# Acid-Base Potential Characterisation in the Southern Highveld Coalfield of Mpumalanga

**by**

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# CHAPTER 1 INTRODUCTION

## 1.1 Background information

Coal is valued for its energy content and has been widely used to generate electricity. 77% percent of South Africa's total electrical energy is generated from coal. According to Trending Top Most report of 2017 (www.trendingtopmost.com), South Africa is ranked seventh in the global coal production after China, United States, India, Australia, Indonesia and Russia. It produces about 260 million tons of coal and is the sixth largest coal exporter having traded about 74 million tons in 2012. The coal is mainly exported to Europe, China and India.

Coal is generally mined by opencast/open pit or underground methods in South Africa. Fifty-one percent of South African coal is produced by underground mining and 49 percent is produced by open cast methods (Department of Energy, 2014). During both coal mining processes, a variety of rock types with different compositions are removed from the surrounding and exposed to atmospheric condition and undergo accelerated weathering (Bhuiyan *et al.*, 2010). These materials are often deposited nearby as mine waste rocks and mine dust which causes a number of environmental problems such as Acid Mine Drainage (AMD).

By definition, AMD is acidic water that is produced when sulphide minerals are exposed to air and water resulting in a chemical reaction that produces acidic mine water (www.miningfacts.org). It is widely accepted that AMD and its potential impact on groundwater resources is one of the most serious environmental concern associated with coal mining (Brady *et al.*, 1997 and Bell *et al.*, 2001). It is therefore seen as one of the great threats to the water resources in South Africa, and it is imperative that the mining industries are able to predict and evaluate the environmental consequences (Usher, 2003) resulting from the AMD. In the mining areas, AMD is the main contaminant of water resources which can render it unsafe for consumption, industrial and agricultural applications. Vermeulen and Usher (2009) reported that water related problems, largely associated with water quality deterioration, due to pyrite oxidation, occur as a result of mining in the South African coal fields. When the acidic mine water is released into the environment, the high salinities of this drainage degrade the water quality considerably (Vermeulen & Usher, 2009).

Today, there are many measures that can be used to investigate the potential impact or effects of AMD, such methods include: Kinetic method, Modelling of oxidation, pollutant generation and release, Modelling of material composition and Acid Base Accounting (ABA). Due to its simplicity, the ABA method is a commonly and preferred method. The ABA provides the basis for evaluating acid mine production potential of ore and waste rock. This study was aimed at assessing the Acid Base Potential of two mines located in the Southern Highveld Coalfield of Mpumalanga using the ABA method.

### 1.1.1 Research aims and objectives

The aim of the study was to assess the acid base potential and leaching of trace elements at Mine 1 and 2 in the Highveld Coalfields in Mpumalanga. The aims were achieved through the following specific objectives:

- Review of the literature on coal mining and its potential environmental impacts in South Africa,
- Collection of geological samples,
- Analysis of mineralogy of samples and determination of the chemical composition of the whole rock and
- Conduct acid base accounting tests.

### 1.1.2 Structure of the dissertation

This dissertation consists of 6 chapters:

- Chapter 1 is the introduction of the dissertation,
- Chapter 2 is a discussion of the study area which includes location, geology, geohydrology and climate,
- Chapter 3 gives a literature background of AMD and the factors that are involved in the process of AMD,
- Chapter 4 investigates the methods that are necessary for geochemical characterisation that were used during analysis,
- Chapter 5 provides results and discussions, and
- Chapter 6 provides conclusion and recommendation of the overall study.

## CHAPTER 2 STUDY AREA DESCRIPTION

## 2.1 Study area location

The study was conducted at two mines, namely Mines 1 and 2 that are located about 10 km from each other in the Highveld coal in Mpumalanga Province of South Africa. Figure 1 is the geographically map showing the location of the study sites in Mpumalanga Province of South African and also the Highveld coal fields where the site is located.

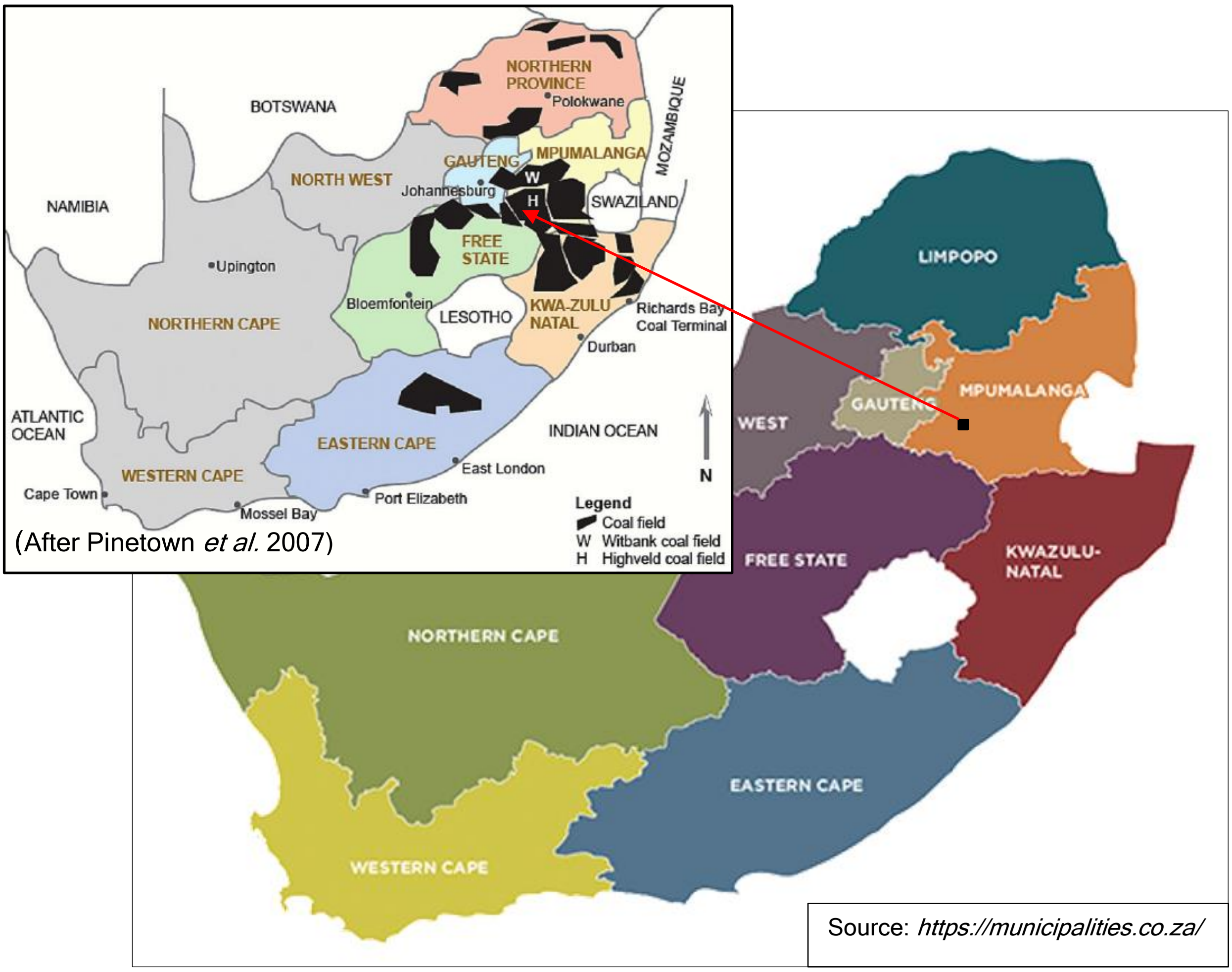


Figure 1: Geographically map showing the location of the study sites in Mpumalanga Province of South African and also the Highveld coal field where the site are located

## 2.2 Geology

### 2.2.1 General

The study sites are located in the Highveld Coalfields of Mpumalanga province. The Coal seams of the Highveld Coalfields are situated in the Vryheid Formation of the Ecca group of the Karoo Supergroup located in the Main Karoo Basin. The Main Karoo Basin overlies the central and eastern parts of South Africa (Figure 2). The geological formations of the Karoo Basin comprise of a succession of 5 groups (Dwyka, Ecca, Beaufort, Stromberg and Drakensberg groups).

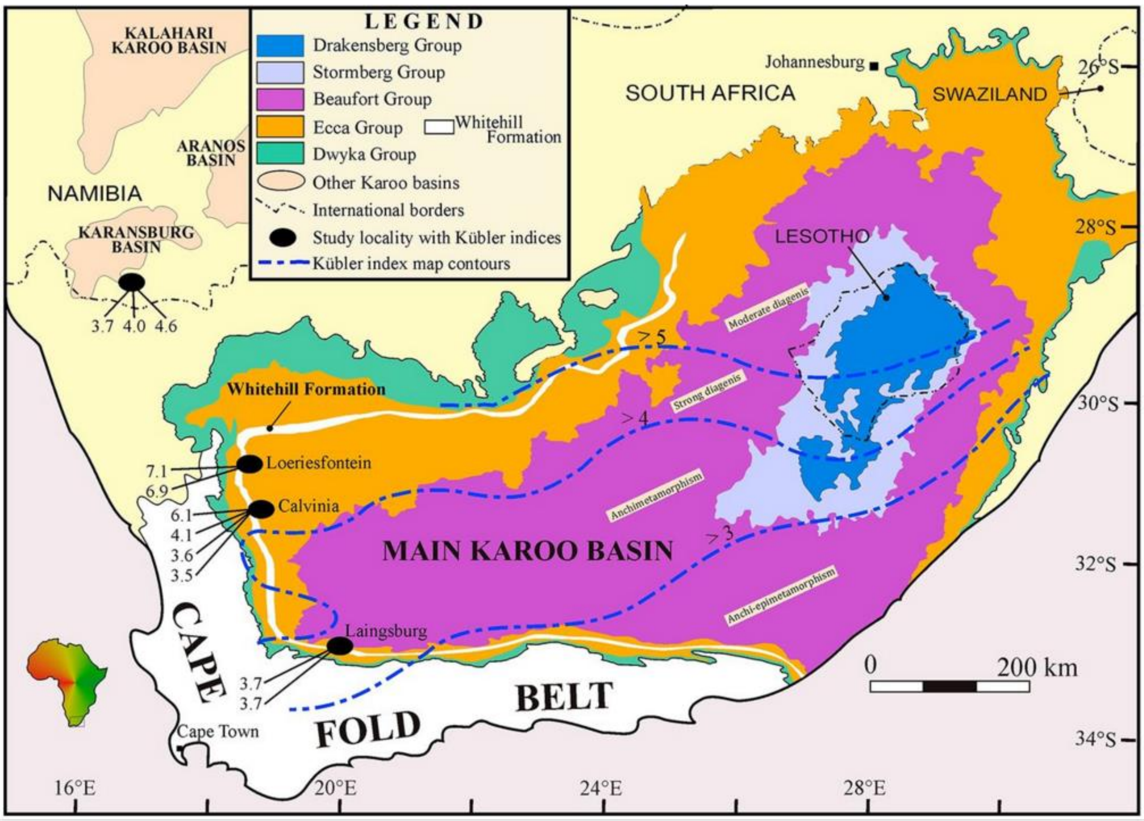


Figure 2 Geological groups of the Main Karoo Basin

Source: *http://sajg.geoscienceworld.org/content/gssajg/118/4/489/F1.large.jpg*

Table 1 show a simplified stratigraphic column of the Karoo Supergroup in the northern portion of the Karoo basin (after South African Committee for Stratigraphy 1980) where the study area is located. In the Highveld Coalfields (Table 1), the Coal seams are situated in the Vryheid Formation of the Ecca group. Thus the geology of the Vryheid Formation is discussed in detail below.

Table 1: Simplified stratigraphic column of the Karoo Supergroup in the northern portion of the Karoo basin (after South African Committee for Stratigraphy 1980)

| PERIOD (AGE) | GROUP | FORMATION | ROCK TYPES |
|---|---|---|---|
| Jurassic (150 my) | | Drakensberg | Basaltic lava |
| Triassic (195 my) | | Clarens | Fine-grained sandstone |
| | | Elliot | Red sandstone, mudstone |
| | | Molteno | sandstone, mudstone |
| Permian (225 my) | Beaufort | Tarkastad | Sandstone, shale |
| | | Estcourt | Sandstone, shale, sub-ordinate coal |
| | Ecca | Volksrust | Shale, sandstone, sub-ordinate coal |
| | | Vryheid | Sandstone, shale, coal |
| | | Pietermaritzburg | Shale |
| Upper Carboniferous (285 my) | | Dwyka | Tillite, varved shale |

### 2.2.2 Vryheid Formation

The stratigraphy of the Vryheid Formation was described by Cadle *et al.,* (1982) as a succession of five coarsening upward sequences which exhibit lateral continuity across the entire region of the Main Karoo Basin. In a complete succession each of the five coarsening-upward sequences starts with fine-grained marine facies grading upwards into coarser delta front and delta plain-fluvial facies (Hancox and Götz 2014).

Vryheid Formation is the only coal bearing formation of the Ecca group and mainly comprises of sandstone, shale and coal sedimentary rocks. The majority of the economically extracted coal in South Africa occurs in rocks of the Vryheid Formation which ranges in thickness from less than 70 m to over 500 m (Hancox and Götz 2014). Six bituminous coal seams are present in a 120m succession of sedimentary lithologies which overlie Dwyka Formation diamictite or pre-Karoo basement and these are described and discussed in detail by Winter (1987). Several coal seams that occur in the Vryheid Formation are associated predominantly with the coarser-grained fluvial facies at the top of each sequence (Hancox and Götz 2014).

Although there are some differences (Winter 1987), the regional stratigraphy in the northern Highveld Coalfield is generally similar to that of the Vryheid Formation in the adjacent central Witbank Coalfield (Le Blanc Smith 1980) and the east Witbank Coalfield (Cairncross and Cadle 1987).

### 2.2.3 Geohydrology

There are two groundwater systems that are present in the study area, namely the weathered and unweathered Ecca Group/Vryheid Formation aquifers (Azzie, 1999 and Grobbelaar, 2001).

#### 2.2.3.1 Weathered Ecca Aquifer

The weathered formation lies between depths of 5 and 12 m below surface and occurs at the interface of soil and bedrock (Pinetown and Boer, 2006). This aquifer is recharged by rainfall. The percentage recharge to this aquifer is estimated to be in the order of 1 - 3% of the annual rainfall (Kirchner *et al.*, 1991). According to Hodgson and Krantz, 1998, the aquifer within the weathered zone is usually generally low yielded (range 100 - 2000 L/hour) because of its insignificant thickness.

Rainfall that infiltrates into the weathered rock reappears on surface at springs where the flow paths are obstructed by a barrier, such as a dolerite dyke, paleo-topographic highs in the bedrock, or where the surface topography cuts into the groundwater level at streams. It is suggested that less than 60% of the water recharged to the weathered zone eventually emanates in streams (Hodgson and Krantz, 1998) and the rest of the water is evapotranspirated or drained by some other means.

#### 2.2.3.2 Unweathered Ecca Aquifers

Unweathered Vryheid Formation consists of sandstones, siltstones, shales and coal. Groundwater within these sediments will be contained within fractures, joints and bedding planes. The Ogies Dyke is impermeable over much of its length and thus compartmentalizes the groundwater. Of all the unweathered sediments in the Ecca the coal seams have the highest hydraulic conductivity (Grobbelaar 2001). The pores within the Ecca sediments are too well-cemented to allow any significant flow of water.

### 2.2.4 Climate and Rainfall

Mpumalanga is a province of two halves, namely the high-lying grassland savannah of the Highveld escarpment and the subtropical Lowveld plains. The capital of the Mpumalanga province is Nelspruit and together with the Kruger National park, they both fall in the Lowveld area. The Lowveld has a tropical climate with warm sub-tropical temperatures and experiences high summer rainfalls. Between the month of September and March this area receives approximately rainfall of 620 mm. (*www.southafrica.com*).

# CHAPTER 3 LITERATURE REVIEW

## 3.1 Introduction

This chapter gives a review of the coal mining activities in South Africa, more specifically in Mpumalanga province. Potential environmental impacts of coal mining activities are discussed with emphasis on Acid Mine Drainage (AMD). AMD is one of the great threats to the water resources in South Africa therefore it is important that the mining industries are able to predict and evaluate the environmental consequences (Usher, 2003). Measures to prevent and reduce the impacts of AMD are discussed.

## 3.2 Coal mining in South Africa

Coal mines in South Africa play an important role in the country's economy, with 90% of all primary energy needs being provided for by coal. Coal is valued for its energy content and since the 1880s, has been widely used to generate electricity. Coal is found in South Africa in 19 coalfields as shown in Figure 3, located mainly in KZN, Mpumalanga, Limpopo and the Free State with lesser amount of coal in Gauteng, North West and Eastern Cape (Jeffrey. 2005). The study area is situated in coal field number 12 in Figure 3. Approximately half of all coal mines in South Africa use open pit mining techniques (opencast) while other half relies on subsurface techniques (underground). Steel and cement industries use coal as a fuel for extraction of iron ore and for cement production. In the US, UK and South Africa, a coal mine together with its structures is a colliery. In Australia, Colliery generally refers to an underground coal mine.

By international standards, South Africa's coal deposit is relatively shallow with thick seams, which make them easier and usually cheaper to mine. At the present production rate, there should be more than 50 years of coal supply left (Dept. of Energy, overview 2014).

## 3.3 Environmental impacts of coal Mining

While coal mining is a pivotal part of the South African economy as it provides energy and jobs to the country, it is nevertheless associated with serious and damaging environmental impacts. The main concern is the impacts of acid mine drainage on the environment. It is widely accepted that acid mine drainage (AMD) and its potential impact on groundwater resources is one of the most serious environmental concern associated with coal mining (Brady *et al.*, 1997; Rose and Cravotta, 1998; Bell *et al.*, 2001).

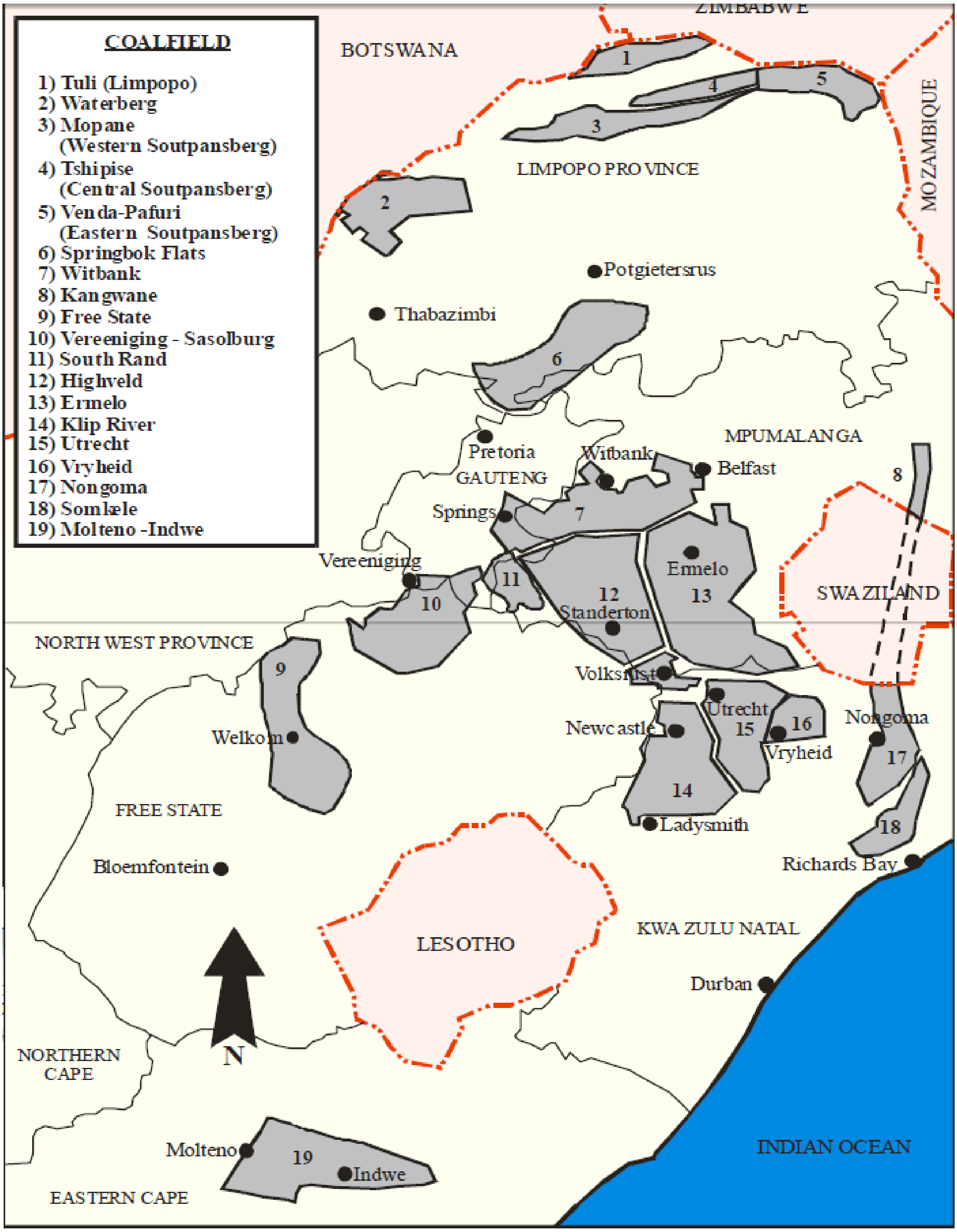


Figure 3: South Africa Coalfields (Jeffrey 2015)

Hydroxide occurs over long distances. Rain penetrates overburden and acquires a certain alkalinity, usually by dissolution of calcite (Caruccio & Geidel, 1978). The amount of alkalinity acquired is determined by the $PCO_2$ of the water and the solubility of calcite which at first is neutralised by the alkalinity in the groundwater. If the acidity generated is greater than the initial alkalinity of water, all the alkalinity will be consumed resulting in acid water. If sufficient oxygen is present, the amount of acidity generated is determined by the amount of reactive pyrite in the coal (Drever, 2002).

In the absence of mining, acid waters are uncommon because dissolved oxygen in gas is insufficient to produce acidity greater than the alkalinity of the groundwater. When mining occurs, additional oxygen is introduced and water movement through the system is accelerated. Oxidation is no longer limited by groundwater transport of oxygen and acidity may result. The bacteria that catalyse the acidity-producing reaction thrive only under acid conditions so once acidity is initiated, acid production becomes more rapid and the acidity problem increases rapidly (Drever, 2002).

Mining practices, present and past, cause environmental problems that can damage ecosystems and human health. Mining disturbs geologic formations that took millions of years to form; likewise, related natural systems and processes are disturbed, e.g. hydrology. Once disruption has taken place a variety of problems may arise, from physical hazards to pollution of water and soil. The most severe and widespread environmental problems almost always have to do with water. Hodgson *et al.,* (2001) pointed out that through advanced planning much can be done to minimise the impact on the mine water during and after mining.

## 3.4 Treatment of mine sites

Treatment of mine sites generally requires pH adjustment, oxidising or reducing (redox) conditions and/ or stabilisation of waste (Costello, 2003). There are two types of treatment technologies:

### 3.4.1 Traditional treatment

Traditional treatments rely on conventional, well-recognised technology to raise pH or create redox conditions. These traditional conditions are Water treatment plant, relocation of waste, covering of waste piles, water diversion tactics and vegetation.

### 3.4.2 Wastewater Treatment Plant

In this type of treatment, waters are removed from their course, treated and then discharged. There are other treatment that are similar to traditional wastewater treatment plant i.e. Oxidation Dosing with Alkali and Sedimentation (ODAS), sulfidisation, sorption and ion exchange and membrane processes like filtration and reverse osmosis. One of the advantages of this treatment is precision, which means it is useful for active mining sites because of its frequent changing water characteristics (Younger *et al.*, 2002).

### 3.4.3 Relocation of waste site

Wastes are shipped off-side to landfills and treatment plants, which is costly. Instead of shipping off the waste, this can be avoided by covering the waste with multiple layer of plastic, cement, soil, rock, vegetation etc. By doing this, solid materials high in metals and acid materials, will not be exposed to the elements and will not cause typical problems associated with mine waste (Pioneer Technical Services, 2002).

### 3.4.4 Divergent of Water

Another tactic is by controlling waste flow near a waste pile by installing trenches and culverts to divert water from the pile.

### 3.4.5 Innovative treatment

Innovative treatment is done by wide range of technologies e.g. Limestone drains, Constructed wetlands, etc.

### 3.4.6 Limestone drains

In this method of treatment, the water is allowed to settle in the pond or wetland to allow metals to precipitate and settle. The only problem with this method is that it causes the limestone to become inactive and causes clogging of the drain (Cravotta *et al.*, 2002).

### 3.4.7 Constructed wetlands

Wetlands are capable of treating water and retaining toxics forms the basis of most passive treatment technologies. There are 2 types of wetlands used to treat mine drainage, namely aerobic and anaerobic. If metal of concern is iron, an aerobic wetland is used as treatment. Anaerobic wetland generally consists of organic substrate, often compost and can be mixed with lime to increase alkalinity (USEPA, 1994).

## 3.5 Acid Mine Drainage

Acid Mine Drainage is a widespread phenomenon in the mining industry worldwide affecting the quality of water at many South African Collieries (Vermeulen and Usher, 2006). Acid Mine Drainage is produced when sulphide-bearing material is exposed to oxygen and water (Akcil *et al.*, 2006). This result in the generation of sulphates, metals and acidity that can have numerous environmental consequences (Usher *et al.*, 2003)

### 3.5.1 Oxidation of metal sulphide

Acid is generated at mine sites when metal sulphide minerals are oxidized. Oxidation of these minerals and the formation of sulphuric acid is a function of natural weathering processes. Oxidation of sulphide minerals consists of several reactions. Each sulphide minerals has a different oxidation rate, example: marcasite and framboidal pyrite will oxidise quickly while crystalline pyrite will oxidise slowly.

Table 2: Particle list of sulphite minerals

| Minerals | Composition |
|---|---|
| Pyrite | $FeS_2$ |
| Marcasite | $FeS_2$ |
| Chalcopyrite | $CuFeS_2$ |
| Chalcocite | $Cu_2S$ |
| Sphalerite | ZnS |
| Galena | PbS |
| Millerite | NiS |
| Pyrrhotite | $Fe_{1-x}$ S (where $0<x<0.2$) |
| Arsenopyrite | FeAsS |
| Cinnabar | HgS |

Source: Ferguson and Erickson 1988

$$2FeS_{2(s)} + 2H_2O + 7O_2 \rightarrow 4H^+ + 4SO_4^{2-} + 2Fe^{2+}$$

Equation 1

In Equation 1, $S_2^{2-}$ is oxidised to form hydrogen ions and sulphate, the dissociation products to sulphuric acid in solution. Soluble $Fe^{2+}$ is also free to further react with oxygen (Equation 2). Oxidation of the ferrous ion to ferric ion occurs more slowly at lower pH values:

$$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2$$

Equation 2

If the ferric ion is formed in contact with pyrite the following reaction can occur (Equation 3), dissolving the pyrite.

$$2FeS_{2(s)} + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{3+} + 2SO_4^{2-} + 16H^+$$

Equation 3

This reaction generates more acid. Ferric iron precipitates as hydrated iron oxide as indicated in the following reaction (Equation 4):

$$Fe^{3+} + 3H_2O \rightarrow Fe(OH)_{3(s)} + 3H^+$$

Equation 4

$Fe(OH)_3$ precipitates and is identifiable as the deposit of amorphous, yellow orange or red deposit on stream bottoms (Yellow boy) as shown in Figure 4 .

Figure 4: Precipitation of a yellow boy at a South African Colliery (Usher (2003))

### 3.5.2 Contributing factors to AMD

The potential for a mine to generate acid and release contaminants is dependent on many factors and is site specific. Ferguson and Erickson (1988) identified primary, secondary and tertiary factors that control acid drainage.

#### 3.5.2.1 Primary Factors

Primary factors required for the generation of AMD include sulphide minerals, water, oxygen, and ferric ion, bacteria to catalyse the oxidation reaction. Both water and oxygen are necessary to generate acid drainage. Water serves as both a reactant and a medium for bacteria in the oxidation process. It also transports the oxidant products and oxygen is required to drive the oxidation reaction (Ferguson and Erickson, 1988).

#### 3.5.2.2 Secondary Factors

Secondary factor act to either neutralise the acid production by oxidation of sulphides or may change the effluent character by adding metals ions mobilised by residual acid. Neutralisation of acid by the alkalinity released when acid react with carbonate minerals is an important mean of moderating acid production. The most common neutralising minerals are calcite and dolomite (Ferguson and Erickson, 1988).

### 3.5.3 Tertiary Factors

Some of tertiary factors affecting acid drainage are the physical characteristics of the material, how acid generating and acid neutralising material are placed, waste and the hydrologic regime in the vicinity. The physical nature of the material such as particle size, permeability and physical weathering characteristics, is important to the acid generation potential. Particle size is a fundamental concern since it affects the surface area exposed to weathering and oxidation (Ferguson and Erickson, 1988).

Very coarse grain material as is found in waste dumps exposes less surface area but may allow air and water to penetrate deeper into the unit exposing more material to oxidation and ultimately produce more acid. In contrast, fine grain material may retard while air and much fined material may limit water flow, however, finer grains expose more surface area to oxidation. The relationships between particle size, surface area and oxidation play a prominent role in acid prediction method.

The hydrology of the area surrounding mine workings and waste units is also important in the analysis of acid generation potential. When acid generation material occurs below the water table, the slow diffusion of oxygen in water retards acid production. This is reflected in the portion of pits or underground workings located below the water table. Where mine walls and underground workings extend above the water table, the flow of water and oxygen in joints may be a source of acids (USEPA, 1994).

## 3.6 Assessment of the AMD potential

Application of acid base accounting procedures has made it possible to quantify the potential of a particular rock or coal sample to produce acid or alkaline waters under mine drainage conditions. A detailed explanation of the experimental procedure followed in applying this technique to the present study can be found in Usher *et al.*, (2003).

The method involves:

### 3.6.1 Hydrogen Peroxide ($H_2O_2$)

- Adding 120 or 80ml of $H_2O_2$ reagent to 1 to 4g of a pulverised sample and allowing it to vivacious or give off bubbles.
- The final pH is measured once the bubbles has ceased or come to an end.
- The supernatant liquid is then analysed for sulphate.
- The %S (total) can also be determined by Leco element analyser if required.
- The actual acid produced during the oxidation of pyrite by $H_2O_2$ is called potential acidity.

- The reaction (Equation 5) which represents the complete oxidation of pyrite is as follows:

$$FeS_2 + 3.75O_{2(aq)} + 1.5H_2O_{(aq)} \leftrightarrow Fe(OH)_{3(s)} + 2SO_4^{2-} + 4H^+$$

Equation 5

The overall pyrite oxidation reaction in Equation 5 will produce 4 moles of $H^+$, 1 mole of $Fe(OH)_{3(s)}$ and 2 moles of $SO_4^{2-}$ for each mole of pyrite oxidised.

### 3.6.2 Neutralising Potential (0.06N of H2SO4)

The neutralising potential is determined by adding 20 ml of 0.06 N of standardised $H_2SO_4$ to 5 g of a pulverised sample. The pH of the mixture must be 2.5 after 24 hours before back titration to a pH of 7. Back titration is carried out with 0.06 NaOH. If the pH is still above 3 after 24 hours, additional acid is added and the process is repeated until the correct pH is obtained (Usher *et. al.* 2003)

The solubility of calcite is different for open and closed system and thus the acid potential (AP) and neutralising potential (NP) for both cases was determined.

**OPEN SYSTEM** - In an open system, carbon dioxide ($CO_2$) dissolves into the atmosphere. Therefore, 1 mole of $FeS_2$ is neutralised by 2 mole of $CaCO_3$.

**CLOSED SYSTEM** - In a closed system, carbon dioxide ($CO_2$) is dissolved in the water and carbonic acid or $H_2CO_3$, is formed.

It follows that the 4 mole of $CaCO_3$ is needed to neutralise 1 mole of $FeS_2$ (Pyrite).

### 3.6.3 Acid Potential (AP)

AP is a measure of the potential of a sample to generate acidity. The amount of calcite required to neutralise a given amount of acid mine drainage depends on the behaviour of $CO_2$ during neutralisation and on the pH reached. If the acid-mine drainage is to be neutralised to pH 6.3 or above, then the following reaction (Equation 6) may be written:

$$FeS_2 + 2CaCO_3 + 3.75O_2 + 1.5H_2O \leftrightarrow Fe(OH)_3 + 2SO_4^{2-} + 2Ca^{2+} + 2CO_2$$

Equation 6

For each mole of pyrite that is oxidised, two mole of calcite are required for acid neutralisation (Equation 6). On a mass ratio basis, for each gram of sulphur present, 3.125g of calcite is required for acid neutralisation.

When expressed in parts per thousand (ppt) of spoil, for each 10 ppt of sulphur (S) present 31.25 ppt of calcite is required for acid neutralisation. The stoichiometry in the previous equation is based on the exsolving of $CO_2$ gas out of the spoil system. In closed system, $CO_2$ is not exsolved and additional acidity from carbonic acid is generated. Cravotta *et al* (1990) proposed that up to 4 mole of calcite might be needed for acid neutralisation. Twice as much calcite would be required for acid neutralisation in a closed system, compared to an open system. On a mass basis for each 10ppt of sulphur present, 62.5ppt of calcite is needed for acid neutralisation in one thousand tonnes of spoil (Cravotta *et.al*, 1990).

Results obtained from the laboratory experimental procedure are used in calculating the acid potential (AP), neutralising potential (NP) and the net neutralising potential (NNP) as follows:

1. $$AP = \left( \frac{SO_4\left(\frac{mg}{l}\right)}{weight\ (g)} \Big/ 1000 \right) \times ml\ H_2O\ or\ H_2O_2 = {kgSO_4}/{t\ of\ sample}$$

2. $$AP\ (Open)(CaCO_3 kg/t) = \frac{SO_4\ kg/t}{48} \times 50$$

3. $$NP\left(\frac{CaCO_3 kg}{t}\right) = {(NH_2SO_4 \times ml\ acid) - (N\ NaOH\ \times ml\ alkali)}\Big/{weight\ (g)} \times 50$$

Thus, the NNP is determined by subtracting the acid potential from the neutralising potential.

NNP (Open) = NP-AP (open)

In a closed system

AP (Closed) AP (Open) x 2 and

NNP (Closed) = NP - AP (Closed) (Hodgson & Krantz, 1998)

There is various type of screening criteria used to interpret acid-base accounting results. In this study the NNP was used as screening criteria. Research has shown that there is a range from -20 to 20kg/t $CaCO_3$ where a sample can become acidic or remain neutral. Thus a sample with a NNP<20 is potentially acid generating and a sample with a NNP>20 might not generate acid (Usher *et. al*, 2003).

## 3.7 Prevention of acid generation

The main strategies to prevent acid generations are prevention or minimization of water circulation through acid generating material by covering with an impermeable cap, which may simply be a soil in relatively arid climate. Another approach is to dispose the materials under water, for example in a flooded mine pit. The solubility of oxygen in water is quite low, so sulphide oxidation in the saturated zone is generally low, limited by the availability of oxygen (Drever, 2002).

# CHAPTER 4 METHODS AND MATERIALS

## 4.1 Introduction

Static method was used to determine whether the samples analysed has the capacity to generate or neutralise an acid and it was also used as a screening method to determine the difference between the acid generating capability and the acid neutralising potential of samples analysed. A description of sampling method from the core logs is provided. The static Acid-Base method (ABA) is used to determine the acid mine drainage potential of the samples. The mineralogical (X-Ray Diffraction (XRD)) and chemical (X-Ray Fraction (XRF)) information is used in conjunction with the ABA to give evidence of the ABA results.

## 4.2 Collection of geological samples

The geological samples were collected from borehole logs (Figure 5) at Mine 1 and Mine 2 which were drilled at different areas. Appendix 1 and Appendix 2 shows how the samples were collected at different depths. Most of the samples consist of sandstone, siltstone, gritstone, dolerite, carbonaceous shale and coal.

### 4.2.1 Mine 1 Samples

Mine 1 sample were collected from 13 borehole logs, namely: F142441, F142446, F142471, O105016, P110030, P110087, R146043, T139228, W569001, Y106148, Z145168, Z145198, and Z145199. Table 3 shows how many samples were collected from each borehole log.

Table 3: Mine 1 Borehole logs and number of sample collected

| Borehole Name | Samples collected | Depths (m) |
|---|---|---|
| F142441 | 6 | 1.7 - 128.56 |
| F142446 | 9 | 5.8 - 161.50 |
| F142471 | 10 | 4.68 - 109.90 |
| O105016 | 9 | 7.3 - 85.56 |
| P110030 | 14 | 3.8 - 141.55 |
| P110087 | 11 | 6.9 - 140.18 |
| R 146 043 | 14 | 5.33 - 170. 34 |
| T139228 | 11 | 2.2 - 145.24 |
| W569001 | 8 | 2.4 - 90.8 |
| Y106048 | 5 | 5.95 - 75.27 |
| Z145168 | 8 | 1.6 - 142.08 |
| Z145198 | 6 | 3.33 - 184 |
| Z145199 | 7 | 0 - 162.3 |
| Total samples collected | | 118 |

Coal samples are also included in the 118 samples collected and were collected from 4 borehole logs; namely: F142471 (4 samples), P110030 (4 samples), P110087 (2 samples) and W569001 (3 samples):

- F142471 coal samples were collected from:
  No4 lower coal seam (C4L)
  No3 coal seam (C3)
  No2 coal seam (C2) and
  No5 coal seam (C5)
- P110030 coal samples were collected from:
  No5 lower coal seam (C5L)
  No4 lower coal seam (C4L)
  No3 coal seam (C3) and
  No2 coal seam (C2)
- P110087 coal samples were collected from:
  No5 lower coal seam (C5L)
  No4 lower coal seam (C4L)
- W569001 coal samples were collected from:
  No4 lower coal seam (C4L)
  No3 coal seam (C3)
  No2 coal seam (C2)

### 4.2.2 Mine 2 Samples

Mine 2 samples were collected from 4 borehole logs, namely: R100001, R100002, Z124027, Z124029 and Z124030. Table 4 shows how many samples were collected from each borehole log:

Table 4: Mine 2 Borehole logs and number of samples collected

| Borehole Name | Samples collected | Depths (m) |
|---|---|---|
| R 100 001 | 13 | 1.62 - 143.1 |
| R 100 002 | 8 | 14.1 - 124.4 |
| Z124027 | 21 | 4.13 - 200.16 |
| Z124029 | 13 | 6.9 - 174.53 |
| Z124030 | 16 | 11.6 - 185.66 |
| Total of samples collected | | 71 |

Coal samples are also included in the 71 samples collected; each borehole logs contain coal samples. R100001 consist of 2 coal samples (C5L, H &M and C4L), R100002 have 1 coal samples (C4L), Z124027 consist of 3 coal samples (C5L, C4L and C4L), Z124029 have only 1 coal sample (C4L) and Z124030 have 4 coal samples (C5H, C5L, C4H & C4L). These samples were collected to determine the acid base potential, whole rock chemical analysis and to supply the mineralogy of the analysed samples.

Figure 5: Mine 1 and Mine 2 Borehole core logs

## 4.3 Mineralogical and whole rock analysis

The X-Ray Diffraction (XRD) technique was used to determine the mineralogy and the X-ray Fluorescence (XRF) technique was used to determine the chemical analysis or whole rock analysis of the samples analysed. Both the XRD and XRF assisted in understanding the process of Acid Mine Drainage in both areas.

### 4.3.1 Mineralogical identification

Mineralogical analysis of the rock sample was done by using X-Ray Diffraction (XRD) technique. The XRD involves the scattering of x-rays by minerals crystals with accompanying variation in intensity due to interferences effects. The XRD analysis evaluates the crystal structure of the materials by passing x-rays through and recording the diffraction or scattering image of the rays. It has been established as probably the most important, convenient and unambiguous technique applied to the study of soil and overburden mineralogical composition (Bish, 1994). The occurrence of pyrite and other sulphide minerals as well as calcite and dolomite can be determined by x-ray diffraction.

### 4.3.2 Whole rock analysis

The whole rock analysis is determined by using X-Ray Fluorescence (XRF) technique, which is used to determine the chemical composition of a rock sample by analysing several elements (Taggart *et al*, 1987). The oxides in the sample were identified using Panalytical Axios XRF machine, the machine has a Rh end window tube, with 4kW anode (consisting of Rh) and a W cathode (filament). It has sequential wavelength dispersive XRF, which measures one element at a time and it measures the wavelength of the X-rays instead of the energy. This machine also has the additional crystals for diffraction when compared to the energy dispersive machines which splits the peaks of the elements for better identification. It also consists of two detectors that are attached to it, namely: a flow detector and a scintillation detector with a NaI crystal (for high energy X-rays) and a flow detector contain P10 gas (for X-rays with low energies). These two detectors can be used for intermediate energies to enhance sensitivity and to analyse a wider range of transition metals (Bruker 2006).

## 4.4 Static Method

Static method which is one of the methods of Acid-Base Accounting (ABA) was used to determine acid-base potential for investigated geochemical layers. Static method provide a rough indication of the acid generating potentials of the various lithological units, it determines the difference between the acid-generating capability and the acid neutralising potential of a particular sample or set of samples.

## 4.5 Determination using acid-base accounting method

Acid-base Accounting (ABA) is an excellent first-order tool to determine whether or not mine waste has the potential to form acidic drainage (Usher *et al*, 2003). The tool was developed by Richard Smith and his associates at the West Virginia University in the late 1960's and was designed to evaluate the acid producing capability of coal mine wastes and can also be used to determine if the rock samples has acid or base producing potential. The following tests are used for ABA method:

### 4.5.1 Paste or Initial pH

5g of sample is measured to 50ml of distilled water and stirred for 1 hour. The solution is then left to stand 24 hours to allow the solubility reaction to be more complete. The initial pH is measured and recorded after 24 hours. The solution is filtered and the leachate analysed by ICP-OES Inductively Coupled Plasma Optical Emission Spectroscopy to determine the water soluble parameters/elements. The results obtained provide the current state of the sample and the pH recording gives an indication of whether the sample is acidic or basic.

#### 4.5.2 Acid potential using Hydrogen Peroxide ($H_2O_2$)

80 ml of 30% $H_2O_2$ is added to 2g of pulverised sample in 5ml increments. The sample is then allowed to react until boiling stops. The higher the sulphur content in the sample, the more violent it will react with the hydrogen peroxide. The solution is left to stand for 24 hours to cool to room temperature; the pH is then recorded after 18-24 hours as oxidised pH. The solution is filtered and analysed for sulphate and other ions.

Hydrogen peroxide is used in this method for its ability to oxidise sulphides (e.g. pyrite) present in a rock or coal sample to sulphate (Price, 1997).

#### 4.5.3 Acid Leachable elements/products

5g of sample is measured and mixed with 50ml of 0.1N $H_2SO_4$ and stirred for 1 hour. The solution is then left to stand for 24 hours to allow the solubility reaction to complete. The pH must be recorded only when it is less than 2.5, if not, few drops of $H_2SO_4$ must be added and left for another 24 hours. Samples are stirred thoroughly after addition of any acid. The pH of less than 2.5 is measured and recorded after 24 hours. The solution is filtered and analysed by ICP-OES.

#### 4.5.4 Neutralising potential using Sulphuric Acid ($H_2SO_4$)

20 ml of ±0,06N $H_2SO_4$ is added to 1g of sample. The pH of this slurry must be below 2.5 after 24 hours, before back titration to pH7 is done with ±0.06 NaOH. If the pH is >2.5, more $H_2SO_4$ is added and the sample is left another 24 hours for the reactions to complete. If the pH is not below 2.5 the next day the above procedure is followed again until the pH is below 2.5, then the sample is titrated to a pH of 7 with the standardised Sodium Hydroxide (NaOH).

The reason for using $H_2SO_4$ for this method is that Acid Mine Drainage contains sulphuric acid; therefore, it will provide a better simulation of the field condition (Price, 1997).

### 4.6 The advantages and the limitations of acid base accounting

Acid-Base Accounting is simply a screening process. It provides no information on the speed or kinetic rate with which acid generation or neutralisation will proceed and because of this limitation, the test work procedures used are referred to as Static procedures Ziemkiewicz and Meek, 1994)

#### 4.6.1 The primary advantages of Acid Base Accounting method are:

a. Short turn-around time for sample processing.

b. Low cost.

c. Relatively simple interpretation of results

d. Interpretation is based on decades of international research or experience.

e. Correlation to field has been shown by case studies.

### 4.6.2 The limitations of Acid Base Accounting (ABA) are as follows:

a. It only provides a possibility of occurrence.

b. Reaction rates are ignored (ABA generally tests the fast reacting species; slow reacting neutralising species will usually not prevent acidification.)

c. Assume instant availability of reactive species.

d. Simple reaction stoichiometry is assumed.

e. Size effect is ignored.

f. Extrapolation to the field is uncertain when volumetric calculations cannot be made.

Despite all these limitations ABA is a very important component of the Acid Base Accounting, Techniques and Evaluation (ABATE). ABATE is also called prediction wheel and has the following components:

a. Onside monitoring data

b. Mineralogy

c. Static Test (ABA)

d. Total Metals & Whole Rock

e. Geochemical Modelling

f. Hydraulic tests

g. Laboratory Kinetic Tests

h. Field tests

The prediction wheel shows that many different aspects are required to arrive at the eventual answer, depending on the type of information required and which of the key questions need answering and to what level of accuracy (Usher, 2003). Predictive capability is best achieved by using a combination of data set and method rather than by relying on one procedure (Cravotta, 1997).

## 4.7 Screening criteria

The criteria to be used are:

a. Net Acid Generation (NAG) test

b. Net Neutralising Potential (NNP)

c. Neutralising Potential Ratio (NPR)

d. % S & NPR

### 4.7.1 Net Acid Generation (NAG) Test pH

In this test, the value will be obtained from acid potential test as explained above. This can serve as a rough guideline but not as stand-alone criteria in categorising the sample (Price, 1997). The table below (Table 5) will be used to indicate the likelihood of net acid generation of the sample upon oxidation.

Table 5: Net Acid-Generating (NAG) Test pH guideline

| Final pH NAG Test | Acid Generating Potential |
|---|---|
| >5.5 | Non-acid generating |
| 3.5 to 5.5 | Low risk acid generating |
| <3.5 | High risk acid generating |

The pure deionised water in equilibrium with $CO_2$ will have a pH value of around 5.69. Therefore, anything above this should be non-acid generating.

### 4.7.2 Net Neutralising Potential (NNP)

Research has shown that there is a range from -20 to 20 kg/t $CaCO_3$ where the sample can become acidic or remain neutral. Where Net Neutralising Potential (NNP) = Neutralising Potential (Kg/t $CaCO_3$) - Acid Generating Potential (Kg/t $CaCO_3$)

The criteria are as follows:

If NNP < 20, the sample has the potential to generate acid

If NNP > 20, the sample has the potential to neutralise acid

### 4.7.3 Neutralising Potential Ratio (NPR)

The ratio of NP value to AP value, or Neutralisation Potential Ratio (NPR=NP/AP), and the acid generating is considered uncertain if the samples have a NPR of less than 4:1 (Usher, 2003).

Table 6: Guidelines for screening criteria based on ABA (Price, 1997)

| Potential for Acid Rock Drainage (ARD) | Initial NPR Screening Criteria | Comments |
|---|---|---|
| Likely | <1:1 | Likely AMD |
| 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. |

### 4.7.4 % S & NPR

It has been shown that for sustainable long-term acid generation, at least 0.3 Sulphide-S is needed. Values below this can yield acidity, but this is likely to be only of short-term significance. Using this and the NPR values, another set of rules can be derived as follows (Price, 1997):

- Sample with less than 0.3% Sulphide-S are regarded as having insufficient oxidisable Sulphide-S to sustain acid generation,
- NPR ratio of >4:1 are considered to have enough neutralising capability,
- NPR ratio of 3:1 to 1:1 are considered inconclusive, and
- NPR ratios below 1:1 with sulphide-S above 0.3% are potentially generating.

## 4.8 Leach test

Leaching is the process by which soluble constituents are dissolved from a solid material (such as rock, soil, or waste) into a fluid by percolation or diffusion (Washington State Department of Ecology 2003). A leaching test can be conducted in the laboratory or field. Leach tests are either static or kinetic. Static leach tests are conducted over a short term (minutes) and are relatively less expensive than kinetic tests, which requires long term (weeks to years) testing. In this study, static laboratory tests were conducted to help identify the elements (some toxic) that go into solution in the overburden, coal seam and interburden formations.

The samples were leached with water, hydrogen peroxide and sulphuric acid. For water leach the samples were collected from the leachate prepared in section 3.5.1. The solution was filtered and analysed by inductively coupled plasma (ICP) for major and trace elements.

For hydrogen peroxide leach the samples were collected from the leachate prepared in section 3.5.2. The solution was filtered and analysed by ICP for major and trace elements.

For sulphuric acid leaching, samples were collected from the leachate prepared in section 3.5.3. Major and trace elements were determined (ICP) on these filtered samples.

# CHAPTER 5 RESULTS AND DISCUSSIONS

## 5.1 Mineralogical and whole rock analysis results

A total of 118 (Mine 1) and 71 (Mine 2) samples were collected respectively from the borehole core logs for mineralogy and whole rock analysis. Out of 118 samples (Mine 1), 13 were coal samples and out of 71 samples (Mine 2), 11 were coal samples. Minerals were detected by using XRD and classification of minerals was presented according to dominance as indicated in Table 7.

Table 7: Percentages for XRD interpretation

| KEY | | |
|---|---|---|
| XX | Dominant Mineral | >50% |
| X | Major Mineral | 20-50% |
| xx | Minor Mineral | 10-20% |
| x | Accessory | 2-10% |
| <x | Trace Mineral | <2% |

The whole rock analysis was performed using X-ray fluorescent spectrometry (XRF). The results of elements analysed are given in wt. %.

### 5.1.1 Mine 1 mineralogical Analysis

The mineral components in the samples analysed are summarised in Appendix 3. Quartz is the dominant mineral in most samples with plagioclase dominating in few samples. Pyrite appeared as minor to trace mineral with a percentage of <2% to 20% only in sample T103 (W569001) which is a coal sample that appear as major mineral with a percentage of 20-50%. Most of the samples consisted of calcite which appeared as minor and trace mineral with a percentage of <2% to 20% and dolomite appeared only in 14 samples out of 118 with a percentage of 2% to 10%. Both calcite and dolomite were found to be the most common neutralising minerals. Siderite which is part of carbonate minerals existed in most of the samples with a percentage of <2% to 20% but appeared in one sample (T100) as major mineral. K-feldspar and koalinite existed in almost all samples from major to accessory. Magnesite appeared in 2 samples only with the concentration of 2 to10%. Analcine appeared only in one sample (T111), which is a coal sample, as major mineral. Most of the samples were found to originate from coal, sandstone and siltstone.

### 5.1.2 Mine 2 mineralogical Analysis

Quartz was the most dominant mineral in all the samples (Appendix 4) with a concentration ranging from 10 to 50%. Plagioclase was dominant in only 4 samples (SF 11, SF 38, SF 50 and SF 57). Only 20 samples from 71 contained pyrite with concentrations ranging from 2 to 20% (accessory to minor). Pyrite was dominant only in sample F68 which was a coal sample and it appeared as trace mineral with a percentage of <2% in samples F6 and F52. The following minerals appeared only in one sample: alunite (SF 66), andalusite (SF 60), amphibole (SF 44) and ilmenite (SF 10) with concentration in the range of 2 to 10%. Anatase and magnetite existed in samples SF 34 and 38 and SF 54 and 57 with a concentration ranging from 2 to 10%. K-feldspar existed in most of the samples with a concentration ranging from 2 to 20%. Kaolinite which is a clay material appear in most of the samples as major mineral with a concentration ranging from 2 to 50%. Calcite and siderite have a concentration ranging from <2% to 20%. Other minerals in the list have a concentration ranging from 2% to 20%. The mica mineral in sample SF 60 appeared as dominant and in sample SF 13, 28 & 59 as major.

### 5.1.3 Mine 1 and Mine 2 whole rock analysis

Samples from mine 1 (Appendix 5) and mine 2 (Appendix 6) consisted mainly of $SiO_2$ and $Al_2O_3$ which have the higher wt. % than the other elements. $SiO_2$ for mine 1 has an average of 57.5 wt.% and mine 2 has $SiO_2$ of 56.6 wt.%. $Al_20_3$ being the second highest with a concentration of 12.9 wt.% and 11.6 wt.% for mine 1 and mine 2 respectively. $Fe_2O_3$ in both list have almost the same concentration, i.e. 5.2 wt.% for mine 1 and 5.1 wt.% for mine 2. The concentration of the rest of the elements was small.

### 5.1.4 Conclusion

Quartz was found to be in all the samples ranging from 2 to 50% at mine 1 and mine 2. Eighty-five percent of the samples contained koalinite from trace to major concentration in mine 1 and only 18% in mine 2. Mine 1 consisted of calcite and dolomite with percentages of 55 and 44 respectively. Mine 2 consisted of calcite with percentage of 43 ranging from trace to accessory. For the whole rock analysis, $SiO_2$ and $Al_2O_3$ were present in both mines as major oxides which is similar to quarts and kaolinite and the presence of calcite and dolomite was supported by the availability of CaO and MgO. Only 22% of the samples contained pyrite ranging from trace to major concentration in mine 1 while at Mine 2, 28% ranged from trace to accessories. It can therefore be concluded that mine 1 has a higher concentration of minerals that can neutralise acid. Mine 2 has more samples that consisted of calcite compared to pyrite (trace to accessory).

## 5.2 Static test results

Acid-Base Accounting was used as a qualitative tool to determine the acid and neutralising potential of the samples. The release of metals from the spoil, rock and coal samples were also determined. The NNP, NPR and S% from the results obtained, are summarised below for each mine. The ABACUS programme (Usher 2003) was used to plot the data. The data used to plot the ABA results is presented in Appendix 7 and Appendix 8.

### 5.2.1 Mine 1 analysis

13 borehole core samples were collected from different areas for Mine 1. 118 samples were selected and analysed. The samples collected consist of sandstone, siltstone, coal and other geological formations shown in Appendix 7.

#### 5.2.1.1 Net Acid Generating Test (NAG) pH for Mine 1

The results for the NAG test are presented in Table 8 to 20. The interpretation of the results helped to assess whether the samples were acid or non-acid generating. The graphs below each table of results were plotted to show the number of samples with the pH value of 5.5, between 5.5 and 3.5 and below 3.5. These graphs were used for further interpretation. The information from Table 5 above was used to indicate the likelihood of net acid generation of the sample upon oxidation.

##### 5.2.1.1.1 F142441 Borehole Core

Six samples were collected from F142441 borehole core log. The samples were taken from depths 1.7m to 128.56m. Table 8 shows the results of the NAG pH test with interpretations as from the ABACUS program. Only one sample (TC35) has a final pH's that is below 3.5 (Figure 6), which means it has a high risk of acid generation. The calculated NNP for this sample was -2.99 kgCaCO3/tonne (Appendix 9). Five samples (T18, T75, T38, T83 and T7) have low risk of generating an acid therefore it indicates that there are enough neutralising minerals to buffer the pH.

Table 8: Results of NAG pH test on F142441 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC18 | 1.7-34.48 | DO | 10.2 | 7.4 | Lower Acid Risk |
| TC75 | 34.48-49.07 | SST | 9.13 | 6.11 | Lower Acid Risk |
| TC38 | 49.07-70.25 | SST,C | 9.29 | 7.02 | Lower Acid Risk |
| TC83 | 70.6-82.75 | SST, SLT, SH | 8.09 | 6.32 | Lower Acid Risk |
| TC7 | 83.45-121.47 | SST, SLT, SH | 8.43 | 7.81 | Lower Acid Risk |
| TC35 | 125.77-128.56 | SST, SLT | 7.89 | 3.28 | Higher Risk Acid Generation |

DO - Dolerite, SST - Sandstone, SLT - siltstone, C - coal, SH -shale

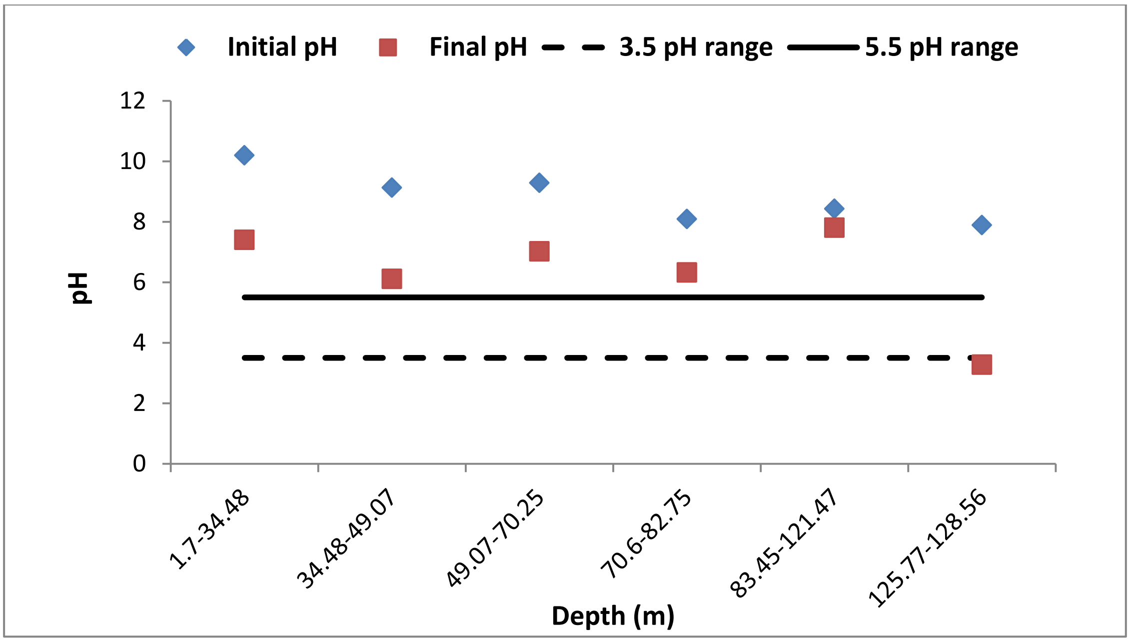


Figure 6: Initial and Final pH showing NAG pH test results of borehole core F142441

#### 5.2.1.1.2 F142446 Borehole

Nine samples were collected from F142446 borehole core log. The samples were taken from depths 5.8m to 161.50m. Table 9 below shows the results of the NAG pH test with interpretations as from the ABACUS program. Samples TC51 and TC41 have final pH's that are below 3.5 (Figure 7), which means they have a high risk of acid generation. Only TC66 sample is between pH of 3.5 and 5.5 and is regarded as having medium risk of acid generation, whereas the remaining samples are non-acid generating (>5.5). Most of the samples in core F142446 show low acid risk, indicating there are enough neutralising minerals to buffer the pH. Therefore, there will be a low risk of acid generation for this core sample.

Table 9: Results of NAG test on F142446 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC66 | 5.8-9 | DO, SST | 8.46 | 4.94 | Medium Risk Acid Generation |
| TC57 | 9.15-34.95 | SST, SLT | 9.34 | 6.78 | Lower Acid Risk |
| TC 62 | 34.95-70.5 | DO | 9.99 | 7.20 | Lower Acid Risk |
| TC10 | 70.5-82.44 | SST, SLT | 9.79 | 7.11 | Lower Acid Risk |
| TC4 | 82.44-91.10 | SST | 9.70 | 6.11 | Lower Acid Risk |
| TC51 | 91.10-112.10 | SST, SLT | 8.78 | 3.34 | Higher Risk Acid Generation |
| TC41 | 112.10-113 | C, SLT, CSH | 8.84 | 1.63 | Higher Risk Acid Generation |
| TC33 | 113.12-155.3 | SST, SLT, C | 8.30 | 7.04 | Lower Acid Risk |
| TC87 | 155.3-161.50 | SST, SLT, C | 9.20 | 5.64 | Lower Acid Risk |
| DO - Dolerite, SST - Sandstone, SLT - siltstone, C - coal, CSH -carbonaceous shale | | | | | |

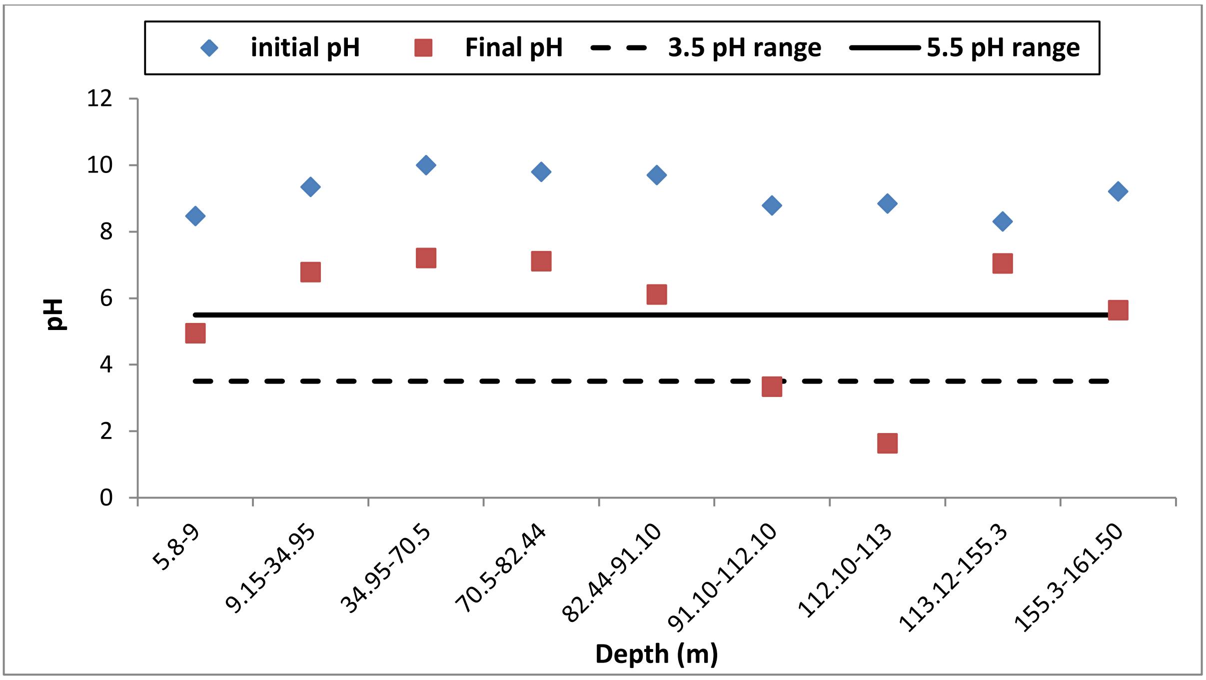


Figure 7: Initial and Final pH showing NAG pH test results of Borehole core F142446

#### 5.2.1.1.3 F142471 Borehole Core

Ten samples from F142471 borehole core were taken from depths 4.68m to 109.90m (Table 10). Five samples (TC114, TC3, TC11, TC112 and TC105) have final pH's that are below 3.5 (Figure 8) and have a high risk of acid generation. Only TC107 sample is between pH of 3.5 and 5.5 and is regarded as having medium risk of acid generation, whereas the remaining samples are non-acid generating (>5.5). The NNP results (Appendix 9) indicates that 60% of samples need to be verified with other tests.

Table 10: Results of NAG pH test on F142471 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC65 | 4.68-12.9 | SLT, SST, KV | 8.3 | 6.69 | Lower Acid Risk |
| TC55 | 12.9-18.82 | SST | 8.64 | 6.19 | Lower Acid Risk |
| TC61 | 18.82-40.85 | SST,SLT, KV | 8.29 | 6.64 | Lower Acid Risk |
| TC114[b] | 40.85-42.38 | C5 | 8.45 | 1.65 | Higher Risk Acid Generation |
| TC3 | 42.38-75.68 | SST, SLT, SH, KV | 7.7 | 3.3 | Higher Risk Acid Generation |
| TC107[b] | 76.09-80.80 | C4H | 7.67 | 4.22 | Medium Risk Acid Generation |
| TC11 | 83.8-84.15 | SLT | 7.98 | 3.07 | Higher Risk Acid Generation |
| TC112[b] | 84.15-84.80 | C3 | 7.56 | 1.6 | Higher Risk Acid Generation |
| TC84 | 84.8-109.4 | SST, SLT, KV, GRT | 8.08 | 6.38 | Lower Acid Risk |
| TC105[b] | 109.4-109.90 | C2 | 7.98 | 3.15 | Higher Risk Acid Generation |
| SST -Sandstone, SLT - Siltstone, SH-shale, GRT - Gritstone, KV - Core loss, C2 -No 2 coal seam, C3 -No 3 coal seam, C4H - No 4 upper coal seam & b = Coal sample | | | | | |

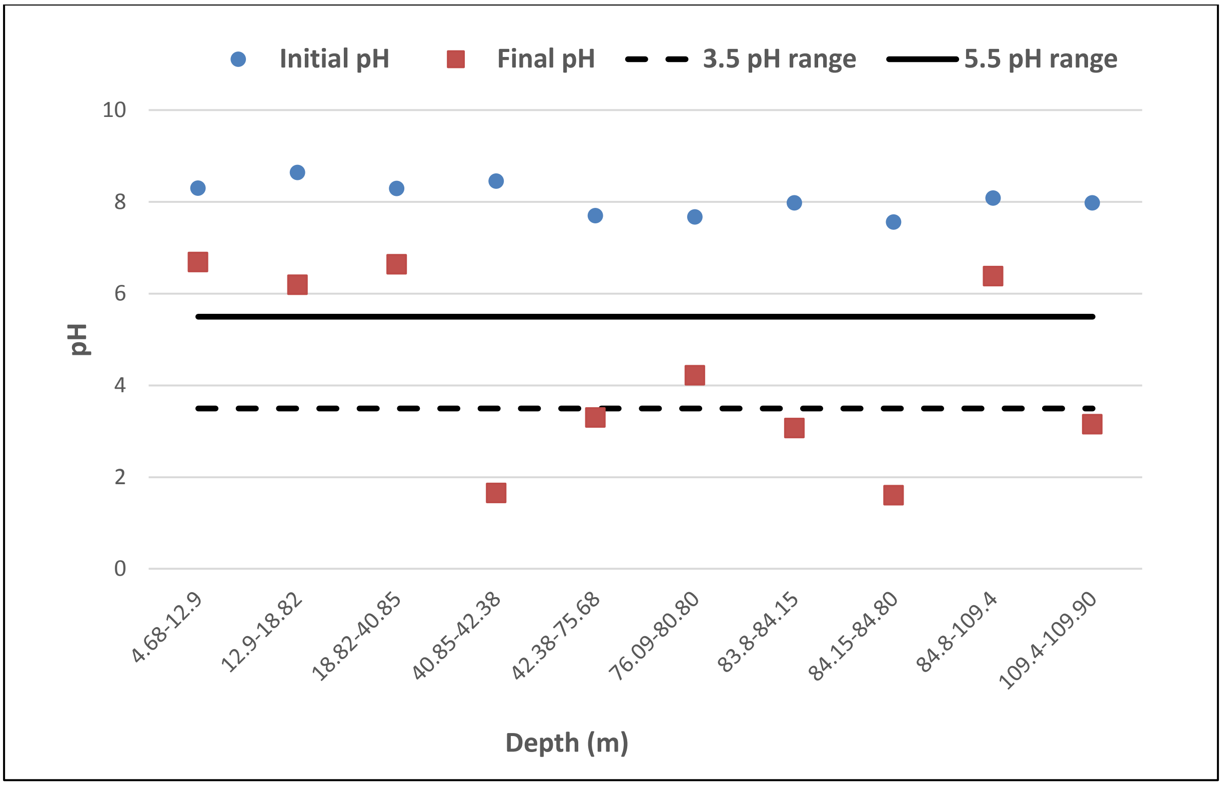


Figure 8: Initial and Final pH showing NAG pH test results of Borehole core F142471

#### 5.2.1.1.4 O105016 Borehole Core

Four (TC113, TC48, TC24 & TC14) of eight samples collected from core O105016 indicates a low risk of acid generation (pH >5.5). Sample TC34 and TC79 indicate a high acid risk with a final pH less than 3.5 (Table 11 Figure 9). Samples TC43 and TC101 (coal sample) had a final pH between 3.5 and 5.5 (medium acid risk). Four samples indicated a low acid risk which means there is enough mineral to minimise the acid.

Table 11: Results of NAG pH test on O105016 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC113 | 20.26-33.5 | SST, SLT | 8.15 | 6.76 | Lower Acid Risk |
| TC48 | 33.5-41.65 | SST, KV | 8.98 | 7.14 | Lower Acid Risk |
| TC43 | 41.65-43.55 | SST,SLT,SH | 8.4 | 4.68 | Medium Risk Acid Generation |
| TC101[b] | 43.55-45.16 | C5H & L | 8.7 | 4.03 | Medium Risk Acid Generation |
| TC34 | 45.16-52.82 | SST,SLT, CSH | 7.57 | 2.92 | Higher Risk Acid Generation |
| TC24 | 52.82-58.99 | DO, KV | 9.64 | 7.89 | Lower Acid Risk |
| TC14 | 58.99-77.95 | SST, SLT, KV, C | 8.95 | 7.35 | Lower Acid Risk |
| TC79 | 80.3-85.56 | SST, SLT, KV, GRT | 7.32 | 2.31 | Higher Risk Acid Generation |
| SST -Sandstone, SLT - Siltstone, DO - Dolerite, CSH -Carbonaceous shale, SH-Shale, GRT - Gritstone, KV - core loss, C - Coal, C5H - No 5 upper coal seam & lower coal seam, b = Coal sample | | | | | |

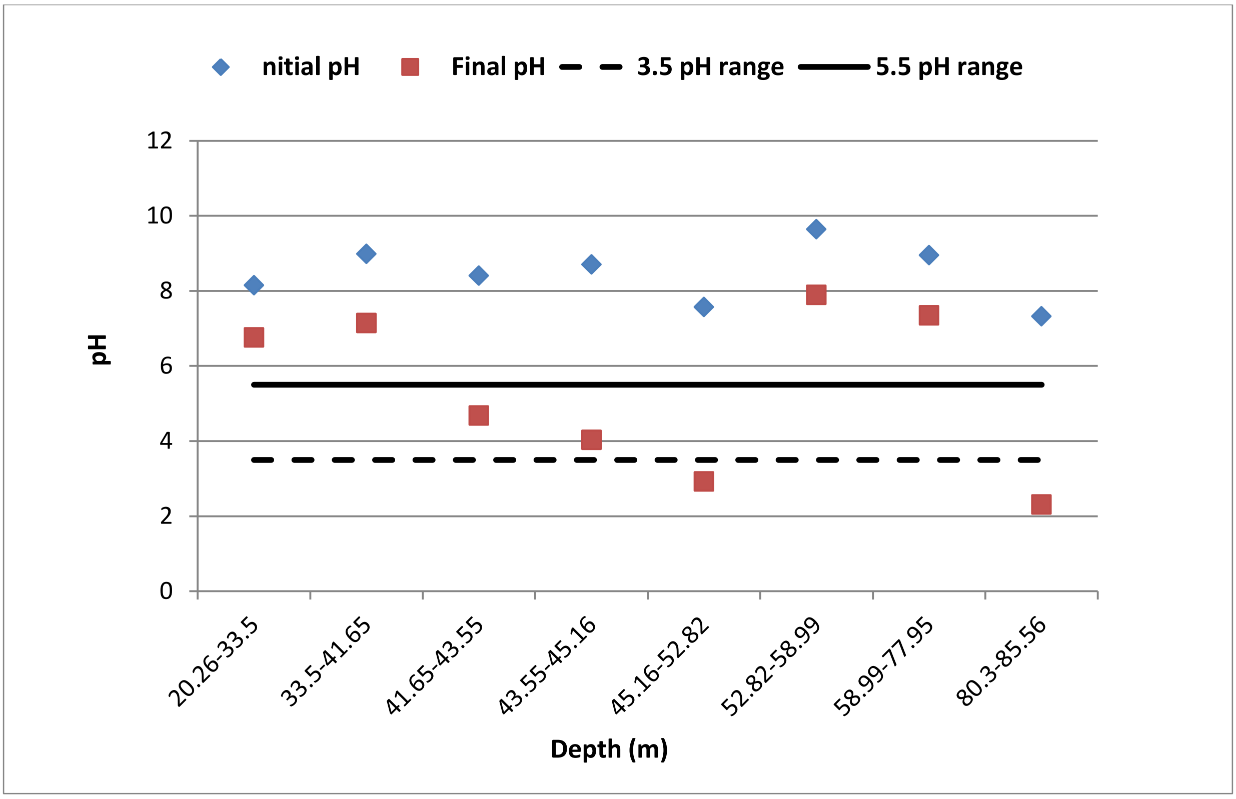


Figure 9: Initial and Final pH showing NAG pH test results of borehole core O105016

#### 5.2.1.1.5 P110030 Borehole Core

The results of the pH's for core P110030 are summarised in Table 12. Based on the interpretation of the pH's results for core P110030 (Table 12), It indicates that five samples have low risk, five samples have high risk and four have medium risk of acid generation (between 3.5 and 5.5). The medium risk samples fall within the grey NNP area (Appendix 9). For future work these samples (grey area) have to be submitted to kinetic testing to confirm the outcome of the samples under "field" weathering which was not part of this study.

Table 12: Results of NAG pH test on P110030 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC49 | 3.8-16.23 | MSB, KV, (OVB) | 8.63 | 6.84 | Lower Acid Risk |
| T52[a] | 16.23-20.7 | DO, KV | 8.77 | 7.03 | Lower Acid Risk |
| T99[a] | 16.23-20.7 | DO, KV | 8.97 | 8.12 | Lower Acid Risk |
| TC1 | 20.7-30.23 | SST, SSL | 8.37 | 6.65 | Lower Acid Risk |
| TC5 | 30.23-42.86 | SST, KV | 8.84 | 6.29 | Lower Acid Risk |
| TC74 | 67.54-68.06 | SH, C | 8.76 | 4.30 | Medium Risk Acid Generation |
| TC117[b] | 67.54-69.54 | C5H | 8.88 | 1.76 | Higher Risk Acid Generation |
| TC104 | 69.54-106.77 | SST, SLT, C | 7.78 | 4.02 | Medium Risk Acid Generation |
| TC109[b] | 106.38-110.22 | C4 | 7.67 | 2.33 | Higher Risk Acid Generation |
| TC82 | 106.77-109.99 | C4L | 7.69 | 3.65 | Medium Risk Acid Generation |
| TC108[b] | 112.75-113.33 | C3 | 7.67 | 1.47 | Higher Risk Acid Generation |

| | | | | | |
|---|---|---|---|---|---|
| TC27 | 109.99-120.22 | C, SST, SLT, CSH | 7.64 | 4.03 | Medium Risk Acid Generation |
| TC98 | 120.22-141.42 | SST, SLT, SH, GRT | 8.26 | 3.12 | Higher Risk Acid Generation |
| TC106[b] | 141.42-141.55 | C2 | 7.61 | 1.58 | Higher Risk Acid Generation |
| DO - Dolerite, SST - Sandstone, SLT - Siltstone, C - coal, CSH -Sarbonaceous shale, MSB - Mudstone bands, KV - Core loss, OVB - Overburden, SH - Shale, SSL - Sandstone lenses, C5H - No 5 Upper Coal Seam, C4 - No 4 coal seam, C4L - No 4 Lower Coal Seam, C3 - No 3 coal seam, C2 - No 2 coal seam, GRT - Gritstone, a = Same Sample , b = Coal Sample | | | | | |

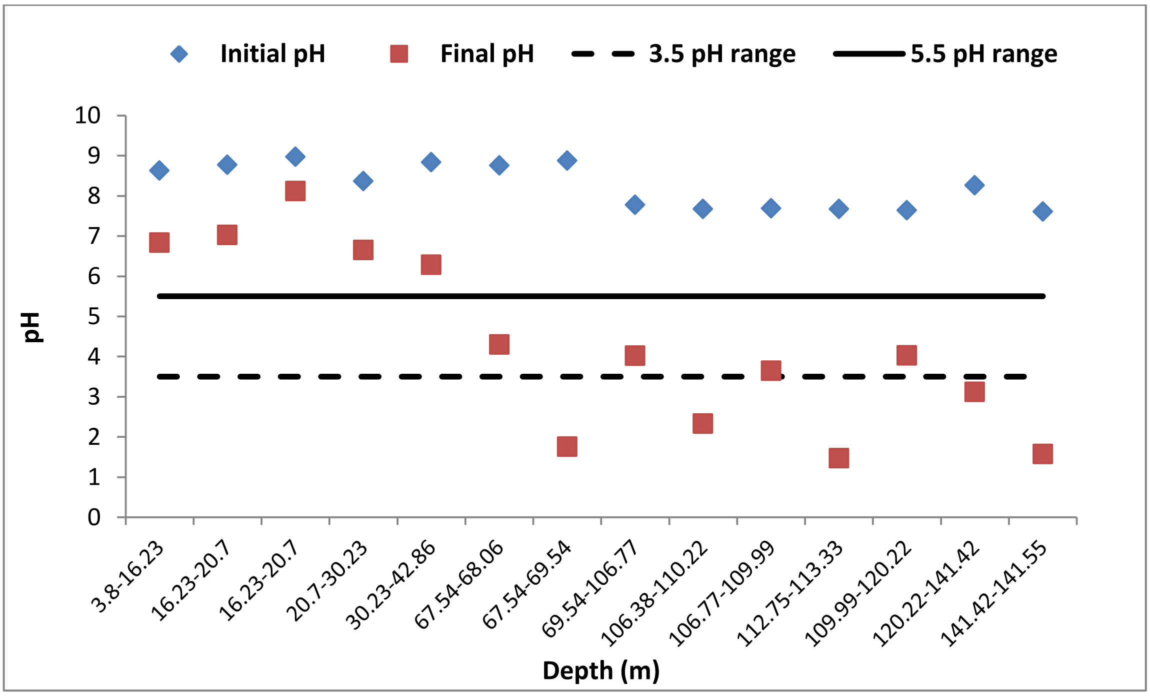


Figure 10: Initial and Final pH showing NAG pH test results of Borehole P110030

#### 5.2.1.1.6 P110087 Borehole Core

The results of the pH's for core P110087 are summarised in Table 13. Based on the interpretation of the pH's results for core P110030 (Table 13), It indicates that four samples have low risk, four samples have high risk and three have medium risk of acid generation (between 3.5 and 5.5) (Figure 11). The medium risk samples fall within the grey NNP area (Appendix 9).

Table 13: Results of NAG pH test on P110087 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC9 | 6-9.93 | DO, KV | 9.15 | 8.21 | Lower Acid Risk |
| TC13 | 9.93-30.18 | DO, SST, SLT, GRT | 8.57 | 5.09 | Medium Risk Acid Generation |
| TC97 | 30.18-40.32 | SST, SLT | 8.99 | 7.3 | Lower Acid Risk |
| TC58 | 40.32-54.77 | SST, SLT | 8.4 | 4.48 | Medium Risk Acid Generation |
| TC23 | 54.77-71.87 | SST, GRT, KV | 8.34 | 3.19 | Higher Risk Acid Generation |
| TC94 | 71.87-89.08 | SST, SLT | 8.45 | 7.58 | Lower Acid Risk |
| TC91[b] | 90.19-90.45 | C5 | 8.68 | 2.68 | Higher Risk Acid Generation |
| TC45 | 90.45-130.50 | SST, SLT, GRT | 7.5 | 3.7 | Medium Risk Acid Generation |
| TC53 | 130.50-133.19 | SST, SLT | 8.4 | 2.94 | Higher Risk Acid Generation |
| TC6 | 133.19-133.97 | GRT, C, SST, SLT | 8.28 | 7.71 | Lower Acid Risk |
| TC73 | 139.15-140.18 | SLT | 7.95 | 2.21 | Higher Risk Acid Generation |

SST - Sandstone, SLT - siltstone, DO - Dolerite, GRT - Gritstone, KV - Core loss, , C5 - No 5 Coal Seam, b = Coal Sample

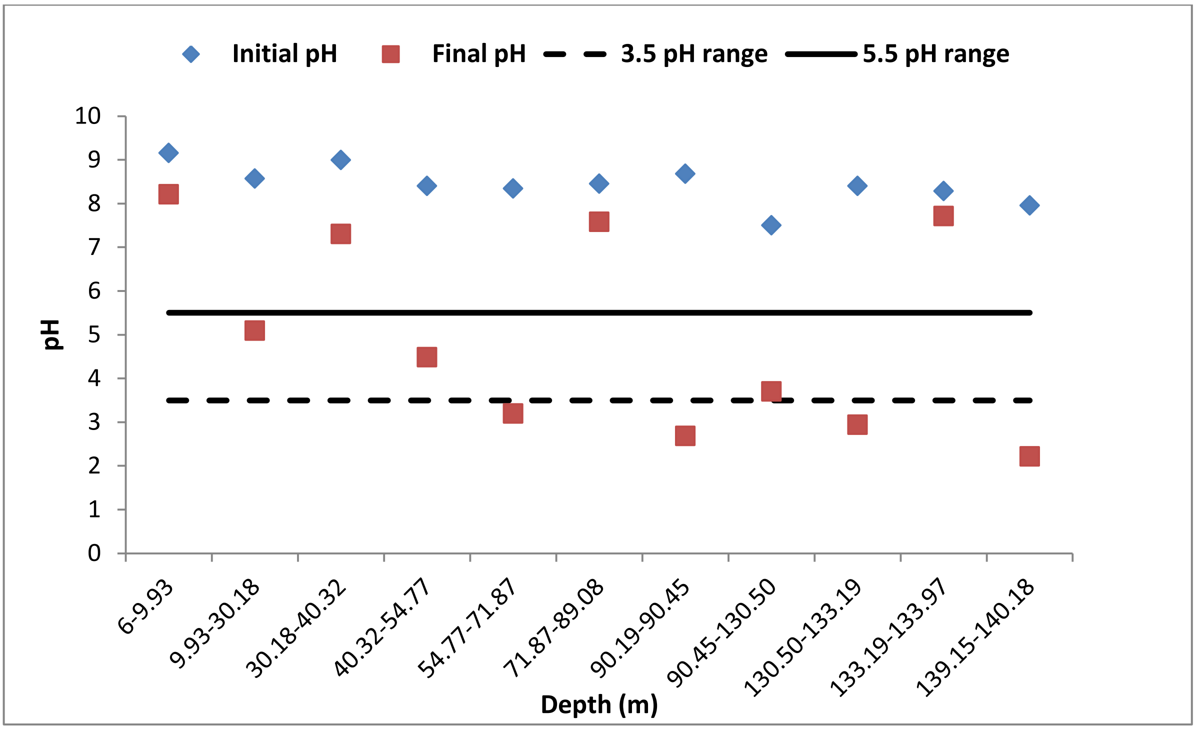


Figure 11: Initial and Final pH showing NAG pH test results of borehole P110087

#### 5.2.1.1.7 R146043 Borehole

Fourteen samples were collected from R146043 borehole core. The samples were taken from depths 5.33m to 170.34m. Four samples (TC28, TC110, 92 and TC118) have final pH's that are below 3.5 as indicated in Table 14 (high risk). TC40 and TC21 samples are between pH of 3.5 and 5.5 and are regarded as having medium risk of acid generation, whereas the remaining samples are non-acid generating (>5.5).

Most of the samples in core R146043 show low acid risk, indicating there are enough neutralising minerals to buffer the pH. Therefore, there will be a low risk of acid generation for this core sample

Table 14: Results of NAG pH test on R146043 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC93 | 5.33-8.17 | KLY, SST | 7.80 | 6.49 | Lower Acid Risk |
| TC116 | 8.17-47.07 | DO | 10.12 | 6.79 | Lower Acid Risk |
| TC47 | 47.07-78.5 | SST, SLT | 9.61 | 7.59 | Lower Acid Risk |
| TC59 | 78.5-94.33 | SST, SLT | 8.58 | 7.17 | Lower Acid Risk |
| TC29 | 94.33-101.9 | SST | 8.71 | 6.40 | Lower Acid Risk |
| TC16 | 101.9-125.08 | SST, SLT | 8.80 | 7.30 | Lower Acid Risk |
| TC28 | 125.08-125.92 | SLT, SH, C | 8.80 | 1.89 | Higher Risk Acid Generation |
| TC110[b] | 125.65-125.92 | C5L | 8.41 | 1.24 | Higher Risk Acid Generation |
| TC40 | 125.92-140.78 | SST, SLT, C, GRT | 8.68 | 4.94 | Medium Risk Acid Generation |
| TC15 | 140.78-141.52 | SST | 8.54 | 8.23 | Lower Acid Risk |
| TC86 | 143.28-160.68 | SST, SLT | 8.23 | 7.53 | Lower Acid Risk |
| TC92 | 160.68-160.98 | CSH | 7.96 | 1.15 | Higher Risk Acid Generation |
| TC21 | 161.15-167.07 | SST | 6.62 | 3.54 | Medium Risk Acid Generation |
| TC118[b] | 167.07-170.34 | C4L | 7.76 | 1.24 | Higher Risk Acid Generation |

KLY- Clayey, SST - Sandstone, DO - Dolerite, SH - Shale, CSH -carbonaceous shale, SLT - siltstone, C5L - No 5 Lower coal seam ,C4L - No 4 Lower coal seam, GRT - Gritstone, b = Coal Sample

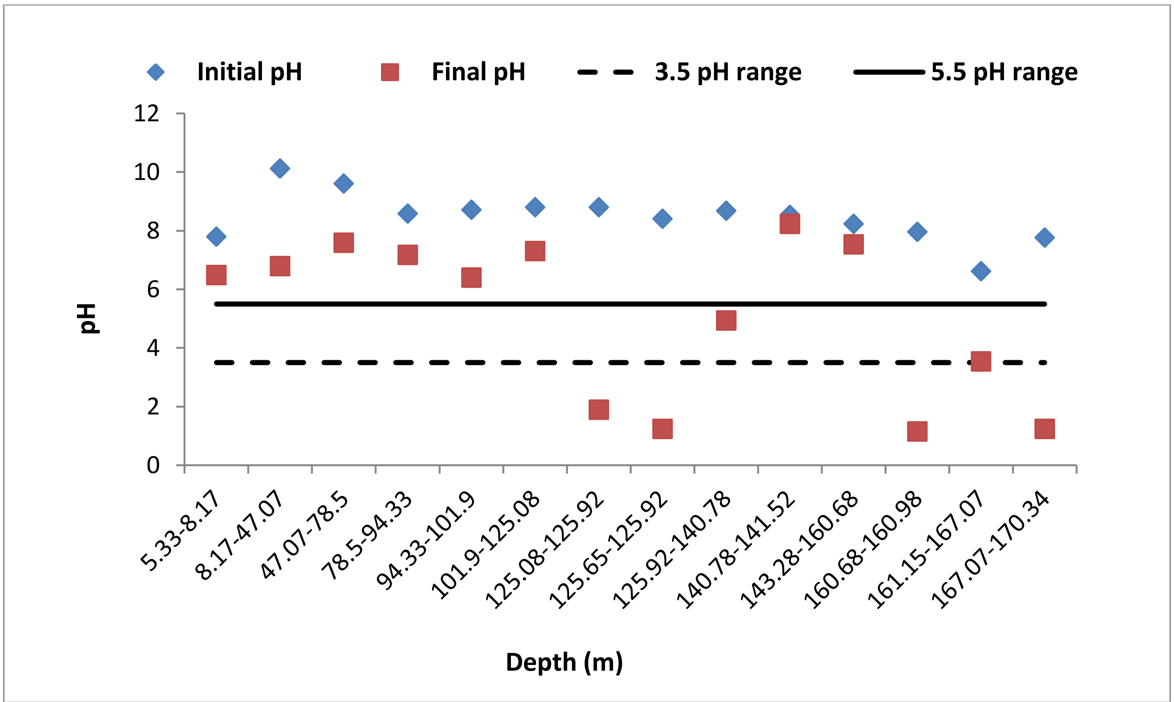


Figure 12: Initial and Final pH showing NAG pH test results of Borehole Z146043

#### 5.2.1.1.8 T139228 Borehole Core

Eleven samples were collected from T139228 borehole core. Five samples (TC39, TC76, TC78, TC56 and TC60) have final pH's that are below 3.5 as indicated in Table 15 (high risk). TC70 and TC96 samples are between pH of 3.5 and 5.5 and are regarded as having medium risk of acid generation, whereas the remaining samples (four) are non-acid generating (>5.5).

Table 15: Results of NAG pH test on T139228 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC70 | 2.2-7.35 | SST, KV | 8.24 | 5.4 | Medium Risk Acid Generation |
| TC44 | 7.35-39.45 | DO | 10.37 | 7.34 | Lower Acid Risk |
| TC36 | 39.45-42.87 | SST, SLT | 10.21 | 7.38 | Lower Acid Risk |
| TC63 | 42.87-43.5 | DO | 9.48 | 7.6 | Lower Acid Risk |
| TC30 | 43.5-82.2 | SST,SLT, KV, GRT | 9.08 | 7.06 | Lower Acid Risk |
| TC39 | 82.2-83.81 | C, CSH, SH | 9.43 | 1.75 | Higher Risk Acid Generation |
| TC76 | 83.81-115.08 | SST,SLT,KV | 7.96 | 3.36 | Higher Risk Acid Generation |
| TC96 | 115.08-117.67 | C, SST, SLT, CSH | 7.87 | 3.85 | Medium Risk Acid Generation |
| TC78 | 115.45-117.67 | C, SST, SLT, CSH | 6.12 | 2.24 | Higher Risk Acid Generation |
| TC56 | 121.35-141.39 | SST,SLT,KV | 7.95 | 3.23 | Higher Risk Acid Generation |
| TC60 | 141.39-145.24 | SST, SLT, SH,C | 8.52 | 2.89 | Higher Risk Acid Generation |
| SST - Sandstone, SLT - Siltstone, DO - Dolerite, CSH -Carbonaceous shale, GRT - Gritstone, KV - Core loss, C - Coal, SH - Shale | | | | | |

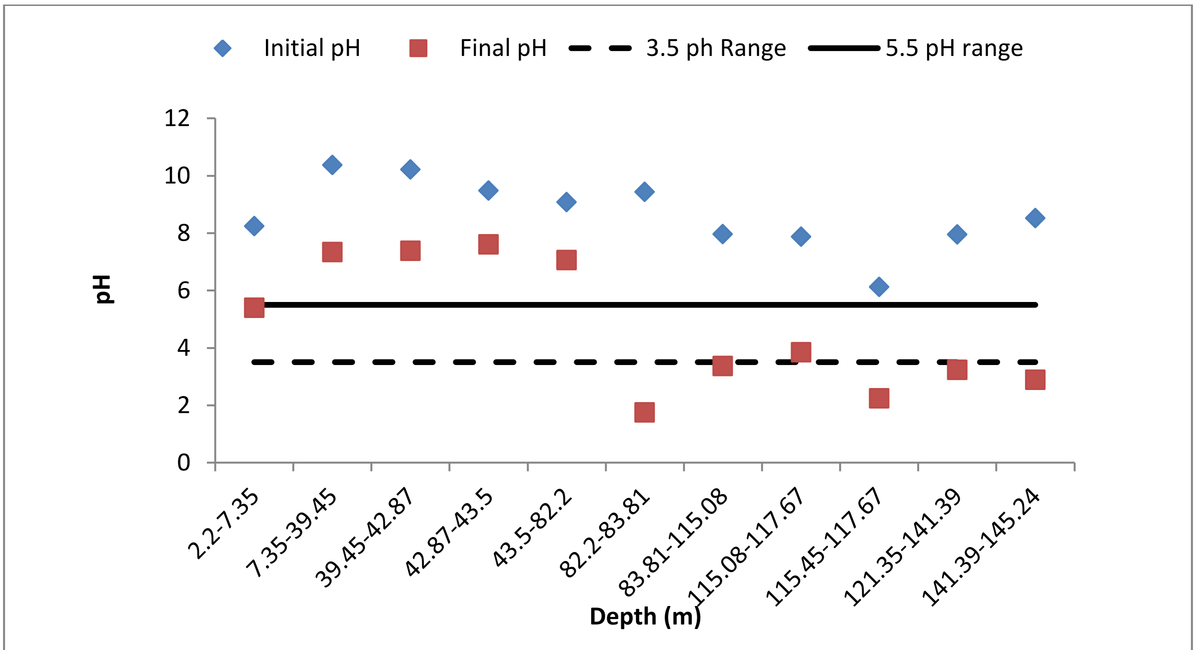


Figure 13: Initial and Final pH showing NAG pH test results of T139228

#### 5.2.1.1.9 W569001 Borehole

Three (TC111, TC102 & TC103) of six samples collected from core W569001 were coal samples. Two samples (T102 & T103) indicate a high risk of acid generation with final pH's less than 3.5. According to the XRD results the samples (T102 & T103) also contain pyrite mineral (Appendix 3). Sample T111 indicates a lower acid risk with a final pH above 5.5 (Table 16 and Figure 14) which means the sample has excess neutralising minerals (Appendix 9) and the calculated NNP for this sample was 47.31 kgCaCO3/tonne. Samples TC80 and TC89 had a final pH between 3.5 and 5.5 (medium acid risk). Four samples indicated a low acid risk which means there is enough mineral to minimise the acid.

Table 16: Results of NAG pH test on W569001 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC69 | 2.4-7.4 | DO, KV | 9.55 | 6.56 | Lower Acid Risk |
| TC80 | 18.7-19.5 | SH, CSH | 7.44 | 3.51 | Medium Risk Acid Generation |
| TC54 | 19.5-55.81 | SST, SLT, KV | 8.77 | 6.74 | Lower Acid Risk |
| TC111[b] | 55.81-59.57 | C4L | 7.64 | 6.01 | Lower Acid Risk |
| TC89 | 59.57-62.8 | SST, SLT, KV | 8 | 3.8 | Medium Risk Acid Generation |
| TC102[b] | 62.8-63.03 | C3 | 7.97 | 1.78 | Higher Risk Acid Generation |
| TC22 | 63.03-90.4 | SST, SLT, KV, SH, GRT, CSH | 9.09 | 6.73 | Lower Acid Risk |
| TC103[b] | 90.4-90.8 | C2 | 7.13 | 1.69 | Higher Risk Acid Generation |

DO - Dolerite, KV - Core loss, SH - Shale, CSH -carbonaceous shale, SST - Sandstone, SLT - siltstone, C4L - No 4 Lower Coal Seam, C3 - No 3 coal seam, C2 - No 2 coal seam, GRT - Gritstone, b - Coal Sample

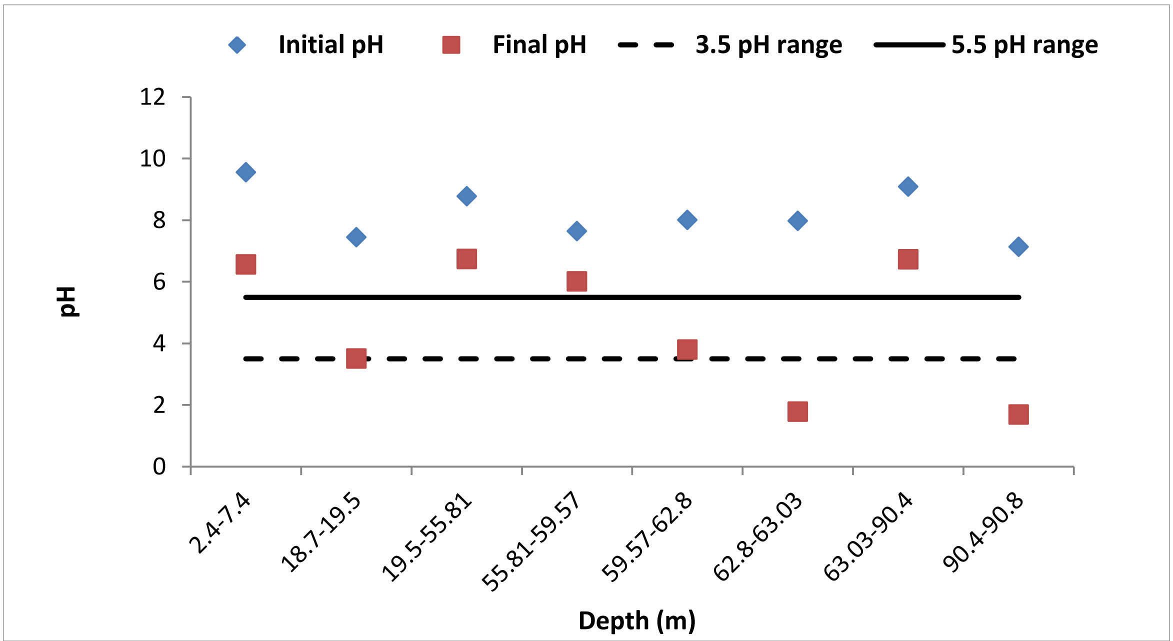


Figure 14: Initial and Final pH showing NAG pH test results of Borehole W569001

#### 5.2.1.1.10 Y106048 Borehole Core

The results of the pH's for core Y106048 are summarised in Table 17. Based on the interpretation of the pH's results for core Y106048 (Table 17), It indicates that two samples have high risk (<3.5) and three have medium risk of acid generation (between 3.5 and 5.5) (Figure 15). The medium risk samples fall within the grey NNP area (Appendix 9).

Table 17: Results of NAG pH test on Y106048 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC32 | 5.95-6.66 | SST, KV | 7.5 | 3.21 | Higher Risk Acid Generation |
| TC12 | 6.66-22.61 | SST,SLT, GRT | 8.18 | 5.1 | Medium Risk Acid Generation |
| TC8 | 22.61-45.06 | SST, SLT, GRT | 8.28 | 5.46 | Medium Risk Acid Generation |
| TC95 | 50.59-70.93 | SST, SLT | 7.97 | 4.53 | Medium Risk Acid Generation |
| TC19 | 70.93-75.27 | SST, SLT,GRT | 8.08 | 3 | Higher Risk Acid Generation |
| KV - Core loss, SST - Sandstone, SLT - siltstone, GRT - Gritstone. | | | | | |

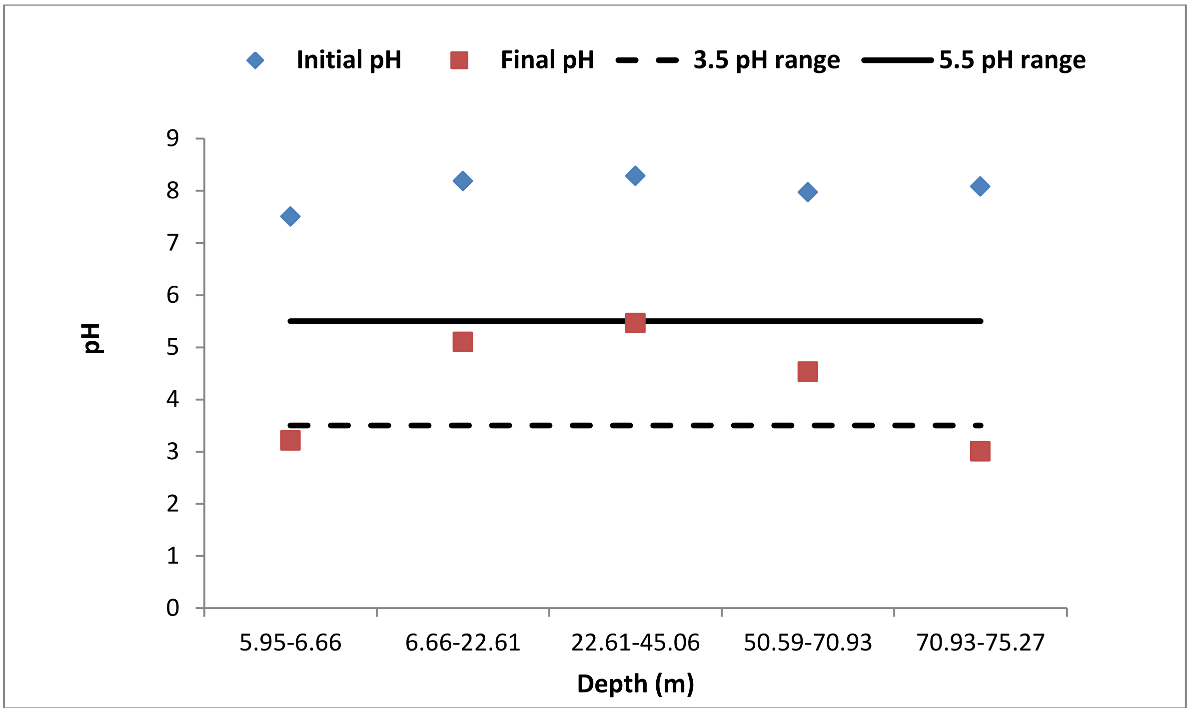


Figure 15: Initial and Final pH showing NAG pH test results of borehole core Y106048

#### 5.2.1.1.11 Z145168 Borehole Core

Eight samples were collected from Z145168 borehole core. Five samples indicate low acid risk (Table 18) Only one sample has a final pH that is below 3.5 as shown in Figure 16 (high risk). TC31 and TC67 samples are between pH of 3.5 and 5.5 and are regarded as having medium risk of acid generation.

Most of the samples in core Z145168 show low acid risk, indicating there are enough neutralising minerals to buffer the pH.

Table 18: Results of NAG pH test on Z145168 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC31 | 1.6-6.1 | SST, GKS, KV | 8.39 | 4.81 | Medium Risk Acid Generation |
| TC115 | 6.1-49.68 | DO | 9.81 | 7.62 | Lower Acid Risk |
| TC100 | 49.68-56.74 | SST, SLT, KV | 9.57 | 7.46 | Lower Acid Risk |
| TC37 | 56.74-57.36 | DO | 9.78 | 8.5 | Lower Acid Risk |
| TC68 | 57.36-68.81 | SST, SLT, MST | 9.35 | 5.78 | Lower Acid Risk |
| TC85 | 68.81-94.75 | SST, SLT, GRT | 8.31 | 6.48 | Lower Acid Risk |
| TC67 | 96.22-136.4 | SST, SLT, C, CSH, DO | 8.16 | 3.77 | Medium Risk Acid Generation |
| TC42 | 139.31-142.08 | SST, SLT | 7.85 | 2.74 | Higher Risk Acid Generation |
| DO - Dolerite, KV - Core loss, , CSH -Carbonaceous shale, SST - Sandstone, SLT - Siltstone, GRT - Gritstone, C - Coal, GKS - Soil clayey mostly sandy, MST -Mudstone | | | | | |

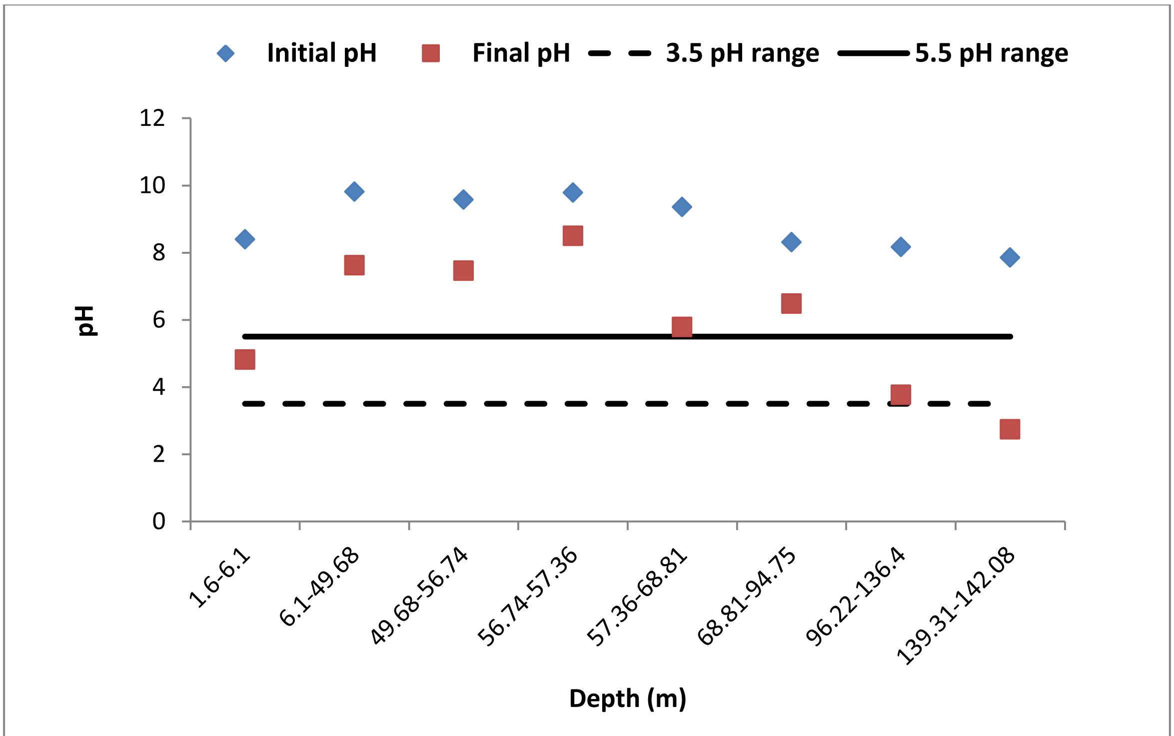


Figure 16: Initial and Final pH showing NAG pH test results of borehole core Z145168

#### 5.2.1.1.12 Z145198 Borehole Core

Figure 17 show three samples (TC2, TC72 and TC88) with a final pH's below 3.5 (high risk) and Three samples (TC71, TC90 and TC26) with a final pH's above 5.5 (low acid risk). The XRD results (Appendix 3) shows that sample all samples with low acid risk contain calcite.

Table 19: Results of NAG pH test on Z145198 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC71 | 3.33-45.04 | DO | 10.12 | 7.75 | Lower Acid Risk |
| TC90 | 45.04-90.02 | SST,SLT,SH | 8.78 | 6.83 | Lower Acid Risk |
| TC26 | 91.03-127.78 | SST,SLT,SH | 8.63 | 7.7 | Lower Acid Risk |
| TC2 | 132.14-134.94 | SST, SLT, C | 7.7 | 2.85 | Higher Risk Acid Generation |
| TC72 | 134.94-151.78 | SST, SLT, SH | 8.03 | 3.07 | Higher Risk Acid Generation |
| TC88 | 151.78-184 | SST, SST,C | 7.88 | 3.02 | Higher Risk Acid Generation |
| DO - Dolerite, SH - Shale, SST - Sandstone, SLT - Siltstone, C - Coal | | | | | |

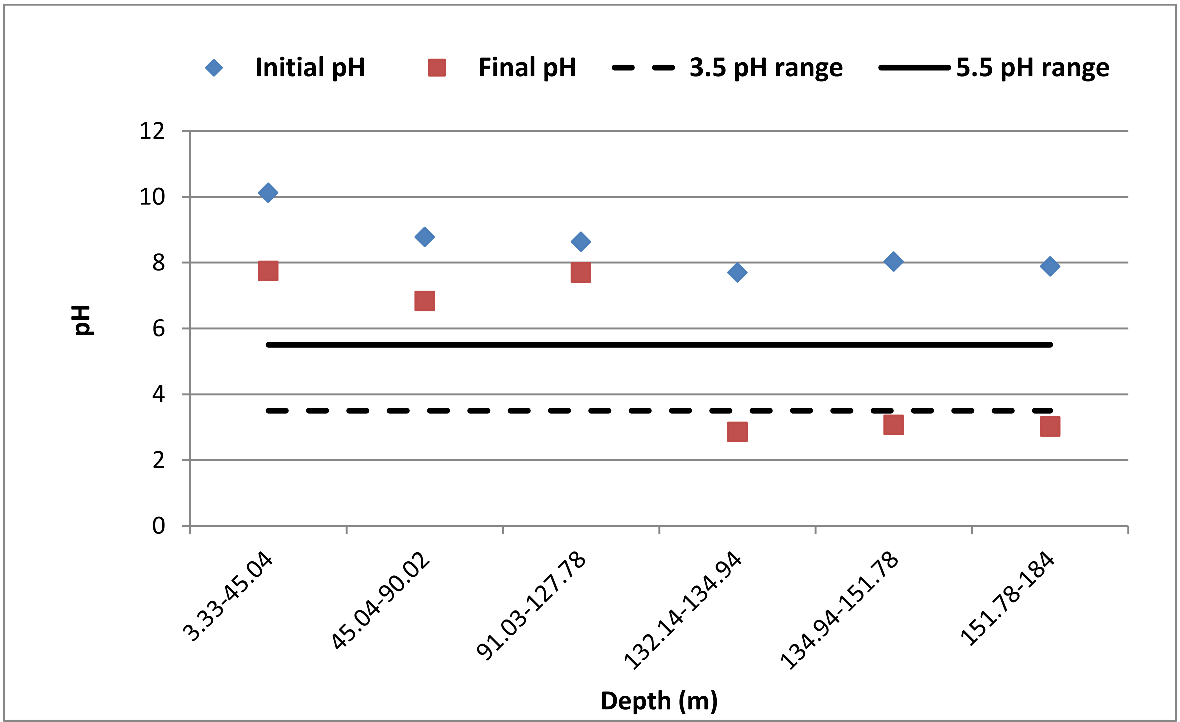


Figure 17: Initial and Final pH showing NAG pH test results of borehole core Z145198

### 5.2.1.1.13 Z145199 Borehole Core

Figure 18 show two samples (TC81 & TC64) with a final pH below 3.5 (high risk of acid generation) (Table 20).The XRD results (Appendix 3) shows that sample TC64 contains pyrite which cause a high risk of acid generation. Sample TC46, TC17, TC50, TC77 and TC20 have a low acid risk with a final pH greater than 5.5. The XRF results for samples TC46 and TC50 (Appendix 5) indicates that it contains a high percentage of CaO. Samples TC77 and TC20 consist of calcite mineral which have the potential to neutralising the acid.

More samples have low risk of generating an acid therefore core samples from Borehole Z145199 will not be expected to generate acid as it has enough minerals to neutralise an acid.

Table 20: Results of NAG pH test on Z145199 core samples

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| TC46 | 0-22.52 | KLY,KV,DO | 9.59 | 6.98 | Lower Acid Risk |
| TC17 | 22.52-28.75 | SST, SLT | 8.79 | 6.82 | Lower Acid Risk |
| TC50 | 28.75-52.14 | DO,KV | 10.18 | 7.64 | Lower Acid Risk |
| TC77 | 52.14-123.92 | SST,SLT,KV,DO,GRT | 8.53 | 7.76 | Lower Acid Risk |
| TC81 | 123.92-124.6 | SH | 8.77 | 1.79 | Higher Risk Acid Generation |
| TC20 | 125.80-159.6 | SST, SLT, C | 8.36 | 7.53 | Lower Acid Risk |
| TC64 | 160.3-162.3 | C, SST | 8.15 | 3.03 | Higher Risk Acid Generation |
| KLY- Clayey, KV - Core loss, DO - Dolerite, SST - Sandstone, SLT - siltstone, SH - Shale, GRT - Gritstone, C - Coal | | | | | |

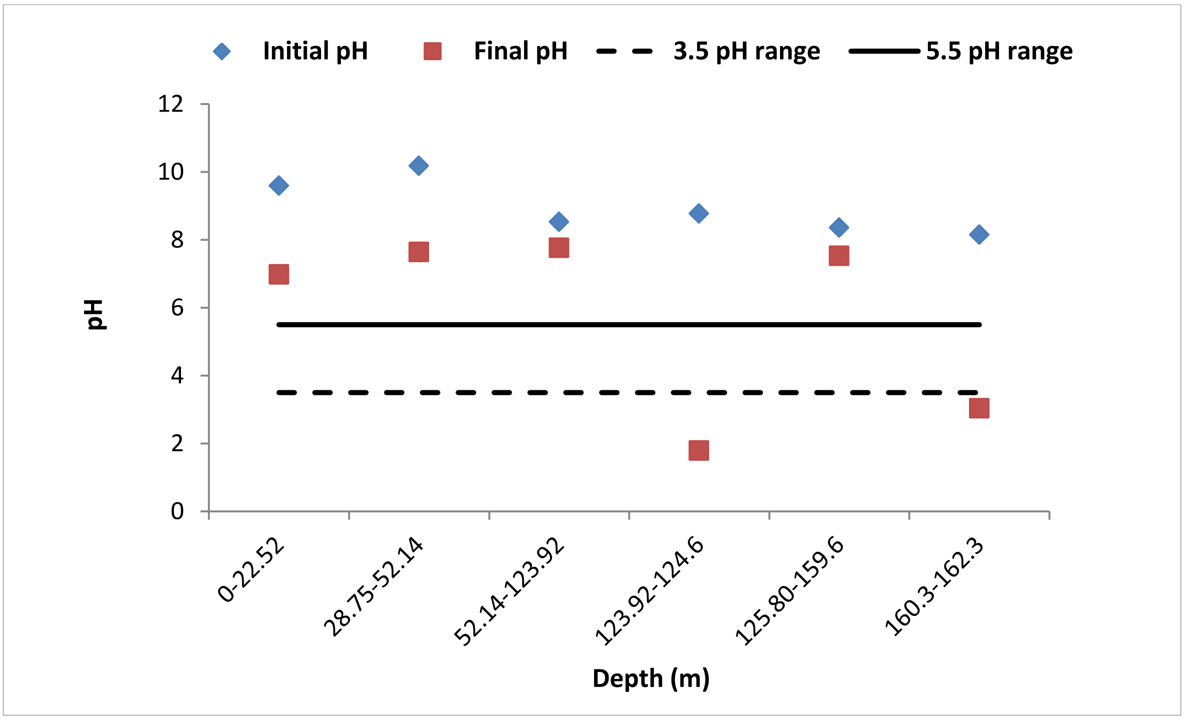


Figure 18: Initial and Final pH showing NAG pH test results of Borehole Z145199

#### 5.2.1.2 Net Neutralising Potential

Figure 19 shows the initial and final pH versus closed NNP results. All samples have initial pH that is greater than 6 which mean samples have not been oxidised in the field. NNP results (Appendix 9) indicates that 62 samples (52.5 %) are inconclusive as they fall within the area of uncertainty -20 to 20kg/t $CaCO_3$ (Figure 19). Samples in this area will need further testing for further confirmation of the oxidisation outcome e.g. Kinetic/Humidity Tests. The NNP results also indicate that 36 samples (30.5 %) are classified as having a neutralising potential. Only 20 samples (17 %) have the potential to generate a net acid with a closed NNP of less than 20kg/t $CaCO_3$.

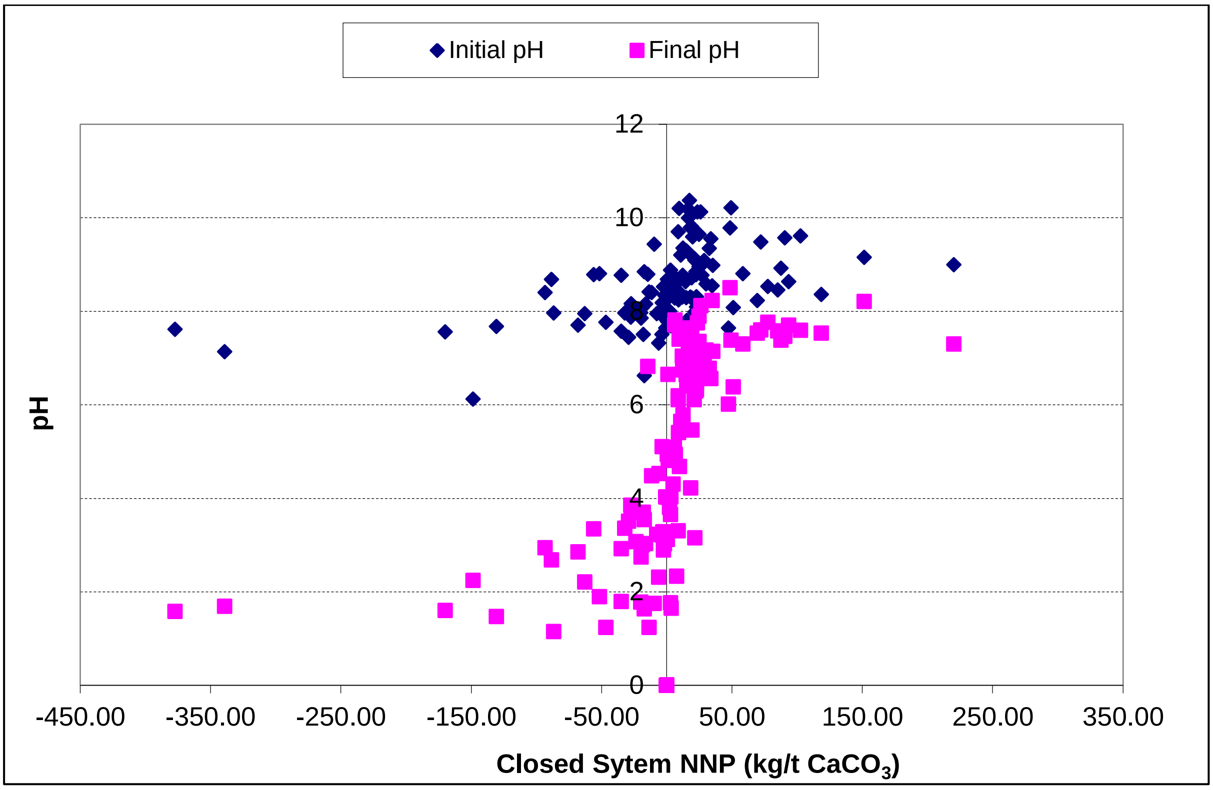


Figure 19: Initial and Final pH vs close NNP

#### 5.2.1.3 Neutralising Potential Ratio (NPR)

The AP and NP data (Appendix 11) obtained for the mines is used to plot the NPR graph (Figure 20). Information from Table 6 was used as a guideline for the interpretation of Figure 20. From this NPR graph, the samples that plot below the green line of 4:1, acidification is unlikely. In samples that plot above the ratio of 1:1, acidification is likely to happen. For this specific mine, more (44.1%) samples plotted below the 4:1 ratio which are unlikely to generate an acid. Only a few (35.6%) samples plotted above 1:1 which are likely to acidify. The samples plotting between 1:1 and 4:1 ratio are inconclusive (20.3%).

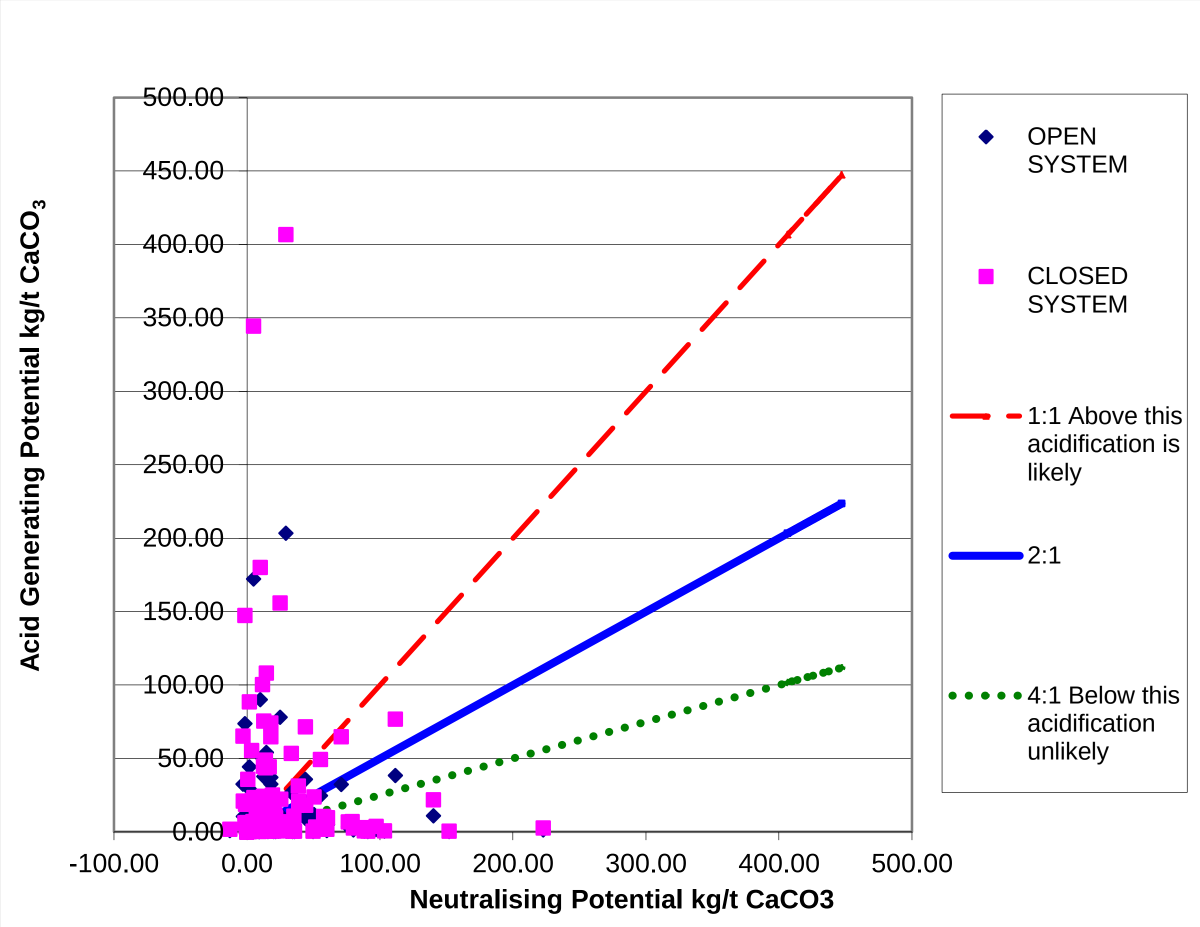


Figure 20: AP vs NP (NPR)

#### 5.2.1.4 Neutralising Potential Ratio (NPR) versus sulphide S

The data from Appendix 11 are used to create the NPR versus percentage S plot. The plots from this graph confirm the results as discussed in the previous headers. Overall there are more (44.1 %) samples plotting in the green area indicating that these samples contain a base potential and no potential to produce acid. The samples plotting in the red area (to the right of 0.3 %S) and below the NPR of 1 (red line) are the samples with the potential to generate acid. The rest of the samples are those plotting in the grey area.

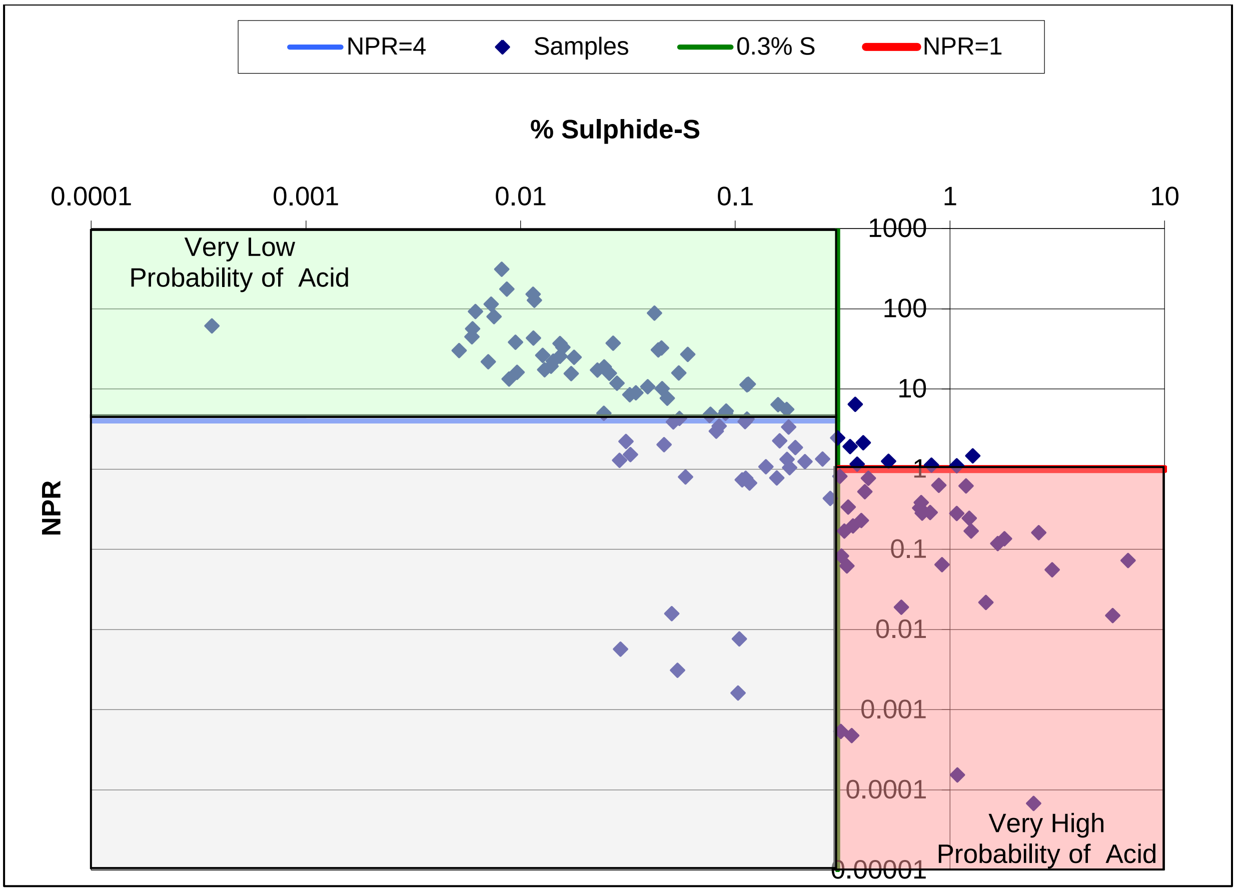


Figure 21: NPR vs Sulphide-S

#### 5.2.1.5 Conclusion

Out of 118 samples analysed from Mine 1, 58 samples (49%) were non-acid generating with a pH's above 5.5, while 22 samples (19%) have a medium risk of generating an acid as their pH values were between 3.5 and 5.5 and the rest (32%) of the samples (38) have the pH's of less than 3.5 which have a high risk of generating an acid (Appendix 7). Most of the samples that have a high risk of generating an acid were coal samples and samples that have a mixture of coal combined with different rock formation. Samples that have a low risk of acid generation they contain calcite and dolomite which are the most common neutralising minerals. Therefore, the risk of acid generation will be on coal seam than on other rock formation.

### 5.2.2 Mine 2 analysis

5 borehole core samples were collected from for Mine 2. 71 samples were selected and analysed. The samples collected consist of sandstone, siltstone, coal and other geological formations shown in Appendix 8.

#### 5.2.2.1 Net Acid Generating (NAG) Test pH

Results for the NAG test are presented in Tables 21 to Table 25. Interpretation of the results helped to assess whether the samples are acid or non-acid generating. The graphs below each table of results are plotted to show the number of samples with a pH above 5.5, between 5.5 and 3.5 and below 3.5. These graphs are used for further interpretation. The information from Table 5 above was used to indicate the likelihood of net acid generation of the sample upon oxidation.

##### 5.2.2.1.1 R100001 Borehole Core

Thirteen samples were collected from R100001 borehole core. The samples were taken from depths 1.62m to 143.10m. Seven samples indicate a lower acid risk with a final pH above 5.5 (Table 21) which means the samples have excess neutralising minerals. Two samples (SF13 and SF2) have final pH's that are below 3.5 as indicated in Figure 22 (high risk). Samples SF1, SF15, SF16 and SF17 are between pH of 3.5 and 5.5 and are regarded as having medium risk of acid generation

Most of the samples in core R100001 show low acid risk, indicating there are sufficient neutralising minerals to buffer the pH.

Table 21: Results of NAG pH test on R100001 core samples

| Lab Number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| SF 11 | 1.62-12.46 | DO | 9.8 | 7.75 | Lower Acid Risk |
| SF 12 | 12.46-24.48 | SST, SLT, GRT | 9.81 | 7.56 | Lower Acid Risk |
| SF 13 | 24.48-25.26 | C, CSH | 9.85 | 2.37 | Higher Risk Acid Generation |
| SF 61[b] | 24.48-25.80 | C5H, C5M, C5L | 8.89 | 5.61 | Lower Acid Risk |
| SF 14 | 25.8-50.66 | SLT, SST | 8.93 | 7.3 | Lower Acid Risk |
| SF 1 | 50.66-51.6 | SLT, GRT | 8.04 | 4.27 | Medium Risk Acid Generation |
| SF 62[b] | 51.6-56.92 | C4L | 8.22 | 6.21 | Lower Acid Risk |
| SF 2 | 56.92-57.14 | SLT | 7.73 | 3.44 | Higher Risk Acid Generation |
| SF 15 | 57.14-85.28 | SST, SLT | 8.6 | 4.51 | Medium Risk Acid Generation |
| SF 16 | 86.82-112.94 | SST | 7.63 | 3.64 | Medium Risk Acid Generation |
| SF 17 | 112.94-116.23 | GRT | 7.55 | 3.51 | Medium Risk Acid Generation |
| SF 18 | 116.23-130.1 | SST, GRT, SLT, WSH | 8.14 | 6.85 | Lower Acid Risk |
| SF 19 | 130.1-143.1 | TIL | 9.24 | 7.83 | Lower Acid Risk |
| DO - Dolerite, SST - Sandstone, SLT - Siltstone, GRT - Gritstone C - Coal, CSH -Carbonaceous shale, , C5H - No 5 Upper Coal Seam, C5M - No 5 Middle Coal Seam, C5L - No 5 Lower Coal Seam, C4L - No 4 Lower Coal Seam, WSH - Varved Shale, TIL - Tillite, b = Coal Sample | | | | | |

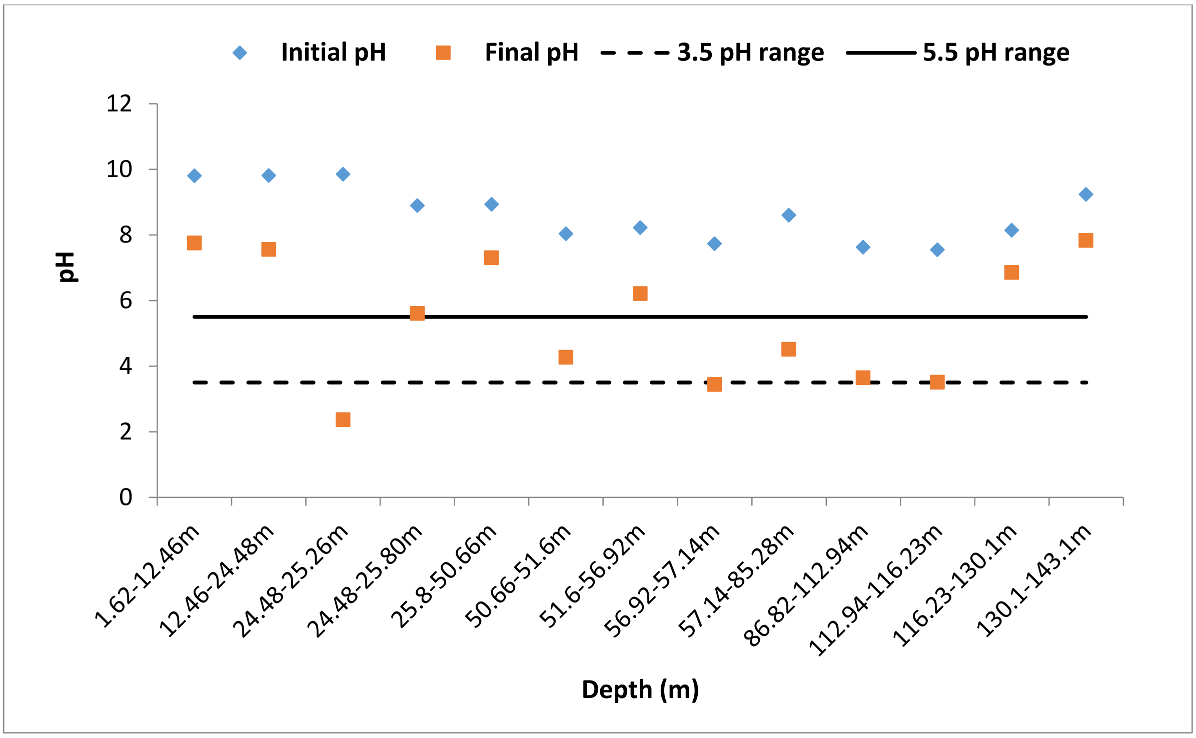


Figure 22: Initial and Final pH showing NAG pH test results of Borehole R100001

### 5.2.2.1.2 R100002 Borehole Core

Figure 23 shows one sample (SF4) with a final pH below 3.5 (high risk). The XRD results (Appendix 3) show that sample SF4 contains pyrite which causes a high risk of acid generation. Samples SF20, SF21, SF3 and SF24 have a low acid risk with a final pH greater than 5.5. The XRF results for samples SF20 and SF21 (Appendix 5) indicates that they contains a high percentage of CaO and they contain calcite which have the potential to neutralising the acid. The medium risk samples fall within the grey NNP area (Appendix 10).

Table 22: Results of NAG pH test on core samples from borehole R100002

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| SF 20 | 14.1-18 | GRD, SST, DO | 9.16 | 7.92 | Lower Acid Risk |
| SF 21 | 18.3-37.5 | SST, SLT | 8.7 | 7.62 | Lower Acid Risk |
| SF 3 | 37.5-37.82 | GRT | 7.86 | 5.91 | Lower Acid Risk |
| SF 63[b] | 37.82-43.08 | C4L | 7.95 | 5.49 | Medium Risk Acid Generation |
| SF 4 | 43.08-45.72 | SST, SLT | 7.92 | 1.84 | Higher Risk Acid Generation |
| SF 22 | 45.72-70.1 | SST, SLT | 8.4 | 4.25 | Medium Risk Acid Generation |
| SF 23 | 71.4-103.8 | SST, GRT | 7.77 | 3.72 | Medium Risk Acid Generation |
| SF 24 | 103.8-124.4 | GRT, TIL, KV | 8.25 | 6.57 | Lower Acid Risk |

DO - Dolerite, KV - Core loss, SH - Shale, CSH -Carbonaceous shale, SST - Sandstone, SLT - Siltstone, C4L - No 4 Lower Coal Seam, GRT - Gritstone, TIL - Tillite, KV - Core loss b = Coal Sample

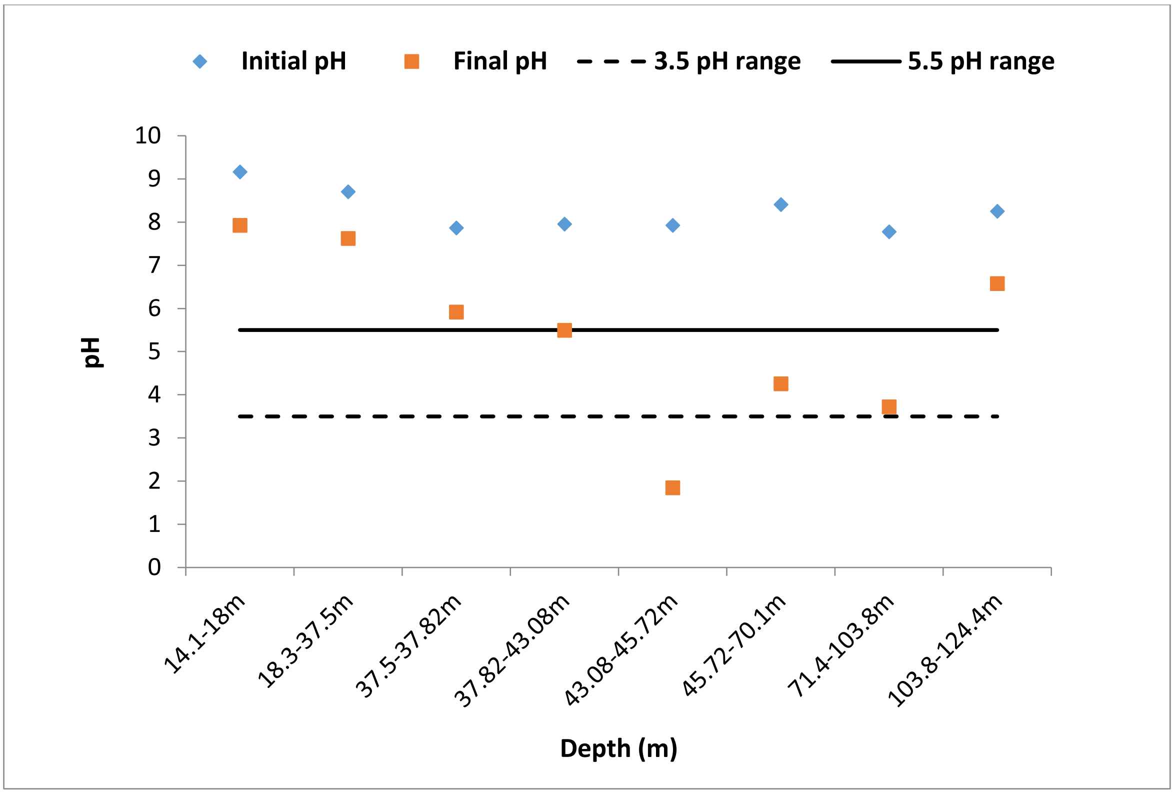


Figure 23: Initial and Final pH showing NAG pH test results of Borehole R100002

#### 5.2.2.1.3 Z124027 Borehole Core

The results of the pH's for core Z124027 are summarised in Table 23. Based on the interpretation of the pH's results for core Z124027 (Table 23), It indicates that six samples have high risk (<3.5). Two samples (SF59 and SF60) have medium risk of acid generation (between 3.5 and 5.5) (Figure 24). The medium risk samples fall within the grey NNP area (Appendix 10). Most (Thirteen) of the samples in core Z124027 show low acid risk, indicating there are enough neutralising minerals to buffer the pH.

Table 23: Results of NAG pH test on core samples from borehole Z124027

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| SF 45 | 4.13-14.04 | DO, KV, | 9.27 | 8.43 | Lower Acid Risk |
| SF 46 | 14.04-48.99 | SST, SLT | 9.54 | 8.1 | Lower Acid Risk |
| SF 47 | 48.99-69.26 | SST, DO | 8.9 | 5.86 | Lower Acid Risk |
| SF 48 | 69.26-90.34 | SST, SLT | 9.05 | 7.22 | Lower Acid Risk |
| SF 49 | 90.44-91.84 | C, CSH | 9.34 | 2.41 | Higher Risk Acid Generation |
| SF 64[b] | 91.84-92.34 | C5L | 8.94 | 7.74 | Lower Acid Risk |
| SF 50 | 92.34-93.61 | DO | 9.89 | 8.22 | Lower Acid Risk |
| SF 51 | 93.61-123.04 | SST, SLT | 8.89 | 7.81 | Lower Acid Risk |
| SF 65[b] | 123.08-123.68 | C4H | 8.31 | 2.29 | Higher Risk Acid Generation |

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| SF 52 | 123.68-125.28 | SH, SST, GRT, SLT | 8.07 | 3.21 | Higher Risk Acid Generation |
| SF 7 | 125.28-125.88 | GRT | 5.57 | 2.33 | Higher Risk Acid Generation |
| SF 66[b] | 125.88-129.68 | C4L | 8.18 | 5.51 | Lower Acid Risk |
| SF 8 | 129.78-134.51 | SLT, SST, C | 7.37 | 2.87 | Higher Risk Acid Generation |
| SF 53 | 134.48-162.76 | SLT, SST, C, DO | 9.21 | 6.67 | Lower Acid Risk |
| SF 54 | 162.54-164.8 | DO, SST, C | 10.33 | 8.5 | Lower Acid Risk |
| SF 55 | 167.2-172.87 | GRT, SLT | 8.72 | 2.52 | Higher Risk Acid Generation |
| SF 56 | 172.87-180.67 | SST, DO | 8.92 | 6.83 | Lower Acid Risk |
| SF 57 | 180.67-183.7 | DO | 9.91 | 8.25 | Lower Acid Risk |
| SF 58 | 183.7-186.86 | SST, SLT | 8.88 | 5.88 | Lower Acid Risk |
| SF 59 | 186.86-189.02 | TIO, SST | 8.32 | 4.37 | Medium Risk Acid Generation |
| SF 60 | 189.02-200.16 | QZT, EOH | 8.65 | 4.32 | Medium Risk Acid Generation |
| DO - Dolerite, SST - Sandstone, SLT - Siltstone, C - Soal, CSH - Carbonaceous shale, MSB - Mudstone bands, KV - Core loss, SH - Shale, C5L - No 5 Lower Coal Seam, C4L - No 4 Lower Coal Seam, C4H - No 4 Upper Coal Seam, GRT - Gritstone, TIO - Tilloid, QZT - Quartzite, EOH - End of hole, b = Coal Sample | | | | | |

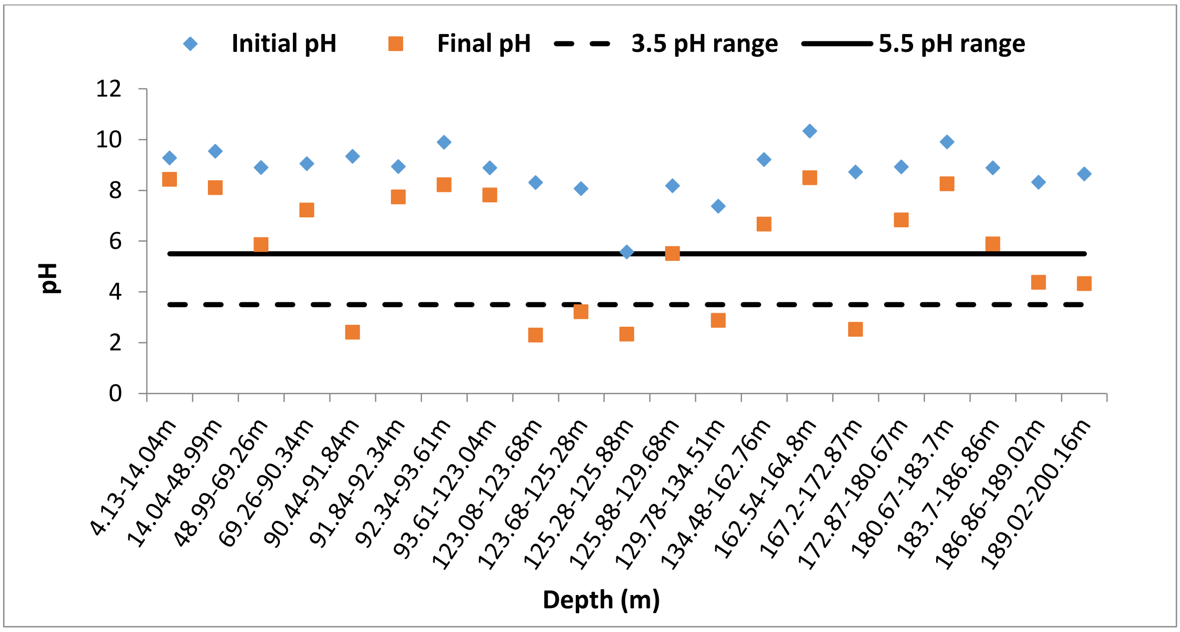


Figure 24: Initial and Final pH showing NAG pH test results of Borehole Z124027

#### 5.2.2.1.4 Z124029 Borehole Core

Figure 25 shows four samples (SF5, SF30, SF31 and SF32) with a final pH below 3.5 (high risk). The XRD results (Appendix 3), indicates that sample SF5 and SF32 contains pyrite which cause a high risk of acid generation. Eight samples have a low acid risk with a final pH greater than 5.5. Only one sample has medium risk. Borehole core Z124029 has more samples with potential of neutralising an acid than potential of generating an acid.

Table 24: Results of NAG pH test on core samples from borehole Z124029

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| SF 25 | 6.9-8.1 | KV, SST | 8.73 | 5.65 | Lower Acid Risk |
| SF 26 | 8.1-61.46 | DO | 10.41 | 7.05 | Lower Acid Risk |
| SF 27 | 61.46-73.68 | SST, SLT, GRT | 10.38 | 6.46 | Lower Acid Risk |
| SF 28 | 73.68-74.72 | C, CSH | 10.09 | 5.91 | Lower Acid Risk |
| SF 29 | 74.72-98.23 | SST, SLT | 9.9 | 6.89 | Lower Acid Risk |
| SF 5 | 98.23-98.88 | SST, SLT | 8.2 | 3.36 | Higher Risk Acid Generation |
| SF 67[b] | 98.88-102.83 | C4L | 8.19 | 5.41 | Medium Risk Acid Generation |
| SF 6 | 102.83-104.6 | GRT | 8.43 | 6.75 | Lower Acid Risk |
| SF 30 | 104.6-132.74 | SST, SLT, GRT | 8.54 | 3.45 | Higher Risk Acid Generation |
| SF 31 | 133.63-136.28 | SST, SLT, GRT | 8.57 | 2.59 | Higher Risk Acid Generation |
| SF 32 | 138.64-158.45 | SST, SLT, GRT | 8.58 | 2.97 | Higher Risk Acid Generation |
| SF 33 | 158.45-165.43 | SST, SLT, TIL | 8.55 | 5.65 | Lower Acid Risk |
| SF 34 | 165.43-174.53 | GR, EOH | 10.26 | 7.9 | Lower Acid Risk |
| KV - Core loss DO - Dolerite, SST - Sandstone, SLT - Siltstone, GRT - Gritstone , C - Coal, CSH - carbonaceous shale, C4L - No 4 Lower Coal Seam, GR - Granite , EOH - End of hole, b = Coal Sample | | | | | |

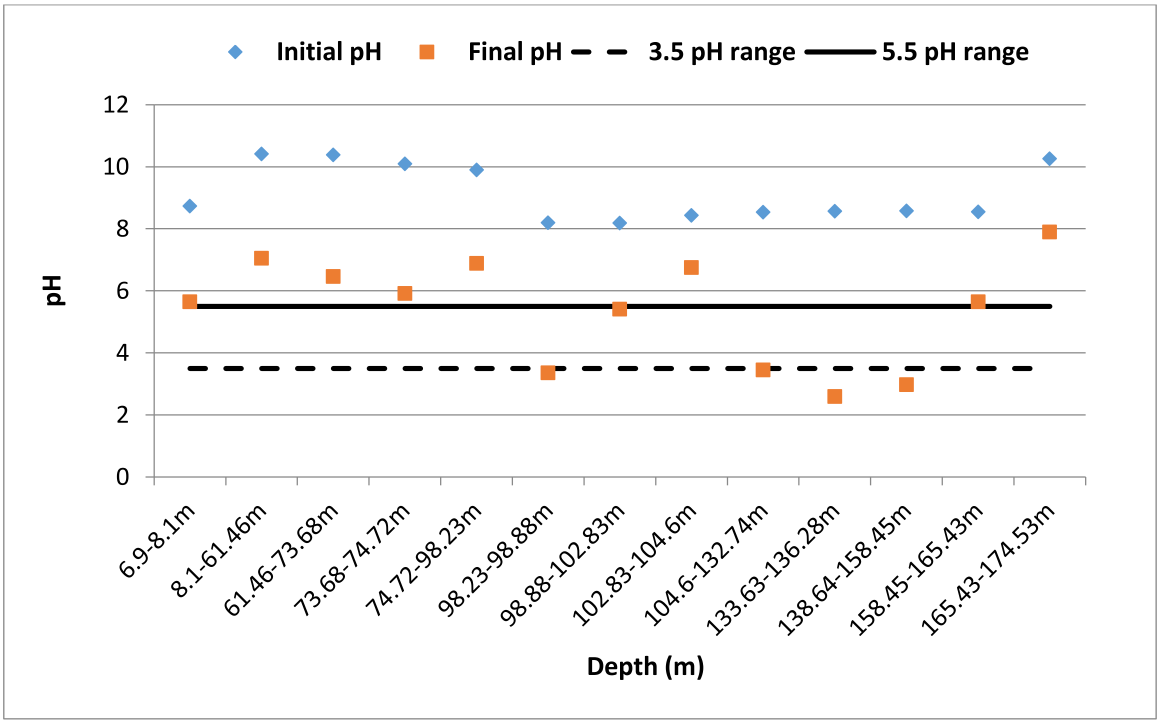


Figure 25: Initial and Final pH showing NAG pH test results of Borehole Z124029

#### 5.2.2.1.5 Z124030 Borehole Core

Four (SF68, SF69, SF70 and SF71) of sixteen samples collected from core Z124030 were coal samples. Three samples (SF68, SF69 and SF70) indicate a high risk of acid generation with final pH's less than 3.5. According to the XRD results the samples (SF68, SF40 and 70) also contain pyrite mineral (Appendix 4). Eight samples indicate a lower acid risk with a final pH's above 5.5 (Table 25 and Figure 26) which means the sample has excess neutralising minerals (Appendix 10). Samples SF35 and SF41 had a final pH between 3.5 and 5.5 (medium acid risk).

Table 25: Results of NAG pH test on core samples from borehole Z124030

| Lab number | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|
| SF 35 | 11.6-12.52 | SST | 9.15 | 5.29 | Medium Risk Acid Generation |
| SF 36 | 12.52-20.8 | DO, KV | 9.11 | 8.84 | Lower Acid Risk |
| SF 37 | 20.8-41.35 | SST, SLT | 8.62 | 6.43 | Lower Acid Risk |
| SF 38 | 41.35-49 | DO | 10.21 | 6.42 | Lower Acid Risk |
| SF 39 | 49-98.3 | SST, SLT | 9.31 | 8.3 | Lower Acid Risk |
| SF 68[b] | 99.2-99.42 | C5H | 8.1 | 2 | Higher Risk Acid Generation |
| SF 40 | 98.3-100.45 | C, SLT | 9.63 | 2.34 | Higher Risk Acid Generation |
| SF 69[b] | 100.45-100.8 | C5L | 9.25 | 2.51 | Higher Risk Acid Generation |
| SF 41 | 100.8-133.37 | SST, SLT | 8.91 | 4.4 | Medium Risk Acid Generation |
| SF 70[b] | 133.37-133.92 | C4H | 8.73 | 1.97 | Higher Risk Acid Generation |
| SF 9 | 133.92-135.56 | GRT | 6.6 | 2.81 | Higher Risk Acid Generation |
| SF 71[b] | 135.56-139.83 | C4L | 8.17 | 6.82 | Lower Acid Risk |
| SF 10 | 139.83-140.6 | SST | 6.96 | 3.34 | Higher Risk Acid Generation |
| SF 42 | 140.6-164.48 | C, SST, SLT, KV | 8.91 | 5.84 | Lower Acid Risk |
| SF 43 | 167.1-168.2 | SLT | 10.11 | 6.66 | Lower Acid Risk |
| SF 44 | 168.2-185.66 | SST, TIO, LAV | 10.25 | 7.09 | Lower Acid Risk |

KV - Core loss DO - Dolerite, SST - Sandstone, SLT - Siltstone, GRT - Gritstone , C - Coal, C5H - No 5 Upper Coal Seam, C5L - No 5 Lower Coal Seam, C4H - No 4 Upper Coal Seam, TIO - Tilloid , LAV- Lava, b = Coal Sample

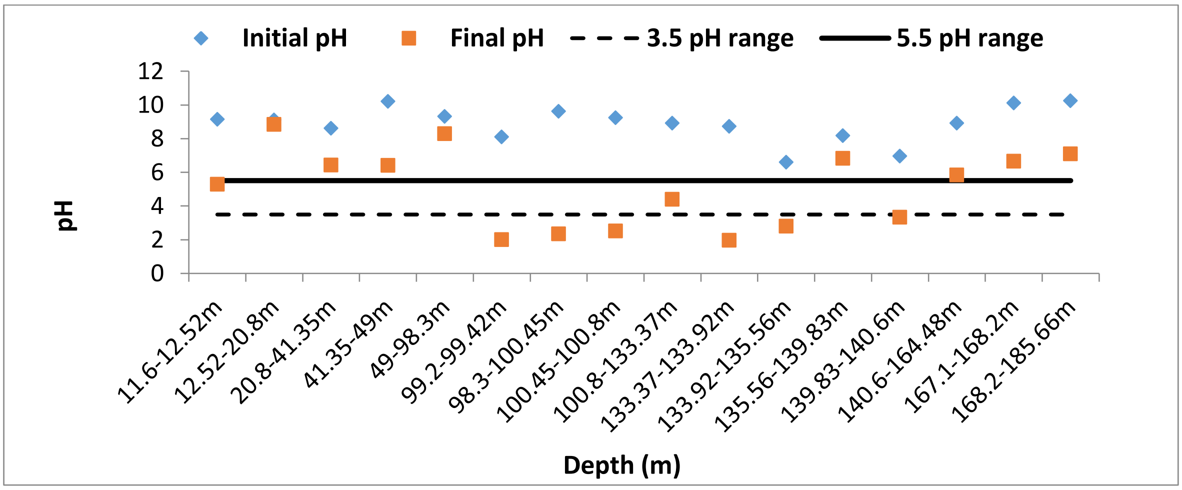


Figure 26: Initial and Final pH showing NAG pH test results of Borehole Z124030

#### 5.2.2.2 Net Neutralising Potential (NNP)

Figure 27 shows the initial and final pH versus closed NNP results. All samples have initial pH that is greater than 6 which mean samples have not been oxidised in the field. NNP results (Appendix 10) indicates that 30 samples (42.3 %) are inconclusive as they fall within the area of uncertainty -20 to 20kg/t $CaCO_3$ (Figure 27). Samples in this area will need further testing for further confirmation of the oxidisation outcome e.g. Kinetic/Humidity Tests. The NNP results also indicate that 31 samples (43.7 %) are classified as having a neutralising potential. Only 10 samples (14 %) have the potential to generate a net acid with a closed NNP of less than 20kg/t $CaCO_3$.

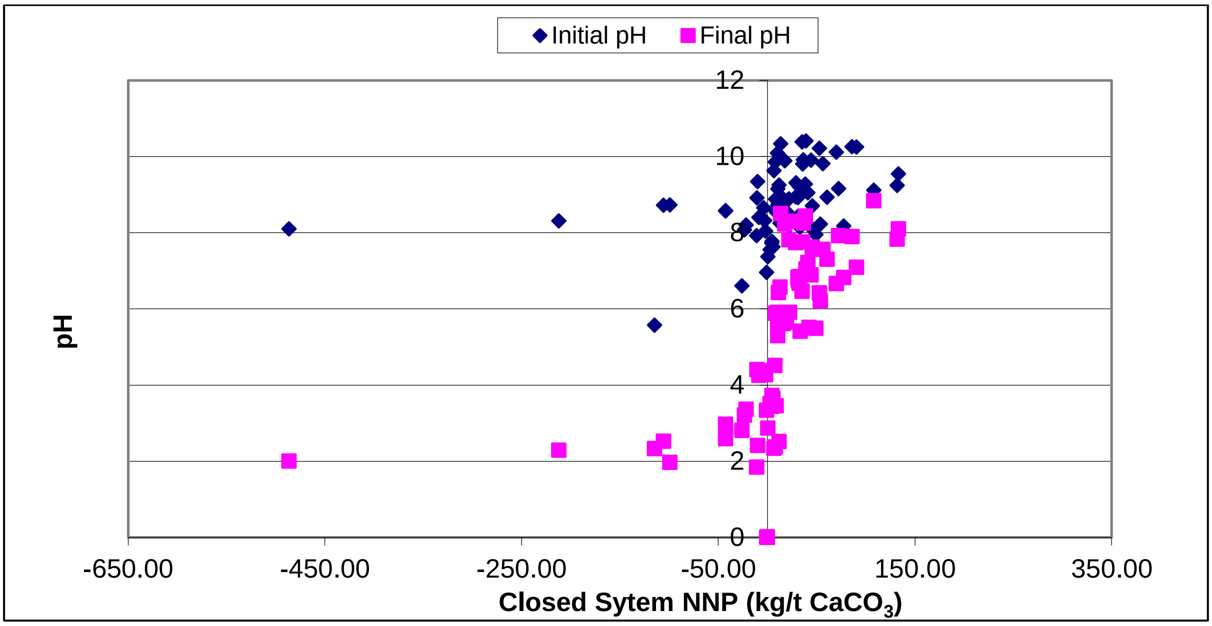


Figure 27 : Initial and Final vs Closed NNP

#### 5.2.2.3 Neutralising Potential Ratio (NPR)

The AP and NP data (Appendix 12) obtained for the mines is used to plot the NPR graph (Figure 28). Information from Table 6 was used as a guideline for the interpretation of Figure 20. From this NPR graph, the samples that plot below the green line of 4:1, acidification is unlikely. Samples that plot above the ratio of 1:1, acidification is likely to occur. For this specific mine, more (69%) samples plotted below the 4:1 ratio which are unlikely to generate acid. Only a few (12.7%) samples plotted above 1:1 which are likely to acidify. The samples plotting between 1:1 and 4:1 ratio are inconclusive (18.3%).

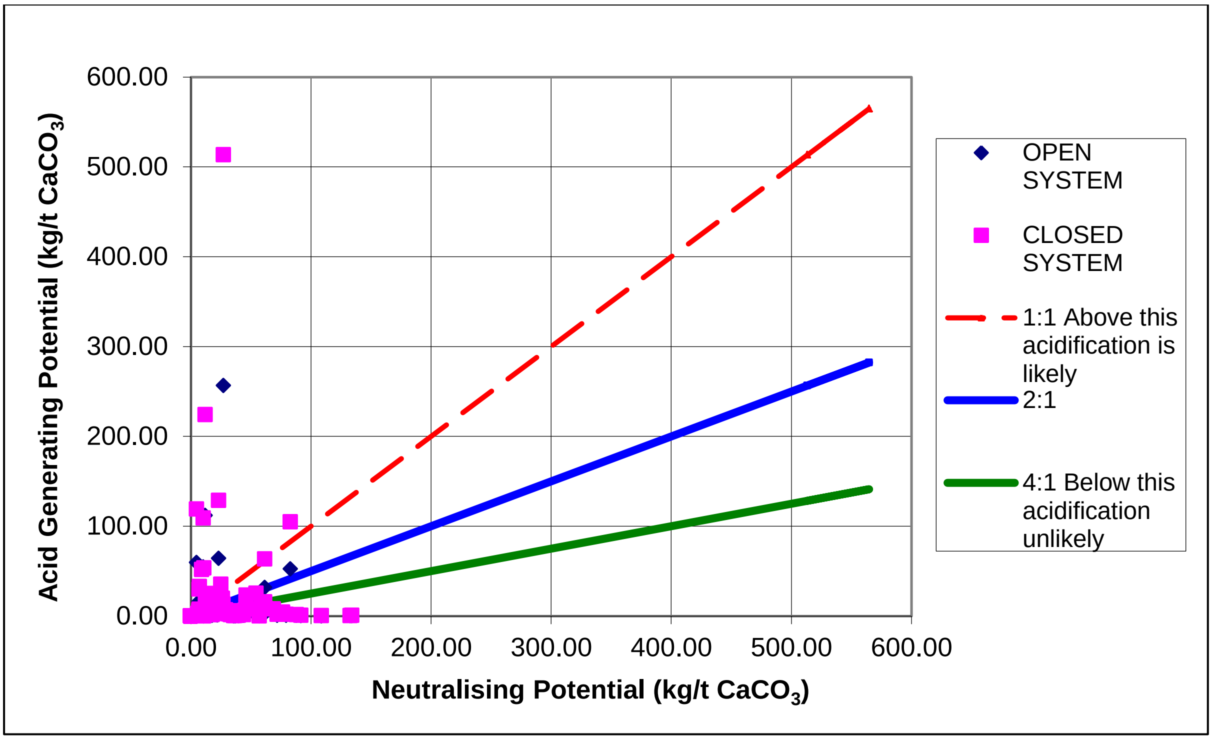


Figure 28: AP vs NP (NPR)

#### 5.2.2.4 Neutralising Potential Ratio (NPR) versus sulphide S

The NPR and percentage S data (Appendix 12) are plotted in the following graph. The plots from this graph confirm the results as discussed in the previous headers. Most (69%) samples plot in the green area indicating that these samples contain a base potential and no potential to produce acid. The samples plotting in the red area (to the right of 0.3 %S) and below the NPR of 1 (red line) are the samples with the potential to generate acid. The rest of the samples are those plotting in the grey area.

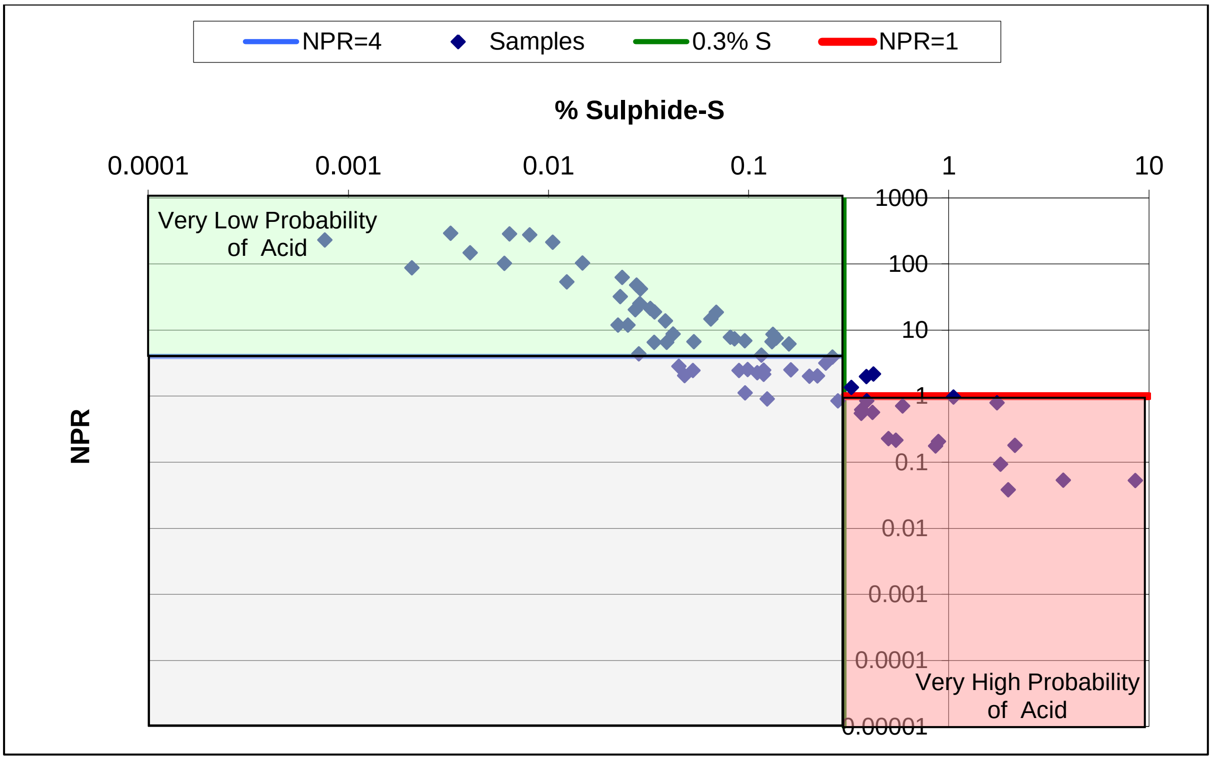


Figure 29: NPR vs Sulphide-S

#### 5.2.2.5 Conclusion

71 Samples from Mine 2 were analysed for NAG pH test and out of 71 samples analysed, 40 samples (56%) were non-acid generating with pH values above 5.5, while 12 samples (17%) have a medium risk of generating an acid as their pH was between 3.5 and 5.5 and the rest (27%) of the samples have the pH of less than 3.5 which have a high risk of generating an acid. The initial and final pH results are shown in Appendix 8. The samples that showed high risk of acid generation contained pyrite and most of them were coal samples. Therefore coal samples have the potential to generate an acid as compared to other geological formations.

### 5.3 Leach Test

Groundwater near mines is often heavily polluted due to oxidation of sulphide minerals like pyrite ($FeS_2$), galena (PbS), sphalerite (ZnS) or arsenopyrite (FeAsS). The pH has a major influence on the mobility of metals and it differs for various metals/elements (Appelo and Postma 2005). In conditions where AMD occurs, metals are leached out of the surrounding lithology and these can contaminate groundwater resources (Blowes and Ptacek, 1994).

Metal and trace element content of the samples tested were analysed using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). The following elements were determined using ICP-OES:  Ag, Al, As, Ba, Be, Ca, Cd, Cr, Co, Cu, Fe, K, Li, Mg, Mn, Mo, Na, Ni, Sb, Se, Sn, Si, Pb, V, Zn, and $SO_4$. The leach results are summarised in the following part.

### 5.3.1 Mine 1 leach test results

The solubility of some of the elements leached in different media (water, hydrogen peroxide and acid leach) for Mine 1 are plotted against the pH for overburden (Figure 30), interburden (Figure 31) and the coal formations (Figure 32).

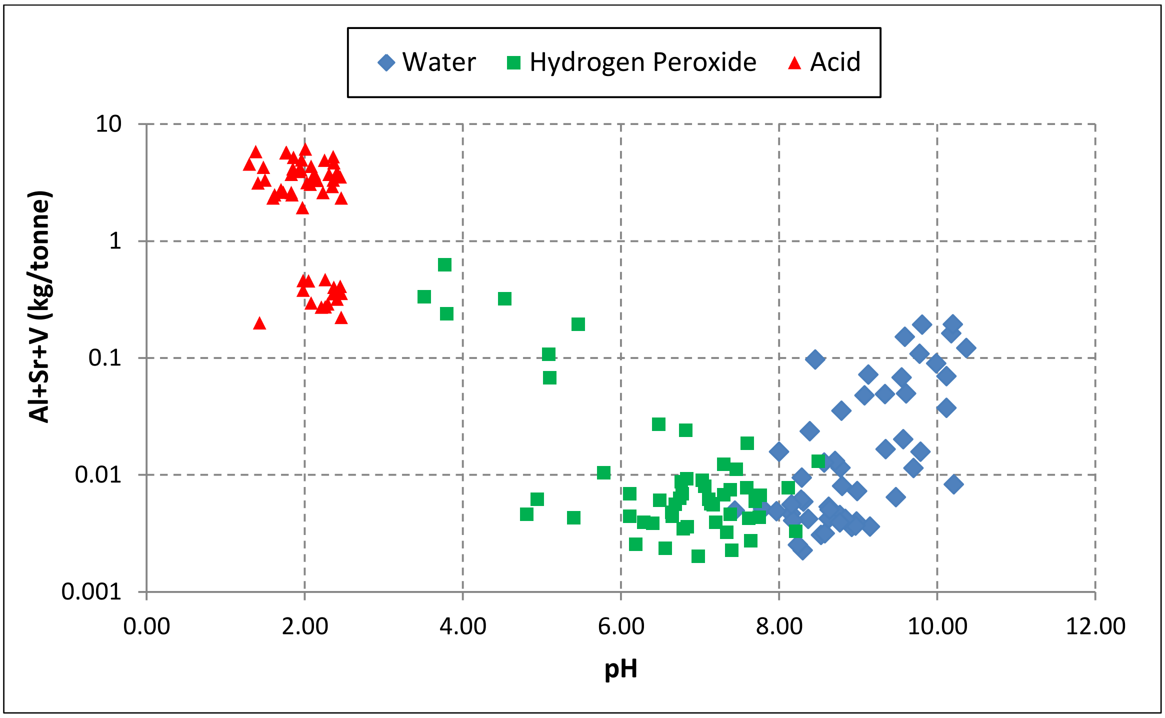


Figure 30: Plot of metal solubility (Al+Sr+V) vs pH (overburden)

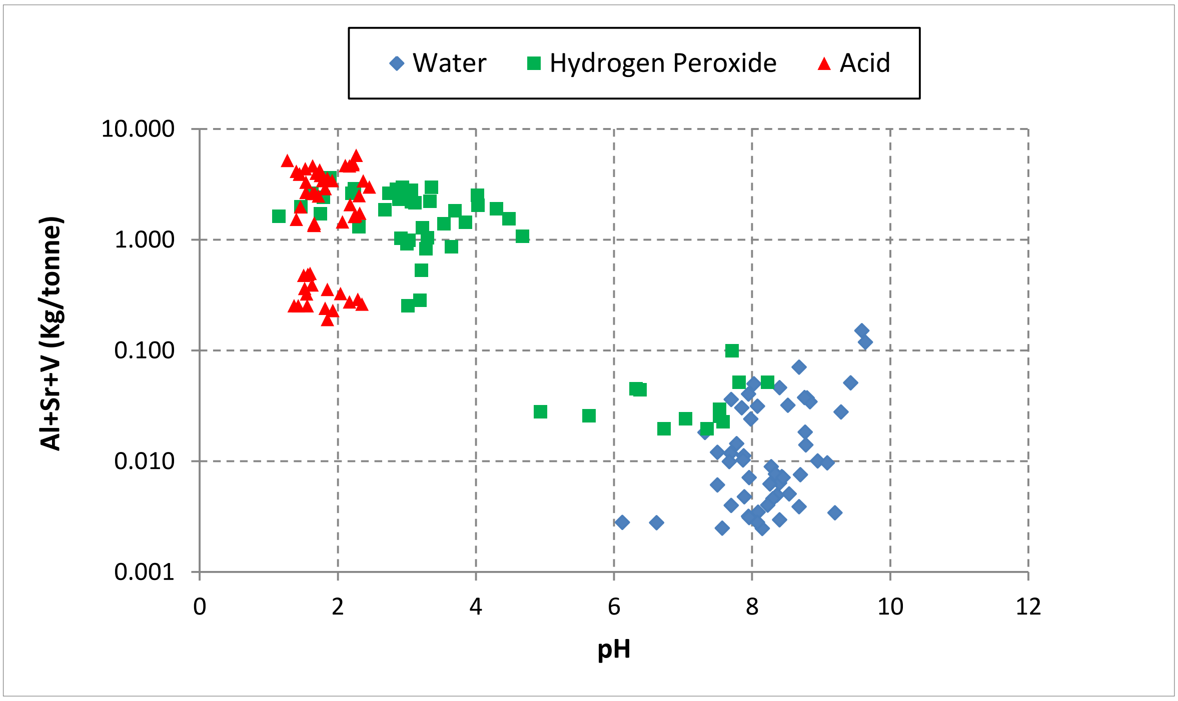


Figure 31: Plot of metal solubility (Al+Sr+V) vs pH (interburden)

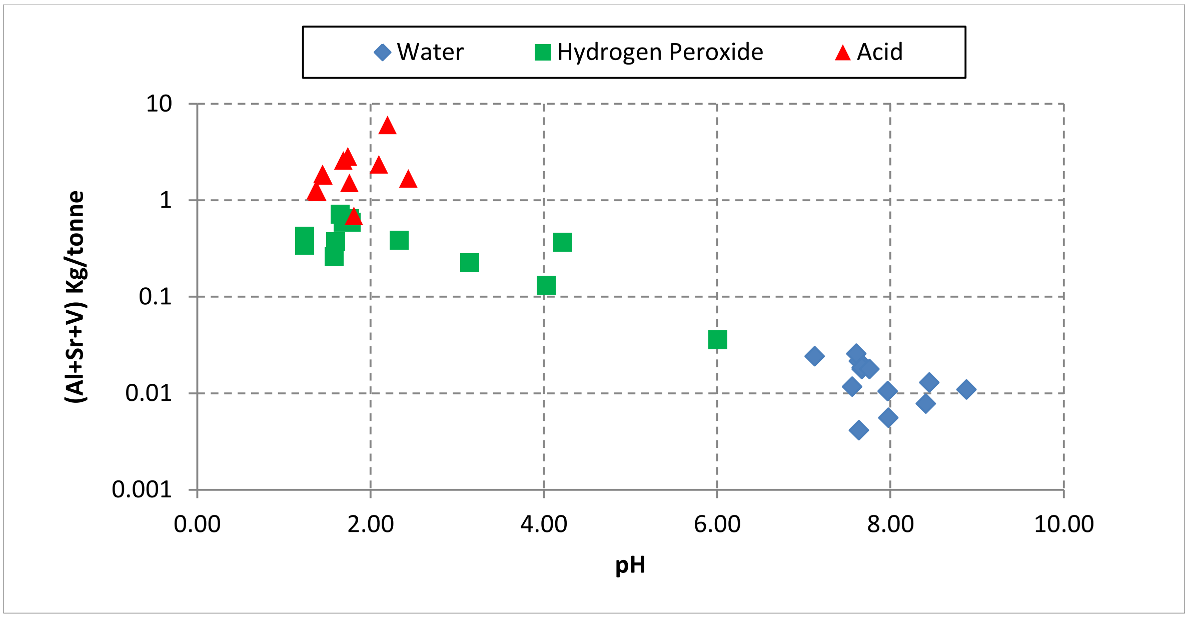


Figure 32: Plot of metal solubility (Al+Sr+V) vs pH (coal formations)

The solubility of the metals varies with the pH.

From these graphs (Figure 30 to Figure 32) it can be seen that the solubility of the metals varies with the pH. The presence of more sulphide minerals causing acidification upon oxidation can be seen in the interburden and coal formations. The peroxide pH results for the overburden demonstrates a minimum pH of 3.51 while for the interburden and coal formations the minimum pH values were 1.15 and 1.24.

Plots of other metals indicate the same trend (Figure 33-36)

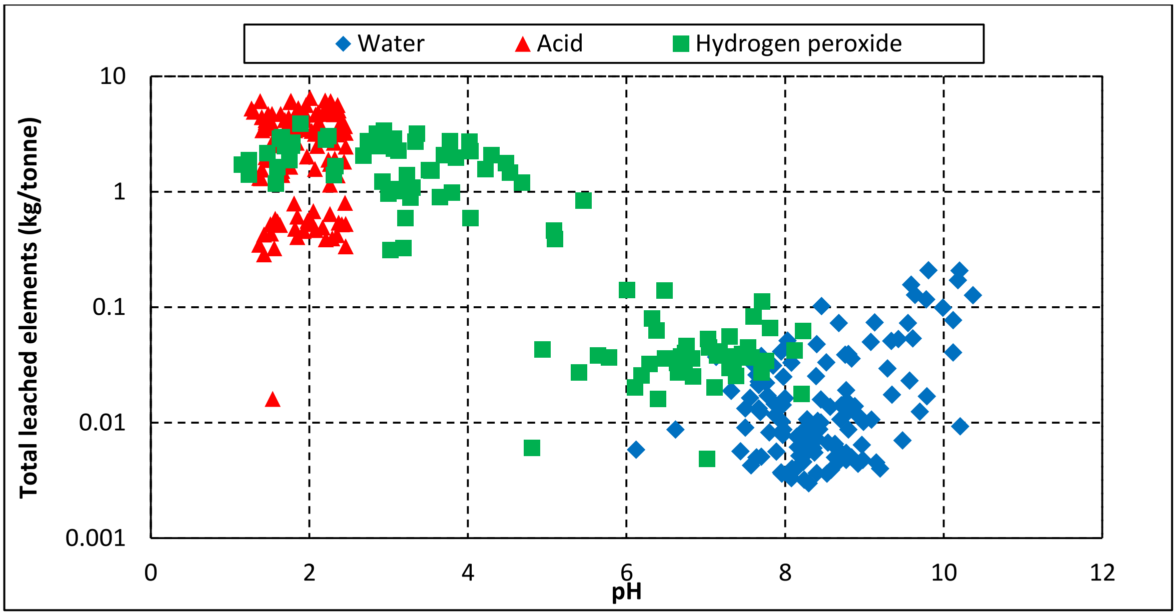


Figure 33: Plot of metal solubility (Total leached elements) vs pH

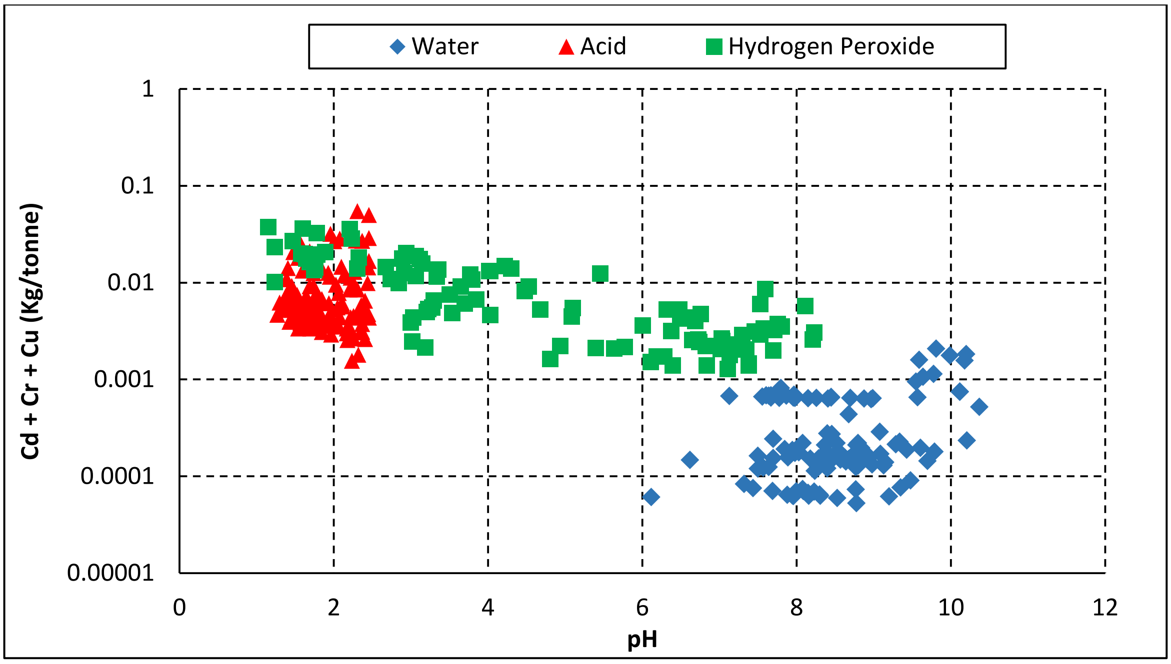


Figure 34: Plot of metal solubility (Cd + Cr + Cu) vs pH

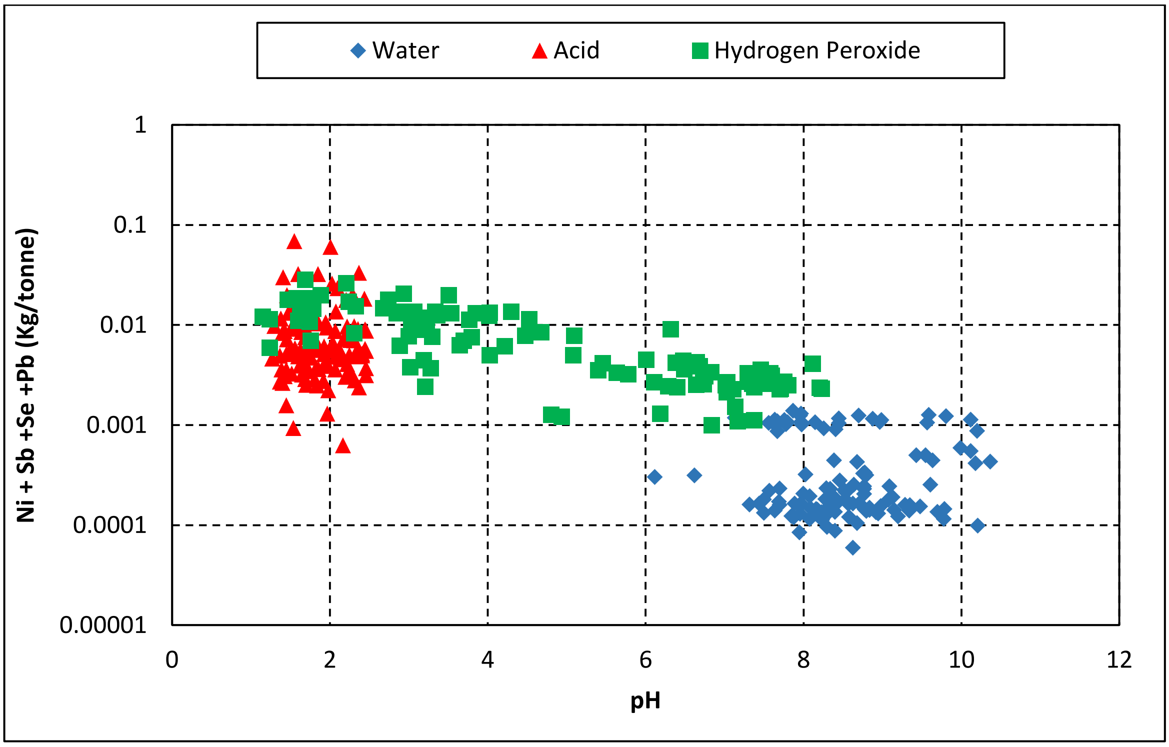


Figure 35: Plot of metal solubility (Ni + Sb + Se + Pb) vs pH

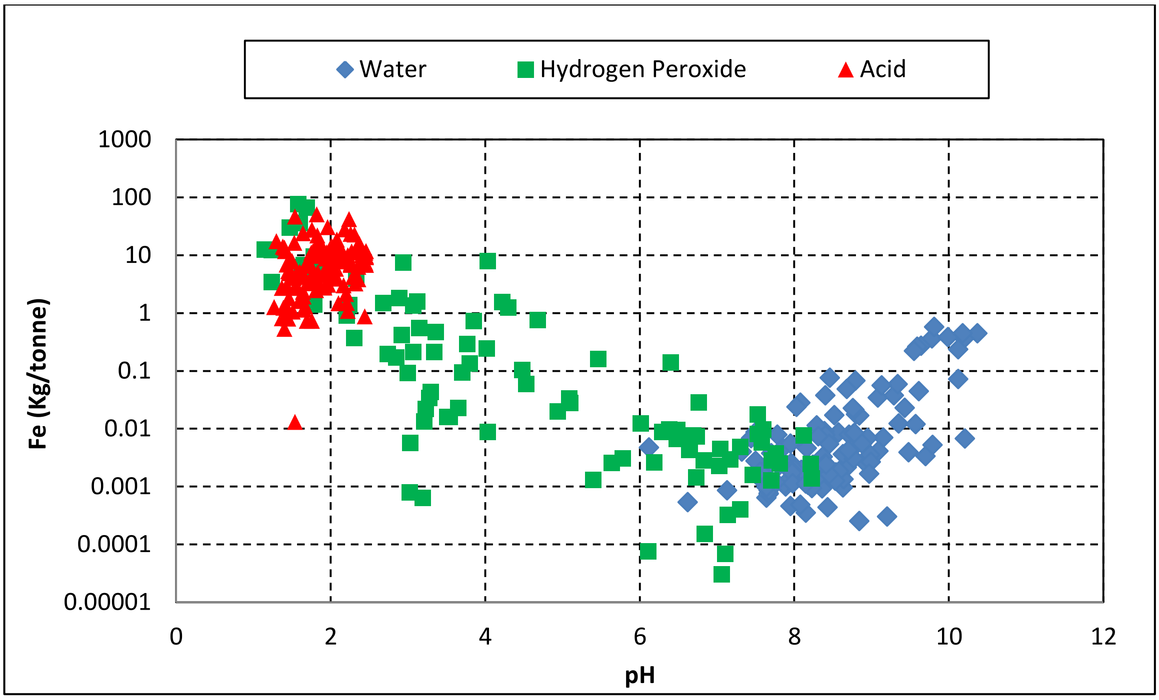


Figure 36: Plot of metal solubility (Fe) vs pH

### 5.3.2 Mine 2 leach test results

The solubility of some of the elements leached in different media (water, hydrogen peroxide and acid leach) for Mine 2 are plotted against the pH for overburden (Figure 37), interburden (Figure 38) and the coal formations (Figure 39).

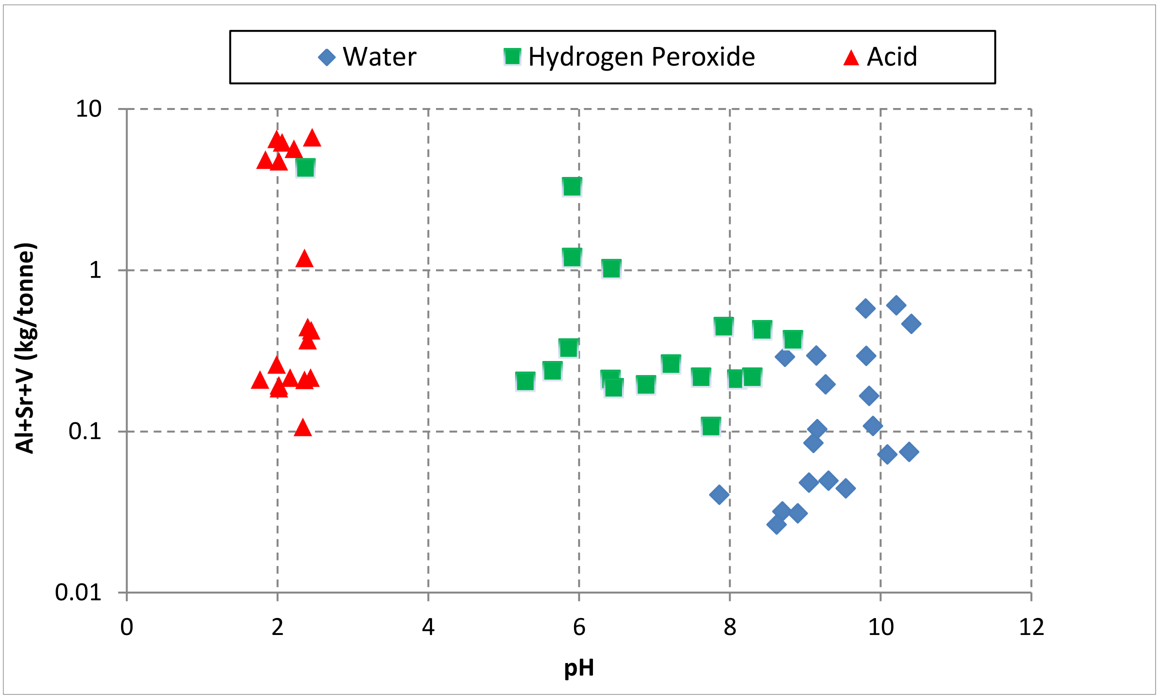


Figure 37: Plot of metal solubility (Al+Sr+V) vs pH (Overburden)

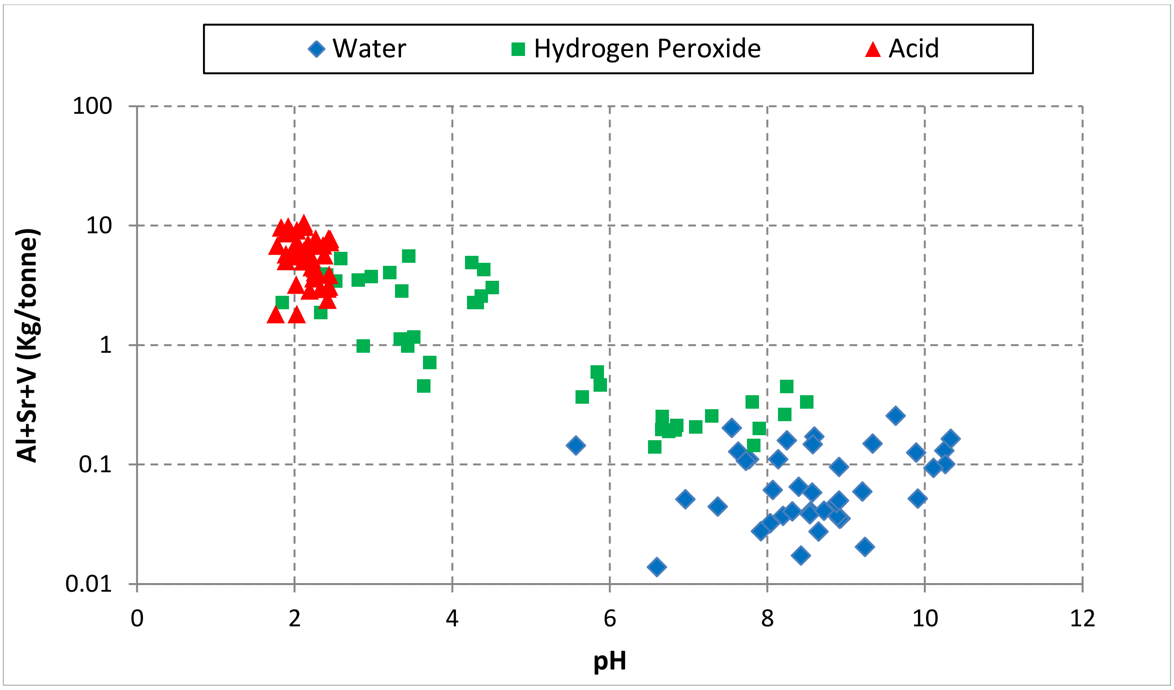


Figure 38: Plot of metal solubility (Al+Sr+V) vs pH (Interburden)

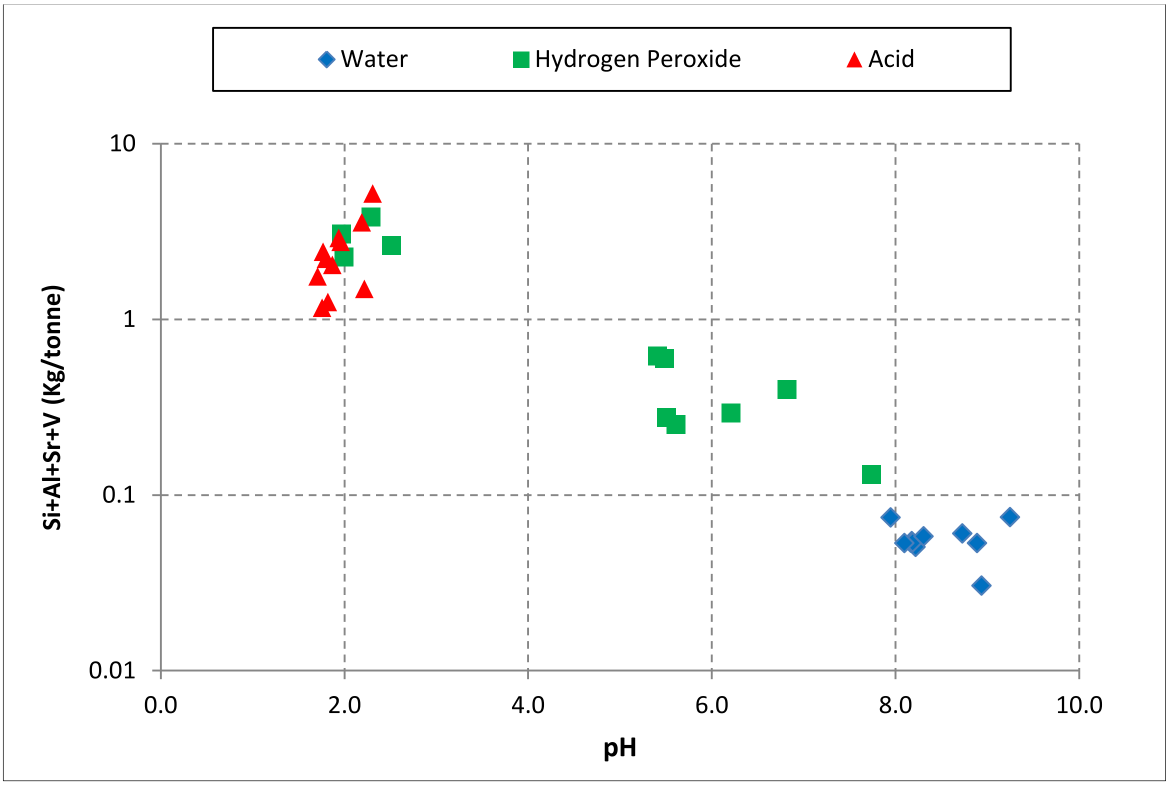


Figure 39: Plot of metal solubility (Al+Sr+V) vs pH (coal formations)

The solubility of the metals in the abovementioned graphs also indicates the influence of more metals in solution at a lower pH. From these graphs (Figure 37-39) the presence of more sulphide minerals in the interburden and coal formation are clear. The peroxide pH results for the overburden demonstrates a minimum pH of 2.37 while for the interburden and coal formations the minimum pH values were 1.76 and 1.96.

Plots of other metals indicates the same trend (Figure 40-43)

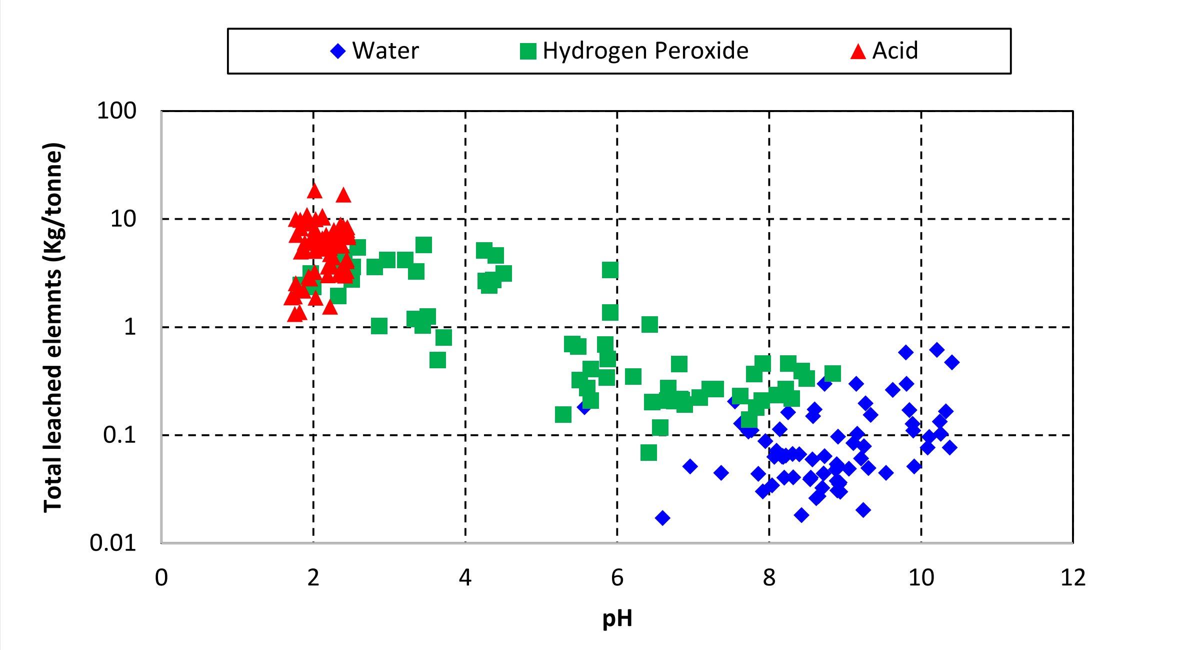


Figure 40: Plot of metal solubility (Total leached elements) vs pH

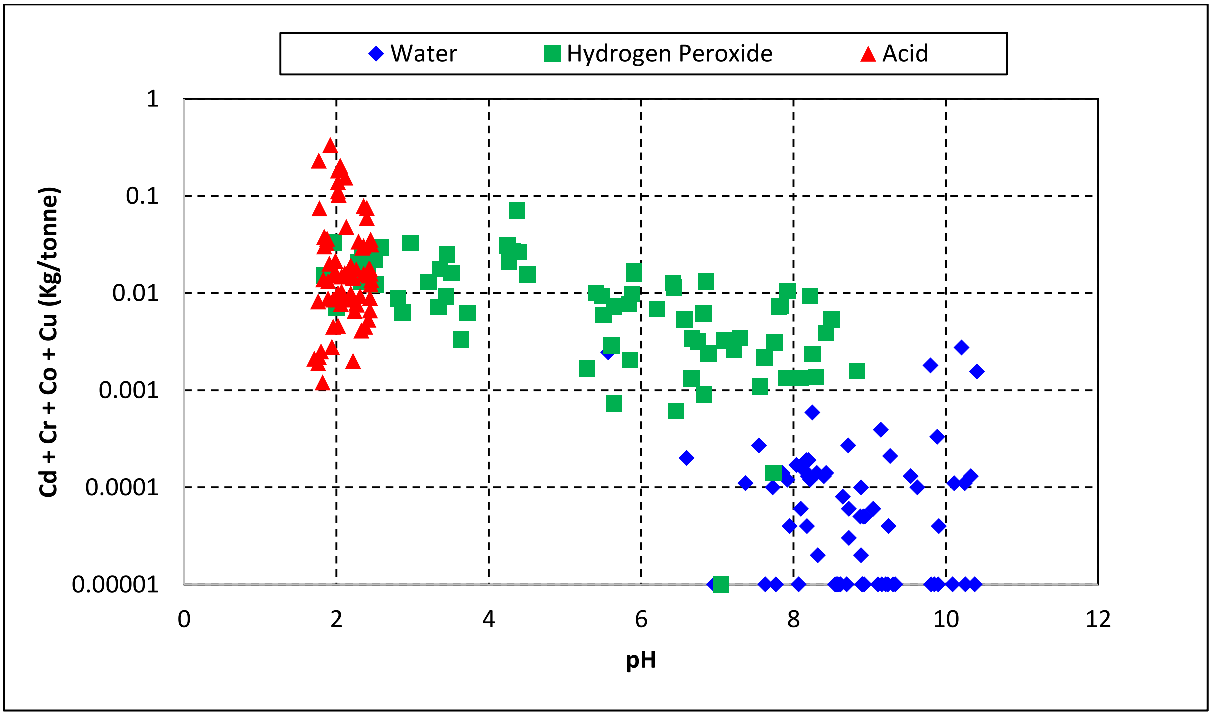


Figure 41: Plot of metal solubility (Cd + Cr +Co + Cu) vs pH

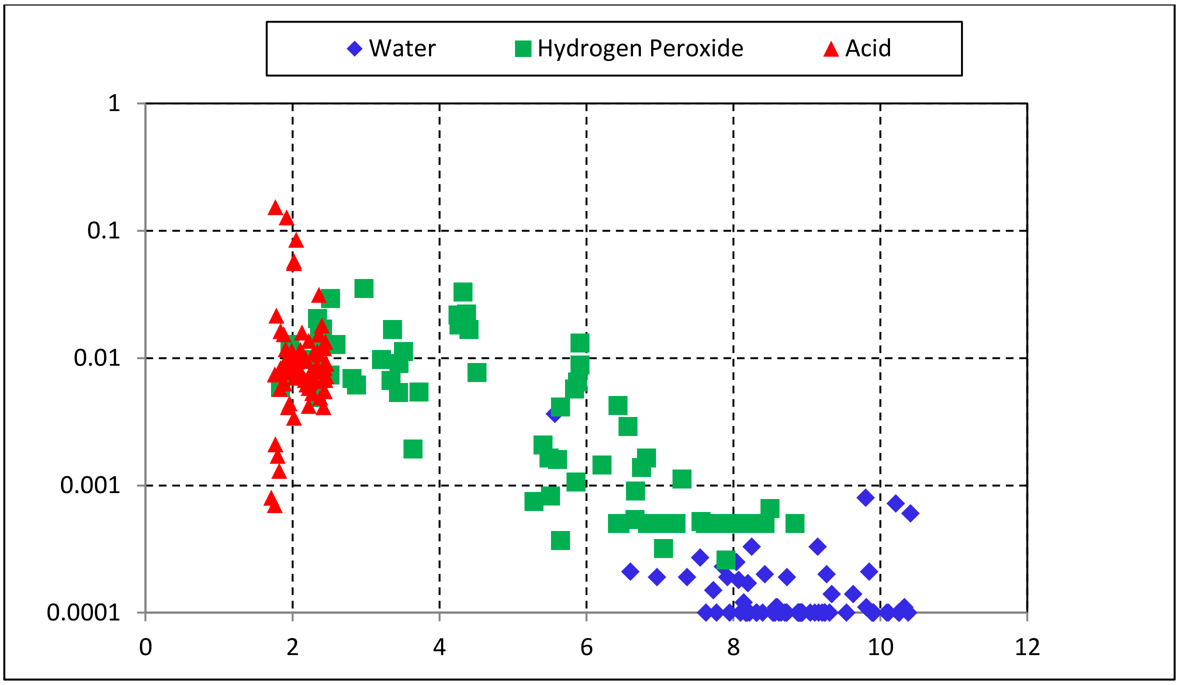


Figure 42: Plot of metal solubility (Ni + Sb + Se + Pb) vs pH

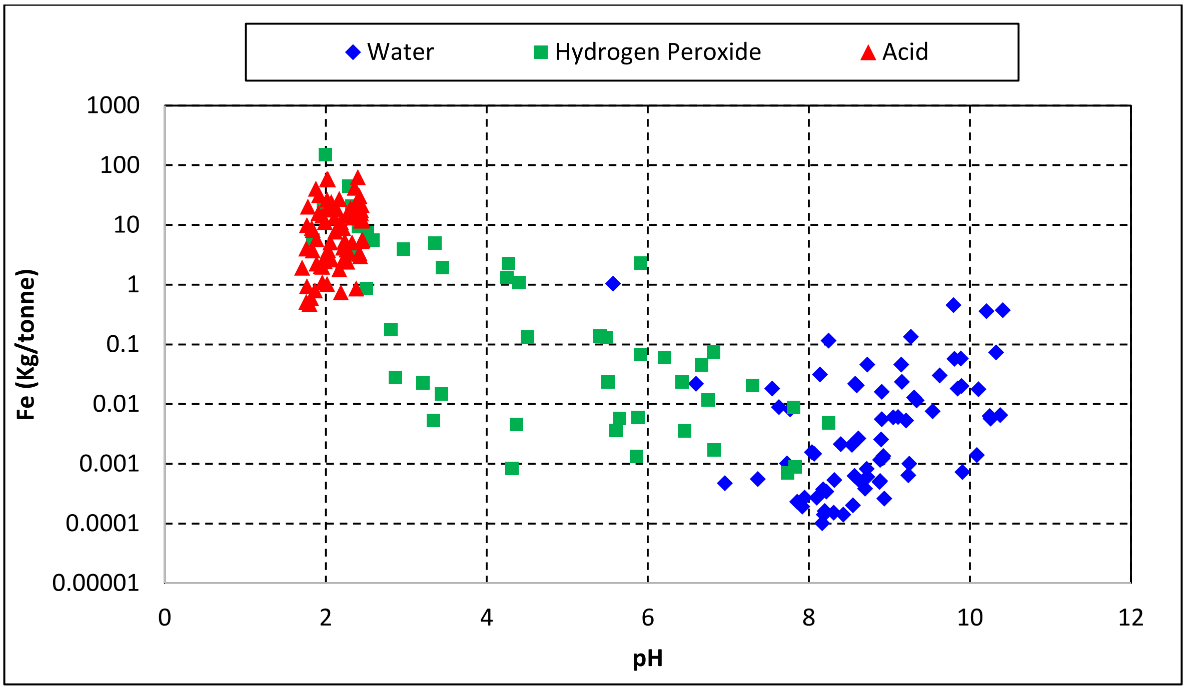


Figure 43: Plot of metal solubility (Fe) vs pH

# CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

This study was successfully conducted to assess the acid base potential at Mine 1 and Mine 2 collieries in the Southern Highveld coalfield in Mpumalanga province of South Africa. In total, 118 and 71 borehole core samples were collected from Mine 1 and Mine 2 sites. The samples were subjected to mineralogical analysis, leach test and acid base counting tests. Site specific findings are now going to be presented. The general conclusions across the two mines are that:

- Both Mines indicated that AMD will be produced from the interburden and coal seam, therefore more care is needed when these layers are exposed during mining.
- All coal samples have a higher risk of acid generation which is attributed to the presence of pyrite in the coal formation. It can therefore be expected that most of the acid generation would be mainly confined to the coal seams. The coal will be removed in the mining process and the pyrite is usually discarded.
- The acid generation risk varies with from one borehole to another but also with depth within the boreholes as influenced by subsurface heterogeneity.
- The results indicate a higher release of elements in an acidic environment. Aluminium, iron, calcium and magnesium are released in the highest concentration in the overburden. (See summary in Table 26 and 27)

Table 26: Comparison of parameters released in different media (overburden, interburden and coal) at Mine 1

| Parameter | Average kg/tonne leach water | Average kg/tonne leached acid | Ratio Acid:Water |
|---|---|---|---|
| pH | 8.97 | 2.03 | |
| Mn | 0.10 | 21.50 | 208.76 |
| Fe | 7.28 | 1001.05 | 137.57 |
| Al | 3.28 | 277.82 | 84.73 |
| Zn | 0.04 | 2.44 | 64.90 |
| Ni | 0.01 | 0.86 | 60.85 |
| Li | 0.01 | 0.39 | 46.91 |
| Sr | 0.07 | 3.28 | 46.70 |
| Ca | 10.51 | 392.27 | 37.31 |
| Mg | 5.09 | 165.82 | 32.60 |
| Cr | 0.01 | 0.21 | 32.58 |
| Cu | 0.03 | 0.91 | 26.87 |
| Pb | 0.01 | 0.11 | 9.37 |
| K | 5.66 | 51.38 | 9.07 |
| V | 0.08 | 0.37 | 4.35 |
| Sb | 0.01 | 0.02 | 3.44 |
| Na | 12.88 | 42.87 | 3.33 |

| Parameter | Average kg/tonne leach water | Average kg/tonne leached acid | Ratio Acid:Water |
|---|---|---|---|
| Ba | 0.02 | 0.03 | 1.42 |
| As | 0.01 | 0.01 | 0.56 |
| Mo | 0.02 | 0.00 | 0.11 |
| Se | 0.01 | 0.00 | 0.03 |

Table 27: Comparison of parameters released in different media (overburden, interburden and coal) at Mine 2

| Parameter | Average kg/tonne leach water | Average kg/tonne leached acid | Ratio Acid:Water |
|---|---|---|---|
| pH | 9.393 | 2.181 | |
| Ni | 0.000 | 0.021 | 312.92 |
| Mn | 0.001 | 0.320 | 304.37 |
| Cr | 0.000 | 0.013 | 240.54 |
| Fe | 0.078 | 15.164 | 194.04 |
| Al | 0.048 | 4.710 | 97.30 |
| Cu | 0.000 | 0.011 | 82.55 |
| Sr | 0.001 | 0.043 | 59.64 |
| Mg | 0.070 | 3.481 | 49.47 |
| Ca | 0.106 | 4.403 | 41.68 |
| V | 0.001 | 0.017 | 24.38 |
| K | 0.065 | 0.668 | 10.20 |
| Li | 0.000 | 0.001 | 8.46 |
| Na | 0.308 | 0.948 | 3.08 |

## 6.1 Site conclusions

### 6.1.1 Mine 1

Important findings at Mine 1 site are that:

- The mineralogical results indicated that 20% of the samples contained pyrite indicating the potential to generate acid. A total of 53% of the samples contained calcite and dolomite was detected only in 12% of the samples. Both of these minerals have the potential to neutralise acid.
- Out of 118 samples analysed for Mine 1, 49% were non-acid generating, 19% had a medium risk of generating acid and the rest of the samples (32%) had a final pH of less than 3.5, which indicates a high risk of acid generation.

### 6.1.2 Mine 2

Important findings at Mine 2 site are that:

- A total of 28% of the samples contained pyrite which is the main mineral of concern with respect to acid generation. The pyrite is mainly associated with coal formation,
- Nearly half of the samples (44%) contained calcite which offers a neutralising potential to acid generation,
- Out of the 71 samples analysed from Mine 2 site, 56% were non-acid generating, while 17% samples had a medium risk of generating acid and 27% samples had a high risk of acid generation.
- From the leach test it can be concluded that Fe is the main trace element as it has the highest concentrations leached in comparison to all the other trace elements. Pyrite is the main source of Fe.

### 6.1.3 A summary/model of the acid generation risk findings for each sample collected from the Mine 1 and Mine 2 site is presented in Figure 45 - Figure 49.

- Graph 44 indicates the topographic distribution of Mine 1 and Mine 2 sampling points.

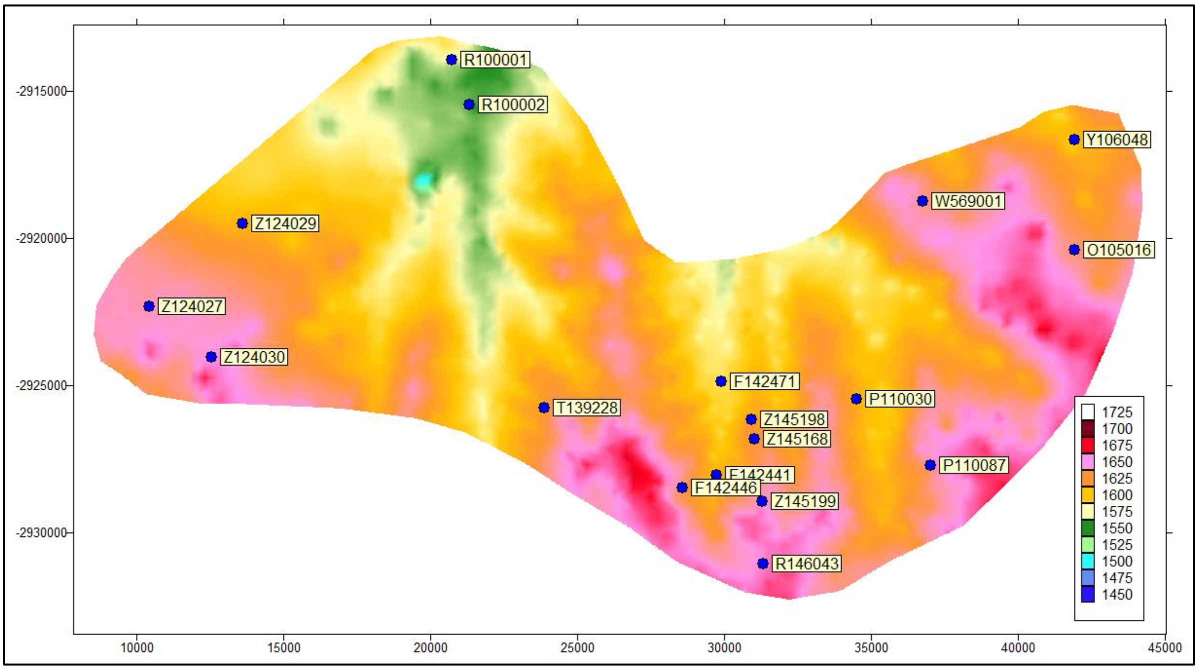


Figure 44: surface contours with borehole positions for Mine1 and Mine 2

- The NAG pH results are graphically presented (Figures 45-49) for Mines 1 and 2. The layers that had a potential for producing acid are clearly demonstrated. Layers are divided into three categories: Low, Medium and High risk.

- Eleven borehole cores at Mine 1 indicated the high risk of acid generation and three at Mine 2 (Figure 45). Samples with high risk (32%) were found to be in the interburden between 40 m and 190 m for Mine 1 and they have low NNP values.
- Mine 2 samples indicated high risk (27%) between 20 m and 60 m, and between 80 m and 180 m. These 27% samples with high risk were coal (low NNP) and sandstone samples that contain pyrite. Most of the acid generation would be mainly found at the coal seams (Figure 46-49). Therefore, more attention is needed to take precautionary measures when these layers are discarded.

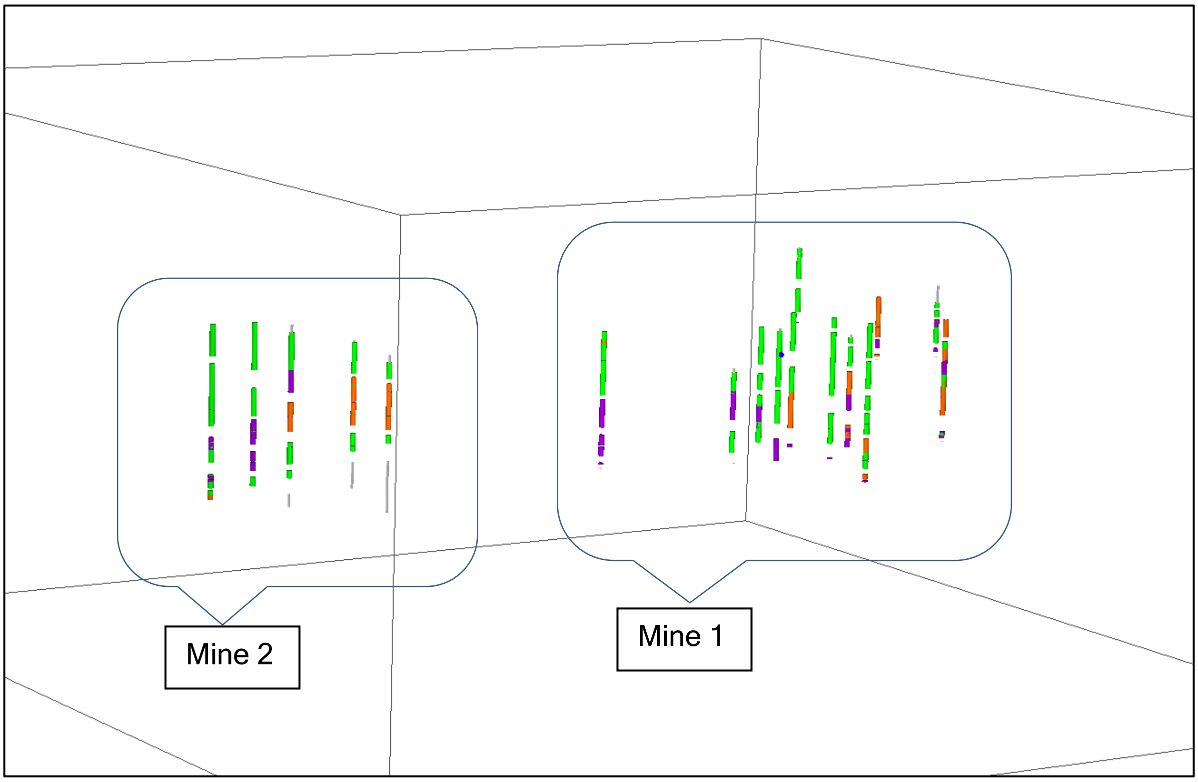


Figure 45: NAG values for each borehole (green = low risk), (Orange - medium risk) & (Purple = high risk)

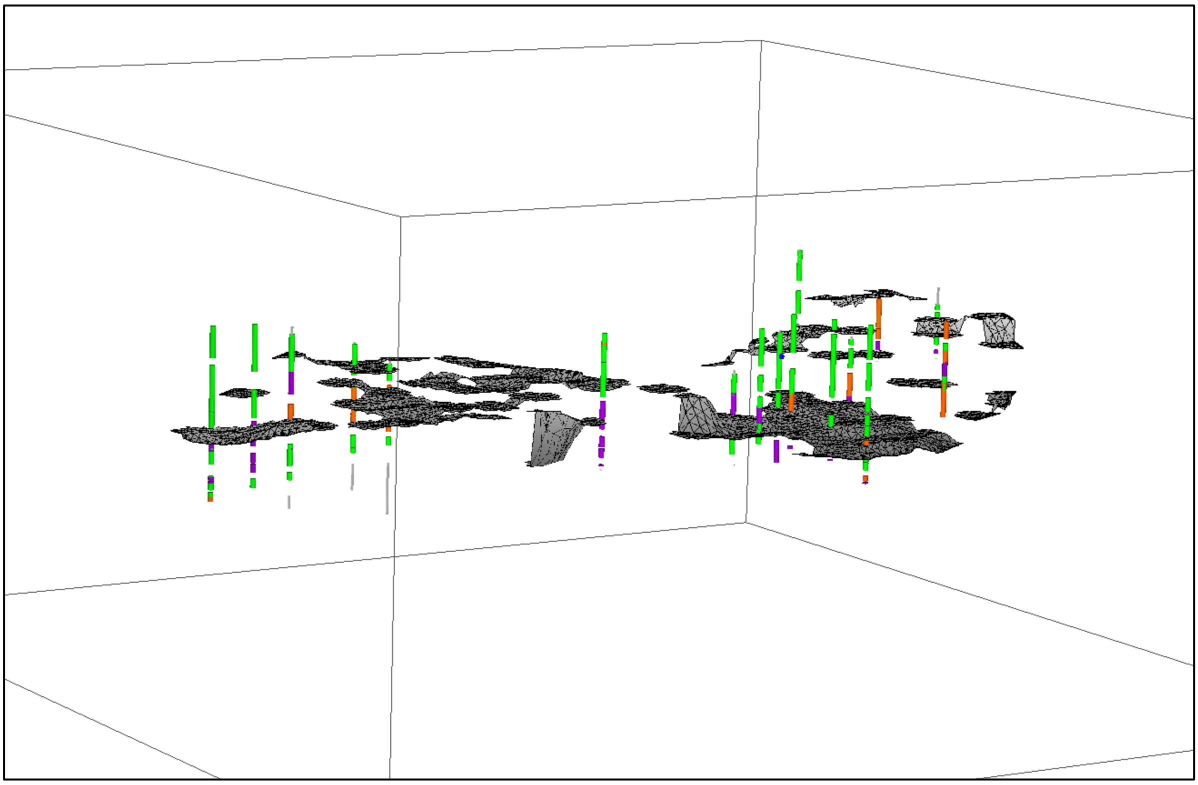

Figure 46: NAG values for each borehole with 5 seam top contours in 3D view

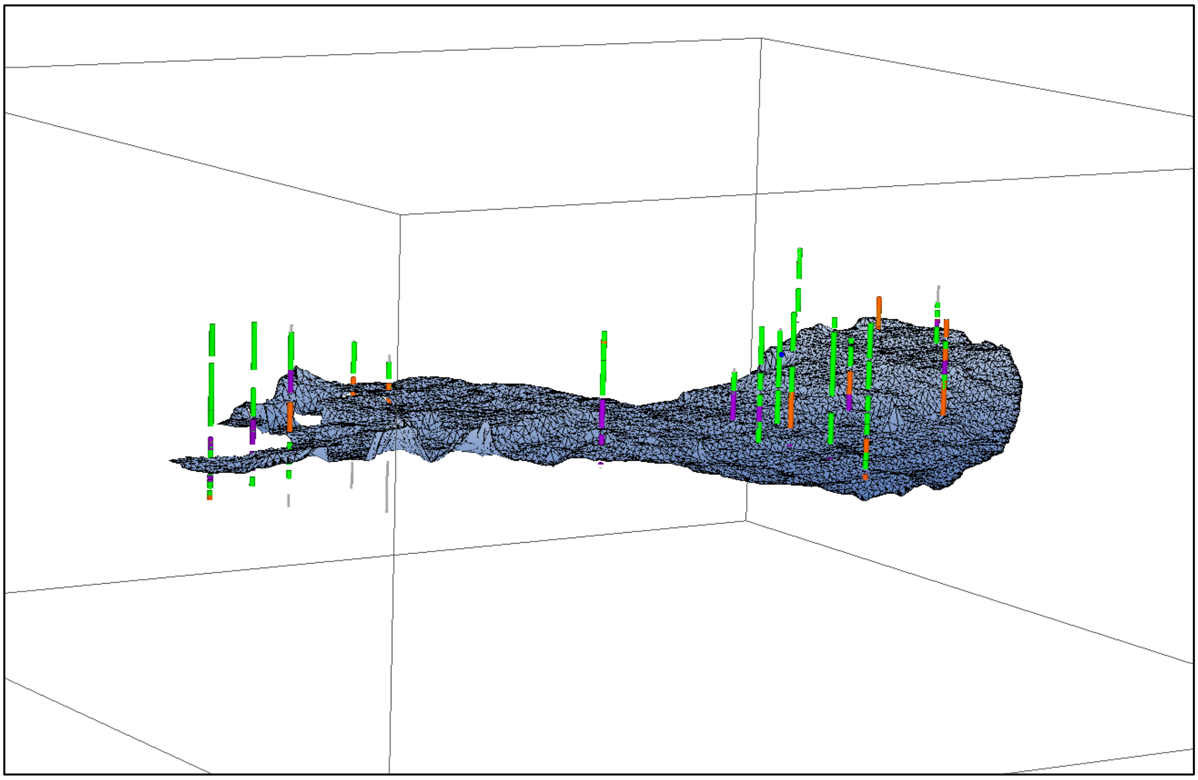

Figure 47: NAG values for each borehole with the 4 seam top contour in 3D view

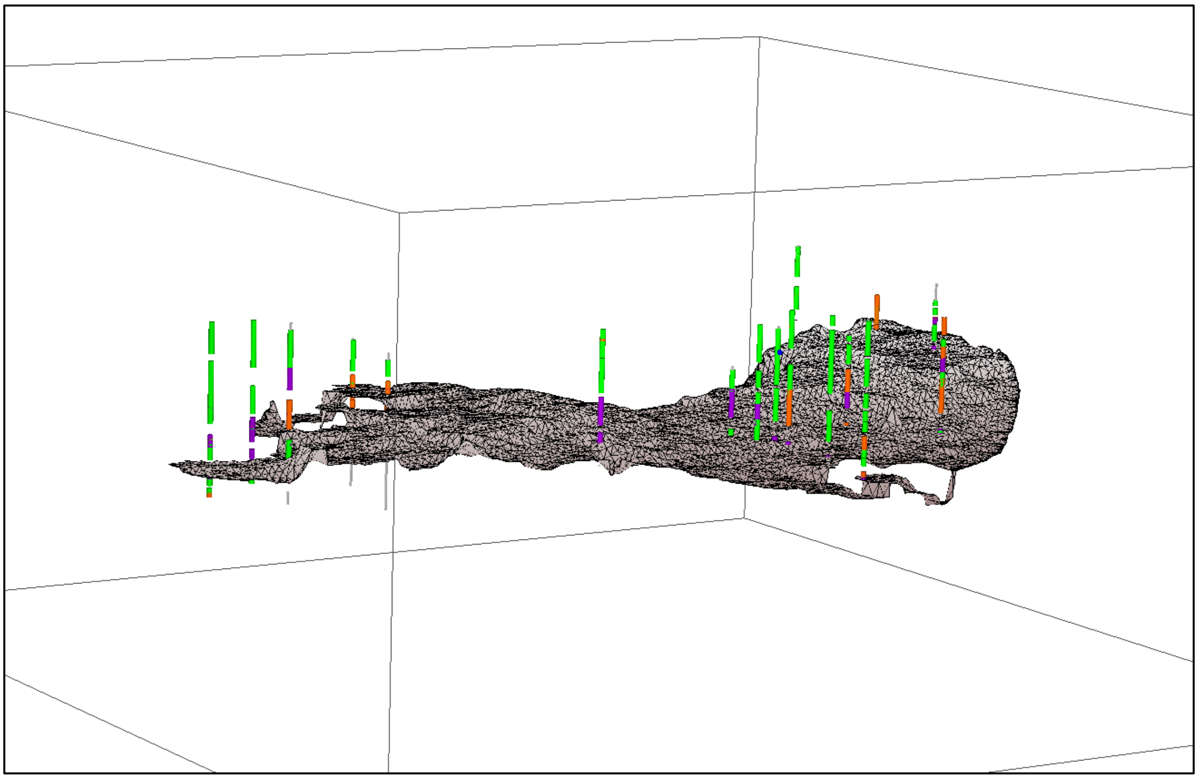

Figure 48: NAG values for each borehole with the 3 seam top contours in 3D view

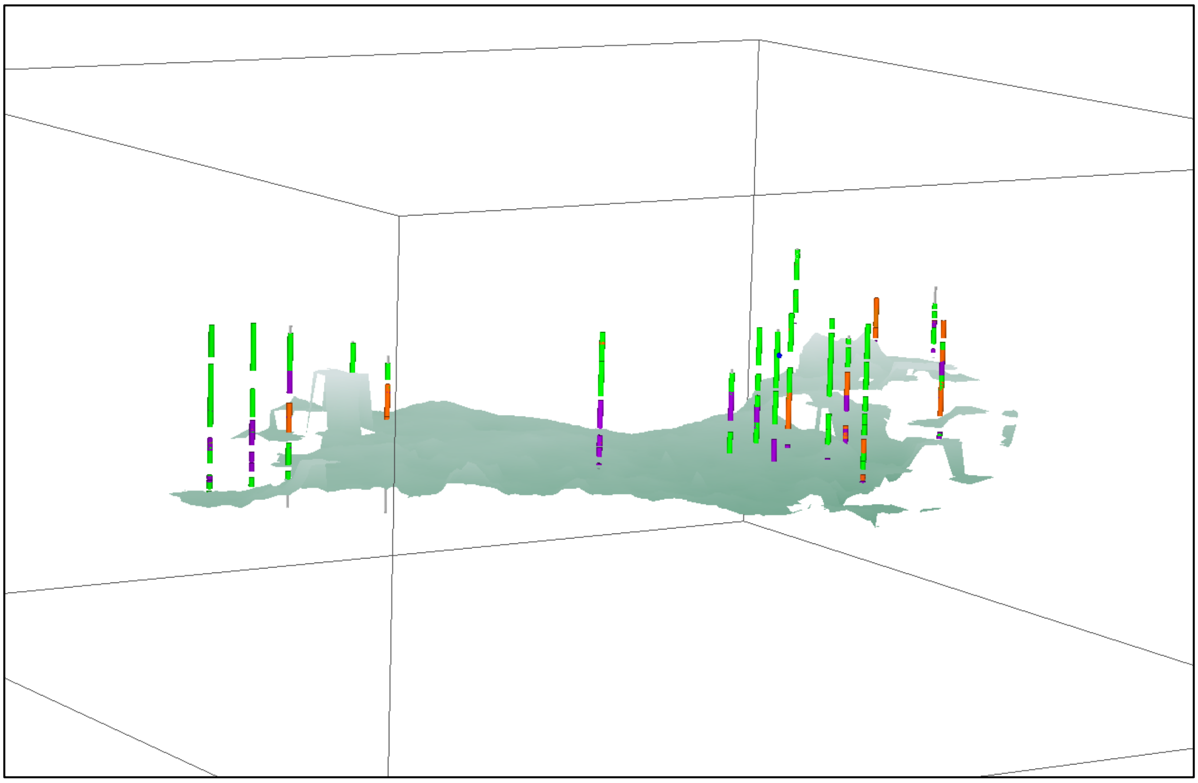

Figure 49: NAG values for each borehole with the 2 seam top contours in 3D view

- Samples that contained layers of sandstone, siltstone and shale had the highest NNP values and these layers can be used as a buffer to neutralise the AMD. These layers consist of dolomite and calcite, CaO and MgO indicating that they will have a potential to neutralise the acid.

## 6.2 Recommendations

Based on lessons learned and experience gained during this study, the following recommendations can be made:

- All results that are inconclusive should be tested with other methods e.g. Kinetic test
- For all samples with high risk for acid generation, control measures need to be put in place.
- For better comparison of samples, it is important to collect samples per each meter depth across all the sampling boreholes.
- For improved decision making, samples tested with the static methods can also be subjected to Kinetic tests assessment.

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## ABSTRACT

Pyrite, iron disulphide is the most common mineral in the metal sulphite and coal deposit. The oxidation of Pyrite and other metal-sulphide minerals by oxygen has a large environmental impact and plays a key role in Acid Mine Drainage (AMD). Environmental impact shows that soil acidity, toxic metal concentrations and vegetation damage are the predominant negative impact of AMD. AMD is a major concern for the mining industry because mining activities tend to increase the amount of rock surface exposed to air and water. Mining companies are increasingly required to evaluate the AMD potential at future mine sites and provide detailed plans to prevent or minimise AMD at all phases of mine operation as part of the environmental Impact assessment (EIA) process.

An investigation was conducted in two mine (Mine 1 and Mine 2) areas in the Southern Highveld Coalfield of Mpumalanga. Mine 1 is an underground coal mine and is situated 10 km outside Trichardt on the road to Bethel. It was established in May 2012 and its shaft supply coal to Sasol Synfuels. Mine 2 is an open-cast coal mine and is situated between 2 towns, amely Trichardt and Kriel. Construction activities started in 1990 and the mine reached full production in September 1992. Both Mines fall in the Karoo Supergroup which comprises of Ecca group formation and consist dominantly of sandstone, siltstone, shale and coal.

The aim of this study was to investigate the acid-base potential of these two Mines. 118 samples were collected from Mine 1 borehole core and 71 samples were collected from Mine 2 borehole core to conduct mineralogical and Acid Base Accounting (ABA) analysis. Acid-base potential leachate were further analysed for major and trace elements using Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES).

Most of the samples analysed for Mine 1 have been found to have High AMD risk at the interburden and these samples have low NNP values, all these samples consisted of coal and they contained pyrite mineral as indicated in the mineralogical analysis. These samples must be taken into consideration to minimise oxidation.

Samples (Mine 1) that contained layers of sandstone, siltstone and shale have the highest NNP values and these layers can be used as a buffer to neutralise the AMD. Therefore Mine 1 will produce an AMD at the coal seam once exposed during mining.

Mine 2 shows that 3 samples have High AMD risk at the interburden while 2 boreholes show the risk between 20m and 60m, and these samples were coal samples and others were sandstone samples and they contained pyrite. These samples that have coal showed low NNP. Therefore most of the acid generation would be mainly found at the coal seams.

Layers that show high NNP values consisted of sandstone, siltstone and shale. They showed no indication of acid generation, therefore they will work as buffers to neutralise the any AMD that will be produced.  Mine 2 also indicate that AMD will be produced at the interburden at layers that contains coal, therefore more consideration is needed when these layers are exposed during mining.

With such condition it is possible for the mines to predict the types of situations that might arise concerning groundwater quality, and implement proper prevention or remediation programs.

# APPENDICES

## Appendix 1: List of samples for Mine 1

a = same sample    b = coal sample

| Sample Name | Lab Number | Depth (m) |
|---|---|---|
| F142441 | TC18 | 1.7-34.48 |
| | TC75 | 34.48-49.07 |
| | TC38 | 49.07-70.25 |
| | TC83 | 70.6-82.75 |
| | TC7 | 83.45-121.47 |
| | TC35 | 125.77-128.56 |
| | | |
| F142446 | TC66 | 5.8-9 |
| | TC57 | 9.15-34.95 |
| | TC62 | 34.95-70.5 |
| | TC10 | 70.5-82.44 |
| | TC4 | 82.44-91.10 |
| | TC51 | 91.10-112.10 |
| | TC41 | 112.10-113 |
| | TC33 | 113.12-155.3 |
| | TC87 | 155.3-161.50 |
| | | |
| F142471 | TC65 | 4.68-12.9 |
| | TC55 | 12.9-18.82 |
| | TC61 | 18.82-40.85 |
| | TC3 | 42.38-75.68 |
| | TC107[b] | 76.09-80.80 |
| | TC11 | 83.8-84.15 |
| | TC112[b] | 84.15-84.80 |
| | TC84 | 84.8-109.4 |
| | TC105[b] | 109.4-109.90 |
| | TC114[b] | C5 |
| | | |
| O105016 | TC25 | 7.3-20.26 |
| | TC113 | 20.26-33.5 |
| | TC48 | 33.5-41.65 |
| | TC43 | 41.65-43.55 |
| | TC101 | 43.55-45.16 |
| | TC34 | 45.16-52.82 |
| | TC24 | 52.82-58.99 |
| | TC14 | 58.99-77.95 |
| | TC79 | 80.3-85.56 |

| Sample Name | Lab Number | Meters |
|---|---|---|
| P110030 | TC49 | 3.8-16.23 |
| | TC52[a] | 16.23-20.7 |
| | TC99[a] | 16.23-20.7 |
| | TC1 | 20.7-30.23 |
| | TC5 | 30.23-42.86 |
| | TC74 | 67.54-68.06 |
| | TC117[b] | 67.54-69.54 |
| | TC104 | 69.54-106.77 |
| | TC109[b] | 106.38-110.22 |
| | TC82 | 106.77-109.99 |
| | TC108[b] | 112.75-113.33 |
| | TC27 | 109.99-120.22 |
| | TC98 | 120.22-141.42 |
| | TC106[b] | 141.42-141.55 |
| | | |
| P110087 | TC9 | 6-9.93 |
| | TC13 | 9.93-30.18 |
| | TC97 | 30.18-40.32 |
| | TC58 | 40.32-54.77 |
| | TC23 | 54.77-71.87 |
| | TC94 | 71.87-89.08 |
| | TC91 | 90.19-90.45 |
| | TC45 | 90.45-130.50 |
| | TC53 | 130.50-133.19 |
| | TC6 | 133.19-133.97 |
| | TC73 | 139.15-140.18 |
| | | |
| R146043 | TC93 | 5.33-8.17 |
| | TC116 | 8.17-47.07 |
| | TC47 | 47.07-78.5 |
| | TC59 | 78.5-94.33 |
| | TC29 | 94.33-101.9 |
| | TC16 | 101.9-125.08 |
| | TC28 | 125.08-125.92 |
| | TC110[b] | 125.65-125.92 |
| | TC40 | 125.92-140.78 |
| | TC15 | 140.78-141.52 |
| | TC86 | 143.28-160.68 |
| | TC92 | 160.68-160.98 |
| | TC21 | 161.15-167.07 |
| | TC118[b] | 167.07-170.34 |

| Sample Name | Lab Nunber | Meters |
|---|---|---|
| T139228 | TC70 | 2.2-7.35 |
| | TC44 | 7.35-39.45 |
| | TC36 | 39.45-42.87 |
| | TC63 | 42.87-43.5 |
| | TC30 | 43.5-82.2 |
| | TC39 | 82.2-83.81 |
| | TC76 | 83.81-115.08 |
| | TC96 | 115.08-117.67 |
| | TC78 | 115.45-117.67 |
| | TC56 | 121.35-141.39 |
| | TC60 | 141.39-145.24 |
| | | |
| W569001 | TC69 | 2.4-7.4 |
| | TC80 | 18.7-19.5 |
| | TC54 | 19.5-55.81 |
| | TC111[b] | 55.81-59.57 |
| | TC89 | 59.57-62.8 |
| | TC102[b] | 62.8-63.03 |
| | TC22 | 63.03-90.4 |
| | TC103[b] | 90.4-90.8 |
| | | |
| Y106048 | TC32 | 5.95-6.66 |
| | TC12 | 6.66-22.61 |
| | TC8 | 22.61-45.06 |
| | TC95 | 50.59-70.93 |
| | TC19 | 70.93-75.27 |
| | | |
| Z145168 | TC31 | 1.6-6.1 |
| | TC115 | 6.1-49.68 |
| | TC100 | 49.68-56.74 |
| | TC37 | 56.74-57.36 |
| | TC68 | 57.36-68.81 |
| | TC85 | 68.81-94.75 |
| | TC67 | 96.22-136.4 |
| | TC42 | 139.31-142.08 |
| | | |
| Z145198 | TC71 | 3.33-45.04 |
| | TC90 | 45.04-90.02 |
| | TC26 | 91.03-127.78 |
| | TC2 | 132.14-134.94 |
| | TC72 | 134.94-151.78 |
| | TC88 | 151.78-184 |

| Sample Name | Lab Number | Meters |
|---|---|---|
| Z145199 | TC46 | 0-22.52 |
| | TC17 | 22.52-28.75 |
| | TC50 | 28.75-52.14 |
| | TC77 | 52.14-123.92 |
| | TC81 | 123.92-124.6 |
| | TC20 | 125.80-159.6 |
| | TC64 | 160.3-162.3 |

Appendix 2: List of samples for Mine 2

b = coal sample

| Sample name | Lab number | Depth (m) |
|---|---|---|
| R 100 001 | SF 11 | 1.62-12.46 |
| | SF 12 | 12.46-24.48 |
| | SF 13 | 24.48-25.26 |
| | SF 61[b] | 24.48-25.80 |
| | SF 14 | 25.80-52.66 |
| | SF 1 | 50.66-51.6 |
| | SF 62[b] | 51.6-56.92 |
| | SF 2 | 56.92-57.14 |
| | SF 15 | 57.14-85.28 |
| | SF 16 | 86.82-112.94 |
| | SF 17 | 112.94-116.23 |
| | SF 18 | 116.23-130.1 |
| | SF 19 | 130.1-143.1 |
| | | |
| R 100 002 | SF 20 | 14.1-18 |
| | SF 21 | 18.3-37.5 |
| | SF 3 | 37.5-37.82 |
| | SF 63[b] | 37.82-43.08 |
| | SF 4 | 43.08-45.72 |
| | SF 22 | 45.72-70.1 |
| | SF 23 | 71.4-103.8 |
| | SF 24 | 103.8-124.4 |
| | | |
| Z124027 | SF 45 | 4.13-14.04 |
| | SF 46 | 14.04-48.99 |
| | SF 47 | 48.99-69.26 |
| | SF 48 | 69.26-90.34 |
| | SF 49 | 90.44-91.84 |
| | SF 64[b] | 91.84-92.34m |
| | SF 50 | 92.34-93.61 |
| | SF 51 | 93.61-123.04 |
| | SF 65[b] | 123.08-123.68 |
| | SF 52 | 123.68-125.28 |
| | SF 7 | 125.28-125.88 |
| | SF 66[b] | 125.88-129.68 |
| | SF 8 | 129.78-134.51 |
| | SF 53 | 134.48-162.76 |
| | SF 54 | 162.54-164.8 |
| | SF 55 | 167.2-172.87 |
| | SF 56 | 172.87-180.67 |

| Sample name | Lab no. | Meters |
|---|---|---|
| Z124027 | SF 57 | 180.67-183.7 |
| | SF 58 | 183.7-186.86 |
| | SF 59 | 186.86-189.02 |
| | SF 60 | 189.02-200.16 |
| | | |
| Z124029 | SF 25 | 6.9-8.1 |
| | SF 26 | 8.1-61.46 |
| | SF 27 | 61.46-73.68 |
| | SF 28 | 73.68-74.72 |
| | SF 29 | 74.72-98.23 |
| | SF 5 | 98.23-98.88 |
| | SF 67[b] | 98.88-102.83 |
| | SF 6 | 102.83-104.6 |
| | SF 30 | 104.6-132.74 |
| | SF 31 | 133.63-136.28 |
| | SF 32 | 138.64-158.45 |
| | SF 33 | 158.45-165.43 |
| | SF 34 | 165.43-174.53 |
| | | |
| Z124030 | SF 35 | 11.6-12.52 |
| | SF 36 | 12.52-20.8 |
| | SF 37 | 20.8-41.35 |
| | SF 38 | 41.35-49 |
| | SF 39 | 49-98.3 |
| | SF 68[b] | 99.20-99.42 |
| | SF 40 | 98.3-100.45 |
| | SF 69[b] | 100.45-100.80 |
| | SF 41 | 100.80-133.37 |
| | SF 70[b] | 133.37-133.92 |
| | SF 9 | 133.92-135.56 |
| | SF 71[b] | 135.56-139.83 |
| | SF 10 | 139.83-140.6 |
| | SF 42 | 140.60-164.48 |
| | SF 43 | 167.1-168.2 |
| | SF 44 | 168.2-185.66 |

## Appendix 3: Mine 1 XRD Mineralogical analysis

| Sample | Lab no. | Quartz | Plagio clase | K-feldspar and/or rutile | Pyro xene | Kaolinite and/ or chlorite | Mica | Side rite | Anke rite | Mag netite | Goethite and/or hematite and/or pyrite | Cal cite | Sme ctite | Anal cime | Mag nesite | Dolo mite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F142441 | TC18 | xx | XX | | xx | | | | x | | | | x | | | |
| | TC75 | XX | x | xx | | x | x | | x | | | | | | | |
| | TC38 | X | xx | X | | xx | x | x | | | | x | x | | | |
| | TC83 | X | x | x | | xx | xx | x | x | | | x | | | | |
| | TC7 | X | xx | xx | | xx | x | xx | | | | | x | | | |
| | TC35 | XX | | xx | | x | | | <x | | | | | | | |
| | | | | | | | | | | | | | | | | |
| F142446 | TC66 | XX | x | xx | | | x | | | | | <x | | | | |
| | TC57 | XX | x | xx | | x | x | | x | | | x | <x | | | |
| | TC62 | xx | XX | | X | | | | | | | | | | x | |
| | TC10 | XX | xx | xx | | x | x | | | <x | | | | | | |
| | TC4 | XX | xx | X | | <x | x | | x | | | <x | | | | |
| | TC51 | X | xx | xx | | xx | x | x | | | <x | x | <x | | | |
| | TC41 | XX | | x | | X | x | | | | | | x | | | |
| | TC33 | XX | xx | xx | | xx | x | x | | | | x | <x | | | |
| | TC87 | X | | xx | | X | xx | | x | | | | | | | |
| | | | | | | | | | | | | | | | | |
| F142471 | TC65 | XX | x | x | | x | x | x | x | | | <x | | | | |
| | TC55 | XX | x | xx | | | x | | | | | | | | | |
| | TC61 | X | x | xx | | xx | x | x | | | | <x | x | | | |
| | TC3 | X | xx | xx | | xx | x | x | | | <x | x | <x | | | |
| | TC107[b] | X | | | | X | | | | | | x | | | | x |
| | TC11 | XX | | xx | | X | x | | | | | | | | | |
| | TC112[b] | X | | | | X | | | | | xx | x | | | | x |
| | TC84 | X | x | X | | xx | xx | X | | | | x | | | | |
| | TC105[b] | X | | | | X | | | x | | x | x | | | | |
| | TC114[b] | X | xx | xx | | X | | | x | | | | | | | x |
| | | | | | | | | | | | | | | | | |
| O105016 | TC25 | XX | xx | | | <x | x | | x | | | x | | | | |
| | TC113 | X | xx | x | | xx | xx | x | | | | | xx | | | |
| | TC48 | XX | xx | xx | | | <x | x | | | | x | | | | |
| | TC43 | X | xx | x | | xx | x | xx | x | | | | | | | |
| | TC101 | xx | x | xx | | xx | xx | x | | | | x | xx | | | |
| | TC34 | XX | x | xx | | xx | x | | | | | | | | | |
| | TC24 | xx | X | x | xx | x | x | | x | | | | x | | | |
| | TC14 | XX | xx | xx | | x | x | x | | | | xx | <x | | | |
| | TC79 | X | x | X | | X | xx | | <x | | | <x | | | | |

| Sample Name | Lab number | Quartz | Plagio clase | K-feldspar and/or rutile | Pyro xene | Kaolinite and/or chlorite | Mica | Side rite | Anke rite | Mag netite | Goethite and/or hematite and/or pyrite | Cal cite | Sme ctite | Anal cime | Mag nesite | Dolo mite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P110030 | TC49 | XX | x | xx | | | x | | x | | | <x | | | | |
| | TC52[a] | XX | x | xx | | xx | x | x | | | <x | x | x | | | |
| | TC99[a] | xx | X | | xx | | | x | x | | | | xx | | | |
| | TC1 | X | x | xx | | xx | x | x | | | | <x | x | | | |
| | TC5 | XX | xx | X | | x | x | | <x | | | x | | | | |
| | TC74 | X | xx | xx | | X | X | xx | | | | | | | | |
| | TC117[b] | X | x | xx | | X | xx | x | x | | | x | | | | |
| | TC104 | XX | | xx | | X | xx | | x | | | | | | | |
| | TC109[b] | XX | | X | | xx | x | | <x | | | | | | | |
| | TC82 | X | x | xx | | X | xx | x | x | | | | | | | |
| | TC108[b] | X | | | | X | | | | | X | x | | | | x |
| | TC27 | X | | x | | X | | | | | X | x | | | | x |
| | TC98 | X | | x | | X | xx | | | | xx | x | | | | x |
| | TC106[b] | xx | x | x | | xx | xx | x | | | | x | xx | | | x |
| | | | | | | | | | | | | | | | | |
| P110087 | TC9 | xx | X | <x | x | x | x | | x | | | xx | x | | | |
| | TC13 | XX | xx | xx | | x | x | x | | | | | <x | | | |
| | TC97 | X | x | xx | | xx | xx | x | x | | | | xx | | | |
| | TC58 | XX | x | xx | | xx | x | x | | | | | | | | |
| | TC23 | XX | x | xx | | x | <x | | x | | | | | | | |
| | TC94 | X | x | xx | | xx | xx | x | | | | x | | | | |
| | TC91 | X | xx | xx | x | xx | xx | xx | | | x | | | | | |
| | TC45 | XX | xx | xx | | x | x | x | | | | | | | | |
| | TC53 | XX | x | x | | xx | x | x | | | x | | <x | | | |
| | TC6 | X | | <x | | x | xx | xx | | | x | x | | | | |
| | TC73 | X | | x | | X | xx | | x | | x | x | | | | |
| | | | | | | | | | | | | | | | | |
| R146043 | TC93 | XX | x | xx | | | x | | x | | | x | | | | |
| | TC116 | x | X | | xx | | | | | | | | xx | | | xx |
| | TC47 | X | x | x | | X | xx | | | | x | | <x | | | |
| | TC59 | XX | xx | X | | x | <x | x | x | | <x | x | | | | |
| | TC29 | XX | x | x | | x | x | x | | | | xx | | | | |
| | TC16 | XX | x | xx | | x | x | x | | | | x | | | | |
| | TC28 | XX | xx | xx | | x | <x | | x | | | x | | | | |
| | TC110[b] | XX | | X | | x | | | | | x | | | | | |
| | TC40 | XX | x | X | | x | x | | <x | | | <x | | | | |
| | TC15 | X | x | xx | | xx | xx | x | x | | | x | | | | |
| | TC86 | X | xx | x | | X | xx | | | | x | | | | | |
| | TC92 | X | x | xx | | xx | xx | | x | | | x | x | | | |
| | TC21 | X | | x | | X | xx | x | | | x | x | | | | x |
| | TC118[b] | X | | | | X | XX | | | | x | x | | | | |

| Sample Name | Lab number | Quartz | Plagio clase | K-feldspar and/or rutile | Pyro xene | Kaolinite and/or chlorite | Mica | Side rite | Anke rite | Mag netite | Goethite and/or hematite and/or pyrite | Cal cite | Sme ctite | Anal cime | Mag nesite | Dolo mite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T139228 | TC70 | XX | xx | xx | | | xx | | | | | | | | | |
| | TC44 | xx | X | | xx | x | | | xx | | | | x | | | |
| | TC36 | XX | x | x | | | xx | | | | x | xx | x | | | |
| | TC63 | x | XX | | xx | | | | x | x | | x | | | | |
| | TC30 | XX | x | xx | | x | x | | x | | | x | | | | |
| | TC39 | XX | x | xx | | xx | x | x | | | | | | | | |
| | TC76 | X | x | xx | | xx | xx | x | x | | x | | | | | |
| | TC96 | X | | x | | xx | xx | xx | | | x | x | | | | |
| | TC78 | XX | | x | | xx | x | | x | | x | | | | | |
| | TC56 | XX | | xx | | xx | x | x | | | | | | | | |
| | TC60 | X | x | xx | | X | xx | | x | | | <x | | | | |
| W569001 | TC69 | x | X | | X | x | xx | | x | | | | | | | |
| | TC80 | X | xx | | | X | X | | | | | | | | | |
| | TC54 | X | xx | xx | | x | x | x | | | | x | | | | |
| | TC111[b] | xx | | | | xx | | | x | | | x | X | X | | x |
| | TC89 | X | | xx | | X | xx | | x | | | <x | | | | |
| | TC102[b] | X | | x | | X | xx | | | | xx | x | | | | x |
| | TC22 | XX | x | xx | | xx | x | x | | | | x | <x | | | |
| | TC103[b] | X | | x | | xx | | | | | X | x | X | | | x |
| Y106148 | TC32 | XX | x | xx | | xx | x | | x | | | | | | | |
| | TC12 | XX | xx | X | | x | <x | x | | | | | | | | |
| | TC8 | X | xx | x | | xx | x | x | | | | | <x | | | |
| | TC95 | X | x | x | | X | xx | x | x | | | x | | | | x |
| | TC19 | XX | | xx | | | | | | | x | | | | | |
| Z145168 | TC31 | XX | x | x | | x | x | | <x | | | | | | | |
| | TC115 | xx | XX | | | | | | | xx | | x | xx | | x | |
| | TC100 | X | x | x | | xx | X | | | | | x | | | | |
| | TC37 | xx | XX | <x | x | | xx | x | x | | | | | | | |
| | TC68 | X | x | xx | | xx | xx | | | | | x | | | | x |
| | TC85 | X | xx | xx | | xx | xx | x | | | | | | | | |
| | TC67 | X | x | xx | x | xx | xx | x | x | | x | x | x | | | |
| | TC42 | X | xx | | | X | x | | | | | | | | | |
| Z145198 | TC71 | xx | X | | X | | | | | | | x | xx | | | |
| | TC90 | X | x | xx | | xx | xx | x | | | | x | | | | |
| | TC26 | XX | xx | xx | | x | x | x | | | | <x | | | | |
| | TC2 | XX | | xx | | X | x | <x | | | | | | | | |
| | TC72 | X | x | X | | X | xx | | x | | | <x | | | | |
| | TC88 | XX | | xx | | x | x | <x | x | | | <x | | | | |

| Sample Name | Lab number | Quartz | Plagio clase | K-feldspar and/or rutile | Pyro xene | Kaolinite and/or chlorite | Mica | Side rite | Anke rite | Mag netite | Goethite and/or hematite and/or pyrite | Cal cite | Sme ctite | Anal cime | Mag nesite | Dolo mite |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Z145199 | TC46 | x | XX | | xx | | | | x | | | | x | | | |
| | TC17 | XX | x | x | | | x | | | x | | | x | | | |
| | TC50 | xx | XX | <x | xx | | | | x | | | | | | | |
| | TC77 | X | x | xx | | xx | xx | x | | | | x | | | | |
| | TC81 | X | xx | xx | | X | xx | x | | | | | | | | |
| | TC20 | X | xx | xx | | x | x | x | x | | | x | | | | |
| | TC64 | XX | | x | | x | x | | x | | <x | | | | | |

# Appendix 4: Mine 2 XRD Mineralogical Analysis

| Sample name | Lab number | QUARTZ | PLAGIOCLASE | K-FELDSPAR/RUTILE | CALCITE | SIDERITE | ANATASE | ANKERITE | PYRITE | ILMENITE | KAOLINITE | CLINOCHLORE | MICA | ILLITE/SMECTITE INTERSTRATIFICATION | SMECTITE | PYROXENE | MAGNETITE | PYROPHYLLITE | SERPENTINE | AMPHIBOLE | ANDALUSITE | ALUNITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 100 001 | SF 11 | xx | XX | | | | | | | | | xx | | | | xx | | | | | | |
| | SF 12 | X | x | x | x | | | | | | | xx | xx | xx | | | | | | | | |
| | SF 13 | X | x | x | | | | | | | | xx | X | | X | | | | | | | |
| | SF 61[b] | X | X | | x | | | | | | X | | | | | | | | | | | |
| | SF 14 | X | x | xx | x | x | | | x | | | xx | xx | xx | | | | | | | | |
| | SF 1 | X | x | xx | | x | | x | | | | X | xx | xx | | | | | | | | |
| | SF 62[b] | X | | | x | | | | x | | X | | | | | | | | | | | |
| | SF 2 | XX | | x | | | | x | | | X | | x | | | | | | | | | |
| | SF 15 | X | x | xx | | | | | | | | X | xx | x | | | | | | | | |
| | SF 16 | XX | xx | | | | | | | | xx | | x | x | | | | | | | | |
| | SF 17 | XX | | x | <x | | | | | | xx | | x | | | | | | | | | |
| | SF 18 | X | x | xx | | xx | | x | | | xx | | xx | | | | | | | | | |
| | SF 19 | X | xx | x | x | xx | | x | | | x | | xx | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| R 100 002 | SF 20 | X | xx | | x | | | | | | xx | | xx | | X | xx | | | | | | |
| | SF 21 | X | x | xx | x | x | | | | | | X | xx | xx | x | | | | | | | |
| | SF 3 | X | x | xx | <x | x | | | | | | X | xx | xx | | | | | | | | |
| | SF 63[b] | X | | xx | | | | | x | | X | | | | | | | | | | | |
| | SF 4 | X | | xx | | | | | x | | xx | | xx | x | | x | | | | | | |
| | SF 22 | X | x | xx | | x | | x | | | | xx | xx | x | | | | | | | | |
| | SF 23 | XX | | xx | | | | | | | xx | | x | | | | | | | | | |
| | SF 24 | XX | x | x | | x | | | | | xx | | x | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| Z124027 | SF 45 | xx | X | | | | | | | | | X | | | | xx | | | | | | |
| | SF 46 | X | x | x | xx | x | | | | | | xx | xx | xx | | | | | xx | | | |
| | SF 47 | X | x | xx | | | | | | | | xx | xx | x | | | | | | | | |
| | SF 48 | X | x | x | x | x | | xx | | | | xx | xx | xx | | | | | | | | |
| | SF 49 | X | x | x | | | | | xx | | xx | | xx | | X | | | | | | | |
| | SF 64[b] | X | xx | | xx | | | | x | | X | | | | | | | | | | | |
| | SF 50 | xx | XX | | | xx | | | | | | | | | | xx | | | | | | |
| | SF 51 | X | x | xx | x | x | | | | | | xx | xx | xx | | | | | | | | |
| | SF 65[b] | X | xx | xx | | | | | x | | X | | | | | | | | | | | |
| | SF 52 | XX | | x | x | | | xx | <x | | xx | | x | x | | | | | | | | |
| | SF 7 | XX | | x | <x | | | | x | | x | | x | | | | | | | | | |

| Sample name | Lab number | QUARTZ | PLAGIOCLASE | FELDSPAR/RUTILE | CALCITE | SIDERITE | ANATASE | ANKERITE | PYRITE | ILMENITE | KAOLINITE | CLINOCHLORE | MICA | ILLITE/SMECTITE INTERSTRATIFICATION | SMECTITE | PYROXENE | MAGNETITE | PYROPHYLLITE | SERPENTINE | AMPHIBOLE | ANDALUSITE | ALUNITE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Z124030 | SF 71[b] | X | | | xx | x | | | | | X | | | | | | | | | | | |
| | SF 10 | X | | xx | | | | | | x | X | | xx | x | | x | | | | | | |
| | SF 42 | X | x | x | | x | | xx | | | | X | xx | xx | | | | | | | | |
| | SF 43 | X | x | x | x | | | | | | | xx | xx | xx | xx | | | | | | | |
| | SF 44 | xx | x | | x | x | | | | | | xx | xx | | xx | | | | xx | xx | | |

Appendix 5: Mine 1 XRF Mineral Analysis

| Sample name | | SiO2 | TiO2 | Al2O3 | Fe2O3 | MgO | MnO | CaO | Na2O | K2O | P2O5 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| F142441 | TC18 | 52.1 | 1.4 | 13.3 | 12.4 | 6.5 | 0.2 | 8.9 | 2.3 | 0.8 | 0.2 | **98.1** |
| | TC75 | 82.0 | 0.2 | 9.9 | 1.9 | 0.4 | 0.0 | 0.9 | 0.7 | 3.6 | 0.1 | **99.9** |
| | TC38 | 68.2 | 0.7 | 14.1 | 4.5 | 1.0 | 0.1 | 0.9 | 0.8 | 3.3 | 0.1 | **93.7** |
| | TC83 | 63.7 | 0.9 | 14.8 | 5.5 | 1.0 | 0.1 | 1.1 | 1.1 | 3.0 | 0.1 | **91.1** |
| | TC7 | 54.0 | 0.6 | 12.2 | 8.1 | 2.0 | 0.1 | 3.4 | 0.4 | 2.9 | 0.4 | **84.1** |
| | TC35 | 76.4 | 0.7 | 13.4 | 0.6 | 0.2 | 0.0 | 0.2 | 0.0 | 2.4 | 0.0 | **93.9** |
| | | | | | | | | | | | | |
| F142446 | TC66 | 82.4 | 0.3 | 9.3 | 2.0 | 0.5 | 0.0 | 0.3 | 1.8 | 3.0 | 0.0 | **99.7** |
| | TC57 | 72.7 | 0.6 | 12.4 | 3.1 | 1.0 | 0.1 | 1.9 | 1.8 | 3.5 | 0.1 | **97.2** |
| | TC62 | 53.1 | 1.5 | 14.0 | 12.5 | 5.8 | 0.2 | 8.9 | 2.5 | 1.0 | 0.2 | **99.6** |
| | TC10 | 70.4 | 0.6 | 11.9 | 3.7 | 0.9 | 0.1 | 1.1 | 0.6 | 2.7 | 0.1 | **92.0** |
| | TC4 | 77.7 | 0.4 | 9.3 | 1.2 | 0.2 | 0.0 | 0.7 | 0.8 | 3.5 | 0.0 | **93.9** |
| | TC51 | 58.6 | 0.8 | 15.6 | 7.7 | 1.5 | 0.1 | 0.9 | 0.7 | 3.1 | 0.1 | **89.1** |
| | TC41 | 39.7 | 0.7 | 17.8 | 3.8 | 1.3 | 0.0 | 0.2 | 0.4 | 2.0 | 0.0 | **66.0** |
| | TC33 | 69.7 | 0.7 | 13.5 | 4.2 | 1.6 | 0.1 | 1.1 | 1.0 | 3.2 | 0.1 | **95.1** |
| | TC87 | 70.0 | 0.8 | 18.4 | 1.0 | 0.4 | 0.0 | 0.5 | 0.9 | 3.3 | 0.0 | **95.2** |
| | | | | | | | | | | | | |
| F142471 | TC65 | 73.6 | 0.5 | 10.9 | 6.4 | 0.8 | 0.1 | 0.9 | 0.4 | 2.7 | 0.2 | **96.6** |
| | TC55 | 85.6 | 0.5 | 8.5 | 1.6 | 0.2 | 0.0 | 0.5 | 0.4 | 3.4 | 0.0 | **100.9** |
| | TC61 | 59.8 | 0.7 | 16.3 | 7.3 | 1.7 | 0.1 | 0.7 | 1.3 | 3.5 | 0.1 | **91.5** |
| | TC3 | 60.4 | 0.8 | 15.3 | 7.5 | 1.5 | 0.1 | 0.5 | 1.1 | 3.2 | 0.1 | **90.5** |
| | TC107[b] | 20.2 | 0.5 | 8.5 | 0.6 | 0.5 | 0.0 | 1.3 | 0.3 | 0.2 | 0.1 | **32.3** |
| | TC11 | 66.7 | 0.8 | 20.5 | 1.0 | 0.1 | 0.0 | 0.1 | 0.9 | 2.5 | 0.0 | **92.7** |
| | TC112[b] | 5.4 | 0.2 | 3.8 | 3.5 | 0.2 | 0.0 | 0.4 | 0.1 | 0.0 | 0.0 | **13.8** |
| | TC84 | 67.0 | 0.6 | 14.0 | 2.6 | 1.2 | 0.1 | 2.8 | 0.1 | 2.8 | 0.1 | **91.2** |
| | TC105[b] | 4.2 | 0.1 | 2.9 | 0.1 | 0.2 | 0.0 | 0.6 | 0.1 | 0.1 | 0.0 | **8.3** |
| | TC114[b] | 22.3 | 0.4 | 9.8 | 2.2 | 0.7 | 0.0 | 0.4 | 0.6 | 1.0 | 0.0 | **37.4** |
| | | | | | | | | | | | | |
| O105016 | TC25 | 72.4 | 0.4 | 10.9 | 2.5 | 0.6 | 0.0 | 4.4 | 0.8 | 3.5 | 0.0 | **95.5** |
| | TC113 | 54.4 | 0.9 | 17.4 | 7.9 | 1.5 | 0.1 | 1.4 | 1.3 | 3.0 | 0.2 | **88.1** |
| | TC48 | 77.2 | 0.3 | 10.7 | 2.1 | 0.4 | 0.0 | 2.0 | 1.5 | 3.3 | 0.0 | **97.6** |
| | TC43 | 46.9 | 0.7 | 15.4 | 12.0 | 1.8 | 0.1 | 0.9 | 0.8 | 2.5 | 0.1 | **81.3** |
| | TC101 | 39.4 | 0.6 | 15.0 | 9.4 | 1.5 | 0.1 | 1.0 | 0.8 | 1.7 | 0.1 | **69.5** |
| | TC34 | 72.2 | 0.7 | 15.9 | 4.0 | 1.2 | 0.0 | 0.5 | 0.4 | 3.3 | 0.1 | **98.3** |
| | TC24 | 52.0 | 1.2 | 14.3 | 11.8 | 5.1 | 0.2 | 9.4 | 1.9 | 0.9 | 0.1 | **96.9** |
| | TC14 | 64.0 | 0.8 | 15.0 | 5.0 | 1.1 | 0.1 | 1.7 | 1.3 | 3.1 | 0.1 | **92.1** |
| | TC79 | 71.9 | 0.7 | 16.6 | 1.0 | 0.3 | 0.0 | 0.1 | 0.0 | 3.0 | 0.0 | **93.7** |

| Sample name | | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | MgO | MnO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| P110030 | TC49 | 80.3 | 0.4 | 9.8 | 3.0 | 0.7 | 0.0 | 1.1 | 0.3 | 2.4 | 0.1 | **98.1** |
| | TC52[a] | 65.8 | 0.6 | 13.4 | 4.4 | 0.8 | 0.1 | 0.7 | 0.8 | 2.8 | 0.1 | **89.6** |
| | TC99[a] | 51.3 | 1.6 | 13.2 | 13.7 | 5.0 | 0.2 | 8.7 | 2.3 | 0.9 | 0.2 | **97.1** |
| | TC1 | 56.2 | 0.9 | 17.5 | 8.0 | 2.0 | 0.1 | 1.0 | 0.8 | 3.3 | 0.2 | **89.9** |
| | TC5 | 83.3 | 0.3 | 9.2 | 1.2 | 0.4 | 0.0 | 1.3 | 0.5 | 3.4 | 0.0 | **99.6** |
| | TC74 | 38.6 | 0.6 | 15.7 | 9.0 | 1.5 | 0.1 | 0.5 | 0.3 | 2.0 | 0.0 | **68.5** |
| | TC117[b] | 21.1 | 0.3 | 8.4 | 1.8 | 0.6 | 0.0 | 0.5 | 0.4 | 0.9 | 0.0 | **34.1** |
| | TC104 | 56.3 | 0.7 | 17.6 | 4.3 | 0.9 | 0.0 | 0.4 | 1.3 | 3.2 | 0.1 | **84.9** |
| | TC109[b] | 23.9 | 0.4 | 9.6 | 1.0 | 0.6 | 0.0 | 1.3 | 0.3 | 0.6 | 0.2 | **37.9** |
| | TC82 | 70.3 | 0.5 | 18.7 | 0.6 | 0.2 | 0.0 | 0.1 | 0.0 | 3.5 | 0.0 | **93.9** |
| | TC108[b] | 6.8 | 0.1 | 3.9 | 2.3 | 0.3 | 0.0 | 0.6 | 0.1 | 0.1 | 0.0 | **14.3** |
| | TC27 | 75.9 | 0.7 | 14.8 | 0.9 | 0.2 | 0.0 | 0.2 | 0.0 | 3.4 | 0.0 | **96.1** |
| | TC98 | 65.1 | 0.7 | 16.1 | 2.7 | 0.7 | 0.0 | 0.3 | 1.2 | 2.6 | 0.1 | **89.7** |
| | TC106[b] | 2.4 | 0.1 | 1.5 | 5.0 | 0.3 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | **10.1** |
| | | | | | | | | | | | | |
| P110087 | TC9 | 45.2 | 0.8 | 13.1 | 10.6 | 6.4 | 0.2 | 13.7 | 1.6 | 1.2 | 0.1 | **92.8** |
| | TC13 | 67.3 | 0.8 | 14.9 | 5.2 | 1.2 | 0.1 | 0.6 | 0.9 | 3.4 | 0.1 | **94.5** |
| | TC97 | 49.1 | 0.5 | 12.7 | 5.4 | 1.3 | 0.1 | 11.8 | 0.7 | 2.2 | 0.8 | **84.5** |
| | TC58 | 69.7 | 0.7 | 14.3 | 4.7 | 1.1 | 0.1 | 0.7 | 0.9 | 2.9 | 0.1 | **95.1** |
| | TC23 | 84.1 | 0.2 | 9.4 | 1.0 | 0.2 | 0.0 | 0.2 | 0.6 | 4.1 | 0.0 | **99.7** |
| | TC94 | 58.9 | 0.6 | 13.8 | 6.5 | 1.6 | 0.1 | 4.5 | 1.6 | 3.0 | 0.3 | **90.8** |
| | TC91 | 31.7 | 0.5 | 12.8 | 5.6 | 1.0 | 0.0 | 0.4 | 0.4 | 1.4 | 0.0 | **53.8** |
| | TC45 | 72.6 | 0.5 | 12.8 | 4.2 | 0.7 | 0.0 | 0.4 | 0.9 | 3.5 | 0.0 | **95.6** |
| | TC53 | 50.4 | 0.9 | 18.3 | 8.1 | 1.4 | 0.1 | 0.5 | 0.7 | 2.7 | 0.1 | **83.1** |
| | TC6 | 47.0 | 0.5 | 4.0 | 22.2 | 1.4 | 0.1 | 2.2 | 0.0 | 1.6 | 0.0 | **79.0** |
| | TC73 | 57.7 | 0.9 | 18.0 | 2.0 | 0.8 | 0.0 | 0.5 | 0.0 | 2.2 | 0.0 | **82.1** |
| | | | | | | | | | | | | |
| R146043 | TC93 | 78.0 | 0.6 | 9.6 | 2.3 | 0.8 | 0.0 | 1.0 | 1.0 | 3.3 | 0.1 | **96.8** |
| | TC116 | 51.6 | 0.9 | 15.4 | 10.6 | 7.7 | 0.2 | 10.6 | 2.6 | 0.7 | 0.1 | **100.5** |
| | TC47 | 70.0 | 0.4 | 10.9 | 2.8 | 0.7 | 0.2 | 5.2 | 0.9 | 3.4 | 0.2 | **94.7** |
| | TC59 | 70.1 | 0.5 | 12.6 | 4.0 | 0.8 | 0.1 | 1.5 | 0.9 | 3.2 | 0.1 | **93.9** |
| | TC29 | 82.1 | 0.3 | 9.7 | 1.1 | 0.4 | 0.0 | 1.1 | 0.9 | 3.9 | 0.0 | **99.5** |
| | TC16 | 55.9 | 0.8 | 15.8 | 6.4 | 1.4 | 0.1 | 3.0 | 0.9 | 3.0 | 0.3 | **87.6** |
| | TC28 | 35.3 | 0.6 | 15.9 | 3.8 | 1.2 | 0.0 | 0.2 | 0.4 | 1.8 | 0.0 | **59.2** |
| | TC110[b] | 7.4 | 0.1 | 4.1 | 0.5 | 0.1 | 0.0 | 0.2 | 0.2 | 0.1 | 0.0 | **12.7** |
| | TC40 | 84.1 | 0.3 | 10.2 | 1.3 | 0.5 | 0.0 | 0.2 | 1.1 | 3.9 | 0.0 | **101.7** |
| | TC15 | 60.3 | 0.3 | 7.8 | 10.2 | 1.7 | 0.2 | 4.8 | 0.6 | 3.0 | 0.1 | **88.8** |
| | TC86 | 61.5 | 0.7 | 13.5 | 6.5 | 1.6 | 0.1 | 2.8 | 0.8 | 2.8 | 0.1 | **90.3** |
| | TC92 | 20.4 | 0.5 | 7.9 | 2.0 | 0.4 | 0.0 | 0.1 | 0.2 | 0.7 | 0.0 | **32.3** |
| | TC21 | 84.4 | 0.4 | 8.4 | 1.7 | 0.0 | 0.0 | 0.1 | 0.0 | 3.2 | 0.0 | **98.1** |
| | TC118[b] | 17.0 | 0.4 | 6.6 | 1.4 | 0.2 | 0.0 | 0.7 | 0.2 | 0.4 | 0.1 | **26.9** |

| Sample name | | SiO2 | TiO2 | Al2O3 | Fe2O3 | MgO | MnO | CaO | Na2O | K2O | P2O5 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T139228 | TC70 | 72.5 | 0.4 | 14.2 | 3.7 | 0.8 | 0.0 | 0.8 | 1.4 | 4.0 | 0.0 | **97.9** |
| | TC44 | 51.5 | 1.4 | 13.2 | 12.6 | 6.5 | 0.2 | 8.6 | 2.5 | 0.9 | 0.2 | **97.5** |
| | TC36 | 66.6 | 0.7 | 14.2 | 6.0 | 1.7 | 0.1 | 2.6 | 1.1 | 3.2 | 0.1 | **96.1** |
| | TC63 | 44.9 | 2.4 | 14.8 | 14.3 | 3.2 | 0.3 | 9.9 | 2.8 | 0.3 | 0.2 | **93.1** |
| | TC30 | 74.0 | 0.6 | 11.9 | 2.8 | 0.6 | 0.0 | 1.7 | 0.8 | 3.4 | 0.1 | **96.0** |
| | TC39 | 41.2 | 0.7 | 17.1 | 3.7 | 1.2 | 0.0 | 0.3 | 0.5 | 2.0 | 0.0 | **66.6** |
| | TC76 | 67.7 | 0.7 | 15.1 | 4.5 | 0.8 | 0.0 | 0.4 | 0.8 | 3.3 | 0.1 | **93.4** |
| | TC96 | 50.3 | 0.4 | 9.5 | 15.4 | 1.6 | 0.1 | 1.1 | 0.2 | 2.2 | 0.0 | **80.9** |
| | TC78 | 72.5 | 0.5 | 11.9 | 3.4 | 0.1 | 0.0 | 0.1 | 0.0 | 2.5 | 0.0 | **90.9** |
| | TC56 | 71.4 | 0.8 | 17.7 | 1.0 | 0.1 | 0.0 | 0.1 | 0.0 | 2.3 | 0.0 | **93.5** |
| | TC60 | 62.8 | 1.0 | 17.9 | 2.9 | 0.9 | 0.0 | 0.3 | 0.4 | 3.3 | 0.1 | **89.5** |
| | | | | | | | | | | | | |
| W569001 | TC69 | 49.1 | 1.1 | 14.2 | 13.8 | 8.0 | 0.2 | 11.5 | 2.7 | 0.3 | 0.2 | **101.1** |
| | TC80 | 42.2 | 0.6 | 14.5 | 20.2 | 2.1 | 0.1 | 1.0 | 0.9 | 1.6 | 0.1 | **83.3** |
| | TC54 | 66.4 | 0.7 | 13.4 | 4.1 | 0.8 | 0.0 | 1.0 | 1.0 | 3.1 | 0.1 | **90.7** |
| | TC111[b] | 9.3 | 0.2 | 4.1 | 0.3 | 0.5 | 0.0 | 2.0 | 0.3 | 0.1 | 0.2 | **17.2** |
| | TC89 | 56.9 | 0.9 | 27.7 | 1.1 | 0.1 | 0.0 | 0.2 | 0.0 | 2.5 | 0.1 | **89.5** |
| | TC102[b] | 11.0 | 0.3 | 6.3 | 1.3 | 0.4 | 0.0 | 1.2 | 0.3 | 0.2 | 0.0 | **20.9** |
| | TC22 | 62.3 | 0.9 | 17.0 | 3.4 | 1.0 | 0.0 | 1.2 | 0.5 | 3.2 | 0.1 | **89.6** |
| | TC103[b] | 19.2 | 0.3 | 7.5 | 7.5 | 0.3 | 0.0 | 0.4 | 0.3 | 0.8 | 0.0 | **36.4** |
| | | | | | | | | | | | | |
| Y106148 | TC32 | 75.5 | 0.8 | 15.6 | 2.4 | 0.4 | 0.0 | 0.3 | 0.1 | 3.9 | 0.0 | **99.0** |
| | TC12 | 74.1 | 0.5 | 11.4 | 3.1 | 0.4 | 0.0 | 0.9 | 1.4 | 3.8 | 0.0 | **95.7** |
| | TC8 | 56.3 | 0.8 | 16.8 | 6.2 | 1.3 | 0.1 | 1.2 | 0.9 | 2.8 | 0.1 | **86.5** |
| | TC95 | 60.9 | 0.9 | 18.7 | 4.3 | 1.0 | 0.1 | 0.6 | 1.0 | 3.4 | 0.1 | **90.9** |
| | TC19 | 93.7 | 0.4 | 4.2 | 1.2 | 0.1 | 0.0 | 0.0 | 0.0 | 2.2 | 0.0 | **101.7** |
| | | | | | | | | | | | | |
| Z145168 | TC31 | 79.2 | 0.5 | 12.1 | 2.5 | 0.7 | 0.0 | 0.5 | 1.2 | 3.0 | 0.1 | **99.8** |
| | TC115 | 52.8 | 1.5 | 13.5 | 12.7 | 5.1 | 0.2 | 8.5 | 2.7 | 1.0 | 0.2 | **98.2** |
| | TC100 | 58.9 | 0.7 | 15.2 | 5.8 | 1.8 | 0.1 | 4.6 | 2.0 | 3.3 | 0.1 | **92.5** |
| | TC37 | 47.2 | 2.0 | 14.5 | 13.9 | 3.3 | 0.2 | 8.1 | 2.3 | 0.8 | 0.2 | **92.6** |
| | TC68 | 73.6 | 0.6 | 14.2 | 3.9 | 1.3 | 0.0 | 0.6 | 1.0 | 3.4 | 0.1 | **98.6** |
| | TC85 | 64.8 | 0.7 | 13.9 | 7.3 | 1.4 | 0.1 | 0.8 | 0.9 | 3.1 | 0.1 | **93.0** |
| | TC67 | 60.9 | 0.7 | 15.5 | 5.4 | 1.1 | 0.1 | 0.6 | 1.6 | 3.2 | 0.1 | **89.2** |
| | TC42 | 64.5 | 0.8 | 22.9 | 1.1 | 0.0 | 0.0 | 0.1 | 0.0 | 2.3 | 0.0 | **91.6** |
| | | | | | | | | | | | | |
| Z145198 | TC71 | 51.6 | 1.3 | 13.6 | 12.3 | 6.8 | 0.2 | 9.3 | 2.3 | 0.8 | 0.2 | **98.4** |
| | TC90 | 66.1 | 0.8 | 15.2 | 6.0 | 1.1 | 0.1 | 1.2 | 0.8 | 3.2 | 0.1 | **94.6** |
| | TC26 | 65.6 | 0.7 | 12.8 | 3.6 | 1.4 | 0.1 | 4.1 | 1.6 | 3.3 | 0.2 | **93.5** |
| | TC2 | 69.4 | 0.6 | 17.7 | 0.6 | 0.1 | 0.0 | 0.1 | 0.0 | 2.6 | 0.0 | **91.1** |
| | TC72 | 63.9 | 1.0 | 17.4 | 2.3 | 0.5 | 0.0 | 0.1 | 0.1 | 3.1 | 0.1 | **88.5** |
| | T88 | 85.4 | 0.5 | 10.1 | 1.0 | 0.1 | 0.0 | 0.1 | 0.0 | 3.5 | 0.0 | **100.7** |

| Sample name | | SiO2 | TiO2 | Al2O3 | Fe2O3 | MgO | MnO | CaO | Na2O | K2O | P2O5 | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Z145199 | TC46 | 51.0 | 1.0 | 14.8 | 10.4 | 7.6 | 0.2 | 10.4 | 1.9 | 0.6 | 0.1 | **98.0** |
| | TC17 | 72.3 | 0.6 | 12.4 | 5.8 | 1.1 | 0.1 | 0.5 | 1.2 | 3.2 | 0.1 | **97.2** |
| | TC50 | 52.4 | 1.6 | 13.0 | 13.5 | 5.4 | 0.2 | 8.5 | 2.7 | 0.9 | 0.2 | **98.4** |
| | TC77 | 60.9 | 0.6 | 12.8 | 8.0 | 1.1 | 0.1 | 3.5 | 0.7 | 2.7 | 0.2 | **90.6** |
| | TC81 | 28.0 | 0.5 | 11.5 | 3.7 | 0.8 | 0.0 | 0.4 | 0.2 | 1.4 | 0.0 | **46.5** |
| | TC20 | 56.9 | 0.6 | 13.2 | 5.2 | 1.9 | 0.1 | 5.6 | 1.0 | 3.0 | 0.1 | **87.6** |
| | TC64 | 88.0 | 0.4 | 8.2 | 0.9 | 0.0 | 0.0 | 0.1 | 0.0 | 3.1 | 0.0 | **100.7** |
| Average | | **57.5** | **0.7** | **12.9** | **5.2** | **1.4** | **0.1** | **2.2** | **0.9** | **2.4** | **0.1** | **83.3** |

# Appendix 6: Mine 2 XRF Mineral Analysis

| Sample name | Lab no. | Al2O3 | CaO | Fe2O3 | K2O | MgO | MnO | P2O5 | SiO2 | TiO2 | Na2O | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| R 100 001 | SF 11 | 14.7 | 10.4 | 11.0 | 0.5 | 7.2 | 0.1 | 0.1 | 51.7 | 0.9 | 2.1 | **98.6** |
| | SF 12 | 12.2 | 2.7 | 3.6 | 3.2 | 0.9 | 0.0 | 0.0 | 71.2 | 0.5 | 1.6 | **95.9** |
| | SF 13 | 18.2 | 0.4 | 4.0 | 1.9 | 1.6 | 0.0 | 0.0 | 46.6 | 0.7 | 0.9 | **74.3** |
| | SF 61[B] | 5.65 | 0.67 | 1.27 | 0.40 | 0.69 | 0.01 | 0.02 | 13.26 | 0.15 | 0.93 | **23.1** |
| | SF 14 | 15.4 | 3.1 | 4.3 | 3.1 | 1.0 | 0.0 | 0.1 | 61.6 | 0.6 | 0.9 | **90.2** |
| | SF 1 | 16.4 | 1.3 | 11.3 | 2.2 | 1.7 | 0.0 | 0.2 | 46.9 | 0.8 | 0.4 | **81.2** |
| | SF 62[B] | 4.71 | 2.17 | 0.36 | 0.16 | 0.64 | 0.01 | 0.14 | 11.79 | 0.20 | 0.41 | **20.6** |
| | SF 2 | 19.4 | 0.1 | 0.8 | 2.1 | 0.2 | 0.0 | 0.0 | 70.0 | 1.1 | 1.0 | **94.7** |
| | SF 15 | 16.1 | 0.2 | 2.3 | 3.2 | 0.5 | 0.0 | 0.1 | 67.4 | 0.6 | 0.7 | **91.3** |
| | SF 16 | 12.3 | 0.1 | 1.0 | 3.3 | 0.3 | 0.0 | 0.0 | 79.7 | 0.4 | 0.5 | **97.6** |
| | SF 17 | 8.5 | 0.1 | 0.7 | 1.9 | 0.1 | 0.0 | 0.0 | 83.1 | 0.6 | 0.7 | **95.8** |
| | SF 18 | 12.9 | 0.4 | 10.5 | 2.3 | 0.9 | 0.1 | 0.1 | 59.6 | 1.7 | 0.5 | **89.1** |
| | SF 19 | 8.9 | 4.1 | 7.3 | 3.2 | 1.8 | 0.1 | 0.1 | 63.3 | 0.3 | 2.3 | **91.4** |
| | | | | | | | | | | | | |
| R 100 002 | SF 20 | 14.4 | 6.6 | 8.1 | 1.7 | 3.9 | 0.1 | 0.1 | 57.8 | 0.8 | 1.2 | **94.7** |
| | SF 21 | 14.0 | 2.4 | 7.3 | 2.8 | 1.2 | 0.1 | 0.1 | 61.3 | 0.7 | 0.9 | **90.6** |
| | SF 3 | 15.4 | 0.8 | 9.5 | 2.5 | 1.5 | 0.0 | 0.1 | 54.7 | 0.7 | 0.4 | **85.4** |
| | SF 63[B] | 2.68 | 1.23 | 0.21 | 0.08 | 0.37 | 0.00 | 0.08 | 6.81 | 0.11 | 0.58 | **12.2** |
| | SF 4 | 10.4 | 0.3 | 1.6 | 2.5 | 0.2 | 0.0 | 0.0 | 67.3 | 0.9 | 1.2 | **84.5** |
| | SF 22 | 17.9 | 0.5 | 2.7 | 2.8 | 0.6 | 0.0 | 0.2 | 59.8 | 0.7 | 0.6 | **85.8** |
| | SF 23 | 11.2 | 0.1 | 0.9 | 2.9 | 0.2 | 0.0 | 0.0 | 80.1 | 0.4 | 0.5 | **96.3** |
| | SF 24 | 10.2 | 0.3 | 4.6 | 3.0 | 0.4 | 0.0 | 0.0 | 75.9 | 0.7 | 1.9 | **97.0** |
| | | | | | | | | | | | | |
| Z124027 | SF 45 | 10.2 | 8.0 | 13.6 | 0.8 | 5.5 | 0.1 | 0.2 | 52.1 | 1.4 | 2.4 | **94.4** |
| | SF 46 | 8.4 | 12.4 | 5.0 | 2.5 | 0.9 | 0.1 | 1.5 | 54.8 | 0.3 | 0.9 | **86.7** |
| | SF 47 | 10.9 | 0.4 | 3.2 | 3.5 | 0.8 | 0.0 | 0.1 | 71.3 | 0.6 | 1.7 | **92.6** |
| | SF 48 | 12.4 | 1.8 | 5.0 | 3.0 | 1.1 | 0.0 | 0.1 | 64.2 | 0.6 | 1.0 | **89.1** |
| | SF 49 | 13.7 | 0.4 | 4.2 | 1.8 | 1.3 | 0.0 | 0.0 | 41.4 | 0.5 | 0.6 | **64.0** |
| | SF 64[B] | 3.52 | 5.33 | 5.24 | 0.20 | 1.22 | 0.03 | 0.00 | 20.36 | 0.10 | 1.26 | **37.3** |
| | SF 50 | 12.2 | 8.6 | 15.6 | 0.4 | 3.8 | 0.1 | 0.2 | 47.1 | 2.0 | 2.1 | **92.1** |
| | SF 51 | 12.4 | 0.7 | 5.7 | 3.1 | 1.0 | 0.0 | 0.1 | 64.2 | 0.5 | 1.0 | **88.6** |
| | SF 65[B] | 7.88 | 0.44 | 5.28 | 0.65 | 0.23 | 0.01 | 0.01 | 22.32 | 0.24 | 0.67 | **37.7** |
| | SF 52 | 11.6 | 0.2 | 1.4 | 1.5 | 0.1 | 0.0 | 0.0 | 77.2 | 0.6 | 1.0 | **93.7** |
| | SF 7 | 3.0 | 0.3 | 4.1 | 0.9 | 0.0 | 0.0 | 0.0 | 89.3 | 0.6 | 0.7 | **98.9** |
| | SF 66[B] | 5.08 | 1.56 | 0.13 | 0.09 | 0.58 | 0.01 | 0.03 | 10.52 | 0.16 | 0.48 | **18.6** |
| | SF 8 | 15.5 | 0.1 | 0.7 | 3.4 | 0.1 | 0.0 | 0.0 | 73.1 | 0.5 | 0.7 | **94.2** |
| | SF 53 | 13.2 | 1.5 | 2.6 | 3.1 | 0.9 | 0.0 | 0.0 | 66.5 | 0.7 | 0.9 | **89.5** |
| | SF 54 | 12.6 | 6.6 | 13.6 | 0.5 | 3.8 | 0.1 | 0.1 | 49.2 | 1.8 | 1.7 | **90.0** |
| | SF 55 | 4.5 | 0.8 | 3.9 | 1.0 | 0.3 | 0.0 | 0.0 | 83.2 | 0.5 | 0.9 | **95.2** |

| Sample name | Lab no. | Al2O3 | CaO | Fe2O3 | K2O | MgO | MnO | P2O5 | SiO2 | TiO2 | Na2O | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Z124027 | SF 56 | 9.3 | 0.8 | 1.5 | 3.7 | 0.5 | 0.0 | 0.0 | 80.0 | 0.2 | 0.8 | **96.8** |
| | SF 57 | 12.2 | 9.8 | 16.7 | 0.4 | 4.9 | 0.1 | 0.2 | 48.9 | 2.0 | 2.6 | **97.7** |
| | SF 58 | 11.0 | 0.4 | 0.9 | 3.0 | 0.3 | 0.0 | 0.0 | 76.7 | 0.4 | 0.5 | **93.1** |
| | SF 59 | 14.0 | 0.3 | 5.2 | 2.2 | 1.2 | 0.0 | 0.2 | 69.3 | 0.7 | 0.3 | **93.4** |
| | SF 60 | 19.2 | 0.6 | 11.0 | 2.9 | 1.5 | 0.0 | 0.2 | 57.3 | 0.7 | 0.4 | **93.8** |
| | | | | | | | | | | | | |
| Z124029 | SF 25 | 10.4 | 0.3 | 1.3 | 4.0 | 0.4 | 0.0 | 0.0 | 80.4 | 0.1 | 2.5 | **99.6** |
| | SF 26 | 15.1 | 10.8 | 10.8 | 0.5 | 7.4 | 0.1 | 0.1 | 54.1 | 0.8 | 2.5 | **102.2** |
| | SF 27 | 14.0 | 1.6 | 4.3 | 3.1 | 1.0 | 0.0 | 0.1 | 69.4 | 0.5 | 1.3 | **95.3** |
| | SF 28 | 16.5 | 0.6 | 3.4 | 1.6 | 1.3 | 0.0 | 0.0 | 43.7 | 0.6 | 1.0 | **68.9** |
| | SF 29 | 15.8 | 2.7 | 6.4 | 3.0 | 1.4 | 0.0 | 0.5 | 56.4 | 0.7 | 0.9 | **87.8** |
| | SF 5 | 12.2 | 1.3 | 9.6 | 2.3 | 1.3 | 0.0 | 0.1 | 52.7 | 0.6 | 1.0 | **81.0** |
| | SF 67[B] | 6.81 | 1.55 | 0.33 | 0.18 | 0.55 | 0.01 | 0.16 | 15.27 | 0.31 | 0.51 | **25.7** |
| | SF 6 | 2.9 | 2.2 | 1.2 | 0.5 | 0.1 | 0.0 | 0.0 | 90.0 | 0.2 | 0.1 | **97.0** |
| | SF 30 | 14.0 | 0.3 | 2.1 | 3.2 | 0.6 | 0.0 | 0.0 | 70.6 | 0.6 | 0.8 | **92.2** |
| | SF 31 | 13.9 | 0.2 | 1.4 | 1.6 | 0.2 | 0.0 | 0.0 | 71.4 | 0.9 | 1.2 | **90.8** |
| | SF 32 | 14.8 | 0.2 | 4.4 | 2.2 | 0.4 | 0.0 | 0.0 | 68.0 | 0.8 | 0.5 | **91.3** |
| | SF 33 | 10.2 | 0.4 | 5.3 | 2.1 | 0.8 | 0.0 | 0.0 | 75.2 | 1.5 | 0.8 | **96.4** |
| | SF 34 | 15.4 | 4.5 | 15.5 | 1.0 | 2.3 | 0.1 | 0.2 | 44.8 | 2.7 | 1.4 | **87.9** |
| | | | | | | | | | | | | |
| Z124030 | SF 35 | 10.2 | 0.3 | 1.3 | 4.0 | 0.4 | 0.0 | 0.0 | 81.1 | 0.2 | 2.0 | **99.6** |
| | SF 36 | 9.0 | 11.8 | 14.8 | 0.5 | 4.3 | 0.3 | 0.1 | 45.7 | 1.3 | 0.6 | **88.4** |
| | SF 37 | 13.2 | 0.3 | 0.8 | 2.0 | 0.3 | 0.0 | 0.0 | 75.9 | 0.5 | 0.8 | **93.8** |
| | SF 38 | 15.6 | 10.6 | 10.3 | 0.5 | 6.4 | 0.1 | 0.1 | 51.4 | 0.9 | 2.3 | **98.1** |
| | SF 39 | 13.7 | 1.1 | 5.2 | 3.4 | 1.2 | 0.0 | 0.1 | 68.3 | 0.5 | 1.3 | **94.9** |
| | SF 68[B] | 1.15 | 0.69 | 7.61 | 0.04 | 0.27 | 0.00 | 0.00 | 3.80 | 0.02 | 0.41 | **14.0** |
| | SF 40 | 12.9 | 0.5 | 5.4 | 1.4 | 1.1 | 0.0 | 0.0 | 32.1 | 0.4 | 0.4 | **54.3** |
| | SF 69[B] | 9.78 | 0.78 | 0.92 | 0.77 | 0.92 | 0.01 | 0.01 | 23.51 | 0.23 | 0.66 | **37.6** |
| | SF 41 | 15.3 | 0.6 | 5.4 | 3.1 | 1.1 | 0.0 | 0.1 | 65.4 | 0.6 | 0.7 | **92.3** |
| | SF 70[B] | 9.66 | 0.24 | 2.36 | 0.44 | 0.23 | 0.01 | 0.02 | 27.12 | 0.37 | 1.08 | **41.5** |
| | SF 9 | 3.7 | 0.0 | 1.5 | 1.1 | 0.1 | 0.0 | 0.0 | 88.8 | 0.3 | 0.9 | **96.4** |
| | SF 71[B] | 3.06 | 1.69 | 0.23 | 0.05 | 0.65 | 0.01 | 0.09 | 6.64 | 0.13 | 0.85 | **13.4** |
| | SF 10 | 13.6 | 0.1 | 0.7 | 2.6 | 0.1 | 0.0 | 0.0 | 75.3 | 0.5 | 0.6 | **93.5** |
| | SF 42 | 17.8 | 0.6 | 4.9 | 3.2 | 1.3 | 0.0 | 0.1 | 60.9 | 0.8 | 0.5 | **90.1** |
| | SF 43 | 15.8 | 3.7 | 5.7 | 2.6 | 1.7 | 0.0 | 0.2 | 61.0 | 0.6 | 1.0 | **92.5** |
| | SF 44 | 15.3 | 5.0 | 9.1 | 0.9 | 4.0 | 0.1 | 0.1 | 53.9 | 0.6 | 0.6 | **89.6** |
| | **Average** | **11.6** | **2.3** | **5.1** | **1.9** | **1.4** | **0.0** | **0.1** | **56.6** | **0.7** | **1.0** | **80.8** |

Appendix 7: Interpretation of ABA pH results (Mine 1)

| Sample Name | Lab no. | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|---|
| F142441 | TC18 | 1.7-34.48 | DO | 10.2 | 7.4 | Lower Acid Risk |
| | TC75 | 34.48-49.07 | SST | 9.13 | 6.11 | Lower Acid Risk |
| | TC38 | 49.07-70.25 | SST,C | 9.29 | 7.02 | Lower Acid Risk |
| | TC83 | 70.6-82.75 | SST, SLT, SH | 8.09 | 6.32 | Lower Acid Risk |
| | TC7 | 83.45-121.47 | SST, SLT, SH | 8.43 | 7.81 | Lower Acid Risk |
| | TC35 | 125.77-128.56 | SST, SLT | 7.89 | 3.28 | Higher Risk Acid Generation |
| | | | | | | |
| F142446 | TC66 | 5.8-9 | DO, SST | 8.46 | 4.94 | Medium Risk Acid Generation |
| | TC57 | 9.15-34.95 | SST, SLT | 9.34 | 6.78 | Lower Acid Risk |
| | TC 62 | 34.95-70.5 | DO | 9.99 | 7.2 | Lower Acid Risk |
| | TC10 | 70.5-82.44 | SST, SLT | 9.79 | 7.11 | Lower Acid Risk |
| | TC4 | 82.44-91.10 | SST | 9.7 | 6.11 | Lower Acid Risk |
| | TC51 | 91.10-112.10 | SST, SLT | 8.78 | 3.34 | Higher Risk Acid Generation |
| | TC41 | 112.10-113 | C, SLT, CSH | 8.84 | 1.63 | Higher Risk Acid Generation |
| | TC33 | 113.12-155.3 | SST, SLT, C | 8.3 | 7.04 | Lower Acid Risk |
| | TC87 | 155.3-161.50 | SST, SLT, C | 9.2 | 5.64 | Lower Acid Risk |
| | | | | | | |
| F142471 | TC65 | 4.68-12.9 | SLT, SST, KV | 8.3 | 6.69 | Lower Acid Risk |
| | TC55 | 12.9-18.82 | SST | 8.64 | 6.19 | Lower Acid Risk |
| | TC61 | 18.82-40.85 | SST,SLT, KV | 8.29 | 6.64 | Lower Acid Risk |
| | TC3 | 42.38-75.68 | SST, SLT, SH, KV | 7.7 | 3.3 | Higher Risk Acid Generation |
| | TC107[b] | 76.09-80.80 | CH4 | 7.67 | 4.22 | Medium Risk Acid Generation |
| | TC11 | 83.8-84.15 | SLT | 7.98 | 3.07 | Higher Risk Acid Generation |
| | TC112[b] | 84.15-84.80 | C3 | 7.56 | 1.6 | Higher Risk Acid Generation |
| | TC84 | 84.8-109.4 | SST, SLT, KV, DRT | 8.08 | 6.38 | Lower Acid Risk |
| | TC105[b] | 109.4-109.90 | C2 | 7.98 | 3.15 | Higher Risk Acid Generation |
| | TC114[b] | No depth | C5 | 8.45 | 1.65 | Higher Risk Acid Generation |
| | | | | | | |
| O105016 | TC25 | 7.3-20.26 | SST, QZT, KV | 8.92 | 7.38 | Lower Acid Risk |
| | TC113 | 20.26-33.5 | SST, SLT | 8.15 | 6.76 | Lower Acid Risk |
| | TC48 | 33.5-41.65 | SST, KV | 8.98 | 7.14 | Lower Acid Risk |
| | TC43 | 41.65-43.55 | SST,SLT,SH | 8.4 | 4.68 | Medium Risk Acid Generation |
| | TC101 | 43.55-45.16 | C5H & L | 8.7 | 4.03 | Medium Risk Acid Generation |
| | TC34 | 45.16-52.82 | SST,SLT, CSH | 7.57 | 2.92 | Higher Risk Acid Generation |
| | TC24 | 52.82-58.99 | DO, KV | 9.64 | 7.89 | Lower Acid Risk |
| | TC14 | 58.99-77.95 | SST, SLT, KV, C | 8.95 | 7.35 | Lower Acid Risk |
| | TC79 | 80.3-85.56 | SST, SLT, KV, GRT | 7.32 | 2.31 | Higher Risk Acid Generation |

| Sample Name | Lab no. | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|---|
| P110030 | TC49 | 3.8-16.23 | MSB, KV, (OVB) | 8.63 | 6.84 | Lower Acid Risk |
| | TC52[a] | 16.23-20.7 | DO, KV | 8.77 | 7.03 | Lower Acid Risk |
| | TC99[a] | 16.23-20.7 | DO, KV | 8.97 | 8.12 | Lower Acid Risk |
| | TC1 | 20.7-30.23 | SST, SSL | 8.37 | 6.65 | Lower Acid Risk |
| | TC5 | 30.23-42.86 | SST, KV | 8.84 | 6.29 | Lower Acid Risk |
| | TC74 | 67.54-68.06 | SH, C | 8.76 | 4.3 | Medium Risk Acid Generation |
| | TC117[b] | 67.54-69.54 | C5H | 8.88 | 1.76 | Higher Risk Acid Generation |
| | TC104 | 69.54-106.77 | SST, SLT, C | 7.78 | 4.02 | Medium Risk Acid Generation |
| | TC109[b] | 106.38-110.22 | C4 | 7.67 | 2.33 | Higher Risk Acid Generation |
| | TC82 | 106.77-109.99 | C4L | 7.69 | 3.65 | Medium Risk Acid Generation |
| | TC27 | 109.99-120.22 | C, SST, SLT, CSH | 7.64 | 4.03 | Medium Risk Acid Generation |
| | TC108[b] | 112.75-113.33 | C3 | 7.67 | 1.47 | Higher Risk Acid Generation |
| | TC98 | 120.22-141.42 | SST, SLT, SH, GRT | 8.26 | 3.12 | Higher Risk Acid Generation |
| | TC106[b] | 141.42-141.55 | C2 | 7.61 | 1.58 | Higher Risk Acid Generation |
| | | | | | | |
| P110087 | TC9 | 6-9.93 | DO, KV | 9.15 | 8.21 | Lower Acid Risk |
| | TC13 | 9.93-30.18 | DO, SST, SLT, GRT | 8.57 | 5.09 | Medium Risk Acid Generation |
| | TC97 | 30.18-40.32 | SST, SLT | 8.99 | 7.3 | Lower Acid Risk |
| | TC58 | 40.32-54.77 | SST, SLT | 8.4 | 4.48 | Medium Risk Acid Generation |
| | TC23 | 54.77-71.87 | SST, GRT, KV | 8.34 | 3.19 | Higher Risk Acid Generation |
| | TC94 | 71.87-89.08 | SST, SLT | 8.45 | 7.58 | Lower Acid Risk |
| | TC91 | 90.19-90.45 | C5 | 8.68 | 2.68 | Higher Risk Acid Generation |
| | TC45 | 90.45-130.50 | SST, SLT, GRT | 7.5 | 3.7 | Medium Risk Acid Generation |
| | TC53 | 130.50-133.19 | SST, SLT | 8.4 | 2.94 | Higher Risk Acid Generation |
| | TC6 | 133.19-133.97 | GRT, C, SST, SLT | 8.28 | 7.71 | Lower Acid Risk |
| | TC73 | 139.15-140.18 | SLT | 7.95 | 2.21 | Higher Risk Acid Generation |
| | | | | | | |
| R146043 | TC93 | 5.33-8.17 | KLY, SST | 7.8 | 6.49 | Lower Acid Risk |
| | TC116 | 8.17-47.07 | DO | 10.12 | 6.79 | Lower Acid Risk |
| | TC47 | 47.07-78.5 | SST, SLT | 9.61 | 7.59 | Lower Acid Risk |
| | TC59 | 78.5-94.33 | SST, SLT | 8.58 | 7.17 | Lower Acid Risk |
| | TC29 | 94.33-101.9 | SST | 8.71 | 6.4 | Lower Acid Risk |
| | TC16 | 101.9-125.08 | SST, SLT | 8.8 | 7.3 | Lower Acid Risk |
| | TC28 | 125.08-125.92 | SLT, SH, C | 8.8 | 1.89 | Higher Risk Acid Generation |
| | TC110[b] | 125.65-125.92 | C5L | 8.41 | 1.24 | Higher Risk Acid Generation |
| | TC40 | 125.92-140.78 | SST, SLT, C, GRT | 8.68 | 4.94 | Medium Risk Acid Generation |
| | TC15 | 140.78-141.52 | SST | 8.54 | 8.23 | Lower Acid Risk |
| | TC86 | 143.28-160.68 | SST, SLT | 8.23 | 7.53 | Lower Acid Risk |
| | TC92 | 160.68-160.98 | CSH | 7.96 | 1.15 | Higher Risk Acid Generation |
| | TC21 | 161.15-167.07 | SST | 6.62 | 3.54 | Medium Risk Acid Generation |
| | TC118[b] | 167.07-170.34 | C4L | 7.76 | 1.24 | Higher Risk Acid Generation |

| Sample Name | Lab no. | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|---|
| T139228 | TC70 | 2.2-7.35 | SST, KV | 8.24 | 5.4 | Medium Risk Acid Generation |
| | TC44 | 7.35-39.45 | DO | 10.37 | 7.34 | Lower Acid Risk |
| | TC36 | 39.45-42.87 | SST, SLT | 10.21 | 7.38 | Lower Acid Risk |
| | TC63 | 42.87-43.5 | DO | 9.48 | 7.6 | Lower Acid Risk |
| | TC30 | 43.5-82.2 | SST,SLT, KV, GRT | 9.08 | 7.06 | Lower Acid Risk |
| | TC39 | 82.2-83.81 | C, CSH, SH | 9.43 | 1.75 | Higher Risk Acid Generation |
| | TC76 | 83.81-115.08 | SST,SLT,KV | 7.96 | 3.36 | Higher Risk Acid Generation |
| | TC96 | 115.08-117.67 | C, SST, SLT, CSH | 7.87 | 3.85 | Medium Risk Acid Generation |
| | TC78 | 115.45-117.67 | C, SST, SLT, CSH | 6.12 | 2.24 | Higher Risk Acid Generation |
| | TC56 | 121.35-141.39 | SST,SLT,KV | 7.95 | 3.23 | Higher Risk Acid Generation |
| | TC60 | 141.39-145.24 | SST, SLT, SH,C | 8.52 | 2.89 | Higher Risk Acid Generation |
| | | | | | | |
| W569001 | TC69 | 2.4-7.4 | DO, KV | 9.55 | 6.56 | Lower Acid Risk |
| | TC80 | 18.7-19.5 | SH, CSH | 7.44 | 3.51 | Medium Risk Acid Generation |
| | TC54 | 19.5-55.81 | SST, SLT, KV | 8.77 | 6.74 | Lower Acid Risk |
| | TC111[b] | 55.81-59.57 | C4L | 7.64 | 6.01 | Lower Acid Risk |
| | TC89 | 59.57-62.8 | SST, SLT, KV | 8 | 3.8 | Medium Risk Acid Generation |
| | TC102[b] | 62.8-63.03 | C3 | 7.97 | 1.78 | Higher Risk Acid Generation |
| | TC22 | 63.03-90.4 | SST, SLT, KV, SH, GRT, CSH | 9.09 | 6.73 | Lower Acid Risk |
| | TC103[b] | 90.4-90.8 | C2 | 7.13 | 1.69 | Higher Risk Acid Generation |
| | | | | | | |
| Y106048 | TC32 | 5.95-6.66 | SST, KV | 7.5 | 3.21 | Higher Risk Acid Generation |
| | TC12 | 6.66-22.61 | SST,SLT, GRT | 8.18 | 5.1 | Medium Risk Acid Generation |
| | TC8 | 22.61-45.06 | SST, SLT, GRT | 8.28 | 5.46 | Medium Risk Acid Generation |
| | TC95 | 50.59-70.93 | SST, SLT | 7.97 | 4.53 | Medium Risk Acid Generation |
| | TC19 | 70.93-75.27 | SST, SLT,GRT | 8.08 | 3 | Higher Risk Acid Generation |
| | | | | | | |
| Z145168 | TC31 | 1.6-6.1 | SST, GKS, KV | 8.39 | 4.81 | Medium Risk Acid Generation |
| | TC115 | 6.1-49.68 | DO | 9.81 | 7.62 | Lower Acid Risk |
| | TC100 | 49.68-56.74 | SST, SLT, KV | 9.57 | 7.46 | Lower Acid Risk |
| | TC37 | 56.74-57.36 | DO | 9.78 | 8.5 | Lower Acid Risk |
| | TC68 | 57.36-68.81 | SST, SLT, MST | 9.35 | 5.78 | Lower Acid Risk |
| | TC85 | 68.81-94.75 | SST, SLT, GRT | 8.31 | 6.48 | Lower Acid Risk |
| | TC67 | 96.22-136.4 | SST, SLT, C, CSH, DO | 8.16 | 3.77 | Medium Risk Acid Generation |
| | TC42 | 139.31-142.08 | SST, SLT | 7.85 | 2.74 | Higher Risk Acid Generation |
| | | | | | | |
| Z145198 | TC71 | 3.33-45.04 | DO | 10.12 | 7.75 | Lower Acid Risk |
| | TC90 | 45.04-90.02 | SST,SLT,SH | 8.78 | 6.83 | Lower Acid Risk |
| | TC26 | 91.03-127.78 | SST,SLT,SH | 8.63 | 7.7 | Lower Acid Risk |
| | TC2 | 132.14-134.94 | SST, SLT, C | 7.7 | 2.85 | Higher Risk Acid Generation |
| | TC72 | 134.94-151.78 | SST, SLT, SH | 8.03 | 3.07 | Higher Risk Acid Generation |
| | TC88 | 151.78-184 | SST, SST,C | 7.88 | 3.02 | Higher Risk Acid Generation |

| Sample Name | Lab no. | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|---|
| Z145199 | TC46 | 0-22.52 | KLY,KV,DO | 9.59 | 6.98 | Lower Acid Risk |
| | TC17 | 22.52-28.75 | SST, SLT | 8.79 | 6.82 | Lower Acid Risk |
| | TC50 | 28.75-52.14 | DO,KV | 10.18 | 7.64 | Lower Acid Risk |
| | TC77 | 52.14-123.92 | SST,SLT,KV,DO,GRT | 8.53 | 7.76 | Lower Acid Risk |
| | TC81 | 123.92-124.6 | SH | 8.77 | 1.79 | Higher Risk Acid Generation |
| | TC20 | 125.80-159.6 | SST, SLT, C | 8.36 | 7.53 | Lower Acid Risk |
| | TC64 | 160.3-162.3 | C, SST | 8.15 | 3.03 | Higher Risk Acid Generation |

Appendix 8: Interpretation of ABA pH results (Mine 2)

| Sample Name | Lab no. | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|---|
| R100001 | SF 11 | 1.62-12.46 | DO | 9.8 | 7.75 | Lower Acid Risk |
| | SF 12 | 12.46-24.48 | SST, SLT, GRT | 9.81 | 7.56 | Lower Acid Risk |
| | SF 13 | 24.48-25.26 | C, CSH | 9.85 | 2.37 | Higher Risk Acid Generation |
| | SF61[b] | 24.48-25.80 | C5H, C5M, C5L | 8.89 | 5.61 | Lower Acid Risk |
| | SF 14 | 25.80-52.66 | SLT, SST | 8.93 | 7.3 | Lower Acid Risk |
| | SF 1 | 50.66-51.6 | SLT, GRT | 8.04 | 4.27 | Medium Risk Acid Generation |
| | SF62[b] | 51.6-56.92 | C4L | 8.22 | 6.21 | Lower Acid Risk |
| | SF 2 | 56.92-57.14 | SLT | 7.73 | 3.44 | Higher Risk Acid Generation |
| | SF 15 | 57.14-85.28 | SST, SLT | 8.6 | 4.51 | Medium Risk Acid Generation |
| | SF 16 | 86.82-112.94 | SST | 7.63 | 3.64 | Medium Risk Acid Generation |
| | SF 17 | 112.94-116.23 | GRT | 7.55 | 3.51 | Medium Risk Acid Generation |
| | SF 18 | 116.23-130.1 | SST, GRT, SLT, WSH | 8.14 | 6.85 | Lower Acid Risk |
| | SF 19 | 130.1-143.1 | TIL | 9.24 | 7.83 | Lower Acid Risk |
| | | | | | | |
| R100002 | SF 20 | 14.1-18 | GRD, SST, DO | 9.16 | 7.92 | Lower Acid Risk |
| | SF 21 | 18.3-37.5 | SST, SLT | 8.7 | 7.62 | Lower Acid Risk |
| | SF 3 | 37.5-37.82 | GRT | 7.86 | 5.91 | Lower Acid Risk |
| | SF63[b] | 37.82-43.08 | C4L | 7.95 | 5.49 | Medium Risk Acid Generation |
| | SF 4 | 43.08-45.72 | SST, SLT | 7.92 | 1.84 | Higher Risk Acid Generation |
| | SF 22 | 45.72-70.1 | SST, SLT | 8.4 | 4.25 | Medium Risk Acid Generation |
| | SF 23 | 71.4-103.8 | SST, GRT | 7.77 | 3.72 | Medium Risk Acid Generation |
| | SF 24 | 103.8-124.4 | GRT, TIL, KV | 8.25 | 6.57 | Lower Acid Risk |

| Sample Name | Lab no. | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|---|
| Z124027 | SF 45 | 4.13-14.04 | DO, KV, | 9.27 | 8.43 | Lower Acid Risk |
| | SF 46 | 14.04-48.99 | SST, SLT | 9.54 | 8.1 | Lower Acid Risk |
| | SF 47 | 48.99-69.26 | SST, DO | 8.9 | 5.86 | Lower Acid Risk |
| | SF 48 | 69.26-90.34 | SST, SLT | 9.05 | 7.22 | Lower Acid Risk |
| | SF 49 | 90.44-91.84 | C, CSH | 9.34 | 2.41 | Higher Risk Acid Generation |
| | SF64[b] | 91.84-92.34 | C5L | 8.94 | 7.74 | Lower Acid Risk |
| | SF 50 | 92.34-93.61 | DO | 9.89 | 8.22 | Lower Acid Risk |
| | SF 51 | 93.61-123.04 | SST, SLT | 8.89 | 7.81 | Lower Acid Risk |
| | SF65[b] | 123.08-123.68 | C4H | 8.31 | 2.29 | Higher Risk Acid Generation |
| | SF 52 | 123.68-125.28 | SH, SST, GRT, SLT | 8.07 | 3.21 | Higher Risk Acid Generation |
| | SF 7 | 125.28-125.88 | GRT | 5.57 | 2.33 | Higher Risk Acid Generation |
| | SF66[b] | 125.88-129.68 | C4L | 8.18 | 5.51 | Lower Acid Risk |
| | SF 8 | 129.78-134.51 | SLT, SST, C | 7.37 | 2.87 | Higher Risk Acid Generation |
| | SF 53 | 134.48-162.76 | SLT, SST, C, DO | 9.21 | 6.67 | Lower Acid Risk |
| | SF 54 | 162.54-164.8 | DO, SST, C | 10.33 | 8.5 | Lower Acid Risk |
| | SF 55 | 167.2-172.87 | GRT, SLT | 8.72 | 2.52 | Higher Risk Acid Generation |
| | SF 56 | 172.87-180.67 | SST, DO | 8.92 | 6.83 | Lower Acid Risk |
| | SF 57 | 180.67-183.7 | DO | 9.91 | 8.25 | Lower Acid Risk |
| | SF 58 | 183.7-186.86 | SST, SLT | 8.88 | 5.88 | Lower Acid Risk |
| | SF 59 | 186.86-189.02 | TIO, SST | 8.32 | 4.37 | Medium Risk Acid Generation |
| | SF 60 | 189.02-200.16 | QZT, EOH | 8.65 | 4.32 | Medium Risk Acid Generation |
| | | | | | | |
| Z124029 | SF 25 | 6.9-8.1 | KV, SST | 8.73 | 5.65 | Lower Acid Risk |
| | SF 26 | 8.1-61.46 | DO | 10.41 | 7.05 | Lower Acid Risk |
| | SF 27 | 61.46-73.68 | SST, SLT, GRT | 10.38 | 6.46 | Lower Acid Risk |
| | SF 28 | 73.68-74.72 | C, CSH | 10.09 | 5.91 | Lower Acid Risk |
| | SF 29 | 74.72-98.23 | SST, SLT | 9.9 | 6.89 | Lower Acid Risk |

| Sample Name | Lab no. | Depth (m) | Geology | Initial pH | Final pH | Interpretation |
|---|---|---|---|---|---|---|
| Z124029 | SF 5 | 98.23-98.88 | SST, SLT | 8.2 | 3.36 | Higher Risk Acid Generation |
| | SF67[b] | 98.88-102.83 | C4L | 8.19 | 5.41 | Medium Risk Acid Generation |
| | SF 6 | 102.83-104.6 | GRT | 8.43 | 6.75 | Lower Acid Risk |
| | SF 30 | 104.6-132.74 | SST, SLT, GRT | 8.54 | 3.45 | Higher Risk Acid Generation |
| | SF 31 | 133.63-136.28 | SST, SLT, GRT | 8.57 | 2.59 | Higher Risk Acid Generation |
| | SF 32 | 138.64-158.45 | SST, SLT, GRT | 8.58 | 2.97 | Higher Risk Acid Generation |
| | SF 33 | 158.45-165.43 | SST, SLT, TIL | 8.55 | 5.65 | Lower Acid Risk |
| | SF 34 | 165.43-174.53 | GR, EOH | 10.26 | 7.9 | Lower Acid Risk |
| | | | | | | |
| Z124030 | SF 35 | 11.6-12.52 | SST | 9.15 | 5.29 | Medium Risk Acid Generation |
| | SF 36 | 12.52-20.8 | DO, KV | 9.11 | 8.84 | Lower Acid Risk |
| | SF 37 | 20.8-41.35 | SST, SLT | 8.62 | 6.43 | Lower Acid Risk |
| | SF 38 | 41.35-49 | DO | 10.21 | 6.42 | Lower Acid Risk |
| | SF 39 | 49-98.3 | SST, SLT | 9.31 | 8.3 | Lower Acid Risk |
| | SF68[b] | 99.20-99.42 | C5H | 8.1 | 2 | Higher Risk Acid Generation |
| | SF 40 | 98.3-100.45 | C, SLT | 9.63 | 2.34 | Higher Risk Acid Generation |
| | SF69[b] | 100.45-100.80 | C5L | 9.25 | 2.51 | Higher Risk Acid Generation |
| | SF 41 | 100.80-133.37 | SST, SLT | 8.91 | 4.4 | Medium Risk Acid Generation |
| | SF70[b] | 133.37-133.92 | C4H | 8.73 | 1.97 | Higher Risk Acid Generation |
| | SF 9 | 133.92-135.56 | GRT | 6.6 | 2.81 | Higher Risk Acid Generation |
| | SF71[b] | 135.56-139.83 | C4L | 8.17 | 6.82 | Lower Acid Risk |
| | SF 10 | 139.83-140.6 | SST | 6.96 | 3.34 | Higher Risk Acid Generation |
| | SF 42 | 140.60-164.48 | C, SST, SLT, KV | 8.91 | 5.84 | Lower Acid Risk |
| | SF 43 | 167.1-168.2 | SLT | 10.11 | 6.66 | Lower Acid Risk |
| | SF 44 | 168.2-185.66 | SST, TIO, LAV | 10.25 | 7.09 | Lower Acid Risk |

Appendix 9: Interpretation of ABA Net Neutralising Potential Results (Mine 1)

| Side name | Lab No. | Depth | Thickness (m) | NNP | NNP x Thickness | Geology | NNP - Interpretation |
|---|---|---|---|---|---|---|---|
| F142441 | TC18 | 1.7-34.48 | 32.78 | 9.60 | 314.67 | DO | Verify with other tests |
| | TC75 | 34.48-49.07 | 14.59 | 21.09 | 307.75 | SST | Probably Excess Neutralising minerals |
| | TC38 | 49.07-70.25 | 21.18 | 15.13 | 320.54 | SST,C | Verify with other tests |
| | TC83 | 70.6-82.75 | 12.15 | 22.74 | 276.31 | SST, SLT, SH | Probably Excess Neutralising minerals |
| | TC7 | 83.45-121.47 | 38.02 | 6.33 | 240.48 | SST, SLT, SH | Verify with other tests |
| | TC35 | 125.77-128.56 | 2.79 | -2.99 | -8.35 | SST, SLT | Verify with other tests |
| | | | | | | | |
| F142446 | TC66 | 5.8-9 | 3.2 | 6.54 | 20.92 | DO, SST | Verify with other tests |
| | TC57 | 9.15-34.95 | 25.8 | 32.77 | 845.57 | SST, SLT | Probably Excess Neutralising minerals |
| | TC 62 | 34.95-70.5 | 35.55 | 16.65 | 591.93 | DO | Verify with other tests |
| | TC10 | 70.5-82.44 | 11.94 | 18.17 | 216.98 | SST, SLT | Verify with other tests |
| | TC4 | 82.44-91.10 | 8.66 | 8.80 | 76.20 | SST | Verify with other tests |
| | TC51 | 91.10-112.10 | 21 | -55.95 | -1174.97 | SST, SLT | Potential Acid Generator |
| | TC41 | 112.10-113 | 0.9 | -17.13 | -15.42 | C, SLT, CSH | Verify with other tests |
| | TC33 | 113.12-155.3 | 42.18 | 12.04 | 507.67 | SST, SLT, C | Verify with other tests |
| | TC87 | 155.3-161.50 | 6.2 | 10.86 | 67.30 | SST, SLT, C | Verify with other tests |
| | | | | | | | |
| F142471 | TC65 | 4.68-12.9 | 8.22 | 18.16 | 149.29 | SLT, SST, KV | Verify with other tests |
| | TC55 | 12.9-18.82 | 5.92 | 8.78 | 52.00 | SST | Verify with other tests |
| | TC61 | 18.82-40.85 | 22.03 | 14.95 | 329.38 | SST,SLT, KV | Verify with other tests |
| | TC3 | 42.38-75.68 | 33.3 | 8.91 | 296.69 | SST, SLT, SH, KV | Verify with other tests |
| | TC107[b] | 76.09-80.80 | 4.71 | 18.50 | 87.11 | C4H | Verify with other tests |
| | TC11 | 83.8-84.15 | 0.35 | -23.69 | -8.29 | SLT | Potential Acid Generator |
| | TC112[b] | 84.15-84.80 | 0.65 | -169.96 | -110.48 | C3 | Potential Acid Generator |
| | TC84 | 84.8-109.4 | 24.6 | 51.16 | 1258.45 | SST, SLT, KV, DRT | Probably Excess Neutralising minerals |
| | TC105[b] | 109.4-109.90 | 0.5 | 21.70 | 10.85 | C2 | Probably Excess Neutralising minerals |
| | TC114[b] | 40.85-42.38 | 1.53 | 3.37 | 5.16 | C5 | Verify with other tests |
| | | | | | | | |
| O105016 | TC25 | 7.3-20.26 | 12.96 | 87.72 | 1136.89 | SST, QZT, KV | Probably Excess Neutralising minerals |
| | TC113 | 20.26-33.5 | 13.24 | 25.50 | 337.57 | SST, SLT | Probably Excess Neutralising minerals |
| | TC48 | 33.5-41.65 | 8.15 | 35.39 | 288.46 | SST, KV | Probably Excess Neutralising minerals |
| | TC43 | 41.65-43.55 | 1.9 | 9.82 | 18.65 | SST,SLT,SH | Verify with other tests |
| | TC101 | 43.55-45.16 | 1.61 | 3.25 | 5.22 | C5H & L | Verify with other tests |
| | TC34 | 45.16-52.82 | 7.66 | -34.98 | -267.92 | SST,SLT, CSH | Potential Acid Generator |
| | TC24 | 52.82-58.99 | 6.17 | 24.76 | 152.76 | DO, KV | Probably Excess Neutralising minerals |
| | TC14 | 58.99-77.95 | 18.96 | 24.75 | 469.27 | SST, SLT, KV, C | Probably Excess Neutralising minerals |
| | TC79 | 80.3-85.56 | 5.26 | -6.24 | -32.80 | SST, SLT, KV, GRT | Verify with other tests |

| Side name | Lab No. | Depth (m) | Thickness (m) | NNP | NNP x Thickness | Geology | NNP - Interpretation |
|---|---|---|---|---|---|---|---|
| P110030 | TC49 | 3.8-16.23 | 12.43 | 14.45 | 179.60 | MSB, KV, (OVB) | Verify with other tests |
| | T52 | 16.23-20.7 | 4.47 | 26.91 | 120.28 | DO, KV | Probably Excess Neutralising minerals |
| | T99 | 16.23-20.7 | 4.47 | 26.17 | 117.00 | DO, KV | Probably Excess Neutralising minerals |
| | TC1 | 20.7-30.23 | 9.53 | 1.01 | 9.64 | SST, SSL | Verify with other tests |
| | TC5 | 30.23-42.86 | 12.63 | 22.24 | 280.93 | SST, KV | Probably Excess Neutralising minerals |
| | TC74 | 67.54-68.06 | 0.52 | 5.02 | 2.61 | SH, C | Verify with other tests |
| | TC117[b] | 67.54-69.54 | 2 | 2.97 | 5.95 | C5H | Verify with other tests |
| | TC104 | 69.54-106.77 | 37.23 | 0.47 | 17.40 | SST, SLT, C | Verify with other tests |
| | TC109[b] | 106.38-110.22 | 3.84 | 7.68 | 29.51 | C4 | Verify with other tests |
| | TC82 | 106.77-109.99 | 3.22 | 2.84 | 9.16 | C4L | Verify with other tests |
| | TC27 | 109.99-120.22 | 10.23 | -0.73 | -7.47 | C, SST, SLT, CSH | Verify with other tests |
| | TC108[b] | 112.75-113.33 | 0.58 | -130.70 | -75.81 | C3 | Potential Acid Generator |
| | TC98 | 120.22-141.42 | 21.2 | 0.57 | 12.02 | SST, SLT, SH, GRT | Verify with other tests |
| | TC106[b] | 141.42-141.55 | 0.13 | -377.21 | -49.04 | C2 | Potential Acid Generator |
| | | | | | | | |
| P110087 | TC9 | 6-9.93 | 3.93 | 151.52 | 595.47 | DO, KV | Probably Excess Neutralising minerals |
| | TC13 | 9.93-30.18 | 20.25 | 5.81 | 117.63 | DO, SST, SLT, GRT | Verify with other tests |
| | TC97 | 30.18-40.32 | 10.14 | 220.34 | 2234.30 | SST, SLT | Probably Excess Neutralising minerals |
| | TC58 | 40.32-54.77 | 14.45 | -11.61 | -167.79 | SST, SLT | Verify with other tests |
| | TC23 | 54.77-71.87 | 17.1 | -1.56 | -26.73 | SST, GRT, KV | Verify with other tests |
| | TC94 | 71.87-89.08 | 17.21 | 85.11 | 1464.70 | SST, SLT | Probably Excess Neutralising minerals |
| | TC91 | 90.19-90.45 | 0.26 | -88.51 | -23.01 | C5 | Potential Acid Generator |
| | TC45 | 90.45-130.50 | 40.05 | -17.91 | -717.36 | SST, SLT, GRT | Verify with other tests |
| | TC53 | 130.50-133.19 | 2.69 | -93.38 | -251.20 | SST, SLT | Potential Acid Generator |
| | TC6 | 133.19-133.97 | 0.78 | 6.06 | 4.73 | GRT, C, SST, SLT | Verify with other tests |
| | TC73 | 139.15-140.18 | 1.03 | -62.80 | -64.68 | SLT | Potential Acid Generator |
| | | | | | | | |
| R146043 | TC93 | 5.33-8.17 | 2.84 | 15.54 | 44.14 | KLY, SST | Verify with other tests |
| | TC116 | 8.17-47.07 | 38.9 | 26.13 | 1016.63 | DO | Probably Excess Neutralising minerals |
| | TC47 | 47.07-78.5 | 31.43 | 102.78 | 3230.38 | SST, SLT | Probably Excess Neutralising minerals |
| | TC59 | 78.5-94.33 | 15.83 | 30.14 | 477.05 | SST, SLT | Probably Excess Neutralising minerals |
| | TC29 | 94.33-101.9 | 7.57 | 19.24 | 145.63 | SST | Verify with other tests |
| | TC16 | 101.9-125.08 | 23.18 | 58.44 | 1354.74 | SST, SLT | Probably Excess Neutralising minerals |
| | TC28 | 125.08-125.92 | 0.84 | -51.68 | -43.41 | SLT, SH, C | Potential Acid Generator |
| | TC110[b] | 125.65-125.92 | 0.27 | -13.44 | -3.63 | C5L | Verify with other tests |
| | TC40 | 125.92-140.78 | 14.86 | 0.50 | 7.40 | SST, SLT, C, GRT | Verify with other tests |
| | TC15 | 140.78-141.52 | 0.74 | 34.99 | 25.89 | SST | Probably Excess Neutralising minerals |
| | TC86 | 143.28-160.68 | 17.4 | 69.46 | 1208.69 | SST, SLT | Probably Excess Neutralising minerals |

| Side name | Lab No. | Depth (m) | Thickness (m) | NNP | NNP x Thickness | Geology | NNP - Interpretation |
|---|---|---|---|---|---|---|---|
| | TC92 | 160.68-160.98 | 0.3 | -86.60 | -25.98 | CSH | Potential Acid Generator |
| | TC21 | 161.15-167.07 | 5.92 | -17.23 | -102.01 | SST | Verify with other tests |
| | TC118[b] | 167.07-170.34 | 3.27 | -46.60 | -152.38 | C4L | Potential Acid Generator |
| | | | | | | | |
| T139228 | TC70 | 2.2-7.35 | 5.15 | 8.98 | 46.26 | SST, KV | Verify with other tests |
| | TC44 | 7.35-39.45 | 32.1 | 17.55 | 563.24 | DO | Verify with other tests |
| | TC36 | 39.45-42.87 | 3.42 | 49.48 | 169.24 | SST, SLT | Probably Excess Neutralising minerals |
| | TC63 | 42.87-43.5 | 0.63 | 72.18 | 45.47 | DO | Probably Excess Neutralising minerals |
| | TC30 | 43.5-82.2 | 38.7 | 28.83 | 1115.68 | SST,SLT, KV, GRT | Probably Excess Neutralising minerals |
| | TC39 | 82.2-83.81 | 1.61 | -9.49 | -15.28 | C, CSH, SH | Verify with other tests |
| | TC76 | 83.81-115.08 | 31.27 | -32.06 | -1002.54 | SST,SLT,KV | Potential Acid Generator |
| | TC96 | 115.08-117.67 | 2.59 | -27.48 | -71.16 | C, SST, SLT, CSH | Potential Acid Generator |
| | TC78 | 115.45-117.67 | 2.22 | -148.69 | -330.09 | C, SST, SLT, CSH | Potential Acid Generator |
| | TC56 | 121.35-141.39 | 20.04 | -7.60 | -152.30 | SST,SLT,KV | Verify with other tests |
| | TC60 | 141.39-145.24 | 3.85 | -2.33 | -8.97 | SST, SLT, SH,C | Verify with other tests |
| | | | | | | | |
| W569001 | TC69 | 2.4-7.4 | 5 | 33.94 | 169.70 | DO, KV | Probably Excess Neutralising minerals |
| | TC80 | 18.7-19.5 | 0.8 | -29.21 | -23.37 | SH, CSH | Potential Acid Generator |
| | TC54 | 19.5-55.81 | 36.31 | 12.34 | 447.99 | SST, SLT, KV | Verify with other tests |
| | TC111[b] | 55.81-59.57 | 3.76 | 47.31 | 177.89 | C4L | Probably Excess Neutralising minerals |
| | TC89 | 59.57-62.8 | 3.23 | 2.26 | 7.29 | SST, SLT, KV | Verify with other tests |
| | TC102[b] | 62.8-63.03 | 0.23 | -19.99 | -4.60 | C3 | Verify with other tests |
| | TC22 | 63.03-90.4 | 27.37 | 21.53 | 589.27 | SST, SLT, KV, SH, GRT, CSH | Probably Excess Neutralising minerals |
| | TC103[b] | 90.4-90.8 | 0.4 | -339.12 | -135.65 | C2 | Potential Acid Generator |
| | | | | | | | |
| Y106048 | TC32 | 5.95-6.66 | 0.71 | -3.71 | -2.64 | SST, KV | Verify with other tests |
| | TC12 | 6.66-22.61 | 15.95 | -3.45 | -55.09 | SST,SLT, GRT | Verify with other tests |
| | TC8 | 22.61-45.06 | 22.45 | 19.33 | 433.88 | SST, SLT, GRT | Verify with other tests |
| | TC95 | 50.59-70.93 | 20.34 | -5.84 | -118.73 | SST, SLT | Verify with other tests |
| | TC19 | 70.93-75.27 | 4.34 | -18.71 | -81.18 | SST, SLT,GRT | Verify with other tests |
| | | | | | | | |
| Z145168 | TC31 | 1.6-6.1 | 4.5 | 1.31 | 5.90 | SST, GKS, KV | Verify with other tests |
| | TC115 | 6.1-49.68 | 43.58 | 19.18 | 835.84 | DO | Verify with other tests |
| | TC100 | 49.68-56.74 | 7.06 | 90.54 | 639.24 | SST, SLT, KV | Probably Excess Neutralising minerals |
| | TC37 | 56.74-57.36 | 0.62 | 48.54 | 30.10 | DO | Probably Excess Neutralising minerals |
| | TC68 | 57.36-68.81 | 11.45 | 12.62 | 144.49 | SST, SLT, MST | Verify with other tests |
| | TC85 | 68.81-94.75 | 25.94 | 22.74 | 590.00 | SST, SLT, GRT | Probably Excess Neutralising minerals |
| | TC67 | 96.22-136.4 | 40.18 | -27.34 | -1098.63 | SST, SLT, C, CSH, DO | Potential Acid Generator |
| | TC42 | 139.31-142.08 | 2.77 | -19.66 | -54.44 | SST, SLT | Verify with other tests |

| Side name | Lab No. | Depth (m) | Thickness (m) | NNP | NNP x Thickness | Geology | NNP - Interpretation |
|---|---|---|---|---|---|---|---|
| Z145198 | TC71 | 3.33-45.04 | 41.71 | 23.48 | 979.17 | DO | Probably Excess Neutralising minerals |
| | TC90 | 45.04-90.02 | 44.98 | 22.55 | 1014.42 | SST,SLT,SH | Probably Excess Neutralising minerals |
| | TC26 | 91.03-127.78 | 36.75 | 93.60 | 3439.70 | SST,SLT,SH | Probably Excess Neutralising minerals |
| | TC2 | 132.14-134.94 | 2.8 | -67.92 | -190.16 | SST, SLT, C | Potential Acid Generator |
| | TC72 | 134.94-151.78 | 16.84 | -2.10 | -35.42 | SST, SLT, SH | Verify with other tests |
| | TC88 | 151.78-184 | 32.22 | -1.74 | -56.05 | SST, SST,C | Verify with other tests |
| | | | | | | | |
| Z145199 | TC46 | 0-22.52 | 22.52 | 19.78 | 445.45 | KLY,KV,DO | Verify with other tests |
| | TC17 | 22.52-28.75 | 6.23 | -14.57 | -90.78 | SST, SLT | Verify with other tests |
| | TC50 | 28.75-52.14 | 23.39 | 16.50 | 385.86 | DO,KV | Verify with other tests |
| | TC77 | 52.14-123.92 | 71.78 | 77.50 | 5563.16 | SST,SLT,KV,DO,GRT | Probably Excess Neutralising minerals |
| | TC81 | 123.92-124.6 | 0.68 | -34.77 | -23.65 | SH | Potential Acid Generator |
| | TC20 | 125.80-159.6 | 33.8 | 118.51 | 4005.59 | SST, SLT, C | Probably Excess Neutralising minerals |
| | TC64 | 160.3-162.3 | 2 | -16.12 | -32.24 | C, SST | Verify with other tests |

Appendix 10: Interpretation of ABA Net Neutralising Potential Results (Mine 2)

| Side name | Lab No. | Depth(m) | Thickness (m) | NNP | NNP x Thickness | Geology | NNP - Interpretation |
|---|---|---|---|---|---|---|---|
| R10001 | SF 11 | 1.62-12.46 | 10.84 | 36.96 | 400.69 | DO | Probably Excess Neutralising Minerals |
| | SF 12 | 12.46-24.48 | 12.02 | 56.73 | 681.94 | SST, SLT, GRT | Probably Excess Neutralising Minerals |
| | SF 13 | 24.48-25.26 | 0.78 | 11.68 | 9.11 | C, CSH | Verify with other tests |
| | SF61[b] | 24.48-25.80 | 1.32 | 17.02 | 22.47 | C5H, C5M, C5L | Verify with other tests |
| | SF 14 | 25.8-52.66 | 26.86 | 64.65 | 1736.49 | SLT, SST | Probably Excess Neutralising Minerals |
| | SF 1 | 50.66-51.6 | 0.94 | 29.87 | 28.08 | SLT, GRT | Verify with other tests |
| | SF62[b] | 51.6-56.92 | 5.32 | 58.16 | 309.39 | C4L | Probably Excess Neutralising Minerals |
| | SF 2 | 56.92-57.14 | 0.22 | 6.10 | 1.34 | SLT | Verify with other tests |
| | SF 15 | 57.14-85.28 | 28.14 | 10.38 | 292.17 | SST, SLT | Verify with other tests |
| | SF 16 | 86.82-112.94 | 26.12 | 6.54 | 170.85 | SST | Verify with other tests |
| | SF 17 | 112.94-116.23 | 3.29 | 4.41 | 14.52 | GRT | Verify with other tests |
| | SF 18 | 116.23-130.1 | 13.87 | 35.59 | 493.57 | SST, GRT, SLT, WSH | Probably Excess Neutralising Minerals |
| | SF 19 | 130.1-143.1 | 13 | 132.44 | 1721.74 | TIL | Probably Excess Neutralising Minerals |
| | | | | | | | |
| R100002 | SF 20 | 14.1-18 | 3.9 | 74.45 | 290.35 | GRD, SST, DO | Probably Excess Neutralising Minerals |
| | SF 21 | 18.3-37.5 | 19.2 | 53.63 | 1029.70 | SST, SLT | Probably Excess Neutralising Minerals |
| | SF 3 | 37.5-37.82 | 0.32 | 34.45 | 11.03 | GRT | Probably Excess Neutralising Minerals |
| | SF63[b] | 37.82-43.08 | 5.26 | 54.22 | 285.19 | C4L | Probably Excess Neutralising Minerals |
| | SF 4 | 43.08-45.72 | 2.64 | 1.62 | 4.28 | SST, SLT | Verify with other tests |
| | SF 22 | 45.72-70.1 | 24.38 | 2.56 | 62.41 | SST, SLT | Verify with other tests |
| | SF 23 | 71.4-103.8 | 32.4 | 6.25 | 202.41 | SST, GRT | Verify with other tests |
| | SF 24 | 103.8-124.4 | 20.6 | 14.11 | 290.56 | GRT, TIL, KV | Verify with other tests |
| | | | | | | | |
| Z124027 | SF 45 | 4.13-14.04 | 9.91 | 39.16 | 388.08 | DO, KV, | Probably Excess Neutralising Minerals |
| | SF 46 | 14.04-48.99 | 34.95 | 133.61 | 4669.84 | SST, SLT | Probably Excess Neutralising Minerals |
| | SF 47 | 48.99-69.26 | 20.27 | 15.19 | 307.85 | SST, DO | Verify with other tests |
| | SF 48 | 69.26-90.34 | 21.08 | 42.20 | 889.53 | SST, SLT | Probably Excess Neutralising Minerals |
| | SF 49 | 90.44-91.84 | 1.4 | 1.09 | 1.53 | C, CSH | Verify with other tests |
| | SF64[b] | 91.84-92.34 | 0.5 | 41.52 | 20.76 | C5L | Probably Excess Neutralising Minerals |
| | SF 50 | 92.34-93.61 | 1.27 | 19.56 | 24.85 | DO | Verify with other tests |
| | SF 51 | 93.61-123.04 | 29.43 | 25.56 | 752.29 | SST, SLT | Probably Excess Neutralising Minerals |
| | SF65[b] | 123.08-123.68 | 0.6 | -100.00 | -60.00 | C4H | Potential Acid Generator |
| | SF 52 | 123.68-125.28 | 1.6 | -8.23 | -13.16 | SH, SST, GRT, SLT | Potential Acid Generator |
| | SF 7 | 125.28-125.88 | 0.6 | -55.04 | -33.03 | GRT | Potential Acid Generator |
| | SF66[b] | 125.88-129.68 | 3.8 | 43.18 | 164.10 | C4L | Probably Excess Neutralising Minerals |

| Side name | Lab No. | Depth(m) | Thickness (m) | NNP | NNP x Thickness | Geology | NNP - Interpretation |
|---|---|---|---|---|---|---|---|
| | SF 8 | 129.78-134.51 | 4.73 | 3.58 | 16.94 | SLT, SST, C | Verify with other tests |
| | SF 53 | 134.48-162.76 | 28.28 | 35.06 | 991.54 | SLT, SST, C, DO | Probably Excess Neutralising Minerals |
| | SF 54 | 162.54-164.8 | 2.26 | 20.24 | 45.75 | DO, SST, C | Verify with other tests |
| | SF 55 | 167.2-172.87 | 5.67 | -41.15 | -233.33 | GRT, SLT | Potential Acid Generator |
| | SF 56 | 172.87-180.67 | 7.8 | 32.09 | 250.31 | SST, DO | Probably Excess Neutralising Minerals |
| | SF 57 | 180.67-183.7 | 3.03 | 36.79 | 111.46 | DO | Probably Excess Neutralising Minerals |
| | SF 58 | 183.7-186.86 | 3.16 | 11.70 | 36.96 | SST, SLT | Verify with other tests |
| | SF 59 | 186.86-189.02 | 2.16 | 5.82 | 12.58 | TIO, SST | Verify with other tests |
| | SF 60 | 189.02-200.16 | 11.14 | 8.18 | 91.10 | QZT, EOH | Verify with other tests |
| | | | | | | | |
| Z124029 | SF 25 | 6.9-8.1 | 1.2 | 10.86 | 13.04 | KV, SST | Verify with other tests |
| | SF 26 | 8.1-61.46 | 53.36 | 40.29 | 2149.79 | DO | Probably Excess Neutralising Minerals |
| | SF 27 | 61.46-73.68 | 12.22 | 35.58 | 434.84 | SST, SLT, GRT | Probably Excess Neutralising Minerals |
| | SF 28 | 73.68-74.72 | 1.04 | 13.97 | 14.53 | C, CSH | Verify with other tests |
| | SF 29 | 74.72-98.23 | 23.51 | 48.32 | 1136.01 | SST, SLT | Probably Excess Neutralising Minerals |
| | SF 5 | 98.23-98.88 | 0.65 | 30.59 | 19.88 | SST, SLT | Potential Acid Generator |
| | SF67[b] | 98.88-102.83 | 3.95 | 36.42 | 143.85 | C4L | Probably Excess Neutralising Minerals |
| | SF 6 | 102.83-104.6 | 1.77 | 38.72 | 68.53 | GRT | Probably Excess Neutralising Minerals |
| | SF 30 | 104.6-132.74 | 28.14 | 11.93 | 335.73 | SST, SLT, GRT | Verify with other tests |
| | SF 31 | 133.63-136.28 | 2.65 | -16.76 | -44.40 | SST, SLT, GRT | Potential Acid Generator |
| | SF 32 | 138.64-158.45 | 19.81 | -15.74 | -311.79 | SST, SLT, GRT | Potential Acid Generator |
| | SF 33 | 158.45-165.43 | 6.98 | 20.70 | 144.49 | SST, SLT, TIL | Verify with other tests |
| | SF 34 | 165.43-174.53 | 9.1 | 87.03 | 791.98 | GR, EOH | Probably Excess Neutralising Minerals |
| | | | | | | | |
| Z124030 | SF 35 | 11.6-12.52 | 0.92 | 10.53 | 9.68 | SST | Verify with other tests |
| | SF 36 | 12.52-20.8 | 8.28 | 108.52 | 898.51 | DO, KV | Probably Excess Neutralising Minerals |
| | SF 37 | 20.8-41.35 | 20.55 | 12.23 | 251.38 | SST, SLT | Verify with other tests |
| | SF 38 | 41.35-49 | 7.65 | 54.92 | 420.17 | DO | Probably Excess Neutralising Minerals |
| | SF 39 | 49-98.3 | 49.3 | 30.49 | 1503.21 | SST, SLT | Probably Excess Neutralising Minerals |
| | SF68 | 99.2-99.42 | 0.22 | -229.70 | -50.54 | C5H (Coal)8 | Potential Acid Generator |
| | SF 40 | 98.3-100.45 | 2.15 | 16.54 | 35.56 | C, SLT | Verify with other tests |
| | SF69 | 100.45-100.8 | 0.35 | 17.98 | 6.29 | C5L (Coal)9 | Verify with other tests |
| | SF 41 | 100.8-133.37 | 32.57 | 7.21 | 234.93 | SST, SLT | Verify with other tests |
| | SF70 | 133.37-133.92 | 0.55 | -44.34 | -24.39 | C4H (Coal)10 | Potential Acid Generator |
| | SF 9 | 133.92-135.56 | 1.64 | -9.33 | -15.29 | GRT | Potential Acid Generator |
| | SF71[b] | 135.56-139.83 | 4.27 | 78.46 | 335.03 | C4L | Probably Excess Neutralising Minerals |
| | SF 10 | 139.83-140.6 | 0.77 | 3.00 | 2.31 | SST | Verify with other tests |
| | SF 42 | 140.6-164.48 | 23.88 | 19.44 | 464.18 | C, SST, SLT, KV | Verify with other tests |
| | SF 43 | 167.1-168.2 | 1.1 | 70.97 | 78.07 | SLT | Probably Excess Neutralising Minerals |
| | SF 44 | 168.2-185.66 | 17.46 | 91.09 | 1590.45 | SST, TIO, LAV | Probably Excess Neutralising Minerals |

Appendix 11: Interpretation of the NP/AP ratio of Mine 1

| Side name | Lab No. | Neutralising Potential Ratio(NP/AP) for Open System | Neutralising Potential Ratio(NP/AP) for Closed System | Interpretation Open System | Interpretation Closed System |
|---|---|---|---|---|---|
| F142441 | TC18 | 5.91 | 2.96 | No Acid Potential | Acid under certain conditions |
| | TC75 | 76.08 | 38.04 | No Acid Potential | No Acid Potential |
| | TC38 | 38.31 | 19.16 | No Acid Potential | No Acid Potential |
| | TC83 | 31.20 | 15.60 | No Acid Potential | No Acid Potential |
| | TC7 | 2.20 | 1.10 | Acid under certain conditions | Acid under certain conditions |
| | TC35 | 0.03 | 0.02 | Likely Acid Generator | Likely Acid Generator |
| | | | | | |
| F142446 | TC66 | 26.61 | 13.31 | No Acid Potential | No Acid Potential |
| | TC57 | 73.57 | 36.79 | No Acid Potential | No Acid Potential |
| | TC 62 | 9.30 | 4.65 | No Acid Potential | No Acid Potential |
| | TC10 | 44.54 | 22.27 | No Acid Potential | No Acid Potential |
| | TC4 | 43.40 | 21.70 | No Acid Potential | No Acid Potential |
| | TC51 | 0.49 | 0.24 | Likely Acid Generator | Likely Acid Generator |
| | TC41 | 0.39 | 0.19 | Likely Acid Generator | Likely Acid Generator |
| | TC33 | 4.49 | 2.25 | No Acid Potential | Acid under certain conditions |
| | TC87 | 8.57 | 4.28 | No Acid Potential | No Acid Potential |
| | | | | | |
| F142471 | TC65 | 23.52 | 11.76 | No Acid Potential | No Acid Potential |
| | TC55 | 32.30 | 16.15 | No Acid Potential | No Acid Potential |
| | TC61 | 30.90 | 15.45 | No Acid Potential | No Acid Potential |
| | TC3 | 7.77 | 3.88 | No Acid Potential | Acid under certain conditions |
| | TC107[b] | 3.80 | 1.90 | Acid under certain conditions | Acid under certain conditions |
| | TC11 | 0.00 | 0.00 | Likely Acid Generator | Likely Acid Generator |
| | TC112[b] | 0.11 | 0.06 | Likely Acid Generator | Likely Acid Generator |
| | TC84 | 12.73 | 6.37 | No Acid Potential | No Acid Potential |
| | TC105[b] | 8.37 | 4.18 | No Acid Potential | No Acid Potential |
| | TC114[b] | 2.64 | 1.32 | Acid under certain conditions | Acid under certain conditions |
| | | | | | |
| O105016 | TC25 | 253.49 | 126.75 | No Acid Potential | No Acid Potential |
| | TC113 | 49.73 | 24.86 | No Acid Potential | No Acid Potential |
| | TC48 | 158.89 | 79.44 | No Acid Potential | No Acid Potential |
| | TC43 | 3.71 | 1.86 | Acid under certain conditions | Acid under certain conditions |
| | TC101 | 2.29 | 1.15 | Acid under certain conditions | Acid under certain conditions |
| | TC34 | 0.04 | 0.02 | Likely Acid Generator | Likely Acid Generator |
| | TC24 | 20.04 | 10.02 | No Acid Potential | No Acid Potential |
| | TC14 | 6.65 | 3.33 | No Acid Potential | Acid under certain conditions |
| | TC79 | 0.02 | 0.01 | Likely Acid Generator | Likely Acid Generator |

| Side name | Lab No. | Neutralising Potential Ratio(NP/AP) for Open System | Neutralising Potential Ratio(NP/AP) for Closed System | Interpretation Open System | Interpretation Closed System |
|---|---|---|---|---|---|
| P110030 | TC49 | 16.93 | 8.46 | No Acid Potential | No Acid Potential |
| | T52 | 4.27 | 2.13 | No Acid Potential | Acid under certain conditions |
| | T99 | 4.91 | 2.45 | No Acid Potential | Acid under certain conditions |
| | TC1 | 3.04 | 1.52 | Acid under certain conditions | Acid under certain conditions |
| | TC5 | 34.42 | 17.21 | No Acid Potential | No Acid Potential |
| | TC74 | 2.66 | 1.33 | Acid under certain conditions | Acid under certain conditions |
| | TC117[b] | 2.47 | 1.23 | Acid under certain conditions | Acid under certain conditions |
| | TC104 | 2.09 | 1.04 | Acid under certain conditions | Acid under certain conditions |
| | TC109[b] | 2.49 | 1.25 | Acid under certain conditions | Acid under certain conditions |
| | TC82 | 4.03 | 2.02 | No Acid Potential | Acid under certain conditions |
| | TC27 | 1.59 | 0.79 | Acid under certain conditions | Likely Acid Generator |
| | TC108[b] | 0.32 | 0.16 | Likely Acid Generator | Likely Acid Generator |
| | TC98 | 2.14 | 1.07 | Acid under certain conditions | Acid under certain conditions |
| | TC106[b] | 0.14 | 0.07 | Likely Acid Generator | Likely Acid Generator |
| | | | | | |
| P110087 | TC9 | 618.77 | 309.39 | No Acid Potential | No Acid Potential |
| | TC13 | 9.91 | 4.95 | No Acid Potential | No Acid Potential |
| | TC97 | 176.60 | 88.30 | No Acid Potential | No Acid Potential |
| | TC58 | 1.04 | 0.52 | Acid under certain conditions | Likely Acid Generator |
| | TC23 | 1.53 | 0.77 | Acid under certain conditions | Likely Acid Generator |
| | TC94 | 64.52 | 32.26 | No Acid Potential | No Acid Potential |
| | TC91 | 0.23 | 0.12 | Likely Acid Generator | Likely Acid Generator |
| | TC45 | 0.46 | 0.23 | Likely Acid Generator | Likely Acid Generator |
| | TC53 | 0.27 | 0.14 | Likely Acid Generator | Likely Acid Generator |
| | TC6 | 2.25 | 1.12 | Acid under certain conditions | Acid under certain conditions |
| | TC73 | 0.34 | 0.17 | Likely Acid Generator | Likely Acid Generator |
| | | | | | |
| R146043 | TC93 | 89.25 | 44.62 | No Acid Potential | No Acid Potential |
| | TC116 | 37.50 | 18.75 | No Acid Potential | No Acid Potential |
| | TC47 | 301.61 | 150.80 | No Acid Potential | No Acid Potential |
| | TC59 | 65.64 | 32.82 | No Acid Potential | No Acid Potential |
| | TC29 | 52.45 | 26.22 | No Acid Potential | No Acid Potential |
| | TC16 | 74.01 | 37.01 | No Acid Potential | No Acid Potential |
| | TC28 | 0.13 | 0.06 | Likely Acid Generator | Likely Acid Generator |
| | TC110[b] | 0.67 | 0.33 | Likely Acid Generator | Likely Acid Generator |
| | TC40 | 2.57 | 1.29 | Acid under certain conditions | Acid under certain conditions |
| | TC15 | 2.91 | 1.46 | Acid under certain conditions | Acid under certain conditions |
| | TC86 | 22.39 | 11.19 | No Acid Potential | No Acid Potential |

| Side name | Lab No. | Neutralising Potential Ratio(NP/AP) for Open System | Neutralising Potential Ratio(NP/AP) for Closed System | Interpretation Open System | Interpretation Closed System |
|---|---|---|---|---|---|
| | TC92 | 0.04 | 0.02 | Likely Acid Generator | Likely Acid Generator |
| | TC21 | 0.16 | 0.08 | Likely Acid Generator | Likely Acid Generator |
| | TC118[b] | 0.56 | 0.28 | Likely Acid Generator | Likely Acid Generator |
| | | | | | |
| T139228 | TC70 | 59.85 | 29.93 | No Acid Potential | No Acid Potential |
| | TC44 | 9.62 | 4.81 | No Acid Potential | No Acid Potential |
| | TC36 | 227.59 | 113.79 | No Acid Potential | No Acid Potential |
| | TC63 | 22.90 | 11.45 | No Acid Potential | No Acid Potential |
| | TC30 | 85.59 | 42.79 | No Acid Potential | No Acid Potential |
| | TC39 | 0.86 | 0.43 | Likely Acid Generator | Likely Acid Generator |
| | TC76 | 0.57 | 0.28 | Likely Acid Generator | Likely Acid Generator |
| | TC96 | 1.23 | 0.62 | Acid under certain conditions | Likely Acid Generator |
| | TC78 | 0.00 | 0.00 | Likely Acid Generator | Likely Acid Generator |
| | TC56 | 0.00 | 0.00 | Likely Acid Generator | Likely Acid Generator |
| | TC60 | 1.33 | 0.67 | Acid under certain conditions | Likely Acid Generator |
| | | | | | |
| W569001 | TC69 | 185.03 | 92.51 | No Acid Potential | No Acid Potential |
| | TC80 | 0.66 | 0.33 | Likely Acid Generator | Likely Acid Generator |
| | TC54 | 6.89 | 3.44 | No Acid Potential | Acid under certain conditions |
| | TC111[b] | 11.07 | 5.53 | No Acid Potential | No Acid Potential |
| | TC89 | 4.43 | 2.21 | No Acid Potential | Acid under certain conditions |
| | TC102[b] | 1.25 | 0.63 | Acid under certain conditions | Likely Acid Generator |
| | TC22 | 9.94 | 4.97 | No Acid Potential | No Acid Potential |
| | TC103[b] | 0.03 | 0.01 | Likely Acid Generator | Likely Acid Generator |
| | | | | | |
| Y106048 | TC32 | 0.01 | 0.00 | Likely Acid Generator | Likely Acid Generator |
| | TC12 | 1.63 | 0.81 | Acid under certain conditions | Likely Acid Generator |
| | TC8 | 7.79 | 3.89 | No Acid Potential | Acid under certain conditions |
| | TC95 | 1.53 | 0.77 | Acid under certain conditions | Likely Acid Generator |
| | TC19 | 0.12 | 0.06 | Likely Acid Generator | Likely Acid Generator |
| | | | | | |
| Z145168 | TC31 | 121.54 | 60.77 | No Acid Potential | No Acid Potential |
| | TC115 | 15.22 | 7.61 | No Acid Potential | No Acid Potential |
| | TC100 | 350.76 | 175.38 | No Acid Potential | No Acid Potential |
| | TC37 | 31.63 | 15.82 | No Acid Potential | No Acid Potential |
| | TC68 | 34.49 | 17.24 | No Acid Potential | No Acid Potential |
| | TC85 | 21.32 | 10.66 | No Acid Potential | No Acid Potential |
| | TC67 | 0.76 | 0.38 | Likely Acid Generator | Likely Acid Generator |
| | TC42 | 0.00 | 0.00 | Likely Acid Generator | Likely Acid Generator |

| Side name | Lab No. | Neutralising Potential Ratio(NP/AP) for Open System | Neutralising Potential Ratio(NP/AP) for Closed System | Interpretation Open System | Interpretation Closed System |
|---|---|---|---|---|---|
| Z145198 | TC71 | 10.61 | 5.31 | No Acid Potential | No Acid Potential |
| | TC90 | 51.14 | 25.57 | No Acid Potential | No Acid Potential |
| | TC26 | 53.82 | 26.91 | No Acid Potential | No Acid Potential |
| | TC2 | 0.00 | 0.00 | Likely Acid Generator | Likely Acid Generator |
| | TC72 | 1.55 | 0.78 | Acid under certain conditions | Likely Acid Generator |
| | TC88 | 1.46 | 0.73 | Acid under certain conditions | Likely Acid Generator |
| | | | | | |
| Z145199 | TC46 | 112.26 | 56.13 | No Acid Potential | No Acid Potential |
| | TC17 | 0.01 | 0.01 | Likely Acid Generator | Likely Acid Generator |
| | TC50 | 17.92 | 8.96 | No Acid Potential | No Acid Potential |
| | TC77 | 60.97 | 30.49 | No Acid Potential | No Acid Potential |
| | TC81 | 0.57 | 0.29 | Likely Acid Generator | Likely Acid Generator |
| | TC20 | 12.88 | 6.44 | No Acid Potential | No Acid Potential |
| | TC64 | 0.34 | 0.17 | Likely Acid Generator | Likely Acid Generator |

Appendix 12: Interpretation of the NP/AP ratio of Mine 2

| Side name | lab No. | Neutralising Potential Ratio(NP/AP) for Open System | Neutralising Potential Ratio(NP/AP) for Closed System | Interpretation Open System | Interpretation Closed System |
|---|---|---|---|---|---|
| R100001 | SF 11 | 37.34 | 18.67 | No Acid Potential | No Acid Potential |
| | SF 12 | 582.88 | 291.44 | No Acid Potential | No Acid Potential |
| | SF 13 | 4.27 | 2.13 | No Acid Potential | Acid under certain conditions |
| | SF61 | 23.68 | 11.84 | No Acid Potential | No Acid Potential |
| | SF 14 | 17.24 | 8.62 | No Acid Potential | No Acid Potential |
| | SF 1 | 1.94 | 0.97 | Acid under certain conditions | Likely Acid Generator |
| | SF62 | 15.09 | 7.55 | No Acid Potential | No Acid Potential |
| | SF 2 | 4.86 | 2.43 | No Acid Potential | Acid under certain conditions |
| | SF 15 | 4.86 | 2.43 | No Acid Potential | Acid under certain conditions |
| | SF 16 | 8.71 | 4.36 | No Acid Potential | No Acid Potential |
| | SF 17 | 4.07 | 2.03 | No Acid Potential | Acid under certain conditions |
| | SF 18 | 15.62 | 7.81 | No Acid Potential | No Acid Potential |
| | SF 19 | 548.89 | 274.45 | No Acid Potential | No Acid Potential |
| | | | | | |
| R100002 | SF 20 | 36.99 | 18.50 | No Acid Potential | No Acid Potential |
| | SF 21 | 7.79 | 3.90 | No Acid Potential | Acid under certain conditions |
| | SF 3 | 3.96 | 1.98 | Acid under certain conditions | Acid under certain conditions |
| | SF63 | 12.33 | 6.16 | No Acid Potential | No Acid Potential |
| | SF 4 | 1.13 | 0.56 | Acid under certain conditions | Likely Acid Generator |
| | SF 22 | 1.23 | 0.62 | Acid under certain conditions | Likely Acid Generator |
| | SF 23 | 5.65 | 2.82 | No Acid Potential | Acid under certain conditions |
| | SF 24 | 13.04 | 6.52 | No Acid Potential | No Acid Potential |
| | | | | | |
| Z124027 | SF 45 | 106.63 | 53.31 | No Acid Potential | No Acid Potential |
| | SF 46 | 425.12 | 212.56 | No Acid Potential | No Acid Potential |
| | SF 47 | 23.68 | 11.84 | No Acid Potential | No Acid Potential |
| | SF 48 | 50.17 | 25.08 | No Acid Potential | No Acid Potential |
| | SF 49 | 1.10 | 0.55 | Acid under certain conditions | Likely Acid Generator |
| | SF64 | 4.29 | 2.15 | No Acid Potential | Acid under certain conditions |
| | SF 50 | 13.23 | 6.61 | No Acid Potential | No Acid Potential |
| | SF 51 | 8.33 | 4.17 | No Acid Potential | No Acid Potential |
| | SF65 | 0.11 | 0.05 | Likely Acid Generator | Likely Acid Generator |
| | SF 52 | 0.45 | 0.23 | Likely Acid Generator | Likely Acid Generator |
| | SF 7 | 0.08 | 0.04 | Likely Acid Generator | Likely Acid Generator |
| | SF66 | 63.86 | 31.93 | No Acid Potential | No Acid Potential |
| | SF 8 | 2.24 | 1.12 | Acid under certain conditions | Acid under certain conditions |
| | SF 53 | 14.70 | 7.35 | No Acid Potential | No Acid Potential |
| | SF 54 | 4.05 | 2.03 | No Acid Potential | Acid under certain conditions |
| | SF 55 | 0.36 | 0.18 | Likely Acid Generator | Likely Acid Generator |
| | SF 56 | 40.35 | 20.17 | No Acid Potential | No Acid Potential |

| Side name | lab No. | Neutralising Potential Ratio(NP/AP) for Open System | Neutralising Potential Ratio(NP/AP) for Closed System | Interpretation Open System | Interpretation Closed System |
|---|---|---|---|---|---|
| | SF 57 | 204.48 | 102.24 | No Acid Potential | No Acid Potential |
| | SF 58 | 4.52 | 2.26 | No Acid Potential | Acid under certain conditions |
| | SF 59 | 1.69 | 0.85 | Acid under certain conditions | Likely Acid Generator |
| | SF 60 | 1.70 | 0.85 | Acid under certain conditions | Likely Acid Generator |
| | | | | | |
| Z124029 | SF 25 | 175.09 | 87.55 | No Acid Potential | No Acid Potential |
| | SF 26 | 42.55 | 21.28 | No Acid Potential | No Acid Potential |
| | SF 27 | 292.87 | 146.44 | No Acid Potential | No Acid Potential |
| | SF 28 | 4.92 | 2.46 | No Acid Potential | Acid under certain conditions |
| | SF 29 | 13.30 | 6.65 | No Acid Potential | No Acid Potential |
| | SF 5 | 1.58 | 0.79 | Acid under certain conditions | Likely Acid Generator |
| | SF67 | 13.68 | 6.84 | No Acid Potential | No Acid Potential |
| | SF 6 | 6.30 | 3.15 | No Acid Potential | Acid under certain conditions |
| | SF 30 | 5.02 | 2.51 | No Acid Potential | Acid under certain conditions |
| | SF 31 | 0.35 | 0.18 | Likely Acid Generator | Likely Acid Generator |
| | SF 32 | 0.41 | 0.20 | Likely Acid Generator | Likely Acid Generator |
| | SF 33 | 17.43 | 8.72 | No Acid Potential | No Acid Potential |
| | SF 34 | 124.87 | 62.44 | No Acid Potential | No Acid Potential |
| | | | | | |
| Z124030 | SF 35 | 460.36 | 230.18 | No Acid Potential | No Acid Potential |
| | SF 36 | 566.83 | 283.41 | No Acid Potential | No Acid Potential |
| | SF 37 | 13.06 | 6.53 | No Acid Potential | No Acid Potential |
| | SF 38 | 29.19 | 14.59 | No Acid Potential | No Acid Potential |
| | SF 39 | 27.40 | 13.70 | No Acid Potential | No Acid Potential |
| | SF68 | 0.11 | 0.05 | Likely Acid Generator | Likely Acid Generator |
| | SF 40 | 2.69 | 1.34 | Acid under certain conditions | Acid under certain conditions |
| | SF69 | 3.97 | 1.98 | Acid under certain conditions | Acid under certain conditions |
| | SF 41 | 1.41 | 0.70 | Acid under certain conditions | Likely Acid Generator |
| | SF70 | 0.19 | 0.09 | Likely Acid Generator | Likely Acid Generator |
| | SF 9 | 0.43 | 0.22 | Likely Acid Generator | Likely Acid Generator |
| | SF71 | 95.76 | 47.88 | No Acid Potential | No Acid Potential |
| | SF 10 | 1.81 | 0.90 | Acid under certain conditions | Likely Acid Generator |
| | SF 42 | 4.98 | 2.49 | No Acid Potential | Acid under certain conditions |
| | SF 43 | 83.12 | 41.56 | No Acid Potential | No Acid Potential |
| | SF 44 | 206.27 | 103.14 | No Acid Potential | No Acid Potential |