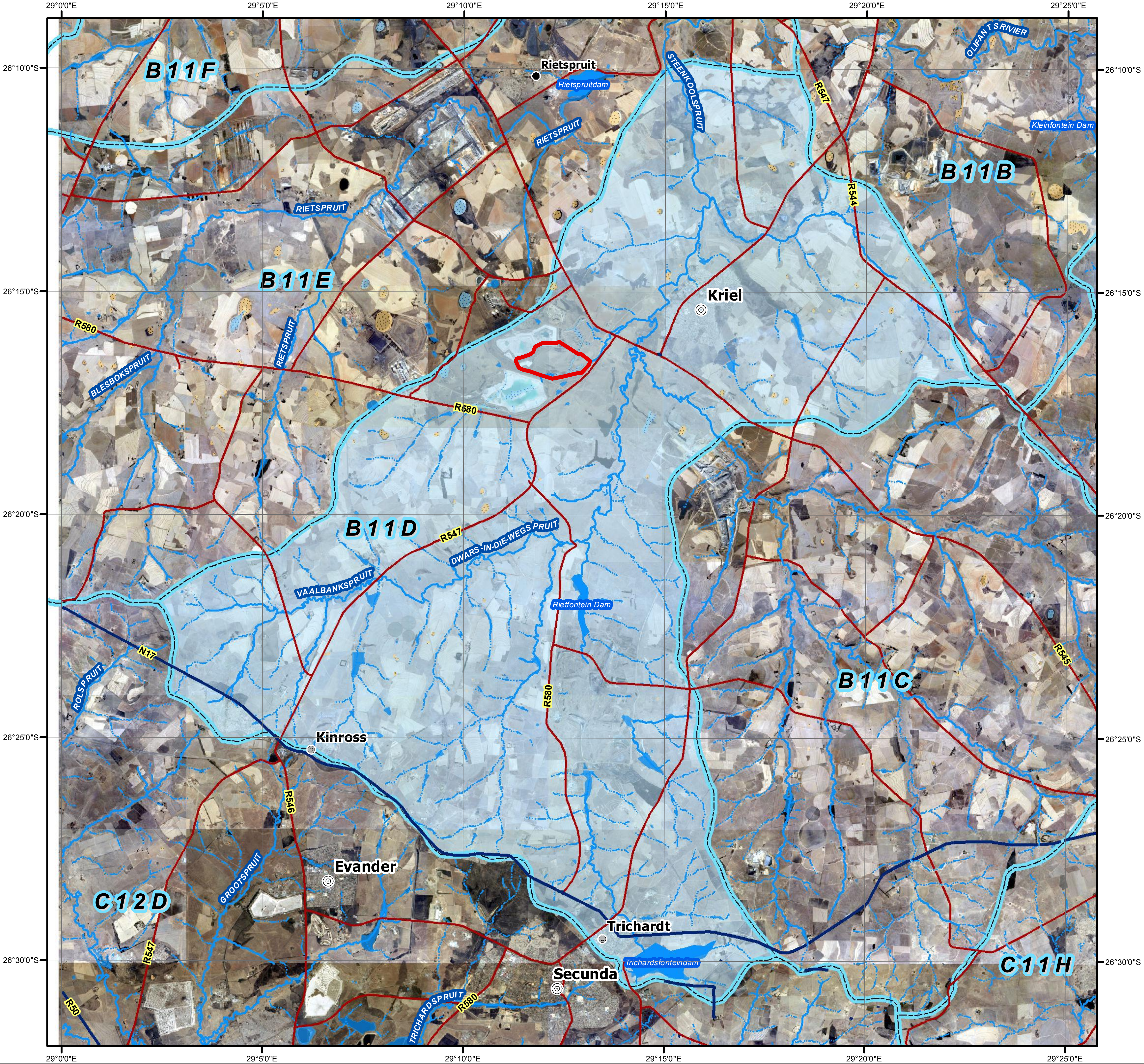

Plan 2

Kriel Power Station IWULA

Quaternary Catchment

Legend

- Project Area
- Secondary Town
- Other Town
- Settlement
- Arterial/ National Route
- Main Road
- Non-Perennial Stream
- Perennial Stream
- Dam / Lake
- Non-Perennial Pan
- Perennial Pan
- Affected Quaternary Catchment
- Quaternary Catchments

DIGBY WELLS ENVIRONMENTAL

• Sustainability • Service • Positive Change • Professionalism • Future Focused • Integrity

Projection: Transverse Mercator
Datum: Cape
Central Meridian: 29°E

Ref #: mpl.ESK2840.201409.114
Revision Number: 1
Date: 25/09/2014

N

0 2 4 8
Kilometres
1:160 000

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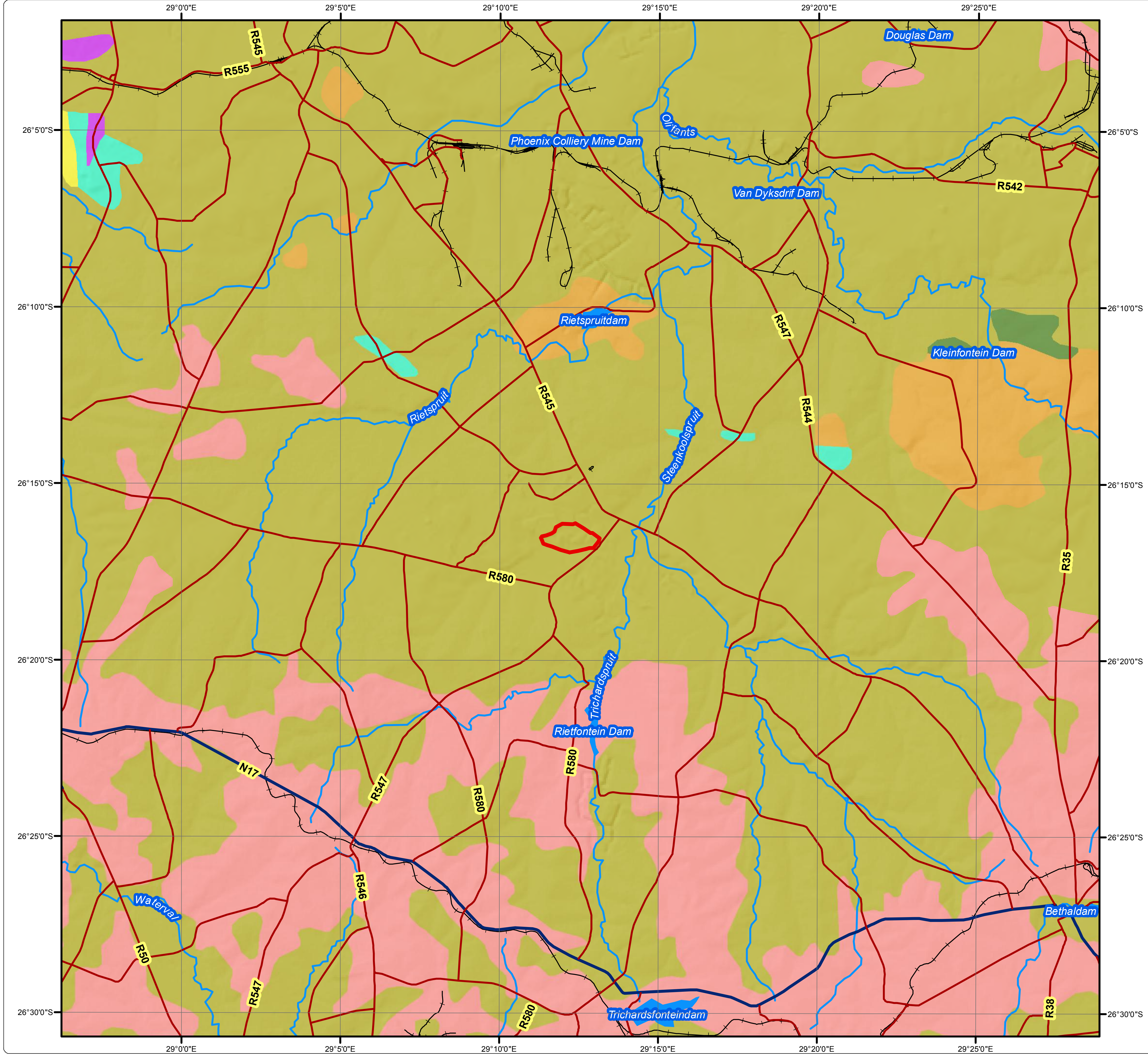

Plan 3

Kriel Power Station IWULA

Regional Geology

Legend

- Project Area
- Main Road
- Arterial / National Route
- Railway Line
- Perennial Stream
- Dam/ Lake

Regional Geology

- Dwarsfontein Cplx
- Karoo Dolerite Sui
- Lebowa Granite Sui, Bushveld Cplx
- Loskop Fm, Transvaal Spgrp
- Madzaringwe Fm, Karoo Spgrp
- Rooiberg Grp, Transvaal Spgrp
- Vaalian Erathem

DIGBY WELLS ENVIRONMENTAL

• Sustainability • Service • Positive Change • Professionalism • Future Focused • Integrity

Projection: Transverse Mercator
Datum: Cape
Central Meridian: 29°E

Ref #: mpl.ESK2840.201412.049
Revision Number: 1
Date: 31/10/2014

N

0 2.5 5 10

Kilometres

1:200 000

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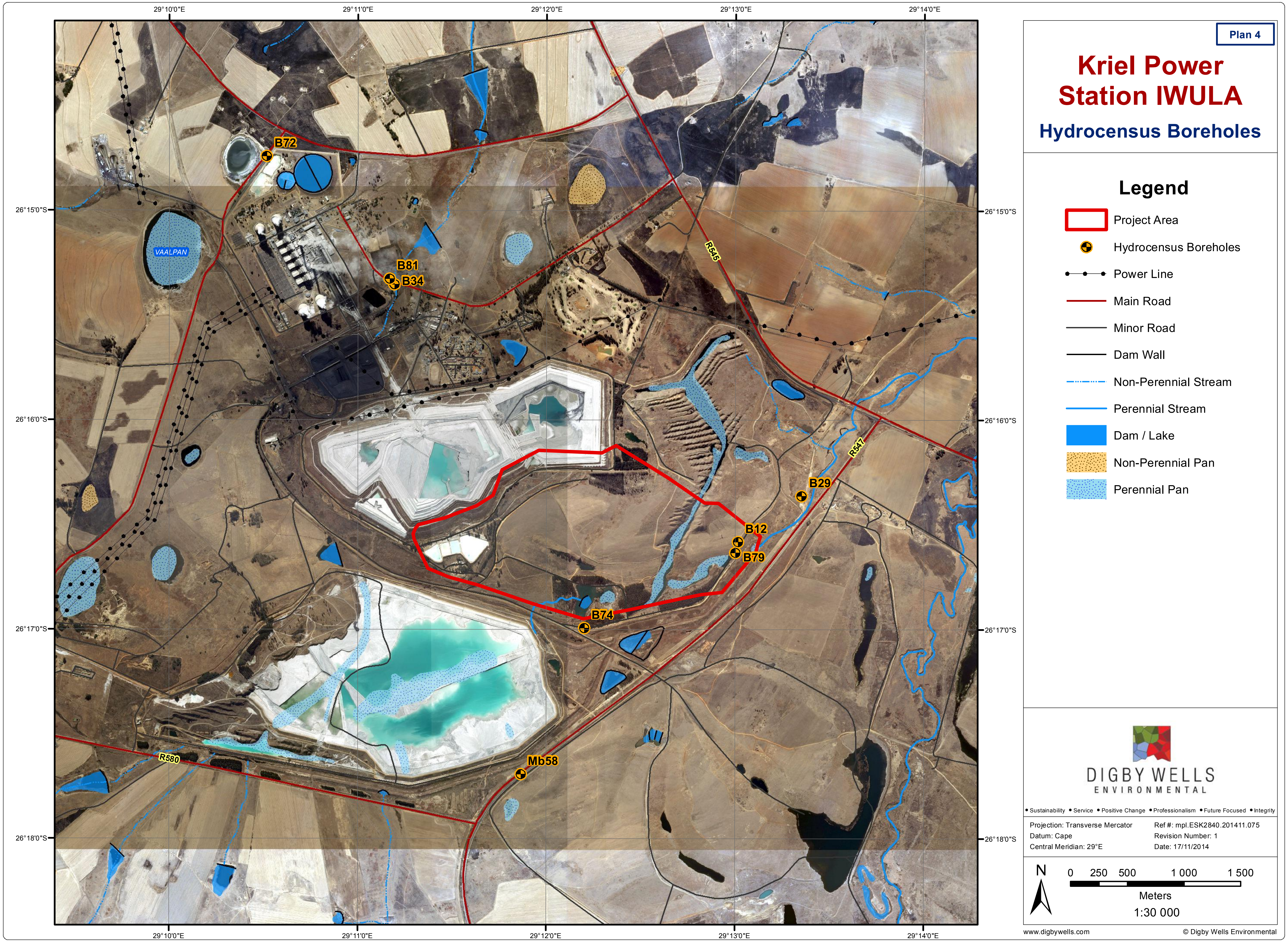
Plan 4
Kriel Power Station IWULA
Hydrocensus Boreholes
Legend
Project Area
Hydrocensus Boreholes
Power Line
Main Road
Minor Road
Dam Wall
Non-Perennial Stream
Perennial Stream
Dam / Lake
Non-Perennial Pan
Perennial Pan
B72
B81
B34
B29
B12
B79
B74
Mb58
VAALPAN
R545
R547
R580
29°10'0"E
29°11'0"E
29°12'0"E
29°13'0"E
29°14'0"E
26°15'0"S
26°16'0"S
26°17'0"S
26°18'0"S
DIGBY WELLS
ENVIRONMENTAL
• Sustainability • Service • Positive Change • Professionalism • Future Focused • Integrity
Projection: Transverse Mercator
Datum: Cape
Central Meridian: 29°E
Ref #: mpl.ESK2840.201411.075
Revision Number: 1
Date: 17/11/2014
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0 250 500 1 000 1 500
Meters
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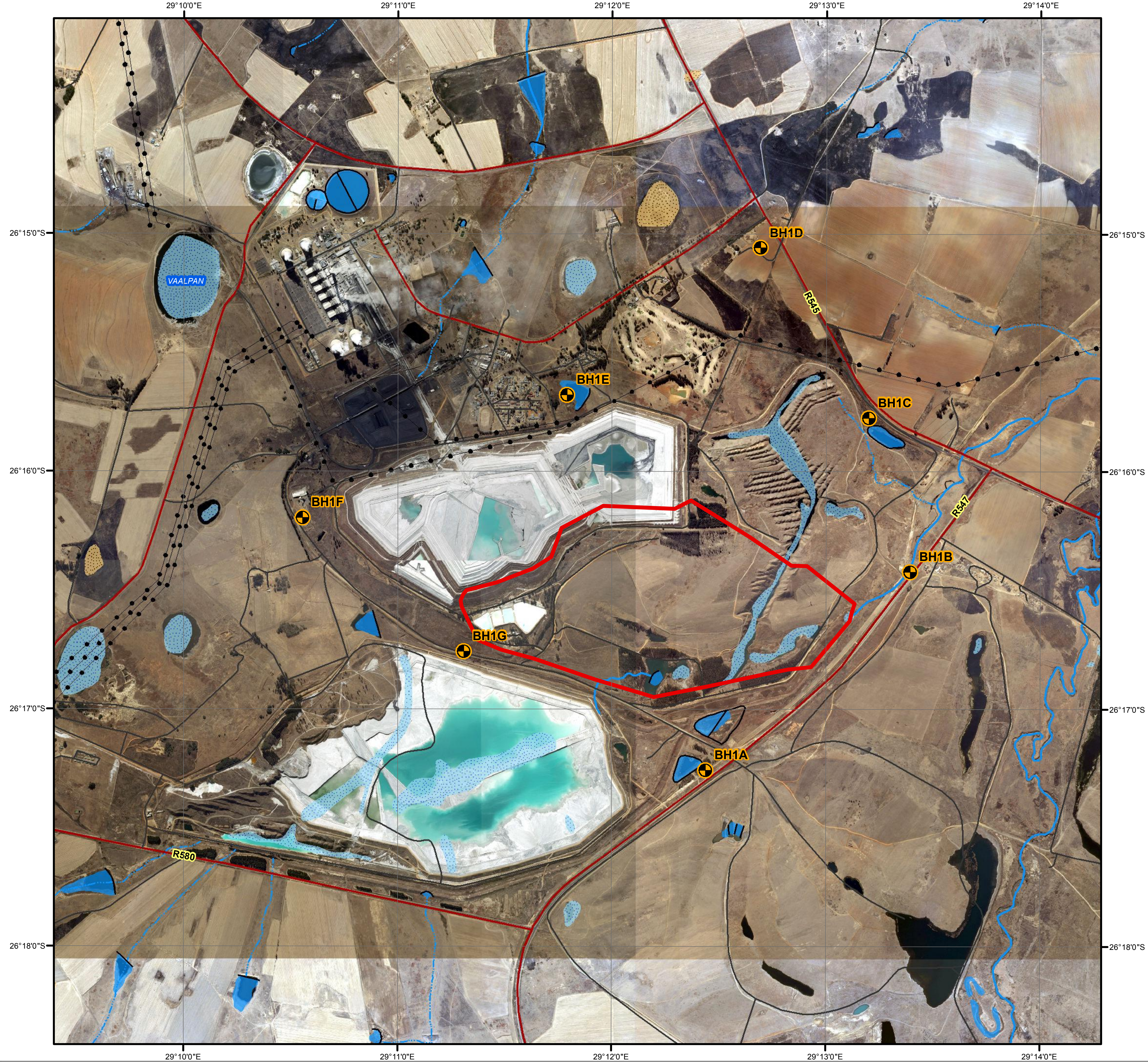
Plan 5

Kriel Power Station IWULA

Recommended Monitoring Boreholes



Legend

- Project Area
- Recommended Monitoring Borehole
- Power Line
- Main Road
- Minor Road
- Dam Wall
- Non-Perennial Stream
- Perennial Stream
- Dam / Lake
- Non-Perennial Pan
- Perennial Pan

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Projection: Transverse Mercator
Datum: Cape
Central Meridian: 29°E

Ref #: mpl.ESK2840.201412.105
Revision Number: 1
Date: 11/12/2014

N

0 0.25 0.5 1 1.5
Kilometres
1:30 000

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Appendix B: Laboratory Certificates

WATERLAB (PTY) LTD

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

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Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
NETT ACID GENERATION

Date received: 2014-09-23 **Date completed: 2014-10-17**
Project number: 1000 **Report number: 48142** **Order number: ESK2840**

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

Nett Acid Generation	**Sample Identification: pH 4.5 & 7.0**				
	ASS3	**ASS2**	**ASS1**	**AEDS1**	**AEDS2**
Sample Number	**16516**	**16517**	**16518**	**16519**	**16520**
NAG pH: (H_2O_2)	9.4	9.6	9.5	9.8	9.9
Titration with NaOH	0.00	0.00	0.00	0.00	0.00
Final pH: (H_2O_2)	9.4	9.6	9.5	9.8	9.9
NAG (kg H_2SO_4 / t)	<0.01	<0.01	<0.01	<0.01	<0.01

Nett Acid Generation	**Sample Identification: pH 4.5 & 7.0**				
	AEDS3	**AEDS4**	**FAS1**	**FAS2**	**FAS2**
Sample Number	**16521**	**16522**	**16523**	**16524**	**16524 D**
NAG pH: (H_2O_2)	9.9	10.0	10.0	9.9	10.0
Titration with NaOH	0.00	0.00	0.00	0.00	0.00
Final pH: (H_2O_2)	9.9	10.0	10.0	9.9	10.0
NAG (kg H_2SO_4 / t)	<0.01	<0.01	<0.01	<0.01	<0.01

Notes:

- Samples analysed with Single Addition NAG test as per Prediction Manual For Drainage Chemistry from Sulphidic Geological Materials MEND Report 1.20.1.
- Please let me know if results do not correspond to other data.

E. Botha
Geochemistry Project Manager

WATERLAB (PTY) LTD

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Persequor Techno Park,
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Facsimile: +2712 – 349 – 2064
Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES
EXTRACTIONS AS 4439.3

Date received:	**23/09/2014**			**Date completed:**	
Project number:	**1000**	**Report number:**	**48142**	**Order number:**	**ESK2840**

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

Analyses	**ASS4**	**ASS3**	**ASS2**	**AEDS1**	**AEDS2**	**AEDS3**	**FAS1**	**ASS1**	**AEDS4**	**FAS2**	
Sample Number	**16515**	**16516**	**16517**	**16519**	**16520**	**16521**	**16523**	**16518**	**16522**	**16524**	
TCLP / Borax / Distilled Water	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**Distilled Water**	**SPLP**	**SPLP**	**SPLP**	
Ratio	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**	**1:20**	
Units	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**LCT0 mg/l**
As, Arsenic	---	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.01
B, Boron	---	0.167	0.104	1.27	0.801	0.997	0.848	0.232	0.518	0.868	0.5
Ba, Barium	---	0.174	0.195	<0.025	0.028	0.033	2.18	0.126	0.048	2.05	0.7
Cd, Cadmium	---	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.003
Co, Cobalt	---	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.5
$Cr_{Total,}$ Chromium Total	---	<0.025	0.036	0.142	0.220	0.141	0.238	<0.025	0.240	0.138	0.1
Cr(VI), Chromium (VI)	---	<0.010	0.029	0.142	0.220	0.141	0.238	<0.010	0.240	0.138	0.05
Cu, Copper	---	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	2.0
Hg, Mercury	---	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.006
Mn, Manganese	---	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.5
Mo, Molybdenum	---	<0.025	<0.025	0.052	0.107	0.027	0.107	<0.025	0.026	0.106	0.07
Ni, Nickel	---	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.07
Pb, Lead	---	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.01
Sb, Antimony	---	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.02
Se, Selenium	---	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	0.01
V, Vanadium	---	<0.025	<0.025	0.136	0.075	0.070	<0.025	<0.025	0.037	<0.025	0.2
Zn, Zinc	---	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	5
Inorganic Anions	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	**mg/ℓ**	
Total Dissolved Solids*	---	222	192	152	150	170	1650	178	192	1692	1000
Chloride as Cl	---	<5	<5	<5	<5	<5	<5	<5	<5	<5	300
Sulphate as SO4	---	63	50	61	69	74	143	81	72	98	250
Nitrate as N	---	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	11
Fluoride as F	---	<0.2	<0.2	<0.2	<0.2	<0.2	0.8	<0.2	<0.2	0.9	1.5
Total Cyanide as CN	---	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.07
pH	---	11.2	11.4	10.6	10.8	10.9	12.2	10.8	11.0	12.3	
Moisture %	---	---	42	26	35	26	0	---	22	0	
Solid %	---	63	---	---	---	---	---	69	---	---	
Organics [s]											
VOC's: Dilution x1 - ug/liter	x1	---	---	---	---	---	---	---	---	---	
Benzene	<2	---	---	---	---	---	---	---	---	---	0.01
Carbon Tetrachloride	<5	---	---	---	---	---	---	---	---	---	0.2
Chlorobenzene	<2	---	---	---	---	---	---	---	---	---	5
Chloroform	<5	---	---	---	---	---	---	---	---	---	15
1,2-Dichlorobenzene	<2	---	---	---	---	---	---	---	---	---	5
1,4-Dichlorobenzene	<2	---	---	---	---	---	---	---	---	---	15
1,2-Dichloroethane	<2	---	---	---	---	---	---	---	---	---	1.5
Ethylbenzene	<2	---	---	---	---	---	---	---	---	---	3.5
Hexachlorobutadiene	<2	---	---	---	---	---	---	---	---	---	0.03
Isopropylbenzene	<2	---	---	---	---	---	---	---	---	---	
MTBE	<5	---	---	---	---	---	---	---	---	---	2.5
Naphthalene	<2	---	---	---	---	---	---	---	---	---	
Styrene	<5	---	---	---	---	---	---	---	---	---	1
1,1,1,2-Tetrachloroethane	<10	---	---	---	---	---	---	---	---	---	5
1,1,2,2-Tetrachloroethane	<10	---	---	---	---	---	---	---	---	---	0.65
Toluene	<10	---	---	---	---	---	---	---	---	---	35
1,1,1-Trichloroethane	<5	---	---	---	---	---	---	---	---	---	15
1,1,2-Trichloroethane	<5	---	---	---	---	---	---	---	---	---	0.6
Xylenes total	<5	---	---	---	---	---	---	---	---	---	25
1,2,4 Trichlorobenzene	<2	---	---	---	---	---	---	---	---	---	3.5
1,2,3 Trichlorobenzene	<2	---	---	---	---	---	---	---	---	---	
Dichloromethane	<20	---	---	---	---	---	---	---	---	---	0.25
1,1-Dichloroethylene	<10	---	---	---	---	---	---	---	---	---	0.35
1,2-Dichloroethylene	<10	---	---	---	---	---	---	---	---	---	2.5
Tetrachloroethylene	<10	---	---	---	---	---	---	---	---	---	0.25
Trichloroethylene	<10	---	---	---	---	---	---	---	---	---	0.25
Polars Dilution: Dilution x1 - mg/liter		---	---	---	---	---	---	---	---	---	
2-Butanone (methyl ethyl ketone)	<50	---	---	---	---	---	---	---	---	---	100
Vinyl Chloride	<1	---	---	---	---	---	---	---	---	---	0.015
Formaldehyde: Dilution x2 - ug/liter		---	---	---	---	---	---	---	---	---	
Formaldehyde	<100	---	---	---	---	---	---	---	---	---	25
SVOC's: Dilution x1 - ug/liter		---	---	---	---	---	---	---	---	---	
Benzo(a)pyrene	<0.1	---	---	---	---	---	---	---	---	---	0.035
Di (2 ethylhexyl) Phthalate	<10	---	---	---	---	---	---	---	---	---	0.5
Hexachlorobenzene	<1	---	---	---	---	---	---	---	---	---	
Nitrobenzene	<1	---	---	---	---	---	---	---	---	---	1
2,4 Dinitrotoluene	<50	---	---	---	---	---	---	---	---	---	0.065
Hexachloroethane	<1	---	---	---	---	---	---	---	---	---	
Total PAH's	<2	---	---	---	---	---	---	---	---	---	N/A
PHENOLS: Dilution x1 - ug/liter	x1	---	---	---	---	---	---	---	---	---	
Cresols	<2	---	---	---	---	---	---	---	---	---	
2-Chlorophenol	<2	---	---	---	---	---	---	---	---	---	15
2,4-Dichlorophenol	<2	---	---	---	---	---	---	---	---	---	10
Pentachlorophenol	<2	---	---	---	---	---	---	---	---	---	
2,4,5-Trichlorophenol	<2	---	---	---	---	---	---	---	---	---	
2,4,6-Trichlorophenol	<2	---	---	---	---	---	---	---	---	---	10
Phenols Speciated (total,non-halogenated)	<20	---	---	---	---	---	---	---	---	---	7
Pesticides: Dilution x1 - ug/liter		---	---	---	---	---	---	---	---	---	
Adrin	<0.1	---	---	---	---	---	---	---	---	---	0.015
Dieldrin	<0.1	---	---	---	---	---	---	---	---	---	0.015
DDT	<0.1	---	---	---	---	---	---	---	---	---	1
DDE	<0.1	---	---	---	---	---	---	---	---	---	1
DDD	<0.1	---	---	---	---	---	---	---	---	---	1
Heptachlor	<0.1	---	---	---	---	---	---	---	---	---	0.015
Chlordane	<0.1	---	---	---	---	---	---	---	---	---	0.05
PCB: Dilution x1 - ug/liter		---	---	---	---	---	---	---	---	---	
Ballsmitters Totals	<5	---	---	---	---	---	---	---	---	---	0.025
TPH: Dilution x1 - ug/liter		---	---	---	---	---	---	---	---	---	
Petroleum H/Cs,C6-C9	<10	---	---	---	---	---	---	---	---	---	N/A
Petroleum H/Cs,C10 to C36	<200	---	---	---	---	---	---	---	---	---	N/A

[s]=subcontracted

WATERLAB (PTY) LTD

WATERLAB

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Email: accounts@waterlab.co.za

CERTIFICATE OF ANALYSES

Digestion AS 4439.3

Date received:	**23/09/2014**			**Date completed:**	**17/10/2014**
Project number:	**1000**	**Report number:**	**48142**	**Order number:**	**ESK2840**

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

Analyses	**ASS4**		**ASS3**		**ASS2**		**ASS1**		**AEDS1**		**AEDS2**		**AEDS3**		**AEDS4**		**FAS1**		**FAS2**		**TCT0 mg/kg**
Sample Number	**16515**		**16516**		**16517**		**16518**		**16519**		**16520**		**16521**		**16522**		**16523**		**16524**		
Digestion	**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		**Aqua Regia**		
Dry Mass Used (g)	**0.25**		**0.25**		**0.25**		**0.25**		**0.25**		**0.25**		**0.25**		**0.25**		**0.25**		**0.25**		
Volume Used (mℓ)	**100**		**100**		**100**		**100**		**100**		**100**		**100**		**100**		**100**		**100**		
Units	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	
As, Arsenic	---	---	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	5.8
B, Boron	---	---	0.081	32	0.080	32	0.086	34	0.333	133	0.327	131	0.399	160	0.322	129	0.305	122	0.301	120	150
Ba, Barium	---	---	1.64	656	1.71	684	1.77	708	1.91	764	1.77	708	1.79	716	1.96	784	1.30	520	1.32	528	62.5
Cd, Cadmium	---	---	0.009	3.60	0.009	3.60	0.009	3.60	<0.005	<2.0	<0.005	<2.0	<0.005	<2.0	<0.005	<2.0	<0.005	<2.0	0.005	2.00	7.5
Co, Cobalt	---	---	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	50
Cr_{Total}, Chromium Total [s]	---	---	0.152	61	0.118	47	0.136	54	0.161	64	0.149	60	0.220	88	0.151	60	0.131	52	0.139	56	46000
Cr(VI), Chromium (VI) Total [s]	---	---	---	<5	---	<5	---	<5	---	<5	---	<5	---	<5	---	<5	---	<5	---	<5	6.5
Cu, Copper	---	---	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	16
Hg, Mercury	---	---	<0.001	<0.4	<0.001	<0.4	<0.001	<0.4	0.039	16	0.003	1.2	<0.001	<0.4	0.001	0.4	<0.001	<0.4	<0.001	<0.4	0.93
Mn, Manganese	---	---	0.763	305	0.800	320	0.839	336	0.502	201	0.559	224	0.543	217	0.627	251	0.581	232	0.619	248	1000
Mo, Molybdenum	---	---	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	40
Ni, Nickel	---	---	0.064	26	0.062	25	0.068	27	0.059	24	0.056	22	0.061	24	0.062	25	0.052	21	0.055	22	91
Pb, Lead	---	---	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	<0.020	<8.00	20
Sb, Antimony	---	---	<0.010	<4.00	<0.010	<4.00	0.012	4.80	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	<0.010	<4.00	0.018	7.20	<0.010	<4.00	10
Se, Selenium	---	---	0.026	10	0.050	20	0.022	8.80	<0.020	<8.00	0.030	12	<0.020	<8.00	<0.020	<8.00	0.025	10	0.031	12	10
V, Vanadium	---	---	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	150
Zn, Zinc	---	---	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	0.038	15	<0.025	<10	<0.025	<10	<0.025	<10	<0.025	<10	240
Inorganic Anions	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	**mg/ℓ**	**mg/kg**	
Total Fluoride [s] mg/kg	---	---	---	185	---	253	---	263	---	274	---	296	---	296	---	346	---	374	---	284	100
Total Cyanide as CN mg/kg	---	---	---	<0.01	---	<0.01	---	<0.01	---	<0.01	---	<0.01	---	<0.01	---	<0.01	---	<0.01	---	<0.01	14
Organics [s]																					
VOC's: Dilution x20 - ug/kg			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Benzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	10
Carbon Tetrachloride	---	<100	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4
Chlorobenzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8800
Chloroform	---	<100	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	700
1,2-Dichlorobenzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	31900
1,4-Dichlorobenzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	18400
1,2-Dichloroethane	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3.7
Ethylbenzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	540
Hexachlorobutadiene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2.8
Isopropylbenzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
MTBE	---	<100	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1435
Naphthalene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Styrene	---	<100	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	120
1,1,1,2-Tetrachloroethane	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	400
1,1,2,2-Tetrachloroethane	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	5
Toluene	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1150
1,1,1-Trichloroethane	---	<100	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1200
1,1,2-Trichloroethane	---	<100	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	48
Xylenes total	---	<100	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	890
1,2,4 Trichlorobenzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3300
1,2,3 Trichlorobenzene	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Dichloromethane	---	<400	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	16
1,1-Dichloroethylene	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	150
1,2-Dichloroethylene	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	3750
Tetrachloroethylene	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	200
Trichloroethylene	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	11600
Polars Dilution: Dilution x20 - mg/kg			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
2-Butanone (methyl ethyl ketone)	---	<1000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	8000
Vinyl Chloride	---	<20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.5
Formaldehyde: Dilution x10 - ug/kg			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Formaldehyde	---	<500	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2000
SVOC's: Dilution x20 - ug/kg			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Benzo(a)pyrene	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.7
Di (2 ethylhexyl) Phthalate	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	40
Hexachlorobenzene	---	<20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Nitrobenzene	---	<20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	45
2,4 Dinitrotoluene	---	<1000	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	5.2
Hexachloroethane	---	<20	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Total PAH's	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	50
PHENOLS: Dilution x20 - ug/kg			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Cresols	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
2-Chlorophenol	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	2100
2,4-Dichlorophenol	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	800
Pentachlorophenol	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
2,4,5-Trichlorophenol	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
2,4,6-Trichlorophenol	---	<40	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1770
Phenols (total,non-halogenated)	---	<400	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	560
Pesticides: Dilution x20 - ug/liter			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Adrin	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.2
Dieldrin	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.2
DDT	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	50
DDE	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	50
DDD	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	50
Heptachlor	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1.2
Chlordane	---	<2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	4
PCB: Dilution x5 - ug/kg			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Ballsmitters Totals	---	<35	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	12
TPH: Dilution x20 - mg/kg			---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	
Petroleum H/Cs,C6-C9	---	<200	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	650
Petroleum H/Cs,C10 to C36	---	<10	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	10000

UTD = Unable to determine

[s]=subcontracted

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CERTIFICATE OF ANALYSES

Date received: 23/09/2014

Project number: 1000 **Report number:** 48142

Client name: Digby Wells Environmetal

Address: Private Bag X 10046, Randburg, 2125

Telephone: 011 789 9495

Analyses	ASS4	
Sample Number	16515	
	Liquid phase	
Organics [s]		
VOC's: Dilution x1 - ug/liter	x1	
Benzene	<2	0.01
Carbon Tetrachloride	<5	0.2
Chlorobenzene	<2	5
Chloroform	<5	15
1,2-Dichlorobenzene	<2	5
1,4-Dichlorobenzene	<2	15
1,2-Dichloroethane	<2	1.5
Ethylbenzene	<2	3.5
Hexachlorobutadiene	<2	0.03
Isopropylbenzene	<2	
MTBE	<5	2.5
Naphthalene	<2	
Styrene	<5	1
1,1,1,2-Tetrachloroethane	<10	5
1,1,2,2-Tetrachloroethane	<10	0.65
Toluene	<10	35
1,1,1-Trichloroethane	<5	15
1,1,2-Trichloroethane	<5	0.6
Xylenes total	<5	25
1,2,4 Trichlorobenzene	<2	3.5
1,2,3 Trichlorobenzene	<2	
Dichloromethane	<20	0.25
1,1-Dichloroethylene	<10	0.35
1,2-Dichloroethylene	<10	2.5
Tetrachloroethylene	<10	0.25

Trichloroethylene	<10	0.25
Polars Dilution: Dilution x1 - mg/liter		
2-Butanone (methyl ethyl ketone)	<50	100
Vinyl Chloride	<1	0.015
Formaldehyde: Dilution x2 - ug/liter		
Formaldehyde	<100	25
SVOC's: Dilution x1 - ug/liter		
Benzo(a)pyrene	<0.1	0.035
Di (2 ethylhexyl) Phthalate	<10	0.5
Hexachlorobenzene	<1	
Nitrobenzene	<1	1
2,4 Dinitrotoluene	<50	0.065
Hexachloroethane	<1	
Total PAH's	<2	N/A
PHENOLS: Dilution x1 - ug/liter	x1	
Cresols	<2	
2-Chlorophenol	<2	15
2,4-Dichlorophenol	<2	10
Pentachlorophenol	<2	
2,4,5-Trichlorophenol	<2	
2,4,6-Trichlorophenol	<2	10
Phenols Speciated (total,non-halogenated)	<20	7
Pesticides: Dilution x1 - ug/liter		
Adrin	<0.1	0.015
Dieldrin	<0.1	0.015
DDT	<0.1	1
DDE	<0.1	1
DDD	<0.1	1
Heptachlor	<0.1	0.015
Chlordane	<0.1	0.05
PCB: Dilution x1 - ug/liter		
Ballsmitters Totals	<5	0.025
TPH: Dilution x1 - ug/liter		
Petroleum H/Cs,C6-C9	<10	N/A
Petroleum H/Cs,C10 to C36	UTD	N/A

UTD = Unable to determine

[s]=subcontracted

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Date completed:	**17/10/2014**
Order number:	**ESK2840**
Contact person:	**Andre van Coller**
Email:	**andre.van.coller@digbywells.com**
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CERTIFICATE OF ANALYSES
ACID – BASE ACCOUNTING
EPA-600 MODIFIED SOBEK METHOD

Date received: 2014-09-23		**Date completed: 2014-10-17**
Project number: 1000	**Report number: 48142**	**Order number: ESK2840**
Client name: Digby Wells Environmetal		**Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125		**Email: andre.van.coller@digbywells.com**
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Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification				
	ASS3	ASS2	ASS1	AEDS1	AEDS2
Sample Number	16516	16517	16518	16519	16520
Paste pH	11.1	11.3	11.4	10.9	11.1
Total Sulphur (%) (LECO)	0.15	0.17	0.19	0.17	0.22
Acid Potential (AP) (kg/t)	4.78	5.25	5.91	5.28	6.88
Neutralization Potential (NP)	42	42	42	65	70
Nett Neutralization Potential (NNP)	37	37	36	60	63
Neutralising Potential Ratio (NPR) (NP : AP)	8.7	8.0	7.1	12	10
Rock Type	III	III	III	III	III

Acid – Base Accounting Modified Sobek (EPA-600)	Sample Identification				
	AEDS3	AEDS4	FAS1	FAS2	FAS2
Sample Number	16521	16522	16523	16524	16524 D
Paste pH	11.1	11.3	12.7	12.8	12.8
Total Sulphur (%) (LECO)	0.23	0.27	0.18	0.19	0.19
Acid Potential (AP) (kg/t)	7.16	8.41	5.75	6.03	6.00
Neutralization Potential (NP)	72	77	30	49	49
Nett Neutralization Potential (NNP)	64	68	24	43	43
Neutralising Potential Ratio (NPR) (NP : AP)	10	9.1	5.2	8.1	8.2
Rock Type	III	II	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

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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

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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)

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Date received: 2014-09-23		**Date completed: 2014-10-17**
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Client name: Digby Wells Environmetal		**Contact person: Andre van Coller**
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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2014-09-23 **Date completed: 2014-10-17**
Project number: 1000 **Report number: 48142** **Order number: ESK2840**

Client name: Digby Wells Environmetal **Contact person: Andre van Coller**
Address: Private Bag X 10046, Randburg, 2125 **Email: andre.van.coller@digbywells.com**
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Composition (%) [s]								
ASS3			ASS2			ASS1		
16516			16517			16518		
Mineral	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error
Amorphous	39.33	2.31	Amorphous	34.54	2.49	Amorphous	39.75	2.4
Calcite	0.99	0.54	Calcite	1.5	0.66	Calcite	2.53	0.78
Hematite	2.02	0.45	Hematite	2.05	0.42	Hematite	1.6	0.42
Magnetite	3.77	0.33	Magnetite	3.79	0.33	Magnetite	3.1	0.33
Mullite	19.97	1.08	Mullite	22.47	1.11	Mullite	19.05	1.05
Plagioclase	18.08	1.47	Plagioclase	18.2	1.62	Plagioclase	19.29	1.53
Pyrite	0.25	0.26	Pyrite	0.41	0.2	Pyrite	0.47	0.3
Quartz	15.6	1.05	Quartz	17.03	1.11	Quartz	14.22	1.02

Composition (%) [s]								
AEDS1			AEDS2			AEDS3		
16519			16520			16521		
Mineral	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error
Amorphous	36.51	2.7	Amorphous	38.06	2.52	Amorphous	35.57	2.73
Calcite	5.94	0.63	Calcite	2.45	0.45	Calcite	4.3	0.66
Hematite	0.14	0.18	Hematite	0.42	0.36	Hematite	0.38	0.33
Magnetite	2.87	0.28	Magnetite	2.55	0.3	Magnetite	2.59	0.29
Mullite	35.48	1.74	Mullite	34.49	1.8	Mullite	36.13	1.83
Plagioclase	2.7	1.56	Plagioclase	1.45	0.84	Plagioclase	3.79	1.29
Pyrite	0.32	0.18	Pyrite	0.76	0.3	Pyrite	0.6	0.29
Quartz	16.04	1.11	Quartz	19.83	1.17	Quartz	16.65	1.08

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CERTIFICATE OF ANALYSES
X-RAY DIFFRACTION

Date received: 2014-09-23
Project number: 1000
Report number: 48142
Date completed: 2014-10-17
Order number: ESK2840

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

Composition (%) [s]								
AEDS4			FAS1			FAS2		
16522			16523			16524		
Mineral	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error	**Mineral**	Amount (weight %)	Error
Amorphous	37.9	2.73	Amorphous	37.14	2.55	Amorphous	39.86	2.25
Calcite	3.95	0.69	Lime	2.18	0.25	Lime	1.96	0.24
Hematite	0.45	0.36	Calcite	0.63	0.48	Calcite	0	0
Magnetite	2.62	0.3	Hematite	0.92	0.39	Hematite	0.92	0.36
Mullite	32.64	1.83	Magnetite	3.55	0.33	Magnetite	3.48	0.3
Plagioclase	3.17	1.26	Mullite	34.05	1.74	Mullite	35.4	1.74
Pyrite	0.57	0.3	Plagioclase	1.78	0.9	Plagioclase	0	0
Quartz	18.7	1.14	Pyrite	0.54	0.33	Pyrite	0.41	0.29
			Quartz	19.22	1.23	Quartz	17.97	1.14

[s] Results obtained from sub-contracted laboratory

Note:

The material submitted was scanned after addition of 20 % Si for quantitative determination of amorphous content and homogenizing using 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-Kα radiation. The phases were identified using X'Pert Highscore plus software.

The relative phase amounts (weight%) were estimated using the Rietveld method. Mathematical errors of the method are shown at the right had side of the amounts.

Comment:

- Due to crystallite size effects results errors may be larger than shown.
- In case the results do not correspond to results of other analytical techniques, please let me know for further fine tuning of XRD results.
- Results are also attached as excel file.
- Mineral names may not reflect the actual compositions of minerals identified, but rather the mineral group.

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Ideal Mineral Formula	
Quartz	Si O2
Plagioclase	(Na , Ca) Al (Si , Al)3 O8
Lime	CaO
Magnetite	Fe34
Pyrite	Fe S2
Calcite	CaCO3
Mullite	$Al_{4.5}Si_{1.5}O_{9.75}$
Hematite	Fe2O3

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Major Elements	Major Element Concentration (wt %)[s]								
	ASS3	ASS2	ASS1	AEDS1	AEDS2	AEDS3	AEDS4	FAS1	FAS2
	16516	16517	16518	16519	16520	16521	16522	16523	16524
SiO_2	49.28	48.99	51.81	47.95	50.34	47.48	48.16	51.38	50.53
TiO_2	1.51	1.5	1.52	1.68	1.6	1.61	1.61	1.730	1.700
Al_2O_3	27.97	28.39	28.58	30.34	29.99	30.54	29.30	30.82	30.66
Fe_2O_3	4.06	3.66	3.92	2.49	2.34	2.43	2.67	2.85	2.650
MnO	0.04	0.04	0.05	0.03	0.03	0.03	0.04	0.03	0.03
MgO	1.27	1.24	1.34	1.4	1.3	1.44	1.35	0.94	0.89
CaO	9.47	9.06	9.57	6.82	6.16	6.99	7.69	7.09	6.82
Na_2O	0.07	0.05	0.03	0.21	0.18	0.34	0.19	0.12	0.15
K_2O	0.72	0.73	0.72	0.86	0.87	0.81	0.93	0.68	0.66
P_2O_5	0.4	0.39	0.43	0.72	0.59	0.69	0.64	0.56	0.54
Cr_2O_3	0.02	0.02	0.02	0.02	0.02	0.04	0.02	0.02	0.02
SO_3	0.85	0.77	0.6	0.6	0.82	0.830	0.990	0.830	0.830
LOI	2.28	2.52	2.04	7.26	6.11	5.11	6.32	1.7	1.17
Total	98.43	97.36	100.63	100.38	100.35	98.34	99.91	98.75	96.65
H_2O-	0.49	0.53	0.31	1.07	2.07	0.76	1.64	0.10	0.16

[s] =Results obtained from sub-contracted laboratory

Notes: % g/g is equivalent to wt %; mg/kg is equivalent to ppm; n.d. = not determined; bold italicised font represents semi-quantitative data; * represents measurements reported in % g/g or wt%.

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Geochemistry Project Manager

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Trace Elements	Trace Element Concentration (ppm) [s]								
	ASS3	ASS2	ASS1	AEDS1	AEDS2	AEDS3	AEDS4	FAS1	FAS2
	16516	16517	16518	16519	16520	16521	16522	16523	16524
As	1.55	4.33	2.47	15.2	16.3	16.40	15.90	11.30	11.70
Ba	814	798	745	954	932	966.00	1021.00	710.00	729.00
Bi	1.3	1.43	0.9	1.56	1.68	1.84	1.36	1.23	1.4
Cd	4.42	5.03	4.78	4.94	3.55	6.85	5.87	4.98	4.62
Ce	187	127	73.9	108	129	101.00	101.00	131.00	117.00
Cl	117	129	122	141	132	99	106	94.6	90.8
Co	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56	<0.56
Cs	2.18	3.8	3.85	4.69	1.85	4.21	7.78	3.2	3.55
Cu	44.8	44	38.2	59.4	58.9	62	57.7	52.6	54
Ga	24.5	24	21.4	45.6	39.8	40.4	40.1	35.3	36
Ge	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Hf	7.37	11.1	3.37	1.92	1.71	6.39	2.95	2.36	6.46
Hg	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00
La	23.1	61.1	42.9	34	44.8	39.9	37.6	62	33.4
Lu	2.58	2.47	2.37	2.17	2.15	2.25	2.22	2.29	2.27
Mo	2.35	2.31	2.35	2.28	2.23	2.3	2.27	2.26	2.25
Nb	32.9	36.4	31.5	41.3	39.2	40.2	40.8	37.8	37.3
Nd	<2.39	<2.39	<2.39	35.6	44	58	46.4	<2.39	<2.39
Ni	39.1	34.8	34.2	51	45.5	53.2	39.4	54.2	46.2
Pb	<2.03	<2.03	<2.03	100	101	111	91	68.6	71.4
Rb	32.7	35.7	29.9	55.5	53	50.8	57.7	38.4	39.1
Sb	4.63	<1.48	<1.48	4.4	4.64	2.66	<1.48	<1.48	2.79
Sc	35	43.2	38.3	33.5	31.4	33.3	35.8	31.2	34
Se	3.02	2.24	2.87	8.99	7.36	8.58	6.86	5.51	6.07
Sm	14.5	14.9	14.1	3.37	7.26	4.38	6.11	8.18	10.5
Sn	18.5	14.5	12.5	18.5	18.4	17.5	19.5	15.5	14.5
Sr	1 908	1 893	1 723	2 569	1 928	2 388	2 340	1 595	1 607
Ta	1.21	1.54	1.82	1.43	1.35	1.61	1.62	2.19	1.76
Te	21.6	17	18.8	17.4	11.4	13.2	16.1	18.4	15.1
Th	25.6	24.7	25.6	33.3	29	30.3	32.3	32.3	30.9
Tl	0.71	0.65	0.37	1.06	0.78	0.95	1.25	0.87	0.84

Results continued on next page

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Trace Elements	Trace Element Concentration (ppm) [s]								
	ASS3	ASS2	ASS1	AEDS1	AEDS2	AEDS3	AEDS4	FAS1	FAS2
	16516	16517	16518	16519	16520	16521	16522	16523	16524
U	14.9	13.6	13.2	23.1	15.3	20.3	18.2	13.8	13.9
V	<7.60	<7.60	<7.60	<7.60	<7.60	<7.60	<7.60	<7.60	<7.60
W	1.33	1.32	1.26	1.18	1.16	1.16	1.3	1.13	1.22
Y	67.3	68.2	61.5	80.6	74.4	76.4	79.5	70.3	71.2
Yb	10.1	10.1	7.34	5.81	4.84	6.8	7.28	3.77	8.88
Zn	32	30.8	30.9	55.3	52.3	50.8	47.5	46.6	43.5
Zr	479	483	444	535	478	518	521	473	479

[s] =Results obtained from sub-contracted laboratory

XRF: Major Element Analysis (Geological)

The samples were prepared by first drying the samples at 100oC for ~3 hours in order to determine loss of moisture content (H_2O-), followed by ashing of the sample at 1000oC until completely ashed, to determine the loss on ignition (LOI). XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using a number of international and national certified reference materials (CRMs).

XRF: Trace Element Analysis (Geological)

XRF analyses were performed using a PANalytical Epsilon 3 XL ED-XRF spectrometer, equipped with a 50kV Ag-anode X-ray tube, 6 filters, a helium purge facility and a high resolution silicon drift detector, calibrated using international and national certified reference materials (CRMs).

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