ENVIRONMENTAL GEOCHEMICAL REPORT

PRELIMINARY GEOCHEMICAL ASSESSMENT OF THE FUTURE PALMIETKUILEN COLLIERY

CANYON COAL

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REPORT PREPARED FOR:

OAKLEAF INVESTMENT HOLDING 95 (PTY)
KHANYE COLLIERY
BRONKHORSTSPRUIT OAK LEAF

7th FLOOR, 13 FREDMAN DRIVE
SANDOWN
GAUTENG

SUMMARY

Geostratum was appointed by *Canyon Coal* to perform a geochemical study for the *Palmietkuilen Colliery.* The following summarizes the report:

Sampling

- A total of 44 samples were collected from 5 exploration boreholes from the proposed *Palmietkuilen Colliery*. Samples of the raw coal, coal product and discard still need to be collected from the coal laboratory and tested.

Mineralogy

- The waste rock samples comprised mainly of quartz and kaolinite. The raw coal comprised mainly of coal and kaolinite, while the coal discard was similar to the coal but with an elevated pyrite content. There was no significant difference in mineralogy observed in the coal collected from the 4 different seams.

Acid-base testing

- Most clastic waste rocks (roughly about 85% of all waste rock) have a very low sulphide content and will not generate acidic drainage. 10% of the clastic waste rocks have a moderate amount of sulphides and have a moderate potential to generate acidic drainage. Roughly about 5% of the clastic rocks (especially carbonaceous rocks and high sulphide containing sandstone adjacent to coal seams) do however have a significant potential to generate localised acidic drainage and will form localised hot-spots within the backfill. The backfill will, therefore, be a heterogeneous mixture of acid generation and non-acid generation rocks; and
- The discard has a higher potential than the raw coal to generate acidity while the product has a lower potential. All raw coal and discard samples have a high sulphide content and will generate acidic drainage in the long term although the samples also have some neutralisation potential which will buffer acidification for some time. Coal product from the top seam has a high sulphide content and has a significant potential to generate acidic drainage over the long-term, however, coal product from the other seams has a much lower acidification potential and neutralisation will buffer against acidification for quite some time.

Waste classification

- It is recommended that the waste rock is classified as Type 4 waste as there were no parameters that exceeded the LCT0 range; and
- Some coal material (coal, discard, coal product) had a few parameters exceeding the LCT0 and thus should be classified as Type 3 waste.

The following aspects will be included in the final geochemical report

- Kinetic leach tests are being performed on waste rock and coal discard samples;
- Conceptual modeling will be conducted to determine the physical-chemical processes and potential impacts of the discard dumps and pit backfill; and

- Numerical geochemical modeling will be performed to estimate the long-term pit water quality with and without discard as well as long-term seepage water quality from the discard dump.

Recommendations from preliminary report

- Coal material in contact with the atmosphere will result in oxidization of the pyrite and subsequent acidification. It is therefore recommended that the coal material is not subjected to atmospheric conditions as far as possible as this will limit the contamination of water seepage from the material. A permanent discard dump on the surface will result in acidification of its seepage water while previous studies have shown that the correct backfilling of discard may result in less water being contaminated. The backfilling of discard will be further investigated and reported in the final geochemical report.

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GLOSSARY

Abbreviation	Term	Description
ABA	Acid-base accounting	A procedure where the acid potential (AP) and neutralization potential (NP) of a rock sample is determined and is used to calculate if the material will produce or neutralize acid
AMD	Acid mine drainage	Is formed under natural conditions where geological strata containing sulphur or metal sulphides is exposed to the atmosphere or oxidizing conditions forming acid water (pH <5) laden with metal and sulphates.
AP	Acid Potential	The ability of the rock to produce acid leaches
AUC	Average Upper Crust	AUC is the composition of rocks exposed at the surface by means of establishing weighted averages and determining averages of the composition of insoluble elements in sedimentary or glacial rocks.
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry	ICP-OES is an analytical technique used for the detection of metals and metalloids in solution down to trace level.
LOI	Loss of Ignition	LOI is a test used in inorganic analytical chemistry, particularly in the analysis of minerals. It consists of strongly heating ("igniting") a sample of the material at a specified temperature, allowing volatile substances to escape, until its mass ceases to change.
NAG	Net-acid Generation	NAG testing determines the balance between the acid producing and the acid consuming components in waste rock material
NNP	Net Neutralization Potential	NNP is the difference of neutralisation potential and acid potential (=NP-AP). The following screening criteria are used: A rock with NNP < 0 kg CaCO3/t will theoretically have a net potential for acidic drainage. A rock with NNP > 0 kg CaCO3/t rock will have a net potential for the neutralization of acidic drainage.
NP	Neutralization Potential	Is the amount of alkaline material in a rock estimated by an acid reaction followed by titration to determine the ability of a rock to neutralize acid leaches
XRD	X-ray Diffraction	Is a laboratory-based technique used to identify crystalline materials by a scattering of x-rays to form an interference pattern that is captured and analysed
XRF	X-ray Fluorescence	Is a laboratory-based technique to determine the bulk chemistry of material by means of x-ray interaction with the material

1 INTRODUCTION

Geostratum was appointed by *Canyon Coal* to perform an environmental geochemical assessment of the proposed *Palmietkuilen Colliery.*

The *Palmietkuilen Colliery* is a proposed open cast mine and beneficiation plant in Gauteng, South Africa. The open cast will be approximately 877 ha in extent with an LOM of 53 years.

1.1 SITE BACKGROUND

The study area is located in a sub-basin of the Witbank Coalfield, often referred to as the Vischkuil-Springs-Witbank Coalfield. The coal seams are inconsistently developed, and where present more closely resemble the South Rand Coalfield. Three seams, namely the Top, Mid, and Bottom are recognized. The Top and Mid Seams can possibly be correlated with the No. 5 and No. 4 coal seams and the thicker Bottom seam appears to represent a combination of the No. 1, 2 and 3 coal seams of the central Witbank Coalfield. The Bottom Seam is generally of poor quality, erratically developed and less economical

1.2 SCOPE OF WORK

The overall objective of the geochemical assessment was to determine the potential for acid rock drainage from the mine waste materials (waste rock, coal, coal product and discard). This will assist in identifying potential impacts on local water quality, provide the basis for developing waste rock and pit void management strategies, and support closure planning. The scope of work was as follows:

- Preliminary assessment including a review of available information and assessment of potential issues and concerns that may be associated with the rock material;
- Development of a sampling plan to collect samples representing the geochemical variability in the rock material;
- Development of an analytical plan including laboratory test methods consistent with international guidelines;
- Interpretation of geochemical test results and quantification of the volume of waste that could generate acid drainage;
- To identify chemical constituents that may be present in future drainage from the mine;
- To perform a waste classification as per the General National Regulation 635 of the Waste Act 59 of 2008; and
- To determine the long-term impact of the backfilled pit and discard dump. Different modelling scenarios will be employed to investigate the effectiveness of some mitigation measures (e.g. waste management strategies).

1.3 METHODOLOGY

The project comprised of a sampling, testing as well as a modelling phase. Currently, the kinetic leach test results, as well as the modelling phase, is still outstanding. The methodology that was followed in this assessment aimed to address all aspects in the scope of work. However, the assessment often needs to be updated during the life of mine to address any gaps in the assessment and to generate an effective closure plan. The methodology followed for the current assessment is outlined below:

- Section 3: Rock samples were collected from exploration boreholes from the proposed *Palmietkuilen Colliery*. The samples were prepared and tested according to the test methods summarized in Table 2 below; and
- Section 4.1: The total element content of the samples was determined by means of X-ray fluorescence (XRF) and the major mineral content by X-ray diffraction (XRD);
- Section 4.2: The long-term net acid generation potential of the material was determined by acid-base testing. Both Acid-base accounting (ABA) and Net-acid generation (NAG) tests were performed to calculate whether the material will produce or neutralize acidic drainage;
- TO BE COMPLETED FOR DRAFT REPORT Section 4.3: Kinetic leach test: Column leach testing (humidity cells) was performed on selected samples to identify persistent chemicals that may potentially leach from the material;
- Section 5: Waste Classification: The data was evaluated in terms of the Standards and Norms of the Waste Act 2002 regulations for waste classification;
- TO BE COMPLETED FOR DRAFT REPORT: Section 6: Conceptual models for the pit backfill and discard dump will be developed. These include the typical physical-chemical processes that will control acid-mine drainage generation. The potential impact on the mine and seepage water from the various facilities will be discussed;
- TO BE COMPLETED FOR DRAFT REPORT: Section 7: Numerical geochemical modelling will be performed to 1) estimate the long-term pit water quality with and without discard backfilling, and 2), to estimate the long-term seepage water quality from the discard dump; and
- Conclusions and recommendations for were provided in Section 8.

2 SAMPLE DESCRIPTION AND ANALYTICAL PLAN

The basement comprised of Transvaal Supergroup rocks overlain by tillite and coal bearing strata from the Vryheid Formation, Ecca Group, Karoo Supergroup. The Vryheid Formation is locally comprised of three coal seams with carbonaceous interburden, which is overlain with a carbonaceous overburden. A typical lithological profile at the mine is summarised in Table 1 below. A complete list of the various waste rock samples is presented in Table 16 in Appendix A.

Rock samples were collected from exploration boreholes from the proposed pit area. A total of 44 waste rock samples were collected from the proposed pit area. Overburden, interburden and floor samples were collected from the PMK 83, PMK 99, PMK 86, and PMK 25 exploration boreholes. The samples were collected to represent the future pit backfill. The individual waste rock samples collected are presented in Appendix A. The lithological zones sampled are summarized in Table 1 below.

Coal seam samples were collected by the exploration geologist from the PMK 24, PMK 25, PMK 65 and PMK 98 boreholes. The samples were sent to *Noko Analytical Services* in *Emahlaleni* to be density separated. The original raw coal, floats (coal product), sinks (discard) were then sent to *Metron Laboratory.* Samples of the bottom seam, lower mid-seam, upper mid-seam and upper seam from the different boreholes were composited into 4 samples each of the coal, discard and product.

The samples were prepared and geochemical testing was performed according to the test methods summarized in Table 2 below by *Metron Laboratory*, *Vanderbijlpark*.

In summary, the following samples were collected:

- 2 soil and clay samples;
- 17 sandstone samples;
- 5 carbonaceous sandstone samples;
- 3 shale samples;
- 5 tillite samples;
- 4 raw coal samples (composite from each seam);
- 4 coal discard samples (composite from each seam); and
- 4 coal product sample (composite from each seam).

Table 1: General lithological profile and summary of samples collected

<table>
<tr><th>Thickness*</th><th>Number of samples</th><th>Lithology</th></tr>
<tr><td rowspan="3">37.03</td><td>2</td><td>Soil: Soil (often clayey).
(Up to about 7 m in boreholes sampled)</td></tr>
<tr><td>16</td><td>Overburden: Highly weathered to slightly weathered sandstone often with yellow and red stains. Sample disintegrate in hand.
(Up to about 18 - 40 m in boreholes sampled)</td></tr>
<tr><td>4</td><td>Overburden: Carbonaceous sandstone and/or shale/mudstone. (Up to about 1-2 m in boreholes sampled)</td></tr>
<tr><td>2.07</td><td>4</td><td>Top coal seam</td></tr>
<tr><td>5.20</td><td>3</td><td>Interburden: Carbonaceous sandstone and/or shale interburden</td></tr>
<tr><td>6.04</td><td>4</td><td>Mid seam (upper and lower)</td></tr>
<tr><td>2.78</td><td>2</td><td>Interburden: Carbonaceous sandstone and/or shale interburden</td></tr>
<tr><td>2.25</td><td>4</td><td>Bottom Seam</td></tr>
<tr><td>~</td><td>5</td><td>Floor: Tillite or carbonaceous sandstone and/or shale/mudstone above Transvaal Supergroup</td></tr>
</table>

* Thickness taken from Preliminary Resource Statement

Table 2: Description of test methods

Test procedure	Expected outcome	Method
Acid-base accounting (ABA) 44 samples	To indicate the long-term potential for AMD assuming all acid is generated by pyrite.	Modified Sobek (Lawrence and Wang, 1996, 1997)
Net-acid generating (NAG) 44 samples	To indicate the net potential for AMD after oxidation with hydrogen peroxide.	ASTM E1915-13
X-ray diffraction 16 samples	Minor to dominant minerals present in rocks.	-
X-ray fluorescence 16 samples	Major oxides and trace elements present in rocks.	ASTM D4326-13

Test procedure	Expected outcome	Method
Reagent water leach 20 samples	To determine chemicals of concern that may potentially leach from samples.	Based on ASTM D3987-12 with additional ICP and UV-VIS analyses.
Aqua regia extraction 20 samples	Indicate elements that can leach from the rock under the acidic leach.	Acid digestion of rock sample with 1:3 HNO_3 to HCl ratio

4 ANALYTICAL TEST RESULTS

4.1 MINERALOGY AND TOTAL ELEMENT ANALYSES

The mineralogical composition of the samples was determined by means of X-ray Diffraction (XRD). The XRD was performed by *XRD Analytical and Consulting*, Pretoria. The total element analyses were performed by means of X-ray fluorescence (XRF) at the *Metron Laboratory*, Vanderbijlpark. The results are reported below as follows:

- A simplified classification of the identified minerals is listed in Table 3; and
- The XRD and XRF results are presented in Tables 4 – 6 below.

The following pertains to the XRD method used:

- The samples were prepared for XRD analysis using a back loading preparation method. They were analysed with a PANalytical Empyrean diffractometer with PIXcel detector and fixed receiving slits with Fe filtered Co-K radiation. The phases were identified using X'Pert Highscore plus software;
- Amorphous phases were not taken into account in the quantification;
- Trace minerals at concentrations below ± 1% are often not detected by means of XRD testing on whole rock samples as the error might become larger than the analyses reported; and
- The weight percentages of the minerals were determined using the Rietveld method (Autoquan Program).

The following pertains to the XRF method and the LOI:

- Samples were analysed using pressed powder pellets;
- Analyses were performed with a Rigaku Supermini 200 with SC and F-PC detectors and fixed receiving slits with Zr of Al filtered Pd-K radiation. The elements were identified using ZSX software; and
- LOI is determined by placing samples in weighed crucibles which are then weighed. Weight loss is measured after heating at 750ºC overnight to remove water, organic matter and carbonates. After heating, the firebrick holding crucibles is allowed to cool completely in the oven or furnace before weighing.

With regard to the mineralogy and total element composition of the samples, the following is noted:

- PMK99 #1: The soil and clay samples comprises mainly of quartz and kaolinite as the dominant and major minerals with minor amounts of smectite present. The mineral assemblage is as follows:
  - Dominant (>40%): Quartz;
  - Major (15-40%): Kaolinite;
  - Minor (5-15%): Smectite; and
  - Trace (<2%): Siderite, Microcline, and Plagioclase;

- PMK99 #2: The weathered yellow sandstone sample comprises mainly of quartz and kaolinite as dominant and major minerals with minor amounts of microcline present. The mineral assemblage is as follows:
    - Dominant (>40%): Quartz;
    - Major (15-40%): Kaolinite;
    - Minor (5-15%): Microcline; and
    - Accessory (2-5%): Muscovite, and Plagioclase.
- PMK99 #3: The grey sandstone sample comprises mainly of quartz and kaolinite as dominant and major minerals with minor amounts of microcline present. The mineral assemblage is as follows:
    - Dominant (>40%): Quartz;
    - Major (15-40%): Kaolinite;
    - Minor (5-15%): Microcline;
    - Accessory (2-5%): Muscovite and Plagioclase; and
    - Trace (<2%): Siderite.
- PMK99 #4: The shale sample comprises dominantly of kaolinite with minor amounts of quartz and muscovite. The mineral assemblage is as follows:
    - Dominant (>40%): Kaolinite;
    - Minor (5-15%): Quartz and Muscovite; and
    - Trace (<2%): Pyrite, Siderite, Microcline, and Plagioclase.
- PMK99 #5: The tillite sample comprises dominantly of quartz and kaolinite with other minerals only present in trace amounts. The mineral assemblage is as follows:
    - Dominant (>40%): Quartz and Kaolinite; and
    - Trace (<2%): Calcite, Muscovite, Microcline, Plagioclase, and Chlorite.
- PMK86 #5: The carbonaceous sandstone sample comprises mainly of quartz and kaolinite as dominant and major minerals with minor amounts of calcite and muscovite. The mineral assemblage is as follows:
    - Dominant (>40%): Quartz;
    - Major (15-40%): Kaolinite;
    - Minor (5-15%): Calcite and Muscovite;
    - Accessory (2-5%): Siderite and Smectite; and
    - Trace (<2%): Microcline, Plagioclase, and Chlorite.
- PMK86 #6: The carbonaceous sandstone sample comprises mainly of kaolinite and quartz as dominant and major minerals with accessory amounts of muscovite, plagioclase, and smectite present. The mineral assemblage is as follows:
    - Dominant (>40%): Kaolinite;
    - Major (15-40%): Quartz;
    - Accessory (2-5%): Muscovite, Plagioclase, and Smectite; and

  - Trace (<2%): Calcite, Pyrite, Siderite, and Microcline, and Chlorite.
- PMK 25 #3: The coarse sandstone sample comprises mainly of calcite and kaolinite as dominant and major minerals with minor amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Calcite;
  - Major (15-40%): Kaolinite;
  - Minor (5-15%): Quartz;
  - Accessory (2-5%): Muscovite and Smectite; and
  - Trace (<2%): Microcline, Plagioclase, and Chlorite.
- Raw coal bottom-seam: The raw coal sample comprises mainly of coal and kaolinite as dominant and major minerals with accessory amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Accessory (2-5%): Quartz; and
  - Trace (<2%): Calcite, Muscovite, Pyrite, Dolomite, and Apatite.
- Raw coal lower mid-seam: The raw coal sample comprises mainly of coal and kaolinite as dominant and major minerals with only trace amounts of other minerals. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Trace (<2%): Calcite, Quartz Muscovite, Pyrite, Dolomite, and Apatite.
- Raw coal upper mid-seam: The raw coal sample comprises mainly of coal and kaolinite as dominant and major minerals with accessory amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Accessory (2-5%): Quartz; and
  - Trace (<2%): Calcite, Muscovite, Pyrite, Siderite, Dolomite, and Apatite.
- Raw coal upper-seam: The raw coal sample comprises mainly of coal and kaolinite as dominant and major minerals with minor amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Minor (5-15%): Quartz; and
  - Trace (<2%): Calcite, Muscovite, Pyrite, Siderite, Dolomite, and Apatite.

- Coal discard bottom-seam: The coal discard sample comprises mainly of coal and kaolinite as dominant and major minerals with minor amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Minor (5-15%): Quartz;
  - Accessory (2-5%): Pyrite and Smectite; and
  - Trace (<2%): Calcite, Muscovite, Dolomite, and Apatite.
- Coal discard lower mid-seam: The coal discard sample comprises mainly of coal and kaolinite as dominant and major minerals with accessory amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Accessory (2-5%): Quartz; and
  - Trace (<2%): Calcite, Pyrite, Smectite, and Dolomite.
- Coal discard upper mid- seam: The coal discard sample comprises mainly of coal and kaolinite as dominant and major minerals with minor amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Minor (5-15%): Quartz; and
  - Trace (<2%): Calcite, Pyrite, Smectite, Dolomite, and Apatite.
- Coal discard upper-seam. The coal discard sample comprises mainly of coal and kaolinite as dominant and major minerals with minor amounts of quartz present. The mineral assemblage is as follows:
  - Dominant (>40%): Coal;
  - Major (15-40%): Kaolinite;
  - Minor (5-15%): Quartz;
  - Accessory (2-5%): Calcite and Pyrite; and
  - Trace (<2%): Muscovite, Smectite, Dolomite, and Apatite.

The following comments could be made with regard to the elemental composition of the rock material compared to the average upper crust (AUC) of Rudnick and Gao (2003):

- PMK99 #1 (soil and clay):
  - Fe_2O_3 and MnO is marginally elevated above the AUC with K_2O being elevated between 3 to 5 times above the AUC; and
  - Trace element significantly elevated (more than 5 times above AUC) include Cr with Rb, Zn, and Zr being only marginally elevated.
- PMK99 #2 (weathered sandstone):
  - MnO is marginally elevated above the AUC with K_2O being elevated between 3 to 5 times above the AUC; and

  - Trace element significantly elevated (more than 5 times above AUC) include Cr with Rb, Zn, and Zr being only marginally elevated.
- PMK99 #3 (sandstone):
  - Al_2O_3, Fe_2O_3, K_2O, is marginally elevated above the AUC; and
  - Trace element significantly elevated (more than 5 times the AUC) include Cr, with Cu and Ni being elevated between 3 to 5 times and Rb, V, and Zn, and Zr being only marginally elevated.
- PMK99 #4 (shale):
  - Al_2O_3 and SiO_2 is marginally elevated above the AUC; and
  - Trace element significantly elevated (more than 5 times) include As and Cr with Cu being elevated between 3 to 5 times and Zn and Zr being only marginally elevated.
- PMK99 #5 (tillite):
  - Fe_2O_3, K_2O, and MnO is marginally elevated above the AUC; and
  - Trace element significantly elevated (more than 5 times) include Cr with Rb and Zn being only marginally elevated.
- PMK86 #5 (carbonaceous sandstone):
  - Al_2O_3, Fe_2O_3, K_2O, MnO is marginally elevated above the AUC; and
  - Trace element significantly elevated (more than 5 times the AUC) include Cr with Ni, Rb, V, Zn, and Zr being only marginally elevated.
- PMK86 #6 (carbonaceous sandstone):
  - Fe_2O_3, K_2O, and MnO is marginally elevated above the AUC; and
  - Trace element significantly elevated (more than 5 times the AUC) include Cr with Ni, Rb, V, Zn, and Zr being only marginally elevated
- PMK 25 #3 (sandstone):
  - CaO is elevated more than 5 times above the AUC with MnO being elevated between 3 to 5 times and Fe_2O_3 being only marginally elevated; and
  - No trace elements were elevated.
- Raw coal bottom-seam:
  - Al_2O_3 marginally elevated above the AUC; and
  - Trace element marginally elevated above the AUC include Cu, V, and Zr.
- Raw coal lower mid-seam:
  - No major elements were elevated above the AUC; and
  - Trace element marginally elevated above the AUC include V and Zr.
- Raw coal upper mid-seam:
  - No major elements were elevated above the AUC; and
  - Trace element marginally elevated above the AUC include V and Zr.

- Raw coal upper-seam:
  - No major elements were elevated above the AUC; and
  - No trace elements were elevated above the AUC:
- Coal discard bottom-seam:
  - Al_2O_3 is marginally elevated above the AUC; and
  - Trace element marginally elevated above the AUC include V and Zr.
- Coal discard lower mid-seam:
  - Al_2O_3 is marginally elevated above the AUC; and
  - Trace element significantly elevated (more than 5 times the AUC) include As with V and Zr being only marginally elevated.
- Coal discard upper mid-seam:
  - Al_2O_3 is marginally elevated above the AUC; and
  - Trace element significantly elevated (more than 5 times the AUC) include As with V and Zr being only marginally elevated.
- Coal discard upper-seam::
  - No major elements were elevated above the AUC; and
  - Trace element marginally elevated above the AUC include Cr and V.
- Elevation above the AUC is, however, not an indication of the leachability of these trace elements and metals.
- *In summary*, the waste rock samples comprised mainly out of quartz and kaolinite with 1 sample comprising dominantly out of calcite. The raw coal samples comprised mainly out of coal and kaolinite while the coal discard also comprising mainly out of coal and kaolinite but with an elevated kaolinite and pyrite content. There was no significant difference in mineralogy observed in the coal collected form the 4 different seams. Cr was detected at elevated concentration in the waste rock samples and As was detected at elevated concentrations in the coal discard samples.

Table 3: Simplified classification of identified minerals

Mineral	*	Formula	Mineral type/group	Sub-group
Apatite		$Ca_5(PO_4)_3(OH,F,Cl)$	Phosphate	Anhydrous Phosphate
Calcite		$CaCO_3$	Anhydrous Carbonates	Calcite group
Chlorite		$(Mg,Fe^{2+},Fe^{3+},Mn,Al)_{12}[(Si,Al)_8O_{20}](OH)_{16}$	Phyllosilicate	Interlayered 1:1, 2:1, and octahedra
Dolomite		$CaMg(CO_3)_2$	Anhydrous Carbonates	Dolomite Group
Kaolinite		$Al_2Si_2O_5(OH)_4$	Phyllosilicate 1:1 layer	Kaolinite group
Quartz		SiO_2	Tectosilicate	Tectosilicates

Muscovite		$KAl_2(AlSi_3O_{10})(OH,F)_2$	Phyllosilicate 2:1 layer	Mica group (Muscovite subgroup)
Plagioclase		$(Na,Ca)(Si,Al)_4O_8$	Tectosilicate	Plagioclase series
Microcline		$KAlSi_3O_8$	Tectosilicate	K(Na,Ba) feldspar subgroup
Smectite		$(0.5Ca,Na)_{0.7}(Al,Mg,Fe)_{4,6}[(Si,Al)_8O_{20}](OH)_4\ nH_2O$	Phyllosilicate 2:1 layer	Smectite group
Pyrite		FeS_2	Sulphides	Pyrite Group
Siderite		$FeCO_3$	Anhydrous Carbonate	Calcite group
* Mineral Type: Blue = Carbonates, Red = Phyllosilicates, Green = Tectosilicates, Brown = Phospahte, Yellow = Sulphides				

Table 4: X-ray diffraction results (weight %)

	PMK99 #1	PMK99 #2	PMK99 #3	PMK99 #4	PMK99 #5	PMK86 #5	PMK86 #6	PMK 25 #3	Raw coal bottom-seam	Raw coal lower mid-seam	Raw coal upper mid-seam	Raw coal upper-seam	Coal discard bottom-seam	Coal discard lower mid-seam	Coal discard upper mid-seam	Coal discard upper-seam
Calcite	-	-	-	-	0.09	6.05	0.01	58.4	1.04	1.04	1.33	1.54	1.04	1.8	1.22	2.48
Quartz	65.57	49.75	43.6	13.85	56.59	41.26	28.37	13.88	2.8	1.57	3.16	7.93	5.29	2.71	6.25	11.67
Kaolinite	27.41	36.27	39.84	77.61	41.38	36.46	58.26	19.57	17.82	20.99	17.89	15.23	35.19	28.19	29.88	19.93
Muscovite	-	3.08	3.36	5.49	1.66	8.18	4.76	2.73	1.02	0.88	1.01	1.13	1.09	-	-	1.31
Pyrite	-	-	-	1.86	-	-	0.49	-	0.22	0.77	1.17	1.03	2.77	1.76	1.29	4.57
Siderite	0.16	-	1.06	0.83	-	2.12	1.2	-	-	-	0.05	0.01	-	-	-	-
Microcline	0.43	7.96	9.23	0.09	0.23	0.9	0.8	0.67	-	-	-	-	-	-	-	-
Plagioclase	1.16	2.94	2.91	0.26	0.04	1.01	2.78	1.26	-	-	-	-	-	-	-	-
Chlorite	-	-	-	-	0.02	0.04	0.14	0.03	-	-	-	-	-	-	-	-
Smectite	5.24	-	-	-	-	3.97	3.18	3.46	1.04	-	-	-	2.38	0.82	1.11	0.68
Dolomite	-	-	-	-	-	-	-	-	0.53	1.14	1.15	0.48	0.49	0.58	0.47	0.17
Apatite	-	-	-	-	-	-	-	-	-	0.14	0.25	-	0.95	-	0.12	0.1
Organic C (Coal)	-	-	-	-	-	-	-	-	75.53	73.46	73.98	72.65	50.8	64.15	59.66	59.08

* Orange = Soil and clay, Yellow = Sandstone, Brown = Carboncaeous sandstone, Purple = Shale, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)

Table 5: X-ray fluorescence major oxides (weight %)

Sample ID	*	LOI	Al_2O_3	CaO	Fe_2O_3	K_2O	MgO	MnO	Na_2O	P_2O_5	SiO_2	TiO_2
PMK99 #1		-	13.4	2.40	12.6	9.04	0.263	0.182	<0.1	0.368	57.7	0.543
PMK99 #2		-	14.4	1.67	9.35	10.3	0.263	0.139	<0.1	0.390	60.2	0.484
PMK99 #3		-	21.6	1.03	21.7	3.12	0.163	0.065	<0.1	0.370	46.7	0.937
PMK99 #4		-	18.0	0.823	1.63	2.64	0.112	<0.01	<0.1	0.349	72.8	0.610
PMK99 #5		-	12.0	11.8	21.0	4.85	0.653	0.170	<0.1	0.383	45.1	0.527
PMK86 #5		-	17.3	1.51	18.8	7.31	0.539	0.173	<0.1	0.378	49.2	0.963
PMK86 #6		-	15.0	2.22	23.5	5.60	0.674	0.139	<0.1	0.376	47.9	0.848
PMK 25 # 3		-	3.55	64.3	16.3	1.37	0.217	0.307	<0.1	0.511	12.4	0.221
Raw coal bottom-seam		57.0%	16.9	1.48	0.913	0.286	0.745	0.0129	0.304	0.064	19.9	0.641
Raw coal lower mid-seam		63.8%	14.0	1.69	1.37	0.261	0.757	0.0134	0.109	0.078	15.8	0.496
Raw coal upper mid-seam		64.9%	12.5	1.93	1.88	0.328	0.814	0.0119	<0.1	0.180	14.5	0.541
Raw coal upper-seam		73.2%	7.92	1.30	1.57	0.181	0.429	<0.01	<0.1	0.022	14.2	0.271
Coal discard bottom-seam		37.3%	23.2	1.26	4.77	0.331	0.646	<0.01	0.213	0.039	29.1	0.919
Coal discard lower mid-seam		45.2%	19.6	2.09	4.22	0.302	0.785	0.010	<0.1	0.063	23.5	0.690
Coal discard upper mid-seam		38.3%	22.1	1.87	3.46	0.440	0.763	<0.01	<0.1	0.162	27.5	0.980
Coal discard upper-seam		45.3%	15.0	1.99	8.57	0.441	0.546	<0.01	<0.1	0.029	26.5	0.531
**AUC	Above AUC		15.4	3.6	11.2	2.8	2.5	0.1	3.3	0.2	66.6	0.6

	3-5 times above AUC	46.2	10.77	33.6	8.4	7.44	0.3	9.81	0.45	-	1.92
	> 5 times higher than AUC	77	17.95	56	14	12.4	0.5	16.35	0.75	-	3.2

* Orange = Soil and clay, Yellow = Sandstone, Brown = Carboncaeous sandstone, Purple = Shale, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)

*** AUC = Average Upper Crust (Rudnick and Gao, 2003)*

Table 6: X-ray fluorescence trace elements (ppm)

Sample	*	LOI	As	Ba	Co	Cr	Cu	F	Nb	Ni	Pb	Rb	Sr	Th	U	V	Zn	Zr
PMK99 #1		-	<40	<100	<40	523	<40	<1000	<40	<40	<40	119	157	<100	<100	<100	71	398
PMK99 #2		-	<40	<100	<40	577	<40	<1000	<40	<40	<40	125	176	<100	<100	<100	67	300
PMK99 #3		-	<40	<100	<40	1171	98	<1000	<40	153	<40	85	30	<100	<100	190	101	220
PMK99 #4		-	64.0	<100	<40	762	87	<1000	<40	45.0	<40	81	57	<100	<100	<100	86	565
PMK99 #5		-	<40	<100	<40	755	<40	<1000	<40	<40	<40	99	76	<100	<100	<100	78	97
PMK86 #5		-	<40	<100	<40	608	<40	<1000	<40	47.0	<40	119	108	<100	<100	191	180	271
PMK86 #6		-	<40	<100	<40	631	<40	<1000	<40	39.0	<40	108	90	<100	<100	149	156	344
PMK 25 # 3		-	<40	<100	<40	<40	<40	<1000	<40	<40	<40	40	45	<100	<100	<100	<40	<40
Raw coal bottom-seam		57.0%	<40	<100	<40	65.0	40.9	<1000	<40	43.0	<40	<40	504	<100	<100	138	<40	318
Raw coal lower mid-seam		63.8%	<40	<100	<40	<40	<40	<1000	<40	<40	<40	<40	757	<100	<100	101	<40	243
Raw coal upper mid-seam		64.9%	<40	<100	<40	50.4	<40	<1000	<40	<40	<40	<40	1440	<100	<100	108	<40	276
Raw coal upper-seam		73.2%	<40	<100	<40	78.9	<40	<1000	<40	<40	<40	<40	147	<100	<100	<100	<40	100
Coal discard bottom-seam		37.3%	<40	<100	<40	73.0	<40	<1000	<40	45.8	<40	54.0	267	<100	<100	173	<40	289
Coal discard lower mid-seam		45.2%	47.7	<100	<40	<40	<40	<1000	<40	<40	<40	62.0	492	<100	<100	123	<40	240
Coal discard upper mid-seam		38.3%	49.3	<100	<40	42.2	<40	<1000	<40	<40	<40	67.8	1540	<100	<100	182	<40	381
Coal discard upper-seam		45.3%	<40	<100	<40	135	<40	<1000	<40	<40	<40	<40	46.5	<100	<100	128	<40	59.7
**AUC	Above AUC		4.8	628	17.3	92	28	557	12	47	17	84	320	10.5	2.7	97	67	193
	3-5 times above		14.4	1884	51.9	276	84	1671	36	141	51	252	960	31.5	8.1	291	201	579

	AUC																
	> 5 times higher than AUC	24	3140	86.5	460	140	2785	60	235	85	420	1600	52.5	13.5	485	335	965

* Orange = Soil and clay, Yellow = Sandstone, Brown = Carboncaeous sandstone, Purple = Shale, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)

*** AUC = Average Upper Crust (Rudnick and Gao, 2003)*

4.2 ACID-BASE TESTING

4.2.1 TERMINOLOGY AND SCREENING METHODS (ABA)

Acid-base accounting (ABA) is a static test where the net potential of the rock to produce acidic drainage is determined. The percentage sulphur (%S), the Acid Potential (AP), the Neutralization Potential (NP) and the Net Neutralization Potential (NNP) of the rock material are determined in this test, as an important first order assessment of the potential leachate that could be expected from the rock material. A description of the different ABA components is given below:

- If pyrite is the only sulphide in the rock the AP (acid potential) is determined by multiplying the percentage sulphur (%S) with a factor of 31.25. The unit of AP is kg $CaCO_3$/t rock and indicates the theoretical amount of calcite neutralized by the acid produced;
- The NP (Neutralization Potential) is determined by treating a sample with a known excess of standardized hydrochloric or sulfuric acid (the sample and acid are heated to ensure reaction completion). The paste is then back-titrated with standardized sodium hydroxide in order to determine the amount of unconsumed acid. NP is also expressed as kg $CaCO_3$/t rock as to represent the amount of calcite theoretically available to neutralize the acidic drainage; and
- NNP is determined by subtracting AP from NP.

In order for the material to be classified in terms of their acid-mine drainage (AMD) potential, the ABA results could be screened in terms of its NNP, %S and NP:AP ratio as follows:

- A rock with NNP < 0 kg $CaCO_3$/t will theoretically have a net potential for acidic drainage. A rock with NNP > 0 kg $CaCO_3$/t rock will have a net potential for the neutralization of acidic drainage. Because of the uncertainty related to the exposure of the carbonate minerals or the pyrite for reaction, the interpretation of whether a rock will actually be net acid generating or neutralizing is more complex. Research has shown that a range from -20 kg $CaCO_3$/t to 20 kg $CaCO_3$/t exists that is defined as a "grey" area in determining the net acid generation or neutralization potential of a rock. Material with an NNP above this range is classified as *Rock Type IV - No Potential for Acid Generation*, and material with an NNP below this range as *Rock Type I - Likely Acid Generating*;
- Further screening criteria could be used that attempts to classify the rock in terms of its net potential for acid production or neutralization. The following screening methods are given in Table 7 below, as proposed by Price (1997), use the NP:AP ratio to classify the rock in terms of its potential for acid generation; and
- Soregaroli and Lawrence (1998) further states that samples with less than 0.3% sulphide sulphur are regarded as having insufficient oxidisable sulphides to sustain long-term acid generation. According to Li (2006), a material with an S% of below 0.1% has no potential for acid generation. Therefore, a material with a %S of above 0.3%, is classified as *Rock Type I -*

Likely Acid Generating, 0.2-0.3% is classified as *Rock Type II*, 0.1-0.2% is classified as *Rock Type III*, and below 0.1% is classified as *Rock Type IV - No Potential for Acid Generation*.

Table 7: Screening methods using the NP: AP ratio (Price, 1997)

Potential for acid generation	NP: AP screening criteria	Comments
Rock Type I. Likely Acid Generating.	< 1:1	Likely AMD generating.
Rock Type II. Possibly Acid Generating.	1:1 – 2:1	Possibly AMD generating if NP is insufficiently reactive or is depleted at a faster rate than sulphides.
Rock Type III. Low Potential for Acid Generation.	2:1 – 4:1	Not potentially AMD generating unless significant preferential exposure of sulphides along fracture planes, or extremely reactive sulphides in combination with insufficient reactive NP.
Rock Type IV. No Potential for Acid Generation.	>4:1	No further AMD testing required unless materials are to be used as a source of alkalinity.

4.2.2 TERMINOLOGY AND SCREENING METHODS (NAG)

The NAG test provides a direct assessment of the potential for a material to produce acid after a period of exposure (to a strong oxidant) and weathering. The test can be used to refine the results of the ABA predictions. In the Net-acid Generating (NAG) test hydrogen peroxide (H_2O_2) is used to oxidize sulphide minerals in order to predict the acid generation potential of the sample. The following relates to the methodology:

- In general, the static NAG test involves the addition of 25 ml of 15% H_2O_2 to 0.25 g of sample in a 250 ml wide mouth conical flask or equivalent. The sample is covered with a watch glass, and placed in a fume hood and a well-ventilated area for about 2 h;
- Once "boiling" or effervescing ceases, the solution is allowed to cool to room temperature and the final pH (NAG pH) is determined; and
- A quantitative estimation of the amount of net acidity remaining (the NAG capacity) in the sample is determined by titrating it with sodium hydroxide (NaOH) to pH 4.5 (and/or pH 7.0) to obtain the NAG Value.

In order to determine the acid generation potential of a sample, the screening method of Miller et al. (1997) is used. See Table 8 below:

Table 8: NAG test screening method (edited from Miller et al., 1997)

Rock Type	NAG pH	NAG Value (H_2SO_4 kg/t)	NNP ($CaCO_3$ kg/t)
Rock Type Ia. High Capacity Acid Forming.	< 4.5	> 10	Negative
Rock Type Ib. Lower Capacity Acid Forming.	< 4.5	≤ 10	-
Uncertain, possibly Ib.	< 4.5	> 10	Positive
Uncertain.	≥ 4.5	0	Negative (Reassess mineralogy)*
Rock Type IV. Non-acid Forming.	≥ 4.5	0	Positive

** If low acid forming sulphides is dominant then Rock Type IV.*

4.2.3 ACID-BASE TEST RESULTS

ABA and NAG test results were performed by *Metron Laboratory*, Vanderbijlpark. The test results are presented as follows:

- The ABA results are presented in Tables 9 below. The results were screened as discussed in Section 4.2.1 above as *Rock Type I to IV*;
- An average of the ABA results for the various lithology's is presented in Table 10;
- An average of the ABA results for the various stratigraphy's is presented in Table 11;
- The potential risk of the various lithologies to generate AMD is presented in Table 12 below;
- The NAG test results are presented in Table 13. The results above were screened as discussed in Section 4.2.2 above as *Rock Type I to IV*; and
- In Figure 2 the NAG value is plotted against the NNP.

From the ABA and NAG test results the following observations could be made:

- The %S was determined through an infrared (IR) detector after sample combustion in an Eltra furnace. The total %S was determined after heating the furnace to ±2200°C and the sulphide %S was determined at 1 000°C. The sulphide %S was used to determine the acidification potential of the samples and the acid potential of the sample was therefore not overestimated;
- The NP/AP indicates the potential for the rock to generate acid drainage, whereas the %S indicated whether this drainage will be over the long term. In Figure 1 the red lines, therefore, assess the acid generation potential, while the horizontal yellow line assesses whether this generation will be over a long term;
- The overburden is comprised of a soft overburden (comprising of soil, clay and highly weathered rock) and a hard overburden (sandstone, siltstone,

and shale). The interburden is mostly comprised of shale and carbonaceous sandstone, and the footwall of tillite; and

- In Table 12 the potential for the rock material to generate acid mine drainage are summarized:
  - *Soil overburden:* 100% (2 out of 2) of the soil samples have no potential to generate acidic drainage (and will generate a very low to no salt load);
  - *Sandstone mostly from weathered sandstone overburden:* This lithology comprises the bulk of the overburden and is often highly weathered with resulting low sulphide S% and, although present, often also low carbonate minerals content. One outlier is present that have a carbonate content of approximately +60%. 24% (4 out 17) of the sandstone samples have a low potential to generate acidic drainage (and will generate a low to medium salt load); 76% (13 out of 17) of the sandstone samples have no potential to generate acidic drainage (and will generate a very low to no salt load);
  - *Carbonaceous sandstone present as interburden or situated just above the coal horizon:* This lithological unit is slightly carbonaceous and situated in close proximity to the coal horizon. 40% (2 out of 5) of the carbonaceous sandstone samples have a high potential to generate acidic drainage (and generate a high salt load); 20% (1 out of 5) of the carbonaceous sandstone samples have a very low potential to generate acidic drainage (and generate a very low to low salt load); 40% (2 out of 5) of the carbonaceous sandstone samples have no potential to generate acidic drainage (and will generate a very low to no salt load);
  - *Shale present as interburden or situated just above the coal horizon:* 66% (2 out of 3) of the shale samples have a high potential to generate acidic drainage (and generate a high salt load); 33% (1 out of 3) of the shale samples have a very low potential to generate acidic drainage (and generate a very low to low salt load);
  - *Coal:* 100% (4 out of 4) of the raw coal samples have a high potential to generate acidic drainage (and generate a high salt load);
  - *Footwall:* 20% (1 out of 5) of the tillite samples have a low potential for acid generation (and will generate a low to medium salt load); 80% (4 out of 5) of the tillite samples have no potential to generate acidic drainage (and will generate a very low to no salt load);
  - *Coal product:* 50% (2 out of 4) of the coal product samples have a medium to high potential to generate acidic drainage (and to generate a medium to high salt load); and 50% (2 out of 4) of the coal product samples have a very low potential to generate acidic drainage (and generate a very low to low salt load);
  - *Coal discard:* 100% (4 out of 4) of the coal discard samples have a high potential to generate acidic drainage (and generate a high salt load);

- *Comparison between ABA and NAG*: In Figure 2 the NAG value was plotted against the NNP. The NAG test confirms the results of the ABA indicating that the samples acidify during the NAG test when having a negative NNP;
- *Conclusion - waste rock:* Most clastic waste rocks (roughly about 85% of all waste rock) have a very low sulphide content and will not generate acidic drainage. 10% of the clastic waste rocks have a moderate amount of sulphides and have a moderate potential to generate acidic drainage. Roughly about 5% of the clastic rocks (some carbonaceous rocks and especially high sulphide containing sandstone adjacent to coal seams) do however have a significant potential to generate localised acidic drainage and will form localised hot-spots within the backfill. The backfill will, therefore, be a heterogeneous mixture of acid generation and non-acid generation rocks; and
- *Conclusion - coal material:* Overall, the discard has a higher potential than the raw coal to generate acidity while the product has a lower potential. All raw coal and discard samples have a high sulphide content and will generate acidic drainage in the long term although the samples also have some neutralisation potential which will buffer acidification for some time. Coal product from the top seam has a high sulphide content and has a significant potential to generate acidic drainage over the long-term, however, coal product from the other seams has a much lower acidification potential and neutralisation will buffer against acidification for quite some time.

Table 9: Acid-base Accounting (ABA) test results

Borehole ID	Sample nr	Thickness (m)	*	Paste pH	Total %C	Sulphide %S	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
PMK83	1	5.89		6.38	0.116	0.000	0.011	0.000	1.26	1.26	>4	Uncertain	Rock Type IV	Rock Type IV
	2	8.9		7.103	0.020	0.001	0.012	0.019	1.609	0.517	>4	Uncertain	Rock Type IV	Rock Type IV
	3	0.6		6.18	0.304	0.287	0.333	8.96	0.956	-8.01	0.107	Uncertain	Rock Type II	Rock Type II
	4	0.3		3.96	5.09	1.45	1.71	45.4	0.00	-45.4	<1	Rock Type I	Rock Type I	Rock Type I
	5	0.9		7.38	1.37	0.026	0.067	0.803	1.93	1.13	2.41	Uncertain	Rock Type IV	Rock Type III
PMK99	1	7.23		6.91	0.083	0.000	0.022	0.000	3.23	3.23	>4	Uncertain	Rock Type IV	Rock Type IV
	2	11.64		7.43	0.05	0.00	0.01	0.00	5.14	5.14	>4	Uncertain	Rock Type IV	Rock Type IV
	3	3.75		6.94	0.346	0.000	0.029	0.000	5.78	5.78	>4	Uncertain	Rock Type IV	Rock Type IV
	4	0.5		3.99	5.09	2.13	2.49	66.6	2.22	-64.3	0.033	Rock Type I	Rock Type I	Rock Type I
	5	2		7.45	0.186	0.010	0.038	0.322	1.29	0.967	4.00	Uncertain	Rock Type IV	Rock Type IV
	6	3		7.29	0.053	0.137	0.181	4.29	2.57	-1.72	0.599	Uncertain	Rock Type III	Rock Type I
PMK86	1	23.68		7.02	0.09	0.00	0.01	0.00	-3.41	-3.41	>4	Uncertain	Rock Type IV	Rock Type IV
	2	3.87		7.29	0.515	0.000	0.022	0.000	4.74	4.74	>4	Uncertain	Rock	Rock

Borehole ID	Sample nr	Thickness (m)	*	Paste pH	Total %C	Sulphide %S	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
													Type IV	Type IV
	3	7.13		7.93	1.51	0.01	0.05	0.34	12.92	12.52	33.03	Uncertain	Rock Type IV	Rock Type IV
	4	1.2		7.91	0.56	0.117	0.184	3.66	5.10	1.43	1.39	Uncertain	Rock Type III	Rock Type II
	5	4.5		7.82	2.25	0.100	0.280	3.13	67.7	64.6	21.6	Rock Type IV	Rock Type III	Rock Type IV
	6	5		6.61	5.09	1.08	1.16	33.9	8.16	-25.7	0.241	Rock Type I	Rock Type I	Rock Type I
	7	3.7		7.58	0.06	0.114	0.145	3.58	1.02	-2.56	0.285	Uncertain	Rock Type III	Rock Type I
	8	3.3		8.07	0.051	0.217	0.290	6.78	2.34	-4.44	0.345	Uncertain	Rock Type II	Rock Type I
	9	5		7.93	0.029	0.000	0.013	0.000	0	0.000	N/A	Uncertain	Rock Type IV	N/A
PMK 24	1	20		6.89	0.08	0.00	0.01	0.03	2.38	2.33	46.74	Uncertain	Rock Type IV	Rock Type IV
	2	7		7.19	0.06	0.00	0.01	0.04	3.02	2.97	51.31	Uncertain	Rock Type IV	Rock Type IV
	3	2		7.45	2.37	0.061	0.274	1.903	102	100	53.6	Rock Type IV	Rock Type IV	Rock Type IV
	4	1.8		6.66	3.29	0.762	1.13	23.8	10.2	-13.6	0.427	Uncertain	Rock Type I	Rock Type I
	5	1		7.63	0.128	0.049	0.090	1.52	1.02	-0.503	0.669	Uncertain	Rock Type IV	Rock Type I
PMK 25	1	28		6.99	0.05	0.00	0.02	0.01	4.09	4.08	539.69	Uncertain	Rock	Rock

Borehole ID	Sample nr	Thickness (m)	*	Paste pH	Total %C	Sulphide %S	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
													Type IV	Type IV
	2	3.38		7.87	0.090	0.001	0.010	0.016	5.75	5.73	351	Uncertain	Rock Type IV	Rock Type IV
	3	1		8.08	7.23	0.000	0.001	0.000	655	655	>4	Rock Type IV	Rock Type IV	Rock Type IV
	4	6.62		7.95	1.46	0.110	0.217	3.45	13.2	9.72	3.82	Uncertain	Rock Type III	Rock Type III
	5	1		7.81	0.191	0.035	0.185	1.08	8.11	7.03	7.48	Uncertain	Rock Type IV	Rock Type IV
	6	0.4		6.73	2.65	0.000	0.084	0.000	2.05	2.05	>4	Uncertain	Rock Type IV	Rock Type IV
	7	6		7.65	0.364	0.020	0.051	0.619	0.329	-0.290	0.531	Uncertain	Rock Type IV	Rock Type I
Raw coal bottom-seam				7.74	47.1	0.779	0.878	24.3	38.5	14.1	1.58	Uncertain	Rock Type I	Rock Type II
Raw coal lower mid-seam				7.57	49.1	1.33	1.47	41.5	54.2	12.7	1.31	Uncertain	Rock Type I	Rock Type II
Raw coal upper mid-seam				7.46	50.9	2.02	2.09	63.0	58.1	-4.93	0.922	Uncertain	Rock Type I	Rock Type I
Raw coal upper-seam				7.31	62.0	1.79	1.81	56.1	38.5	-17.5	0.687	Uncertain	Rock Type I	Rock Type I
Coal product bottom-seam				6.83	64.6	0.260	0.269	8.13	50.7	42.6	6.24	Uncertain	Rock Type III	Rock Type IV
Coal product lower mid-Seam				6.82	64.6	0.266	0.261	8.31	70.2	61.9	8.45	Uncertain	Rock Type III	Rock Type IV
Coal product upper mid-seam				6.72	65.8	0.321	0.343	10.0	69.7	59.7	6.94	Uncertain	Rock Type I	Rock Type IV

Borehole ID	Sample nr	Thickness (m)	*	Paste pH	Total %C	Sulphide %S	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Coal product upper-seam				6.88	64.1	1.32	1.34	41.3	32.4	-8.92	0.784	Uncertain	Rock Type I	Rock Type I
Discard bottom-seam				6.67	22.2	2.63	3.32	82.3	17.0	-65.4	0.206	Uncertain	Rock Type I	Rock Type I
Discard lower mid-seam				6.83	27.5	2.73	3.02	85.3	39.2	-46.0	0.460	Uncertain	Rock Type I	Rock Type I
Discard upper mid-seam				6.67	22.4	2.38	2.61	74.4	31.3	-43.1	0.421	Uncertain	Rock Type I	Rock Type I
Discard upper seam				6.71	28.6	6.03	7.98	188	31.4	-157	0.167	Uncertain	Rock Type I	Rock Type I

* Orange = Soil and clay, Yellow = Sandstone, Brown = Carboncaeous sandstone, Purple = Shale, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)

Table 10: Average Acid-base Accounting (ABA) results as per lithology

Lithology	Number of samples	*	Paste pH	Total %C	Sulphide %S	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Soil and clay	2		6.65	0.100	0.000	0.016	0.000	2.24	2.24	>4	Rock Type IV	Rock Type IV	Rock Type IV
Sandstone	16*		7.38	0.250	0.049	0.083	1.54	3.78	2.12	149	Uncertain	Rock Type IV	Rock Type IV
Carbonaceous sandstone	5		7.21	2.36	0.298	0.456	9.32	34	25.0	31.1	Rock Type IV	Rock Type II	Rock Type IV
Shale	3		5.30	3.88	1.23	1.47	38.5	5.13	-33.3	1.92	Rock Type I	Rock Type I	Rock Type II

Lithology	Number of samples	*	Paste pH	Total %C	Sulphide %S	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP $CaCO_3$ kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Tillite	5		7.48	0.420	0.048	0.085	1.51	1.43	-0.084	1.64	Uncertain	Rock Type IV	Rock Type II
Raw Coal	4		7.52	52.3	1.48	1.56	46.2	47.3	1.10	1.12	Uncertain	Rock Type I	Rock Type II
Coal product	4		6.81	64.8	0.543	0.552	17.0	55.8	38.8	5.60	Uncertain	Rock Type I	Rock Type IV
Coal discard	4		6.72	25.1	3.44	4.23	108	29.7	-77.9	0.313	Uncertain	Rock Type I	Rock Type I

* Orange = Soil and clay, Yellow = Sandstone, Brown = Carboncaeous sandstone, Purple = Shale, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)

*PMK25 #3 is not included as it is an outlier with an NP of 655

Table 11: Average Acid-base Accounting (ABA) results as per stratigraphy for waste rocks

Stratigraphy	Number of samples	Paste pH	Total %C	Sulphide %S	Total %S	AP $CaCO_3$ kg/t	NP $CaCO_3$ kg/t	NNP CaCO3 kg/t	NP/AP	Rock Type NNP	Rock Type %S	Rock Type NP/AP
Overburden waste rock	22	7.42	1.01	0.08	0.13	2.63	41.32	38.63	85.43	Rock Type IV	Rock Type IV	Rock Type IV
Interburden waste rock	5	5.50	3.28	0.93	1.15	28.94	3.08	-25.86	0.19	Rock Type I	Rock Type I	Rock Type I
Basement waste rock	5	7.48	0.42	0.05	0.09	1.51	1.43	-0.08	1.64	Uncertain	Rock Type IV	Rock Type II

Table 12: Potential for various lithologies to generate acid drainage

Lithology	Number of samples	%S > 0.3	%S > 0.3	%S 0.1 - 0.3	%S 0.1 - 0.3	%S <0.1	%S <0.1
		NP/AP < 2	NP/AP > 2	NP/AP <2	NP/AP > 2	NP/AP < 2	NP/AP > 2
Soil and clay	2						100%
Sandstone	17			24%			76%
Carbonaceous sandstone	5	40%			20%		40%
Shale	3	66%			33%		
Tillite	5			20%		40%	40%
Raw coal	4	100%					
Coal product	4	25%	25%		50%		
Coal discard	4	100%					
Potential for acid mine drainage		Likely/possibly acid generating. High salt load.	Medium potential for acid generation. Medium to high salt load.	Low to medium potential for acid generation. Low to medium salt load.	Very low potential for acid generation. Very low to low salt load.	No potential for acidic drainage. Very low/no salt load.	No potential for acidic drainage. Very low/no salt load.

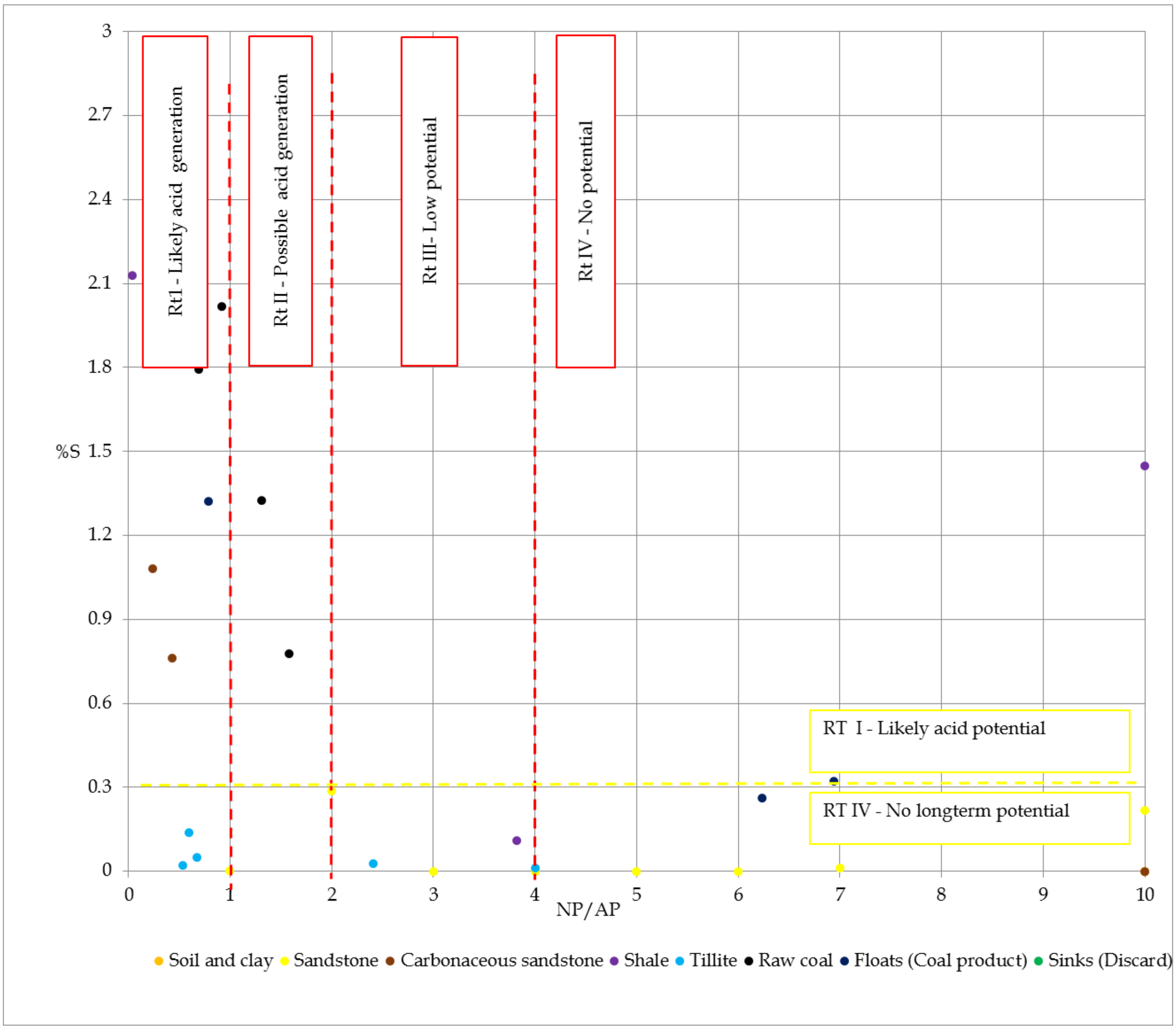

Figure 1: Classification of samples in terms of %S (samples below 3%) and NP/AP (samples below 10)

Table 13: Net acid generation (NAG) test results

Borehole ID	Sample nr	*	NAG pH: (H_2O_2)	NAG (kg H_2SO_4/t)	NNP ($CaCO_3$ kg/t)	Rock Type
PMK83	1		4.94	0.000	1.26	Rock Type IV
	2		5.19	0.000	0.517	Rock Type IV
	3		2.97	7.60	-8.00	Rock Type Ib
	4		2.41	38.0	-45.4	Rock Type I
	5		3.57	2.01	1.13	Rock Type Ib
PMK99	1		6.86	0.000	3.23	Rock Type IV
	2		5.15	0.000	5.14	Rock Type IV
	3		5.54	0.000	5.78	Rock Type IV

Borehole ID	Sample nr	*	NAG pH: (H_2O_2)	NAG (kg H_2SO_4/t)	NNP ($CaCO_3$ kg/t)	Rock Type
	4		2.34	55.2	-64.3	Rock Type I
	5		4.23	0.500	0.967	Rock Type Ib
	6		3.57	1.80	-1.72	Rock Type Ib
PMK86	1		5.34	0.000	-3.41	Uncertain
	2		4.93	0.000	4.74	Rock Type IV
	3		6.38	0.000	12.5	Rock Type IV
	4		3.97	1.40	1.43	Rock Type Ib
	5		7.51	0.000	64.6	Rock Type IV
	6		2.61	26.5	-25.7	Rock Type I
	7		3.62	1.60	-2.56	Rock Type Ib
	8		3.2	3.30	-4.44	Rock Type Ib
	9		4.77	0.000	0.000	Rock Type IV
PMK 24	1		5.41	0.000	2.33	Rock Type IV
	2		5.90	0.000	2.97	Rock Type IV
	3		7.99	0.000	100	Rock Type IV
	4		2.94	11.7	-13.6	Rock Type I
	5		4.09	0.848	-0.503	Rock Type Ib
PMK 25	1		6.18	0.000	4.08	Rock Type IV
	2		5.67	0.000	5.73	Rock Type IV
	3		7.61	0.000	655	Rock Type IV
	4		5.84	0.000	9.72	Rock Type IV
	5		6.26	0.000	7.03	Rock Type IV
	6		3.44	4.05	2.05	Rock Type Ib
	7		3.95	1.15	-0.290	Rock Type Ib
Raw coal bottom-seam			6.94	0	14.1	Rock Type IV
Raw coal lower mid-seam			6.14	0	12.7	Rock Type IV
Raw coal upper mid-seam			2.1	60.4	-4.93	Rock Type I
Raw coal upper-seam			2.07	53.5	-17.5	Rock Type I
Coal product bottom-seam			7.08	0	42.6	Rock Type IV
Coal product lower mid-seam			6.77	0	61.9	Rock Type IV
Coal product upper mid-seam			6.85	0	59.7	Rock Type IV
Coal product upper-seam			2.15	41.2	-8.92	Rock Type Ia
Discard bottom-seam			2.27	57.9	-65.4	Rock Type Ia

Borehole ID	Sample nr	*	NAG pH: (H_2O_2)	NAG (kg H_2SO_4/t)	NNP ($CaCO_3$ kg/t)	Rock Type
Discard lower mid-Seam			2.57	35.2	-46.0	Rock Type Ia
Discard upper mid-seam			2.55	35.0	-43.1	Rock Type Ia
Raw coal bottom-seam			2.19	137	-157	Rock Type Ia

* Orange = Soil and clay, Yellow = Sandstone, Brown = Carboncaeous sandstone, Purple = Shale, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)

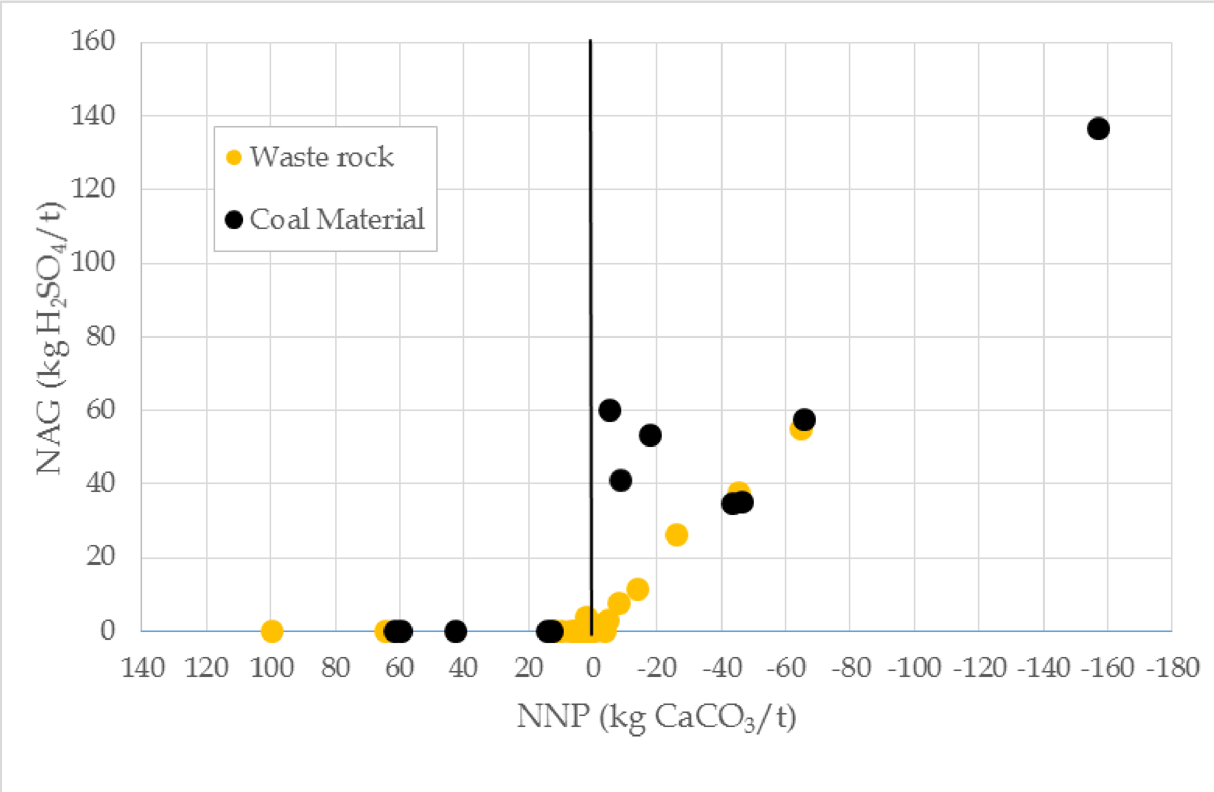

Figure 2: Graph of the correlation of the NAG value against the NNP

5 WASTE CLASSIFICATION

5.1 LEGAL FRAMEWORK

5.1.1 RELEVANT WASTE ACT DOCUMENTATION:

The classification and definitions herein considered the following documents:

- National Environmental Management: Waste Act 59 of 2008 (hereafter called NWA 59 of 2008) as amended by:
    - National Environmental Management Laws Amendment Act 14 of 2013 - Government Notice 530 in Government Gazette 36703 dated 24 July 2013. Commencement date: 24 July 2013;
    - National Environmental Management: Waste Act 59 of 2008 - Commencement of Part 8 in Chapter 4 (sections 35 – 41) – 2 May 2014 [Proc. No. 26, Gazette No. 37547 dated 11 April 2014];
    - National Environmental Management: Waste Amendment Act 26 of 2014 - Government Notice 449 in Government Gazette 37714 dated 2 June 2014. Commencement date: 2 June 2014; and
    - National Environmental Management Laws Amendment Act 25 of 2014 – Government Notice 448 in Government Gazette 37713 dated 2 June 2014. Commencement date: 2 September 2014.
- Government Notice 635, National Environmental Management: Waste Act 59 of 2008: National Norms and Standards for the Assessment of Waste for Landfill Disposal (hereafter called GNR 635); and
- Government Notice 636, National Environmental Management: Waste Act 59 of 2008: National Norms and Standards for Disposal of Waste to Landfill (hereafter called GNR 636).

5.2 SCHEDULE 3 DEFINED WASTES:

Several waste types are defined in Schedule 3 of the Waste Amendment Act 26 of 2014 as Category A (Hazardous waste) or Category B (General waste). The following summarizes the schedule as far as it may concern residue mine material:

Category A: Hazardous Waste

"hazardous waste" means any waste that contains organic or inorganic elements or compounds that may, owing to the inherent physical, chemical or toxicological characteristics of that waste, have a detrimental impact on health and the environment and includes hazardous substances, materials or objects within business waste, residue deposits and residue stockpiles as outlined below.

In terms of mine residue waste which is included under Schedule 3, Category A:

"*residue deposits*" means any residue stockpile remaining at the termination, cancellation or expiry of a prospecting right, mining right, mining permit, exploration right or production right;

"*residue stockpile*" means any debris, discard, tailings, slimes, screening, slurry, waste rock, foundry sand, mineral processing plant waste, ash or any other product derived from or incidental to a mining operation and which is stockpiled, stored or accumulated within the mining area for potential re-use, or which is disposed of, by the holder of a mining right, mining permit or, production right or an old order right, including historic mines and dumps created before the implementation of this Act.

Residue deposits and residue stockpiles include:

Wastes resulting from exploration, mining, quarrying, and physical and chemical treatment of minerals	(a) wastes from mineral excavation
	(b) wastes from physical and chemical processing of metalliferous minerals
	(c) wastes from physical and chemical processing of non-metalliferous minerals
	(d) wastes from drilling muds and other drilling operations

Category B: General Waste

"general waste" means waste that does not pose an immediate hazard or threat to health or to the environment, and includes-

(a) domestic waste;

(b) building and demolition waste;

(c) business waste;

(d) inert waste; or

(e) any waste classified as non-hazardous waste in terms of the regulations made under section 69, and includes non-hazardous substances, materials or objects within business, domestic, inert, building and demolition wastes as outlined below:

"inert waste" means waste that:

(a) Does not undergo any significant physical, chemical or biological transformation after disposal;

(b) Does not burn, react physically or chemically biodegrade or otherwise adversely affect any other matter or environment with which it may come into contact; and

(c) Does not impact negatively on the environment, because of its pollutant content and because the toxicity of its leachate is insignificant; and which include:

Inert waste	(a) discarded concrete, bricks, tiles and ceramics
	(b) discarded glass

	(c) discarded soil, stones and dredging spoil

5.3 WASTE CLASSIFICATION

5.3.1 METHODOLOGY

- The material was evaluated according to Government Notice 635, National Environmental Management: Waste Act 59 of 2008: National Norms and Standards for the Assessment of Waste for Landfill Disposal (hereafter called GNR 635);
- According to GNR 635 all the chemicals that could reasonably be expected to occur in the waste should be tested for: "*The TC of all the elements and chemical substances specified in section 6 of these Norms and Standards that are known to occur, likely to occur or can reasonably be expected to occur in the waste must be determined*";
- According to GNR 635 the test results should be compared to the total and leachable concentration thresholds as follows: "*The total concentration (TC) and leachable concentrations (LC) limits of the chemical substances in the waste must be compared to the threshold limits specified in section 6 of these Norms and Standards for total concentrations (TCT) and leachable concentrations (LCT) of specific elements and chemical substances. Based on the TC and LC limits of the elements and chemical substances in the waste exceeding the corresponding TCT and LCT limits respectively, the specific type of waste for disposal to landfill must be determined in terms of section 7 of these Norms and Standards*";
- According to GNR 635 the particular waste destined for disposal to landfill, the type of waste is determined as follows:
  a. Wastes with any element or chemical substance concentration above the LCT3 or TCT2 limits (LC> LCT3 or TC> TCT2) are Type 0 Wastes;
  b. Wastes with any element or chemical substance concentration above the LCT2 but below or equal to the LCT3 limits, or above the TCT1 but below or equal to the TCT2 limits (LCT2 < LC ≤ LCT3 or TCT1 <TC ≤ TCT2), are Type 1 Wastes;
  c. Wastes with any element or chemical substance concentration above the LCT1 but below or equal to the LCT2 limits and all concentrations below or equal to the TCT1 limits (LCT1 < LC ≤ LCT2 and TC ≤ TCT1) are Type 2 Wastes;
  d. Wastes with any element or chemical substance concentration above the LCT0 but below or equal to the LCT1 limits and all TC concentrations below or equal to the TCT1 limits (LCT0 < LC ≤ LCT1 and TC ≤ TCT1) are Type 3 Wastes;
  e. Wastes with all element and chemical substance concentration levels for metal ions and inorganic anions below or equal to the LCT0 and TCT0 limits (LC ≤ LCT0 and TC ≤ TCT0), and with all chemical substance concentration levels also below the following total concentration limits for organics and pesticides, are Type 4 Wastes;
  f. Notwithstanding the above, wastes with all element or chemical substance leachable concentration levels for metal ions and inorganic

anions below or equal to the LCT0 limits are considered to be Type 3 Waste, irrespective of the total concentration of elements or chemical substances in the waste; and

- The TC of the material was also evaluated against the Average Upper Crust (AUC). This was performed in order to indicate how background rock would classify according to the TC. The average composition of the upper continental crust was determined from weighted averages of the compositions of rocks exposed at the surface Rudnick and Gao (2003).

5.3.2 CLASSIFICATION RESULTS

The test results are presented as follows:

- Table 14 presents the total concentration of some elements as determined by Aqua Regia digestion, the average upper crust (AUC), as well as the Total Concentration Threshold (TCT) listed under Section 6 of GNR 635; and
- Table 15 presents the test results of reagent water leaching for monofilled waste according to AS 4439.3 for the different materials.

With regard to the classification results, the following:

- The TC of the aqua regia leachate was below TCT1 for all parameters but above TCT0 in the following samples:
  - PMK99 #1 leached Ba, Cu, Mn, Mo, and Pb above TCT0;
  - PMK99#5 leached Cu above TCT0;
  - PMK99#6 leached Cu above TCT0;
  - PMK25#3 leached Cu above TCT0;
  - Bottom seam raw coal leached Pb above TCT0;
  - Upper mid-seam raw coal leached Cu above TCT0;
  - Upper seam raw coal leached Cu above TCT0;
  - Bottom seam coal product leached Pb above TCT0;
  - Lower mid-seam leached coal product leached Ba above TCT0;
  - Bottom seam discard leached Cu and Pb above TCT0;
  - Lower mid-seam discard leached Cu above TCT0;
  - Upper mid-seam discard leached Cu above TCT0; and
  - Upper seam discard leached As, Cu, and Pb above TCT0;
- It is recommended that the rock samples are not strictly classified according to the TCT0 value because of the low TCT0 threshold values. The AUC in Table 23 represents the average concentration of elements in the upper continental crust including rock (sub)-outcrops and serves as a background reference for the geochemical composition of rock near the earth's surface. The TCT0 for Ba and Cu are below the AUC; for As, Mn and Pb, the TCT0 is close to (not more than twice) the AUC. This implies that almost all natural rock and soils in the earth crust would classify as Type 3 waste based upon the TCT0 value;

- The LC of the reagent water leach was above LCT0 in the following samples:
  - Lower mid-seam coal product leached Ba above LCT0
  - Upper mid-seam coal product leached Ba above LCT0;
  - Bottom seam discard leached As above LCT0; and
  - Upper mid-seam discard leached chloride and Cd above LCT0.
- The rock samples are classified as follows according to the LCT threshold:
  - It is recommended that the waste rock is classified as Type 4 waste as there were no parameters that exceeded the LCT0 range;
  - Some coal material (coal, discard, coal product) had a few parameters exceeding the LCT0 and thus should be classified as Type 3 waste;
  - Coal material in contact with the atmosphere will result in oxidization of the pyrite and subsequent acidification. It is therefore recommended that the coal material is not subjected to atmospheric conditions as far as possible as this will limit the contamination of water seepage from the material; and
  - The COD of the waste rock sample indicated no organic content and further testing for organic material would not be required.

5.3.3 DISPOSAL OF MATERIAL

The following relate to the disposal of the material according to GNR 635:

- The Class D liner setup is depicted in Figure 3 below. According to GNR 636: "*Type 4 waste may only be disposed of at a Class D landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a G:L:B+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (2nd Ed., DWAF, 1998)*"; and
- The Class C liner setup is depicted in Figure 4 below. According to GNR 636: "*Type 3 Waste may only be disposed of at a Class C landfill designed in accordance with section 3(1) and (2) of these Norms and Standards, or, subject to section 3(4) of these Norms and Standards, may be disposed of at a landfill site designed in accordance with the requirements for a G:L:B+ landfill as specified in the Minimum Requirements for Waste Disposal by Landfill (DWAF MR, 1998)*".

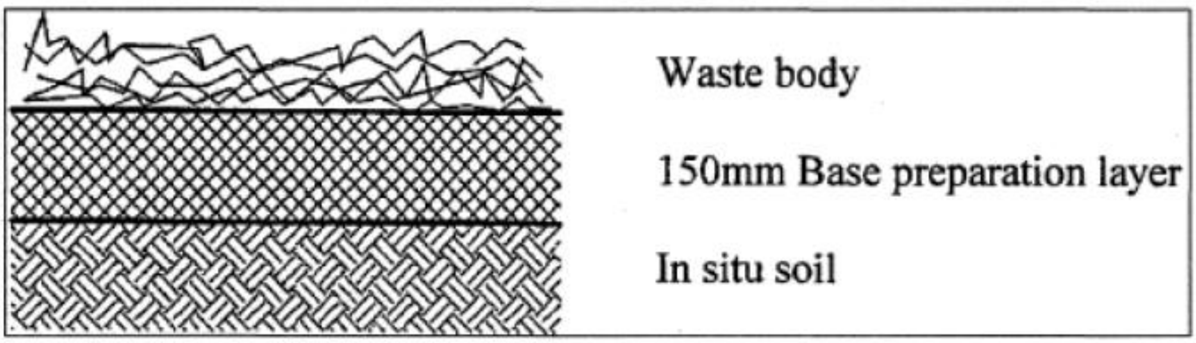

Figure 3: Class D landfill (GNR 636)

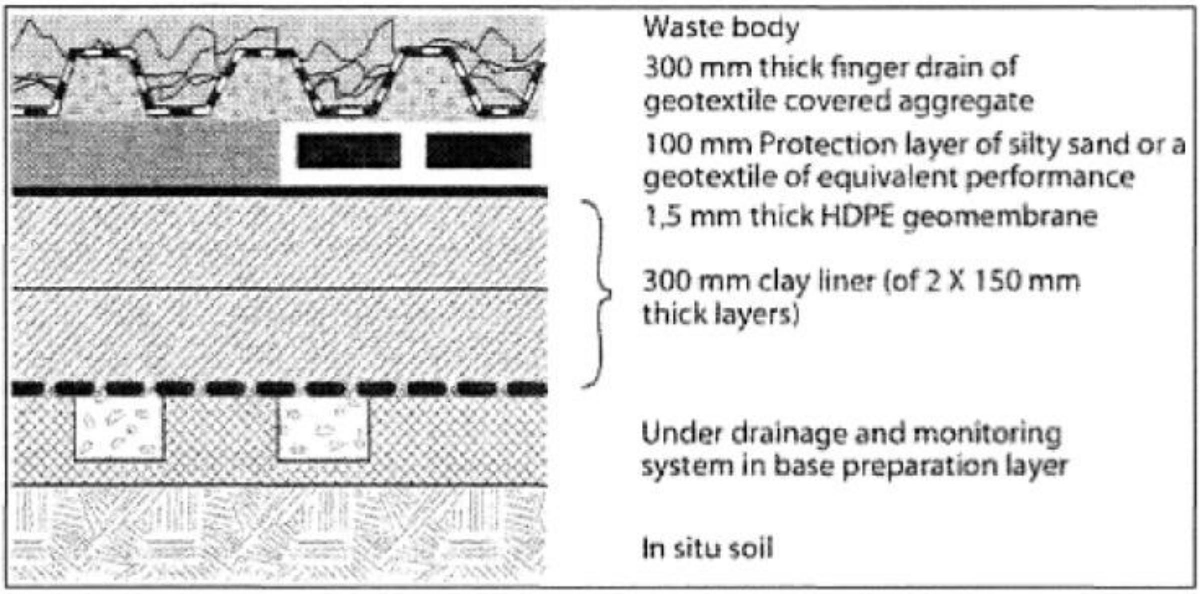

Figure 4: Class C landfill (GNR 636)

Table 14: Total concentration of parameters as determined by ICP after aqua regia digestion (mg/kg)

	Aqua Regia																				*** GNR 635		
Lab ID	CJP558	CJP559	CJP563	CJP565	CJP573	CJP574	CJP590	DLJ 401	DLJ 402	DLJ 403	DLJ 404	DLJ 415	DLJ 416	DLJ 417	DLJ 418	DLK 501	DLK 502	DLK 503	DLK 504	**AUC	TCT 0	TCT 1	TCT 2
Sample ID	PMK99 #1	PMK99 #2	PMK99 #3	PMK99 #5	PMK86 #5	PMK86 #6	PMK 25 # 3	Bottom seam	Lower mid-seam	Upper mid-seam	Upper seam	Bottom seam	Lower mid-seam	Upper mid-seam	Upper seam	Bottom Seam	Low Mid-Seam	Upper Mid Seam	Upper Seam				
*																							
Al	40382	10905	10034	8267	17901	19630	12589	6976	6519	7415	2854	4602	3296	3823	2233	8131	8219	9971	5930	-	-	-	-
As	<3	<3	<3	<3	<3	<3	<3	1.97	1.23	2.61	4.6	1.46	<1	1.33	1.85	4.92	3.29	2.27	7.95	4.8	5.8	500	2000
B	18.5	17	13.9	<3	13.8	10.6	10.5	1.24	17.4	41.6	41.3	3.15	23.9	35.1	45.3	7.08	18.7	26.4	40.1	17	62.5	6250	25000
Ba	398	70.4	27	43	57.3	89.8	92.4	25.5	31.8	42.6	22.6	138	220	100	13.9	11.2	17.8	32.1	8.41	628	150	15000	60000
Be	<3	<3	<3	<3	<3	<3	<3	1.47	1.46	1.48	<1	1.23	1.13	1.23	<1	1.5	1.5	1.16	<1	2.1	-	-	-
Ca	1792	1865	780	357	18266	1509	169658	9308	12069	16267	9700	12229	16310	14661	9912	6960	14524	11209	12168	-	-	-	-
Cd	<3	<3	<3	<3	<3	<3	<3	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.09	7.5	260	1040
Co	27.6	5.17	3.9	4.12	8.89	14.5	4.5	2.46	1.6	1.43	3.05	2.7	1.03	1.06	1.04	4.42	1.48	<1	5.07	17.3	50	5000	20000
Cr	147	34.6	29.1	22.6	48.1	47.6	17.2	11.6	8.53	14.9	17.2	8.69	6.04	8.58	12.2	12	9.66	14.1	30.9	92	46000	800000	N/A
Cu	62.1	9.86	6.75	21.9	23	32.9	21.9	10.6	12.9	26.4	17.3	4.71	3.77	4.9	14.3	55	49.8	49.6	183	28	16	19500	78000
Fe	73744	19614	13454	1338	32038	32466	36913	3426	5466	10898	6827	1072	981	1324	4615	20183	19031	17267	55847	-	-	-	-
K	2863	2893	2851	937	5457	4838	2212	655	753.3	1345	380	618	745	893	309	715	858	1479	740	-	-	-	-
Mg	3099	1361	1725	268	4376	5716	3313	2370	3266	3781	1379	2711	3540	3006	1337	1702	2752	2405	1548	-	-	-	-
Mn	1499	276	202	49	290	269	847	90.7	87.8	91.3	30.4	146	103.5	99	28	56.1	70.5	58.8	47.4	632	1000	25000	100000
Mo	70.9	15.6	9.42	11.8	27.9	32.7	19.2	19	16.8	20.3	9.17	13	8.79	9.99	6.66	21.7	23	28.4	23.5	1.1	40	1000	4000
Na	281	194	178	171	221	308	189	320	281.8	351	78	354	368	243	174	388	352	331	7.38	-	-	-	-
Ni	42.7	12.6	7.76	10.1	16.4	33.9	10.7	11.3	6.13	4.83	16.8	12.2	3.07	3.38	9.89	20.3	7.28	6.31	18.2	47	91	10600	42400
Pb	20.6	9.43	7.31	13.6	12.9	16.2	6.98	25.5	6.6	8.32	12.2	25.5	7.05	6.18	8.42	33.9	12.5	8.76	15.4	17	20	1900	7600

	Aqua Regia																			**AUC	*** GNR 635		
Lab ID	CJP558	CJP559	CJP563	CJP565	CJP573	CJP574	CJP590	DLJ 401	DLJ 402	DLJ 403	DLJ 404	DLJ 415	DLJ 416	DLJ 417	DLJ 418	DLK 501	DLK 502	DLK 503	DLK 504		TCT 0	TCT 1	TCT 2
Sample ID	PMK99 #1	PMK99 #2	PMK99 #3	PMK99 #5	PMK86 #5	PMK86 #6	PMK 25 # 3	Bottom seam	Lower mid-seam	Upper mid-seam	Upper seam	Bottom seam	Lower mid-seam	Upper mid-seam	Upper seam	Bottom Seam	Low Mid-Seam	Upper Mid Seam	Upper Seam				
*																							
Sb	<5	<5	<5	<5	<5	<5	<5	<1	<1	<1	<1	<1	<1	<1	1.04	<1	1.33	<1	<1	0.4	10	75	300
Se	<5	<5	<5	<5	<5	<5	<5	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	0.09	10	50	200
Sr	<3	5.89	<3	9.5	18.9	<3	83.4	135	288	691.4	86.6	156	322	654	66.4	80.3	233	591	42.4	320	-	-	-
V	98.5	18	15.1	4.21	27.9	38.1	14.7	17.2	16.1	19.2	29.7	17	16.7	13.3	24.1	12.1	16.4	16.2	29.5	97	150	2680	10720
Zn	29.8	34	31.4	24.4	45.9	92	28.2	11.2	6.79	8.25	10.3	10.8	8.9	5.51	5.05	16.1	5.27	6.02	11.9	67	240	160000	640000
* Orange = Soil and clay, Yellow = Sandstone, Brown = Carbonaceous sandstone, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)																							

***AUC = Average Upper Crust (Rudnick and Gao, 2003)*

**** GNR 635 = Government Notice 635, National Environmental Management: Waste Act 59 of 2008: National Norms and Standards for the Assessment of Waste for Landfill Disposal*

Table 15: Analyses of the reagent water leach AS 4439.3 (mg/l)

Distilled Water Leach (1:20)																				*GNR 635 Reagent water leach 1:20 (AS 4439.3)			
Sample ID	PMK 99 #1	PMK 99 #2	PMK 99 #3	PMK 99 #5	PMK 86 #5	PMK 86 #6	PMK 25 #3	Bottom seam coal	Lower mid-seam	Upper mid-seam	Upper seam	Bottom seam coal	Lower mid-seam	Upper mid-seam	Upper seam	Bottom Seam	Low Mid-Seam	Upper Mid Seam	Upper Seam	LCT 0	LCT 1	LCT 2	LCT 3
*																							
COD	0	7.7	2.8	6.8	8.1	10.2	6.3	9.0	9.2	28.5	-	15.9	26.1	26.7	-	21.4	29.6	18.9	19.5	-	-	-	-
pH	6.95	7.27	7.25	7.2	7.73	7.61	8.16	8.04	8.02	7.93	8.05	8.04	8.03	8	8.07	8	8.03	8.08	7.99	-	-	-	-
Sulphate as SO_4	<5	<5	8.69	<5	9.74	55	<5	27.1	38.3	52.5	56.8	<5	<5	<5	43.4	85.6	51.9	51	162	250	12500	25000	100000
Chloride as Cl	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5.12	198	147	157	88.7	194	294	356	164	300	15000	30000	12000
Nitrate as N	<0.2	2.05	0.42	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	11	550	1100	4400
Fluoride as F	0.64	0.31	0.35	0.33	0.37	<0.1	0.31	0.24	0.36	0.26	0.13	0.15	0.21	0.15	0.14	0.24	0.35	0.29	0.2	1.5	75	150	600
As	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.011	<0.01	<0.01	<0.01	0.01	0.5	1	4
B	<0.01	<0.01	0.014	0.023	0.022	<0.01	<0.01	0.107	0.231	0.352	0.228	0.084	0.223	0.32	0.197	0.097	0.218	0.239	0.142	0.5	25	50	200
Ba	<0.01	0.014	<0.01	<0.01	0.026	0.032	<0.01	0.106	0.294	0.363	0.205	0.372	0.774	0.927	0.277	0.313	0.426	0.408	0.158	0.7	35	70	280
Cd	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.004	<0.003	0.003	0.15	0.3	1.2
Co	<0.01	<0.01	<0.01	<0.01	<0.01	0.013	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.5	25	50	200
Cr	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.1	5	10	40
Cu	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.038	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	2	100	200	800
Mn	<0.06	<0.06	<0.06	<0.06	<0.06	0.107	<0.06	<0.06	<0.06	<0.06	<0.06	0.147	<0.06	0.074	<0.06	0.165	0.071	0.068	0.072	0.5	25	50	200
Mo	<0.01	<0.01	<0.01	<0.01	0.012	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.015	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.015	0.07	3.5	7	28
Ni	<0.01	<0.01	<0.01	<0.01	<0.01	0.022	0.023	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	3.5	7	28
Pb	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.5	1	4
Sb	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.02	1	2	8
Se	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.5	1	4

	Distilled Water Leach (1:20)																			*GNR 635 Reagent water leach 1:20 (AS 4439.3)			
Sample ID	PMK 99 #1	PMK 99 #2	PMK 99 #3	PMK 99 #5	PMK 86 #5	PMK 86 #6	PMK 25 #3	Bottom seam coal	Lower mid-seam	Upper mid-seam	Upper seam	Bottom seam coal	Lower mid-seam	Upper mid-seam	Upper seam	Bottom Seam	Low Mid-Seam	Upper Mid Seam	Upper Seam	LCT 0	LCT 1	LCT 2	LCT 3
*																							
V	0.012	0.01	<0.01	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.2	10	20	80
Zn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.029	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	5	250	500	2000

* Orange = Soil and clay, Yellow = Sandstone, Brown = Carbonaceous sandstone, Light blue = Tillite, Black = Raw coal, Dark blue = Floats (Coal product), Green = Sinks (Discard)

6 FINAL DISCUSSION AND CONCLUSIONS

Based on the results of the geochemical assessment, the following conclusions could be made:

Acid-base testing

- Most clastic waste rocks (roughly about 85% of all waste rock) have a very low sulphide content and will not generate acidic drainage. 10% of the clastic waste rocks have a moderate amount of sulphides and have a moderate potential to generate acidic drainage. Roughly about 5% of the clastic rocks (especially carbonaceous rocks and high sulphide containing sandstone adjacent to coal seams) do however have a significant potential to generate localised acidic drainage and will form localised hot-spots within the backfill. The backfill will, therefore, be a heterogeneous mixture of acid generation and non-acid generation rocks;
- The discard has a higher potential than the raw coal to generate acidity while the product has a lower potential. All raw coal and discard samples have a high sulphide content and will generate acidic drainage in the long term although the samples also have some neutralisation potential which will buffer acidification for some time. Coal product from the top seam has a high sulphide content and has a significant potential to generate acidic drainage over the long-term, however, coal product from the other seams has a much lower acidification potential and neutralisation will buffer against acidification for quite some time;

Waste classification

- It is recommended that the waste rock is classified as Type 4 waste as there were no parameters that exceeded the LCT0 range;
- Some coal material (coal, discard, coal product) had a few parameters exceeding the LCT0 and thus should be classified as Type 3 waste;

The following aspects will be included in the final geochemical report

- Kinetic leach tests are being performed on waste rock and coal discard samples;
- Conceptual modeling will be conducted in order to determine the physical-chemical processes and potential impacts of the discard dumps and pit backfill;
- Numerical geochemical modeling will be performed in order to estimate the long-term pit water quality with and without discard as well as long-term seepage water quality from the discard dump;

Recommendations from preliminary report

- Coal material in contact with the atmosphere will result in oxidization of the pyrite and subsequent acidification. It is therefore recommended that the coal material is not subjected to atmospheric conditions as far as possible as this will limit the contamination of water seepage from the material. A permanent discard dump on the surface will result in acidification of its seepage water while previous studies have shown that the correct backfilling of discard may result in less water being contaminated. The backfilling of discard will be further investigated and reported in the final geochemical report.

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APPENDIX A

PALMIETKUILEN COLLIERY GEOCHEMICAL ASSESSMENT

DESCRIPTION OF WASTE ROCK SAMPLES

APPENDIX A - Table 16: Description of samples

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 83 #1	1	0-5.89	5.89		Soil and clay	
PMK 83 #2	2	8.68-17.58	8.90		Weathered sandstone with subordinate siltstone layers	
PMK 83 #3	3	22-22.6	0.600		Sandstone	
PMK 83 #4	4	23.30-23.60	0.300		Shale	

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 83 #5	5	46.1-47	0.900		Tillite	
PMK 99 #1	1	0-7.23	7.23		Soil and clay	
PMK 99 #2	2	8.33-19.97	11.64		Weathered yellow sandstone	
PMK 99 #3	3	19.97-23.72	3.75		Grey sandstone with subordinate mudstone layers	

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 99 #4	4	27.50-28.00	0.500		Shale	
PMK 99 #5	5	48.00-50.00	2.00		Tillite	
PMK 99 #6	6	50.00-53.00	3.00		Tillite	
PMK 86 #1	1	0.00-23.68	23.68		Highly weathered sandstone	

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 86 #2	2	23.68-27.55	3.87		Carbonaceous sandstone with subordinate layers of siltstone	
PMK 86 #3	3	27.55-34.68	7.13		Carbonaceous sandstone and siltstone with carbonate vein	
PMK 86 #4	4	35.80-37.00	1.20		Carbonaceous sandstone with subordinate layers of siltstone	
PMK 86 #5	5	37.50-42.00	4.50		Carbonaceous sandstone with singular thick chlorite layer	

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 86 #6	6	45-50	5.00		Carbonaceous sandstone with subordinate mudstone and siltstone	
PMK 86 #7	7	50.00-53.70	3.70		Coarse white sandstone	
PMK 86 #8	8	53.70-57.00	3.30		Sandstone with subordinate layers of siltstone	
PMK 86 #9	9	57.00-62.00	5.00		Coarse red and brown sandstone	

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 24 #1	1	5.00-27.00	20.00		Highly weathered sandstone	
PMK 24 #2	2	27.00-34.00	7.00		Coarse grey and brown sandstone with subordinate layers of siltstone	
PMK 24 #3	3	35.00-37.00	2.00		Fine grey carbonaceous sandstone with subordinate layers of carbonaceous siltstone	
PMK 24 #4	4	40.00-41.80	1.80		Carbonaceous coarse sandstone and interlayered shale	

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 24 #5	5	58.00-59.00	1.00		Tillite	
PMK 25 #1	1	0-28	28.00		Highly weathered sandstone with subordinate layers siltstone	
PMK 25 #2	2	28-31.38	3.38		Coarse grey sandstone	
PMK 25 #3	3	31.38-32.38	1.00		Coarse sandstone with carbonates	

ID	Sample Nr	Depth (m)	Thickness	*	Description	Sample photo
PMK 25 #4	4	32.38-39	6.62		Carbonaceous shale with sandstone lenses	
PMK 25 #5	5	39-40	1.00		Sandstone	
PMK 25 #6	6	40-40.4	0.400		Carbonaceous sandstone	
PMK 25 #7	7	80-86	6.00		Tillite