A DETAILED ACID BASE ACCOUNTING STUDY OF THE COAL-BEARING KAROO FORMATIONS IN THE WATERBERG COALFIELD

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by

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EXECUTIVE SUMMARY

Introduction

The large resource base coal zones of the Waterberg Coalfield, located in the Limpopo Province, will enable the mining of coal in this area and will continue into the future. As the demand for energy in South Africa increases in the coming years, the coal produced from this area will prove essential.

Coal can either be extracted by opencast pit or subsurface mining methods, depending on the depth and quality of the coal seams. However, opencast pit mining methods produce more waste rock than subsurface methods, due to the removal of the lithologies both over and in-between the coal zones. The oxidation of iron sulphides, present within the discard dumps and coal stockpiles, can influence the hydrochemistry of the groundwater. The main concern is the generation of Acid Rock Drainage (ARD). During mining operations, the open pit can be backfilled with plant discards, overburden and interburden or various combinations thereof. On completion of mining the open pit is covered with topsoil.

The main aim of the study was to identify the potential of acid generation from the overburden, interburden and plant discard that will be removed and placed on the discard dumps, and possibly used as backfill material. Acid Base Accounting (ABA) is used as a prediction tool to determine the acid potential of the lithological units.

Objectives

The objectives were:

1. To determine the acid-base potential of all the different geological layers.

2. To determine the best methods of how to handle these spoils and discards in order to minimize the risk of acid generation.

3. If underground mining methods will be practised, what mining methods will be best to minimize the risk of acid generation? This was not investigated as too little information is available for such future mining.

4. Identify which further research need to be undertaken concerning the impact of mining of the Waterberg coal reserves on water resources.

Geology

There are two main coal-bearing Formations in the Waterberg. The upper Grootegeluk Formation (previously the Volksrust Formation) ranges in depth from 60 to 110 m in the south and the lower Vryheid Formation, a more carbonaceous and interbedded sequence, at approximately 55 m in thickness (Jeffrey, 2005). This is composed of areas with full successions of coal where all the coal bearing strata of the Grootegeluk Formation is present. The Grootegeluk formation is partly weathered away (i.e. not all the coal bearing strata is present and weathering can be present at different stratigraphic levels in the formation. Other parts consist of all the coal strata of the Grootegeluk Formation (Upper Ecca) were the absent due to weathering and only the Volksrust formation (Middle Ecca) is present. The Ecca Group comprises of a lower arenaceous portion and more argillaceous upper portion with numerous coal seams. At the time of deposition, a fluvial deltaic

environment that covered a large part of South Africa existed. At Grootegeluk the Ecca group is divided into Upper, Middle and Lower Ecca. Currently the Upper and Middle Ecca are mined with coal layers divided into 11 zones with a total thickness of 111 m. Upper and Middle Ecca are separated by an interbed of finely laminated carbonaceous shale to coaly shale of 2.6 m thick.

There appears to be in general upwards decrease of coal to mudstone ratio present within certain zones. The Grootegeluk Formation has a distinctive upper coal unit with well-developed thick coal layers alternating with well-developed mudstone layers. Towards the bottom of the succession both coal and mudstone layers alternate more frequently and are thinner.

Geohydrology

The groundwater potential of the Formations is limited due to the low permeability, storage and transmissivity. The Eenzaamheid Fault forms the southern boundary within the study area. This boundary separates the area into two distinct geological units, the Karoo Supergroup to the north of the fault, and the Mokolian Supergroup to the south fault. The Environmental Impact Assessment Report that was done in the Lephalale area reported no artesian boreholes or large-scale groundwater abstraction, even along numerous faults in this area. Geological structures normally enhance the groundwater potential by increasing the permeability and transmissivity of the host rock. The fractured fault zones (e.g. Eenzaamheid fault) within the study area are possible areas of increased groundwater potential. However, based on observations made during his study, Bester (2009) believes the Eenzaamheid and Daarby Faults are impermeable and the variation in water levels seen at the drilled boreholes supports the impermeable nature of the faults. Bester (2009) also assumes that the three main faults in the study area (Eenzaamheid, Daarby and Zoetfontein) serve as no flow boundaries, with deeper water levels on the western side of the Daarby Fault than on the eastern side. The faults themselves, do however act as zones with higher transmissivity.

There are two distinct types of aquifers found in the groundwater system of the geological Formations of the Waterberg Coalfields. The two aquifers in the area are associated with an upper weathered (sandy) material groundwater system and an underlying competent and fractured rock material groundwater system.

Sample collection for testing

Presently, the only active mine in the Waterberg area, is the Grootgeluk Coal Mine (GCM). Coal is currently mined by opencast methods since 1980 when the mine was commissioned. All the samples collected are from the area south west of the Daarby fault where the coal layers are shallow and opencast mining will be applied to mine these coal reserves. Deeper coal reserves are found to the north east of the Daarby fault. These coal reserves will be mined by underground mining and it is not to be undertaken in the near future.

Recently, a lot of exploration was done in the area where shallow coal is present and opencast mining will be applied. Samples for this study were collected from the remaining exploration drill core samples that were still available. Most overburden samples were collected from newly drilled Grootgeluk Coal Mine samples. In most of the samples only the

interburden could be harvested/obtained since the coal layers were removed for analyses and quality identification by the different mining companies.

Geological samples were collected for the use of ABA analysis to determine whether the rocks found in the study area will generate acid upon oxidation. ABA analysis also predicted the base potential that different rock types have; this potential counters the acid generation. A total number of 836 samples were collected and analysed from the various localities. These companies include Sekoko, Sasol, Resgen and Exxaro. The various samples cover a wide range in the study area, including the different respective depths of weathering (Middle Ecca, no coal, full succession coal and weathered in parts).

The Run of Mine (ROM) coal from GCM from the Upper Ecca contains a large amount of intercalated shale (55-65% ash content), and must be beneficiated to produce coal products. The intercalated shale and mudstone produce a typical coal yield of ±50% with the remainder classified as plant discard. The mining and beneficiation process therefore leads to a substantial amount of material that can potentially produce ARD. The beneficiation process of the coal is product specific and was subjected to the gravity separation which is either single or double wash. Composite samples received consisted of processing plant discard from the Grootegeluk Mine. The composites ranged over the different densities at which the coal is separated and also from the various zones, depending on which succession the material was originally mined from.

Method of Investigation

Acid Base Accounting

In order to assess the various acid and base producing potentials of the material sampled from various sections in the study area, ABA tests were performed. This consists of two parts of tests, ***static*** and ***kinetic*****.** The static test provides a rough indication of the acid generation potentials of the various lithological units. The kinetic test is done over a period of 20 weeks and helps to establish which of the samples are prone to produce acid by exposing it to water and oxygen and to establish the rate of constituent leaching.

Acid Base Accounting tests were performed on samples collected within the Waterberg Coalfield from Sasol, Sekoko, Resgen and Grootegeluk mines. The ABA testing included static, kinetic and leachate tests. Additionally, the mineralogy of selected samples were analysed by means of XRD and XRF to determine the specific rocks and formative minerals that could possibly lead to acid generation.

The results from the ABA tests were used to indicate the acid generating potential of the overburden, interburden and composites. Elements that will be leached in the vicinity of the mining area will influence the quality of the chemistry of the groundwater.

Except for 2 samples, all the composite samples received turned acidic upon oxidation. The composites are discard fractions that were obtained after different density treatments at the mine. The samples with the best base potential (not turning acidic), were the overburden samples from Grootegeluk. Most geological layers adjacent to the coal bearing layers contained an acid potential. Both shale and mudstone have both acid and neutralising

potential, while most of the sandstones beneath 60m have a distinct acid generating potential.

The amount of metals that go into solution increases as the pH decrease. This is an important factor to keep in mind especially with samples used as neutralising material. The metals are usually toxic. The total salts leached into the environment (aquifers topsoil) will also increase due to the solubilisation of elements suddenly exposed to weathering.

The concluded acid generation potential of each lithology was then considered during the process of determining an optimal backfilling methodology. The Grootegeluk Colliery is the only coal mine currently in the Waterberg Coalfield, and was therefore used as a case study for determining the optimal backfilling method. It was concluded that the currently applied backfilling method at the Grootegeluk Colliery is the most appropriate backfilling method, because it promises the lowest long-term environmental risk for water contamination. It was concluded that the backfilling method applied at the Grootegeluk Mine can also be applied to other mines within the Waterberg Coalfield as a recommended guideline.

Results and conclusions

Static tests

Sasol: Static ABA tests were performed on 231 individual samples from Sasol. Sasol samples were located in the Full succession from the overburden, interburden and coal samples. Samples from this area were taken from the full succession and consist of rocks from the coal, interburden and overburden samples. Overburden samples consist of mudstone while interburden materials have coal, sandstone and shale samples.

Samples with a NPR less than 4 and more than 1, are the samples that contain low sulphides and low neutralising minerals. The samples are expected to turn acidic but just until the sulphide minerals are depleted. The majority of the samples (55%) pose a high risk of acid generation from the interburden and coal samples. A 35% low acid generating risk exists from interburden samples. The Vryheid formation (Middle Ecca) consists of most samples that are acidic generators more than the Volksrust formation, which contains more carbonaceous material.

Resgen: A total of 153 samples from Resgen were collected and analysed from the farms Zoetfontein and Lisbon. Resgen samples were collected from the Middle Ecca and taken from various depths between 1 m to 72 m. The sample material included overburden and interburden.

The ABA results indicated that the calcrete, mudstone and shale samples from Resgen had both a neutralizing, and acid generating potential. The sandstone samples showed inconclusive data which categorises the material as either having an acid or neutralizing potential. Mixtures of shale with mudstone and sandstone showed the potential to produce acid. Samples with a medium to high risk of acid generation occur in almost equal proportions. Over 25% of the Resgen samples have an excess of acid potential which classifies the samples as having a higher risk for acid generation. Approximately 40% of the samples have a higher potential to neutralise acid. The remaining 35% have a medium risk to generate acid.

Sekoko: The samples collected from Sekoko comprise overburden and interburden selected from drilling cores taken from the Middle Ecca. Static ABA tests were performed on 41 individual samples from Sekoko. Sampling took place from various depths between 23 m and 141 m and from the areas which are partly weathered at 27 m to 61 m.

The samples taken from the Middle Ecca consisted of medium to coarse grained sandstone and in most cases contained pyrite mineral. The % Sulphide-S against the NPR indicated a limited quantity of samples that have a high risk to produce acid. The NPR indicates the limited base potential of some of the samples. The ABA results for sandstone and mudstone samples indicated an acid producing potential. Samples with a medium to high risk of acid generation occur in almost equal proportions. Over 50% of the Sekoko samples have an excess of acid potential and are classified as a high acid generation risk. About 40% of the samples have a higher base potential. The remaining samples are inconclusive and require further testing.

Grootegeluk: Static ABA tests were performed on 292 Grootegeluk overburden samples taken from different boreholes. Overburden samples from Grootegeluk were collected from the three differently geological regions, based on weathering of the Ecca. The initial and final pH results are shown as a detailed table in Appendix G.

The initial pH of the samples is >6.6. The majority of the samples have a low risk to generate acid, with final pH values between 5.9 and 8.47. Only four samples show a medium acid risk with a final pH of 3.6 to 5.29. Over 50% of the Grootegeluk samples have an excess base potential. Approximately 25% of the samples have a high acid potential. The remaining 25% have a medium risk to generate acid.

Composite samples: Static ABA tests were performed on 119 Composite samples, taken from different fractions of the processing plant discard.

The initial and final pH results indicate that all the samples have a very high risk for acid generation. Approximately 95% of the samples have a higher acid potential. The remaining 5% have a medium risk to generate acid.

Leach tests

The leachate characteristic of the samples and coal indicates the results observed in different pH conditions.

- Sulphate has the highest concentration when compared with other constituents, and increases as the pH decreases; the high concentration are associated the presence of pyrite in coal and interburden sandstone samples.
- The concentrations of the lead, nickel and zinc are higher when compared to the rest of the metal concentrations. The dissolution of these elements increases in an acidic environment, and are similar to the various sample locations.
- Areas where more overburden samples were analysed show lower quantities of iron and sulphate which is due to lesser sulphide minerals that are present within the mudstones, shales and calcrete samples.
- Carbonate concentration increase the pH of the system for acidic environments. The carbonate minerals will eventually be depleted from the system and depending on the

environment and the amount of acidic minerals present the pH will decrease or stay neutral.

- Sodium ranges from low to intermediate levels; the higher sodium levels often coincide with high pH-levels, suggesting the presence of sodium carbonate species.

Mineralogy

Based on the static ABA results, X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses were done. XRF is a semi-quantitative whole rock analyses used mainly to identify the chemical compositions of major and trace elements from selected samples. XRD is a quantitative method that identifies the minerals present within the samples. In total 50 samples were subjected to XRD and XRF analyses.

The mudstones have both neutralising and acid generating potentials which are associated with their mineral chemistry. The mineral chemistry for the sandstones from the three successions all have quartz, kaolinite, pyrite, muscovite, rutile and siderite with the exception of hematite for partly weathered successions and feldspar and ilmenite for the Middle Ecca successions. On average the samples acidifying and those with a base potential, contain similar concentrations of SiO_2. The major difference is between the CaO and MgO of the samples with a base potential to 50% less in the samples acidifying.

Kinetic tests

Samples for kinetic testing were selected based on the results from the static ABA tests. The kinetic tests are intended to mimic the physicochemical processes of weathering found at mining sites, usually at an accelerated rate. These tests require more time and are considerably more expensive than static tests. The samples were chosen to be representative of the lithologies present in the study area. The leachate was analysed for pH, conductivity, sulphate, acidity and alkalinity. The analyses are used to confirm the AMD risk associated with a range of ABA values linked to the specific lithologies. Based on the static and kinetic ABA data a useful handling plan for the material from the mining and processing area can be developed.

A total of 68 samples were tested to determine the acid generating potential. The samples consisted of overburden, interburden and composite plant discards.

Full succession samples: Some of the cells from this area had initial pH values that were already acidic. Of interest too is the fact that these cells are cells with excess acid potential (AP) over neutralising potential (NP). From an acid generation point of view, these results tie in well. The other pH values were initially neutral and remained neutral throughout the testing, while a few samples went from neutral to acidic over the testing period. The high SO_4 values at the beginning of the test work suggest that some oxidation occurred in the samples prior to initiation of the kinetic cell test.

Middle Ecca samples: The pH results from the Middle Ecca samples remained approximately neutral and increased slightly over the 20 weeks testing time. The high sulphate values at the beginning of the tests are those that go into solution and are not mainly due to oxidation since the pH of the samples stayed neutral. The kinetic results obtained in the time frame of this experiment coincides with the results obtained with the static ABA. This occurred even

though the acidic pH values of the final static pH results were not obtained over the time of the experiment, confirming the contribution of surface area to the reaction rate. The total salts liberated by the Middle Ecca Formations are much lower than that of the other succession samples tested.

Partly weathered samples: All the partly weathered samples retained their initial pH values at the start of the kinetic testing with small variations. No samples changed from their neutral pH to acidic. There appears to be two liberations for the sulphate within the sample. The first liberation of the sulphate can be from oxidation products already present, because of oxidation of the sample prior to the test. The second liberation is most likely due to the fresh oxidation of species in the sample. The cumulative plot shows an increase in sulphate over time. At this low acidic pH, it is assumed that the process would be self-sustaining and would continue to produce sulphate.

Combination samples: Eleven kinetic cells were run with a combination of samples selected from the static ABA results. All samples were combined in a ratio of 1:1, while one sample (sample SM2) was comprised of 25% of each of the contributing sample.

The result showed a slight increase in calcium over time, and also explains the decrease of sulphate as the calcium probably acts as a buffer within the samples. The pH for the majority of the samples stays at relatively neutral values. The iron and sulphate graphs, clearly indicate that acidification of the samples are in most cases linked to pyrite oxidation. There is an increase in TDS over time, which indicates that the samples have a high salt load. These salts can be released if exposed to rain. The rain would leach salt from the material over time.

Overall summary of results

Overburden

The ABA analyses indicated a dominantly neutralising potential for overburden samples, as well as an acidic potential for the shale units on top of the coal. The samples that did not show a clear distinction were subjected to further kinetic tests. The samples that were analysed over a period of 20 weeks indicated non-acid producing potentials and some with neutralising potentials.

The initial pH values from the overburden samples were neutral to start with and remained neutral throughout the testing. The sulphate values show a decline over the first week as the oxidised products are removed from the system. This suggests that the sulphide oxidation occurred prior to kinetic testing.

The cumulative mass of sulphate produced, indicated that the overburden samples do not continue to produce sulphate, but rather reaches a constant rate where sulphide is produced. The cumulative plot shows how this flattens over the course of the testing time to provide a better spread of production rates. During the kinetic tests, the results for calcium and alkalinity were relatively high. The relatively low calcium values indicate that carbonates are immediately available and demonstrate the balance between the released alkalinity and the acidity generated. If the balance between the alkalinity and the acidity stays positive, the system will not acidify.

Interburden

The ABA analyses showed that the analysed interburden samples contained both acidic and neutralising potentials. Interburden and mixtures of acidic and neutralising interburden was selected to run kinetic tests on. The purpose was to show the extent to which acid producing interburden, mixed with a neutralising component, could reduce the acidic nature of the samples. Mudstone, shale and calcrete layers indicated a neutralising potential, while sandstone had a relatively high acid generating potential. The sulphate values show a slight decline over the first few weeks of testing, with a gradual increase for the remainder of the test. The slight increase is due to the oxidised products being flushed from the system. The gradual increase of the interburden samples suggests sulphide oxidation occurred during the kinetic testing. The cumulative mass of sulphate produced, showed that the interburden samples continue to produce sulphate and did not appear to reach a constant rate of sulphate production. The cumulative plot demonstrates the increase in relative rates of sulphate production over the course of the testing time. With prolonged exposure the system would acidify as sulphate is released into the system. Calcium and alkalinity results showed high calcium values, with relatively low alkalinity for the interburden material .The high calcium values indicate the availability of carbonates, whereas in this case the carbonates are not immediately available.

Plant discards/composites

The plant discards consist of unwanted material that remains after coal separation, also known as composite samples. The different density composite samples were analysed and indicated that they all have a high potential to produce acid.

Mixed overburden, interburden and discards: The overburden and interburden have already been mentioned as neutralising and acidic, respectively. A combination (predetermined mixture ratio) of overburden, interburden and composites, can potentially reduce the risk of acid generation within the pit. Kinetic tests on mixtures of overburden, interburden and composite material showed that the acidic nature of the samples were reduced.

Interburden and ash: Ash in general has a high neutralising potential. The analysed ash samples from the Matimba Power Station had pH values that ranged from 9.30 to 10.91. The alkalinity component and the addition of any acid generating material would reduce the risk of acid generation. If ash however becomes acidic it can mobilise heavy metals into the natural system and can become harmful. The experiment conducted on the interburden leachate and ash demonstrated the reduction potential ash has for acidic water.

Application of results to lithology units

The ABA and kinetic tests highlighted the lithological units that are prone to turn acidic or poses a neutralising potential.

Partly weathered successions: The units that showed an acidic nature were mostly the coal samples, as well as the sandstone found underneath the coal layers. In the sandstone samples the quartz, kaolinite, pyrite, muscovite, ilmenite and rutile minerals were positively identified.

Middle Ecca successions: The geological units analysed from this succession revealed more acid producing sections than of the partly weathered successions. The geological units that were prone to become acidic were shale, mudstone and both coarse and medium grained sandstone. The units predominantly contain quartz, kaolinite, pyrite, muscovite, rutile, ilmenite and feldspar. The fine grained sandstone, calcrete and soil all indicated a neutralising potential. The main minerals identified within these geological units were quartz, kaolinite, muscovite, siderite, calcite, dolomite and rutile.

Full successions: The dominant geological units that have an acid producing potential were the sandstone and the coal units. These units consist of quartz, kaolinite, muscovite, pyrite, siderite and rutile. The mudstone and shale units all showed a neutralising potential and the minerals identified within these units included quartz, kaolinite, muscovite, pyrite, hematite, marcasite and calcite.

Spoils Management

Discards are generated during mining operations when coal is extracted from intermittent rock waste. Spoils consist of mined overburden and noneconomic mineral deposits removed during mining operations. The composition of spoils vary greatly depending on the area, depth and lithology where mined. The amount and type of waste generation is a direct result of the method used during the mining process namely surface open cast, underground mining and blasting or continuous mining. Backfilling methods must in general fit in with the mine design. The type of backfill that is going to be used is also usually identified during the design stages.

There is a need to dispose large amounts of colliery waste or spoil in such a manner that the least amount of damage is done to the surrounding environment. About 80% of waste is dry or solid spoil and usually tipped on site close to the pit head. The other form of waste generated is a wet by-product during the washing of the coal. This requires a different method of disposal and in some countries they make use of lagooning. The main environmental effects of these processes include visual intrusion, loss of land, noise and dust from vehicle movement during tipping of dry waste, and potential water pollution. The various activities have an immediate visible effect on the local area but the effect can be much deeper.

Extraction, beneficiation and processing of metals and industrial mineral ores produce mining wastes. Waste can be divided into categories which include:

- Waste rock, when material is moved to gain access to ore and excludes any material that is used during reclamation.
- Tailings, usually in a slurry form, from beneficiation processes.
- Mine water, water that infiltrates mines during extraction including groundwater or precipitation.
- Processing waste, residuals after beneficiation process, such as smelting and electrolytic refining operations.

Placement of backfill is one of the tools used in managing voids created during mining processes and reduces the cost and impact of a separate waste disposal site or process. Different scenarios are discussed in this investigation:

- *Overburden:* The ABA analyses showed a predominantly neutralising potential for overburden samples as well as an acidic potential for the shale units near the coal. The samples that did not show a clear distinction was further tested by kinetic testing. Backfilling with overburden directly into the opencast pit would not acidify, but rather neutralise the surrounding area. The groundwater system would not be influenced in a negative way. In the event of heavy rain and infiltration, no acid would be produced nor be introduced into the system.
- *Interburden*: The ABA analyses showed that the interburden samples analysed contained both acidic and neutralising potentials. Backfilling with only interburden has a high possibility of acid production that would reach the groundwater system. In favourable conditions (exposed to oxygen and water), the interburden would generate acid over a longer period of time. The quantity and quality of the interburden material is not suitable to use as filler alone in the pit.
- *Plant discards/composites:* Plant discards consist of the unwanted material that remains after coal separation, also known as composite samples. The different density composite samples were analysed and indicated that they all have a high potential to produce acid. The main risks associated with discard are the sulphide potential that leads to the generation of acid upon exposure to oxygen and moisture. There is a risk for metals to mobilise in surface or groundwater when they are liberated in acidic conditions. There can also be contaminant influx due to precipitation, creating runoff from discard storage piles. Backfilling with composite or discard material would influence the groundwater system in a negative way, especially if the discards are exposed to favourable conditions (oxidation and water). The best way to decrease the risk would be to immediately fill the pit with water. It should be mentioned that to channel water is costly and regarded as not feasible. Although the immediate fill using water would reduce the spontaneous combustion of waste material, it cannot be the best solution for managing discard.
- *Mixed overburden, interburden and discards/composites:* The overburden and interburden have already been mentioned, as neutralising and acidic, respectively. A suitable ratio of overburden, interburden and composite material will have a positive effect on the surroundings after they are placed back into the pit. Acid generation from these materials will be neutralised in the pit in the event that they are exposed to favourable conditions. Kinetic tests on mixtures of overburden, interburden and composite material confirmed that the acidic nature of the samples could be reduced. In the event that the buffer potential of the mixed overburden and interburden failed to reduce acid generation, exposure to oxygen and water would accelerate the acid generating process. This scenario currently does not have enough data to propose how long the system would buffer itself, and more research is needed.
- *Interburden and ash:* The co-disposal of interburden and ash material will result in an excess of neutralising potential. The material properties of interburden, with both an acid and neutralising potential, would not lead to acid production due to the high neutralising potential of the fly-ash material. If fly-ash was intermittently layered in between samples prone to produce acid, it would positively affect the surrounding area and neutralise any

acidic threat to the system. The best option would be to co-dispose ash and interburden into layers and cover it with a layer of compacted fly-ash. The compacted ash top layer will act as a seepage reducer, and in the event that water managed to seep in, it would not produce acid. The long term effect of ash cannot be stated with certainty other than that it has a high neutralising potential and can be co-disposed with acidic material to reduce an acid generating potential. The acid producing spoils can also be buried on-site with ash or other neutralising material surrounding it. For underground mines ash can be introduced as a low-permeability fill or grout within the voids, fractures, subsurface openings and to reduce the contact of acid generating rocks to water and air.

Proposed handling of spoils

Based on the investigated scenarios, the mixture and/or layering of a combination of material would be recommended. The layered option proposed by Adamski (2003) which is the current means of backfilling at Grootegeluk Mine, has the lowest long-term environmental risk for water impact. It reduces ARD rates and leaches alkalinity into underlying acid generating discard material. The backfilling method scenarios investigated are based on the current method applied at the Grootegeluk Colliery. From these scenarios, two types of backfilling for ash and different discard should be considered and possibly implemented in the mining industry. The types of systems for backfilling are discussed as two options, one in the event prior to disposal and the other as the disposal of waste in layers. Either Option 1 or 2 can be implemented depending on the economic motivation or viability of each option.

The design objectives for any backfill pit cover should include the following:

- Reduce the ingress of atmospheric oxygen to the underlying waste material to the minimum acceptable level
- Reduce entry of meteoric water to the underlying waste material to less than 5% of annual precipitation at the site
- Provide a medium for establishing a sustainable vegetation cover that is consistent with the final land use of the area.

Summary of Conclusions

The following main conclusions were made:

Chemical and biological processes play an important role in the production, release, mobility, and attenuation of contaminants in ARD waters. The rate of oxidation can vary depending on the accessibility of air, moisture and microbes to the Pyrite surfaces. The type of mining and mineral processing plays a part in the initiation of the acid mine waters in the mining environment, and the methods that are employed have to be used in connection with the appropriate remediation and treatment to minimise the generation of ARD. Neglect to these factors can cause ARD problems that will be hard to control once it has begun.

The ABA results determined that the interburden and discards used as backfill material has a potential to generate acid. This includes the composite samples with various densities from the processing plant. While overburden material has a neutralising potential.

The ABA illustrated that the shale and mudstone samples have both acid and neutralising potentials and the majority of sandstone samples beneath 60 m have a distinct acid generating potential.

The amount of metal in solution increases as the pH drops. Majority of the samples that were analysed exhibit a similar trend where a decrease in pH causes an increase in the heavy metals. The calcium and magnesium carbonate analysed have a natural buffer capacity that will increase the pH. Calcium and magnesium will increase until they are depleted from the calcite, dolomite and siderite minerals they are hosted within. Depending on the ratio of acidic to buffer material, an acidic system can be neutralised. Sulphate and iron has the highest concentration when compared to other analytes, which increases as the pH drops. The high concentration may be due to the presence of pyrite in the coal and interburden sandstone samples. Overburden samples have the lowest sulphate concentration which is ten times lower and more when compared to all areas of analysis as well as composite samples.

The pH directly affects the type of metals that are mobilised. In pH conditions around 2 there is a high leaching of heavy metals occurring. Various analytes are released at different pH values. Nickel and other constituents' increases in solution at lower pH environments.

The amounts of TDS from the full, partly weathered and Middle Ecca successions are directly related to the iron and sulphate values. The increase of these elements increases the amount of salts that are liberated from the samples. The Middle Ecca has a lower total salts that are liberated than the full and partly weathered successions.

The fly ash from Matimba Power Station has a high potential to reduce acidity. The fly ash showed a limited alkalinity over time, in the event of an acidic condition persisting for long periods. The readily available soluble salts in ash will result in higher salt loads that will be mobilised into the pit water.

The composite material can be used as backfill material within the pit. It only becomes a risk upon exposure to oxygen and water. The Waterberg area has a relatively low annual rainfall, high evaporation and deep groundwater levels, thus the risk to produce acid from infiltrating water is limited. The risk of exposure to oxygen leads to the spontaneous combustion of discard material.

Based on the investigated scenarios for backfilling, the mixture and or layering of a combination of material are recommended. Either Option 1 or 2 can be implemented depending on the economic motivation or viability of each option.

The layered option proposed by Adamski (2003), which is the current means of backfilling at Grootegeluk Mine, has the lowest long-term environmental risk for water impact. It reduces ARD rates and leaches alkalinity into underlying acid generating discard material.

The process of mining and beneficiation, stockpiling of coal, coal products and waste is an important factor in management practice, as it makes the environment and water more vulnerable to degradation. More care should be taken in understanding and managing exposed rock or waste piles, which creates paths for pollution migration. It is also important to understand the physical characteristics of the mine waste/stockpiles such as permeability

and weathering, which play a role in accelerating the process of ARD. Prints of mismanagement, neglect and a lack of knowledge have left areas with abandoned mines with ARD issues.

Aims and Accomplishments

The defined contractual deliverables were all met and can be seen in the deliverable reports prepared for the Water Research Commission (WRC). The final products of the project include comprehensive data sets obtained from the numerous Acid Base Accounting (ABA) tests performed, a recommended backfilling procedure for mining the Waterberg Coalfield and scientific papers.

The objectives were:

- *To determine the acid-base potential of all the different geological layers.*

Far more samples were analysed with static and kinetic procedures, as more material was made available than initially planned for. This resulted in a far more detailed understanding of the acid/neutralising potential of the different geological layers and plant discards. However, more can still be done in the mixing of these different compositions to find the optimal potential for handling of the material.

- *To determine the best methods of how to handle these spoils and discards in order to minimize the risk of acid generation.*

All the different scenarios i.e. overburden, interburden, plant discards/composites, and a mix of them all were discussed in this document. A composite interburden/ash mix was also discussed. The proposed handling of the spoils was also discussed.

- *If underground mining methods will be practised, what mining methods will be best to minimize the risk of acid generation?*

It was decided by the reference group during the first meeting that this was not to be investigated as too little information is available for such future mining.

- *Identify which further research need to be undertaken concerning the impact of mining of the Waterberg coal reserves on water resources.*

Recommendations were made to run the kinetic cells for longer periods of time to obtain a more accurate real-time answer on the acid/base potential of the different geological layers and the composites obtained from these different materials. This will increase the confidence factor in proposing how to handle the spoils and composites of spoils.

ACKNOWLEDGEMENTS

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List of abbreviations

ABA	Acid Base Accounting
AMD	Acid Mine Drainage
ANFO	Ammonium Nitrate/Fuel Oil
AP	Acid Potential
ARD	Acid Rock Drainage
CCB	Coal Combustion by-Product
CCR	Coal Combustion Residue
CCW	Coal Combustion Waste
DMR	Department of Mineral Resources
DWA	Department of Water Affairs
EC	Electrical Conductivity (mS/m)
EIA	Environmental Impact Assessment
Eskom	Electricity Supply Commission of South Africa
FS	Full Succession
GCM	Grootegeluk Coal Mine
GDP	Gross Domestic product
GG2	Grootegeluk mine washing plant
HiPRO	High- recovery precipitations reverse osmosis
LE	Lower Ecca
ME	Middle Ecca
MKB	Main Karoo Basin
NNP	Net Neutralising Potential
NP	Neutralising Potential
NPR	Neutralisation Potential Ratio
RO	Reverse Osmosis
ROM	Run of Mine
SABS	South African Bureau of Standards
TDS	Total Dissolved salts
UE	Upper Ecca
WMA	Water Management Area
WP	Weathered in parts

1 Introduction

The main aim of the study is to identify the potential for acid generation from the overburden, interburden and plant discard that will be removed and placed on the discard dumps, and possibly used as backfill material. Acid Base Accounting (ABA) is used as a prediction tool to help determine lithological units that can generate acid. ABA tests were performed on samples collected within the Waterberg Coalfield from Sasol, Sekoko, Resgen and Grootegeluk. The ABA testing included static, kinetic, and leachate tests. Additionally, the mineralogy of selected samples was investigated to determine the specific rocks and formative minerals that could possibly lead to acid generation. Opencast mining is still used at this moment since 1980 and Grootegeluk is the only active mine up to date.

1.1 Location of study area

The study area is located within the Limpopo Province of South Africa. The study area covers the Waterberg Group lithologies, due to the coal bearing nature of the Group. Geological samples were collected for the use of acid-base accounting (ABA) analysis to determine whether the rocks found in the study area will generate acid upon oxidation. In total 828 samples were collected, this consisted of 709 samples from over and interburden and 119 composite samples. The samples were obtained from various companies including Sekoko, Sasol, Resgen and Exxaro. The distribution of the samples over the study area, as well as the respective successions of the samples, is located within, as shown in Figure 1-2.

The Grootegeluk Colliery is the largest coal mine currently in the Waterberg Coalfield, and was subsequently used as a case study for the investigation into an optimal backfilling method. It was concluded that the currently applied backfilling method at the Grootegeluk Mine is the most appropriate backfilling method, because it promises the lowest long-term environmental risk for water contamination. It also concluded that the backfilling method applied at the Grootegeluk Mine can be applied to other mines within the Waterberg Coalfield, with recommendations from this research on how to place the spoils as a guideline.

1.2 Sample collection for testing

Geological samples were collected for the use of ABA analysis to determine whether the rocks found in the study area will generate acid upon oxidation. ABA analysis also predicted the base potential that different rock types have; this potential counters the acid generation. A total number of 836 samples were collected and analysed from the various localities. These companies include Sekoko, Sasol, Resgen and Exxaro. The various samples cover a wide range in the study area, including the different respective depths of weathering (Middle Ecca, no coal, full succession coal and weathered in parts).

1.2.1 Borehole samples

An example of core collected from the various companies is shown in Figure 1-1. Sekoko and Sasol provided borehole material with different diameter that was pulverized for analytical purposes. Borehole core (6 cm diameter) from Sekoko was handpicked from the remaining interburden left over after the coal seams had been removed. The borehole core (12 cm diameter) from Sasol was complete with the coal seams still in place. Pulverized samples from Resgen were pulverised further for laboratory use. The chip samples from Exarro's Grootegeluk Coal Mine (GCM) consisted of overburden in one meter intervals in the respected areas. The extent of boreholes from Sekoko ranged from 0m to 146.75 m in depth. Sasol has the deepest borehole range of 0 to 196.4 m in depth. The overburden material from Grootegeluk covers the top few meters at the sample positions.

Figure 1-1: Core sample from exploration borehole near the GCM, with large pyrite hosted within the coal.

The distribution of the samples over the study area, as well as the respective successions the samples are located within, are shown in Figure 1-2. Based on the levels of weathering, the area is divided into three general areas. The ABA that was done in the particular areas at different depths, indicate various potentials to generate acid.

1.2.2 Ash samples

The Matimba Power Station disposes of ash produced during the power generation process on surface fly ash dumps to the south of the power station. Fly-ash samples were collected from the conveyor belt dump on the 27th of November 2013.

1.2.3 Composite samples

The Run of Mine (ROM) coal from GCM from the Upper Ecca contains a large amount of intercalated shale (55-65% ash content), and must be beneficiated to produce coal products.

The intercalated shale and mudstone produce a typical coal yield of ± 50% with the remainder classified as plant discard. The mining and beneficiation process therefore leads to a substantial amount of material that can potentially produce ARD.

The beneficiation process of the coal is product specific and was subjected to the gravity separation which is either single or double wash. The double wash plant produces a low ash coal (± 10% ash) which is used as blend coking coal and middling products (± 35% ash) in power generation. These products operate at a relative density of 1.80 g/cc. In contrast, a single wash plant produces only power station coal and operates at a higher relative density of 1.90 g/cc. The newer plants at Grootegeluk operate at relative densities of ± 2.10 g/cc during beneficiation.

The composite samples received from Exxaro Mine consisted of processing plant discard from the Grootegeluk Mine. The composites ranged over the different densities at which the coal is separated and also from the various zones, depending on which succession the material was originally mined from.

A complete list of samples, received and analysed by the Institute for Groundwater studies from the various companies (Sasol, Exxaro, Resgen and Sekoko), are summarised in Table 1-A. The table includes the number of samples and the succession from which the boreholes were sampled. Based on the depths of weathering, the samples are grouped into different categories and discussed.

Table *1-A: The samples received and analysed from the different locations*. FS – full succession, ME - Middle Ecca, WP- weathered in parts.

Area	Borehole	Renamed samples	Number of samples	Succession type
GROOTEGELUK	JY309LQ17	JA	46	WP
	JY309LQ18	JB	20	WP
	JY309LQ14	JC	24	WP
	MY311LQ26	MA	19	FS
	MY311LQ28	MB	26	FS
	VP313LQ16	VA	38	WP
	VP313LQ17	VB	19	WP
	VP313LQ19	VC	36	WP
	VP313LQ18	VD	24	WP
RESGEN	SZP24	RA	61	ME
	SZP25	RB	68	ME
	SLP14	RC	56	ME
SASOL	G250040	WGH	47	FS
	W228030	W	38	FS
	G226006	WGA	18	FS
	G226014	WGC	15	FS
	G226010	WGB	24	FS
	G256039	WGE	3	WP
	G256038	WGF	2	FS
	V264007	WVA	9	ME
	V264008	WVB	8	WP
	V264009	WVC	8	WP
	G226010	WGG	15	FS
	G218016	WGD	17	FS
	R303015	WRA	8	
	T261019	WTA	2	ME
	T261018	WTB	5	WP
	T261016	WTC	9	WP
	T261017	WTD	7	FS
SEKOKO	DP712001	DP01	11	ME
	DP712002	DP2	7	ME
	DP712003	DP3	6	ME
	PS93	PS93	1	WP
	PS94	PS94	1	WP
	S131	S131	1	
	DM19	DM19	1	
	SV35	SV35	3	WP
	PS95	PS95	3	WP
	PM18	PM18	3	WP
COMPOSITE			119	

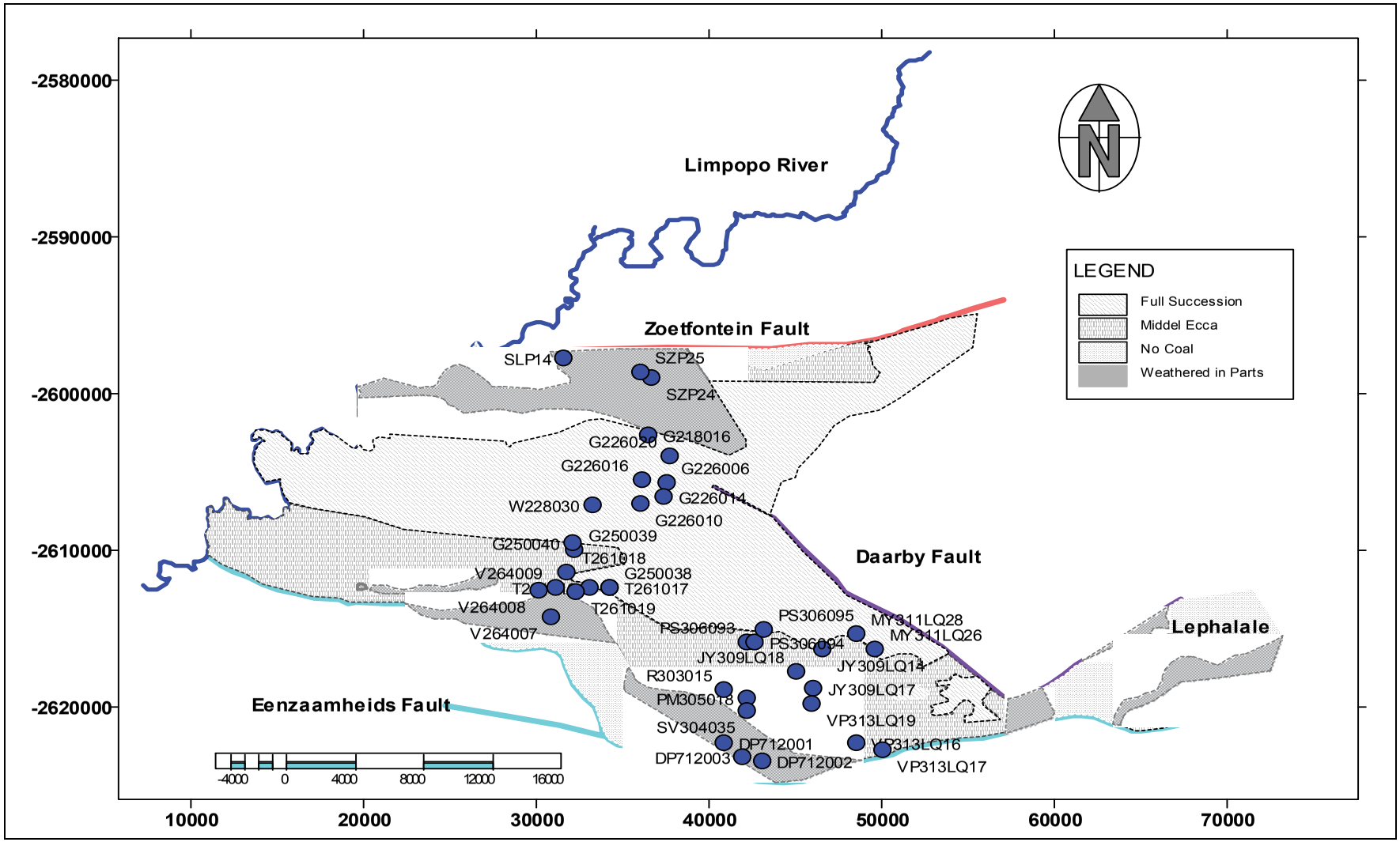

Figure 1-2: The three major faults with the weathered zones, as proposed by Bester (2009) and the different sampled areas

2 Overview

The overview includes the local and structural geology, geohydrology and sampling from the respective areas. In total 828 samples were collected from different lithological units within the coal-bearing Ecca Formation.

2.1 Geology

The coalfields of South Africa are located within the Karoo Sequence (Figure 2-1). The coal seams were deposited in an east-west orientated graben, approximately 190 to 260 million years ago. The Ecca Group of the Karoo sequence is host to the vast majority of coal beds found in South Africa. The dominant coal mine producing areas are located in the northwest to north eastern portions of the Main Karoo Basin (MKB). The subsidiary basins north of the main Karoo deposits are also increasing in coal mining activities.

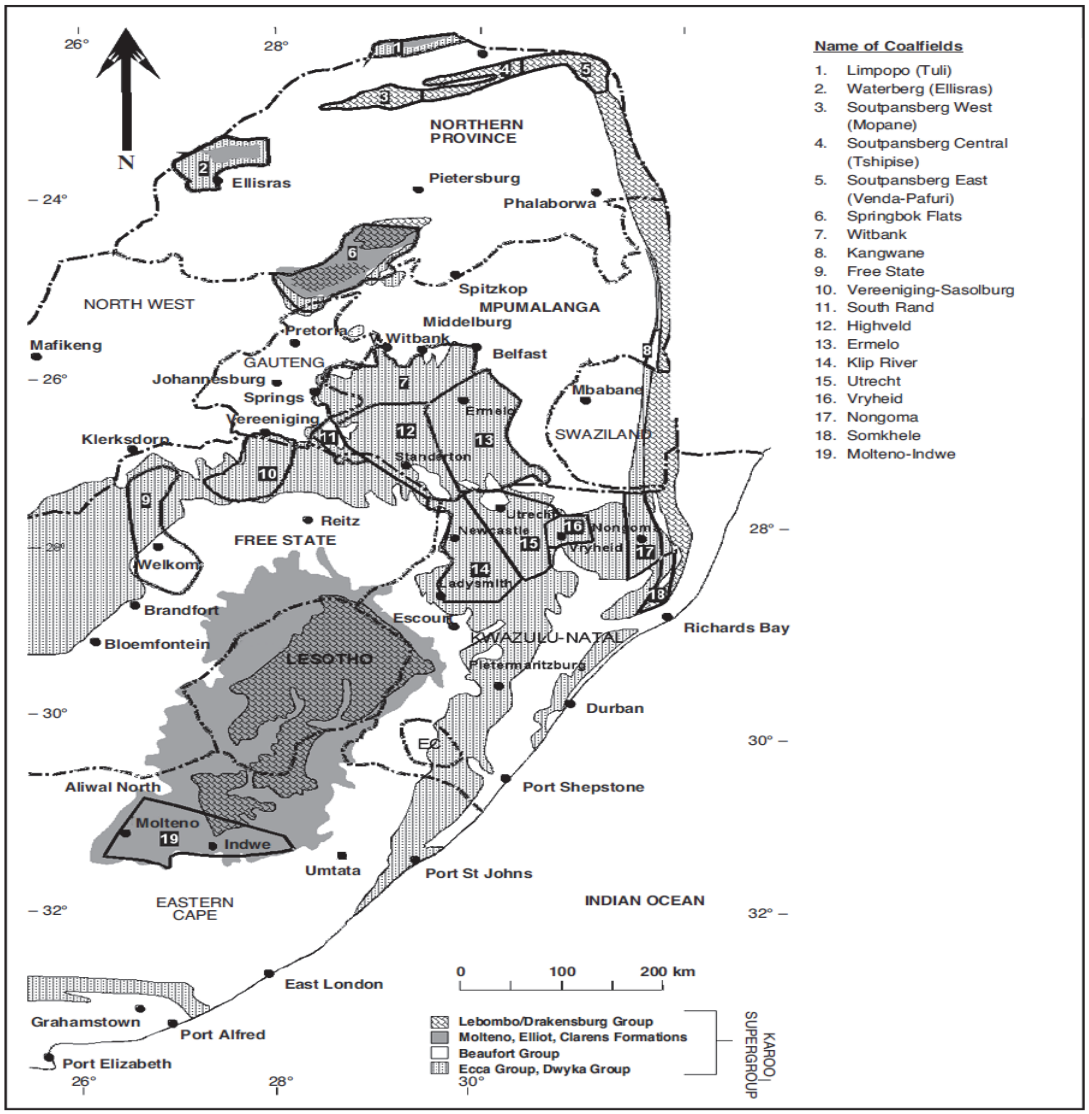

Figure 2-1: The distribution of the coalfields of South Africa (Jeffrey, 2005)

2.1.1 Local Geology

There are two main coal-bearing Formations in the Waterberg (Figure 2-2). The upper Grootegeluk Formation (previously the Volksrust Formation) ranges in depth from 60 to 110 m in the south and the lower Vryheid Formation, a more carbonaceous and interbedded sequence, at approximately 55 m in thickness (Jeffrey, 2005).

This is composed of areas with full successions of coal where all the coal bearing strata of the Grootegeluk Formation is present. The Grootegeluk formation is partly weathered away (i.e. not all the coal bearing strata is present and weathering can be present at different stratigraphic levels in the formation. Other parts consist of all the coal strata of the Grootegeluk Formation (Upper Ecca) were the absent due to weathering and only the Volksrust formation (Middle Ecca) is present.

The Ecca Group comprises of a lower arenaceous portion and more argillaceous upper portion with numerous coal seams. At the time of deposition, a fluvial deltaic environment that covered a large part of South Africa existed. At Grootegeluk the Ecca group is divided into Upper, Middle and Lower Ecca. Currently the Upper and Middle Ecca are mined with coal layers divided into 11 zones with a total thickness of 111 m. Upper and Middle Ecca are separated by an interbed of finely laminated carbonaceous shale to coaly shale of 2.6 m thick.

There appears to be in general upwards decrease of coal to mudstone ratio present within certain zones. The Grootegeluk Formation has a distinctive upper coal unit with well-developed thick coal layers alternating with well-developed mudstone layers. Towards the bottom of the succession both coal and mudstone layers alternate more frequently and are thinner.

Originally the Ecca Group coals of the Waterberg Basin were divided into zones 1, 2, 3, 4A, 4, 5A, 5B, 5C, 6A, 6B, 6C and 7 numbered from the bottom up (De Jager, 1976). The Grootegeluk Coal Mine (GCM) has changed the division into eleven coal zones used to date. According to De Jager (1976) zones 1, 2, 3, 4A and 4 of the Vryheid Formation consist of predominantly dull coal seams. The coal from these zones are suitable for power generation as a raw coal that does not have to be beneficiated and thus very little plant discards will be produced. Zones 5-11 assigned to the overlaying Grootegeluk Formation with intercalated bright coal and mud layer (Figure 2-2). The Waterberg Coalfield is thus divided into 11 coal-bearing zones coal seams (Figure 2-3) Benches 1-5 from the upper zone (Grootegeluk Formation) and 6-11 (poor quality coal) is found in the lower zone (Vryheid Formation). The benches from the Grootegeluk Formation typically contain bright coals at the base and grade upwards into shale. The GCM (Grootegeluk coal mine) (at present the only operating coal mine in the Waterberg Coalfield) benches 2, 3 and 4 yield a coking coal on beneficiation. Bench 5 produces a thermal grade coal (high phosphorus) and benches 6-11 are dull coals, highly interbedded with mudstone and carbonaceous mudstone. The presence of fine mudstone intercalations in the Waterberg Coalfield causes higher beneficiation of the coals (Jeffrey, 2005).

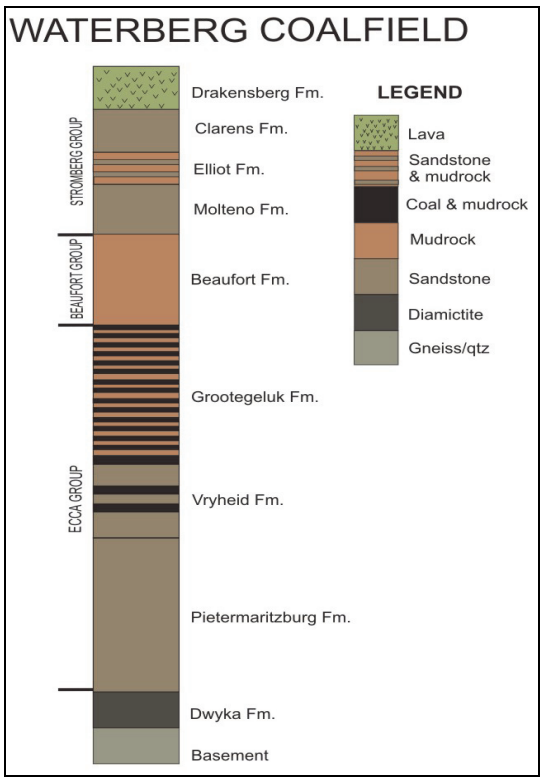

Figure 2-2: The stratigraphic units for the Dwyka, Ecca and Beaufort Groups in the Waterberg Basin (Modified from Faure et al., 1996).

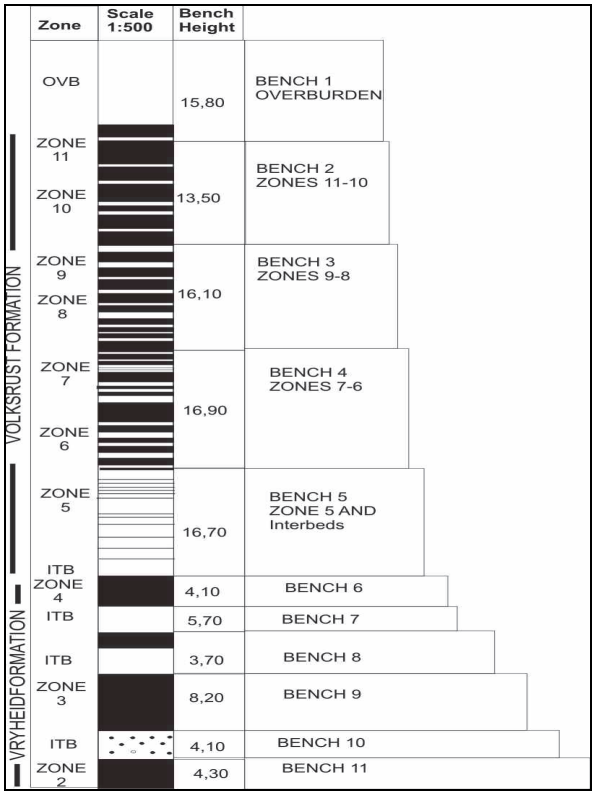

Figure 2-3: Stratigraphic column with the lithological units for the Grootegeluk Formation in the Waterberg Coalfield. OVB- overburden and ITB- interburden (Dreyer, 1999).

2.1.2 Structural geology

The Waterberg coalfield is bounded by the Eenzaamheid and Zoetfontein Faults on the southern and northern margins, and extend approximately 80 km east-west and 40 km north-south (Figure 2-5). The post-Karoo Daarby Fault, with a displacement of 200 to 400 m, divides the coalfield into a shallower western area and a deeper north-eastern area. Smaller faults that are mostly unmapped subdivide the coalfield into blocks (Jeffrey, 2005). Due to the presence of the Daarby Fault, the coal seams are located at deeper depths to the east and north/east. The coal seams in the west are shallower and can be extracted by opencast mining. Vermeulen *et al*. (2011) describes the three main categories identified by Dreyer (1999) according to the weathered geology (Figure 2-4).

The categories are illustrated in Figure 2.4. The full successions of coal are where all the coal bearing strata of the Grootegeluk Formation is present. The Grootegeluk Formation is partly weathered away, i.e. not all the coal bearing strata is present and weathering can be present at different stratigraphic levels in the Grootegeluk Formation. The coal strata of the Grootegeluk Formation is absent due to weathering and the Volksrust Formation (Middle Ecca) is all that can be seen (Figure 2-4).

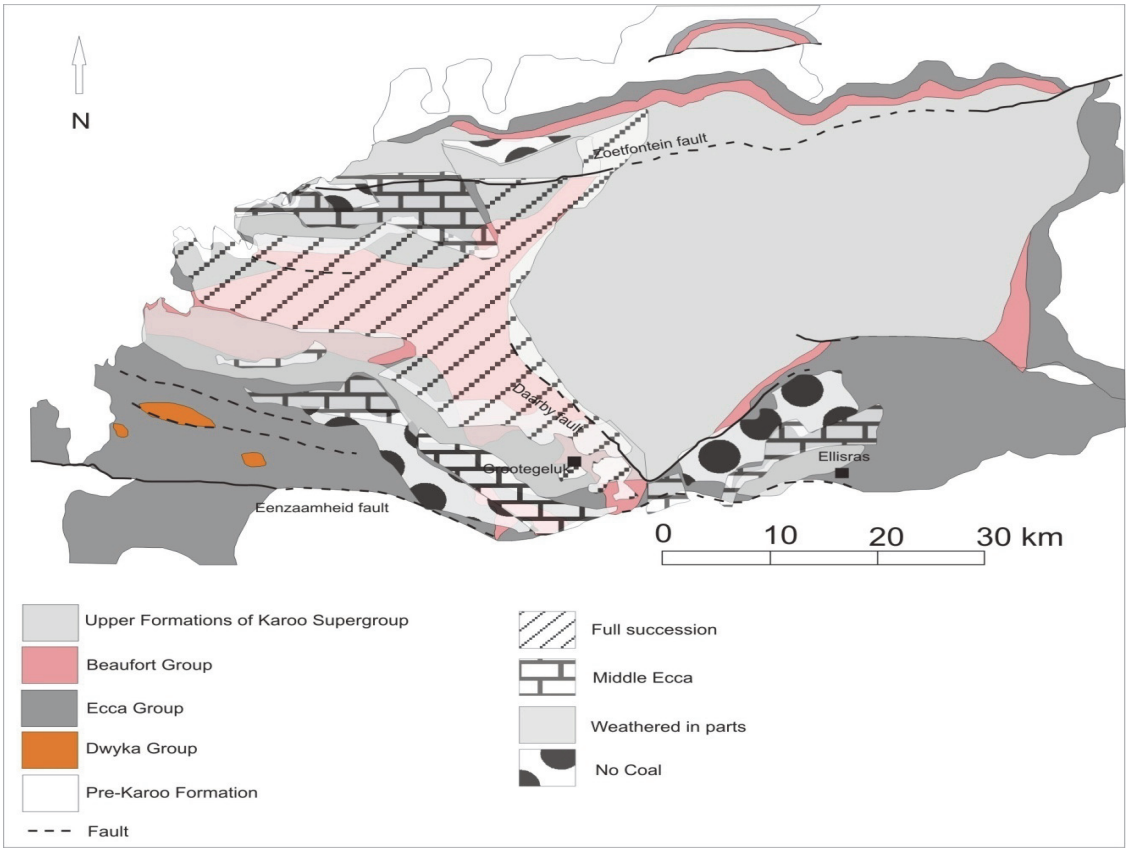

Figure 2-4: A generalised geological map of the Waterberg Basin. Coal is open-cast mined at the GCM which is approximately 25km west of Ellisras (Modified from Snyman, 1998 and Bester, 2009).

The Daarby fault with its north east then north west trend is a combination of two faults that have the same throw and throw directions. The Daarby fault has a downthrow of 360 m to the north and dips at an angle between 50° and 60°. The fault brings the upthrown Beaufort and Ecca Groups in the south into contact with downthrown Letaba, Clarens and Red Bed Formations in the north (Johnstone, 1989). The Eenzaamheid fault is located south of the Daarby fault with a 250 m throw to the north at a near vertical angle. The upthrown Waterberg Group on the southern side is in contact with the downthrown Beaufort and Ecca Groups on the northern side of the fault.

Between the Daarby and Eenzaamheid faults there are associated smaller faults present (Figure 2-5). The associated faults have varying strikes, throws and throw directions. The most important geohydrological aspect of the faulting is the increase in rock permeablility for both the Beaufort and Ecca Groups.

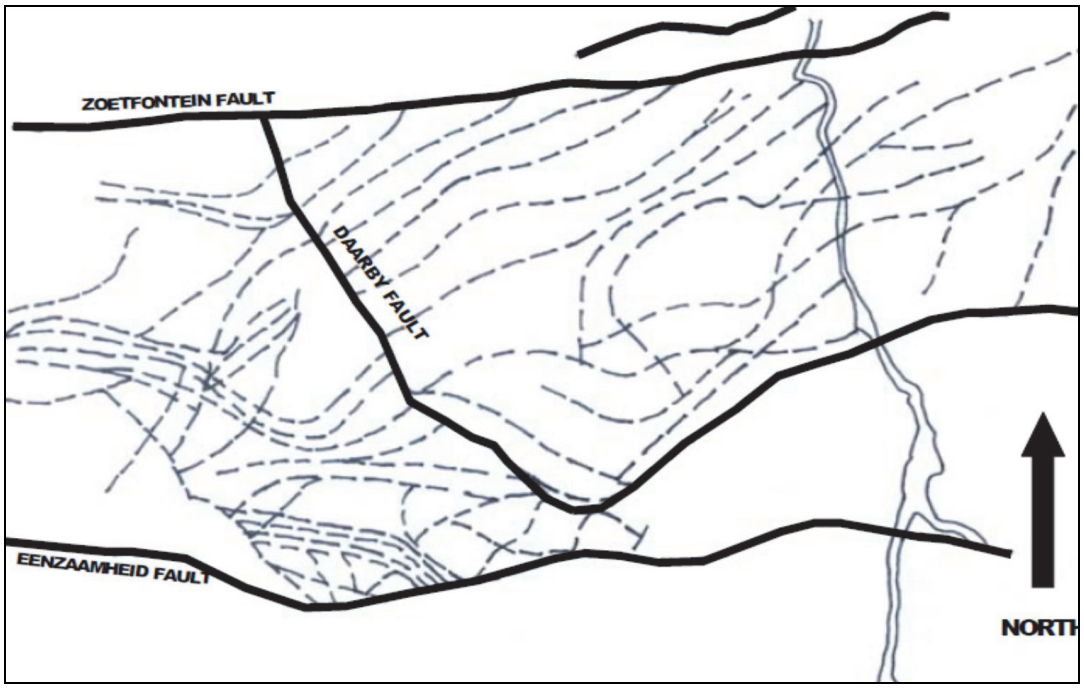

Figure 2-5: Structural geology of the major faults; Daarby, Eenzaamheid and Zoetfontein and minor faulting (after Roux, 2004).

2.2 Geohydrology

The groundwater potential of the Formations is limited due to the low permeability, storage and transmissivity. The Eenzaamheid Fault forms the southern boundary within the study area. This boundary separates the area into two distinct geological units, the Karoo Supergroup to the north of the fault, and the Mokolian Supergroup to the south fault. The Environmental Impact Assessment Report that was done in the Lephalale area (EIA, 2006) reported no artesian boreholes or large-scale groundwater abstraction, even along numerous faults in this area.

Geological structures normally enhance the groundwater potential by increasing the permeability and transmissivity of the host rock. The fractured fault zones (e.g. Eenzaamheid fault) within the study area are possible areas of increased groundwater potential. However, based on observations made during his study, Bester (2009) believes the Eenzaamheid and Daarby Faults are impermeable and the variation in water levels seen at the drilled boreholes supports the impermeable nature of the faults. Bester (2009) also assumes that the three main faults in the study area (Eenzaamheid, Daarby and Zoetfontein) serve as no flow boundaries, with deeper water levels on the western side of the Daarby Fault than on the eastern side. The faults themselves, do however act as zones with higher transmissivity.

There are two distinct types of aquifers found in the groundwater system of the geological Formations of the Waterberg Coalfields. The two aquifers in the area are associated with an upper weathered (sandy) material groundwater system and an underlying competent and fractured rock material groundwater system.

The annual rainfall that eventually reaches the groundwater table is about 1-2%. The calculated evaporation (1800-2000 mm/a) is higher than the average rainfall in the area (285-560 mm/a). This seasonal variation is also reproduced in the borehole yields and the influence is so strong, that for the rainy season the yields can be around 1-3 l/s, but decrease remarkably during the dry seasons. In some areas the upper aquifer will be completely dry during the dry season.

The water levels of the Lower and Middle Ecca are higher than in the Upper Ecca which suggests confined aquifer conditions (Roux, 2004). The general depth to groundwater level ranges between 20 and 40 mbgl. Normally the groundwater level contours reflect the topographical contours at a moderate gradient. This however differs in the areas where there is large scale external impacts on the groundwater environment during the lowering of the groundwater level through mine dewatering, and where the geology and aquifer interactions are not excessively complex. A report on the sustainable development of the Waterberg Coalfields in 2010 stated that the groundwater flow direction follows the topography in a north-north westerly direction.

2.3 Case Study: Grootegeluk Mine

The Grootegeluk Open Pit Mine is located to the south of the Daarby Fault (Figure 2-6). The type of mining performed here requires blasting and mechanical excavation on individual benches. The mined pit is currently at zone 3, located about 100 m below surface. The mine annually extracts about 15 million tons of run of mine products from the pit (Johnstone, 1989), of which 3.5 million tons are power station grade coal, 1.82 million tons coking coal and the remaining 9.7 million tons plant discards. Overburden and the discards are mixed and placed on waste dumps north of the Daarby Fault.

The Grootegeluk Mine has the largest coal washing facility in the world. Clean coal production at Grootegeluk Mine is about 16 million tons per year and consists mainly of four

products; coking coal, power station (steam) coal and metallurgical coal and powder coal injection coal (Adamski, 2003). The raw coal is of high ash content and large coal beneficiation plants are needed to meet the production targets. This is the main reason why five plants have been erected at Grootegeluk Mine since 1980 to produce high quantities of coal.

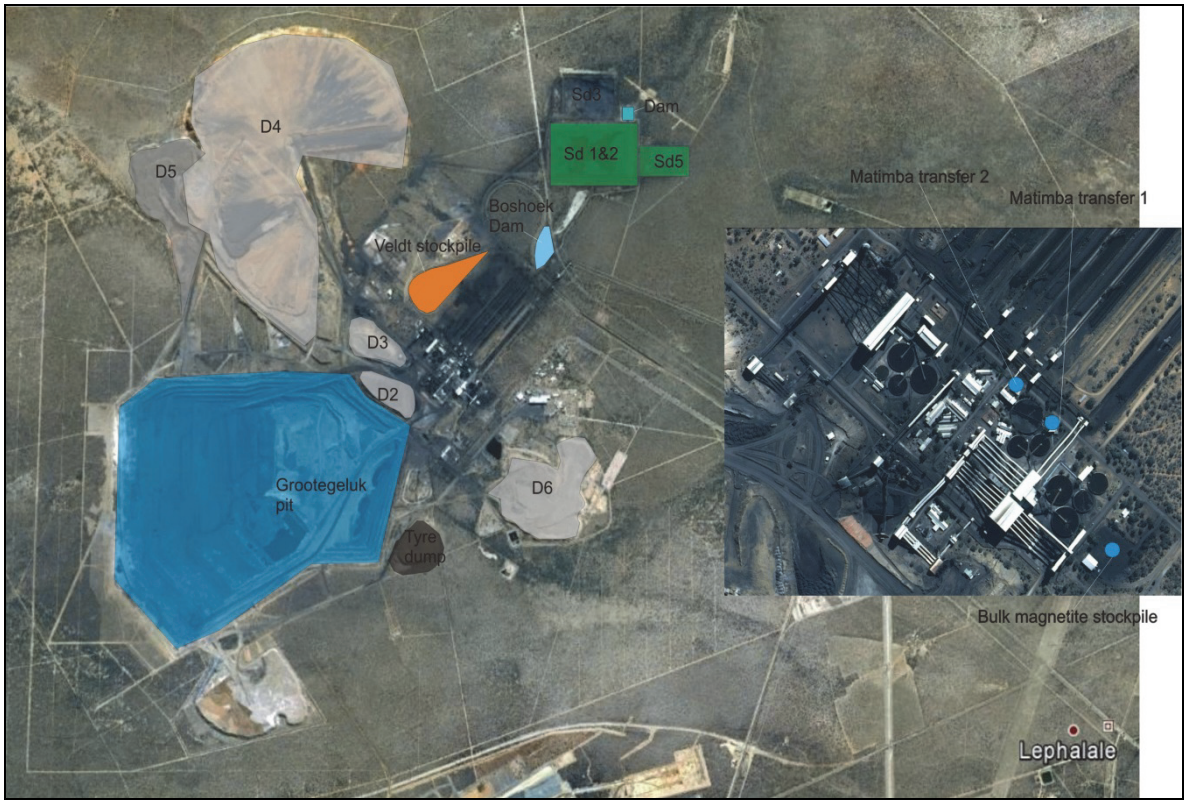

Figure 2-6: The Grootegeluk pit (blue), Processing plant (right insert), discard dumps (D2-D6), slime dams (Sd1, 2 and 5)

2.3.1 Water use and management

Bester (2009) studied the groundwater flow based on observations made near the Grootegeluk Mine and determined the influence the mine would have on the surrounding aquifers. The addition of new open pit mines is understood to alter the flow direction of groundwater. During the creation of the open pits, the topography is changed and directly affects the groundwater flow. The newly created depression will divert water into the pit and in extreme situations reverse the groundwater flow.

Water levels south of the Daarby Fault surrounding the open pit show a steady decline in regional piezometric levels. This decline is due to the continual dewatering of the open pit. The decline from an 890 mamsl before mining operations, to 840 mamsl at the then open pit, was calculated by Johnstone (1989). Further declines in groundwater levels around the pit could be expected.

Conversely, water levels north of the Daarby Fault show a steady increase in the regional piezometric level of one or two meters per year. This increase is only after the summer rainfall events, but there appears to be a continuous recharge throughout the year which could indicate that recharge could be from other sources. Johnstone (1989) estimated the amount of process water and water from the open pit (introduced to the area north of the Daarby fault) at approximately 2000 m^3 per day. He also reports waste dump permeabilities that are 100 times that of the adjacent soils of the dumps.

The major contrast between the water levels north and south of the Daarby Fault suggests two aquifer units on each side, with little if any hydraulic connection between the two. The different water levels on opposite sides of the fault again indicate the impermeability of the fault.

2.3.2 Mining and processing

Grootegeluk Mine commenced in 1980 to produce a blend of coking coal for steelworkers' coke ovens (Kumba Resources, 2012). Thermal coal was produced as a co-product in the washing plant (GG1). It is stored and used at Matimba Power Station. GG2 (second washing plant) was specially constructed to produce power station thermal coal in order to enhance and retrieve the full tonnage of thermal coal for Matimba Power Station. The raw coal consists of finely inter-bedded layers of sandstone and shale and thus needs to be crushed in order to liberate the coal.

Various mining spoils or mining waste is produced during different processes of the mining operation. The three main types of waste produced by the Grootegeluk Colliery include overburden that needs to be stripped to reach the coal layers during open cast mining, interburden (consists of material between coal layers that are not viable to mine) and coal discards from beneficiation plants. The plant discards have a high propensity towards spontaneous combustion, which is due to their high carbon content. The inter-burden material is very prone to spontaneous combustion because of its carbonaceous nature. The major problem associated with such a large quantity of waste is the safe storage and disposal in a way that will prevent the occurrence of spontaneous combustion.

The discard materials that need to be handled are mixtures of discards from various plants and waste from benches both with unknown properties. The lack of detailed knowledge about material properties complicates the design of a “safe” heap.

2.3.3 Effect of mining on surface water

The area has no dominant surface water features that are permanent in the Waterberg Coalfield. The surface water can only be seen in rainy seasons, as it appears as water pools. Changes in the surface water have been noted in the pit bottom sump as well as the seepage from the exposed faces to the sump (Roux, 2011). The challenge of contamination is more prominent in the wet seasons, when the exposed faces of the pit and its oxidation

products are washed. The oxidation products have contributed mainly to the increase in total dissolved salts, electrical conductivity and the sulphate concentration which contributes to the acidification of the water.

Surface water contamination occurs as the result of overflow, spillage or excess water due to process problems or natural events that channel from the plant area via the storm water drainage system to the slimes handling facility. The type of contamination that will therefore occur in the surface water bodies will be similar to that of groundwater, with an exception of hydrocarbon contamination that will occur as the result of oil spillages from the mining fleet.

2.3.4 Water quality

Most of the Grootegeluk mine's infrastructure is situated north of the Daarby Fault. The mining operation has caused a raise in water levels of the water in the aquifers on the north eastern side of the Daarby Fault and changed the groundwater chemistry in this compartment (aquifers). The water dams, washing areas, slimes dams and storm water dams were unlined which caused the seepage to go to the aquifers. This contributed greatly to the change in the water chemistry and water level. In the mining compartment, the water level is lowered (Bester, 2009)

A comparison between the groundwater entering the open pit and the groundwater from the Beaufort/Ecca aquifer shows high total dissolved solids (particularly sulphate, magnesium and calcium). The impermeable Daarby Fault results in most of the groundwater that enters the pit to originate from the Beaufort/Ecca sediments. The high values of calcium, magnesium and sulphate salts are presumed to be mobilised by percolating rain water that dissolves salts from joints and fractures. Along with the lowering of the water levels, the previously saturated Ecca sediments are exposed to oxygen which increases the precipitation of salts along fractures and bedding planes. Rain water migrates to the groundwater through these fractures, resulting in the dissolution of salts and increase in the total dissolved solid content of the groundwater as well as being the reason for the difference in water quality.

The Matimba Fly Ash Dump is situated on the Zwartwater farm. This area has higher EC values than the surrounding study area. The major difference is attributed to the following reasons (Bester**,** 2009):

- The natural causes can be credited to the position of drilled boreholes.
- The boreholes south of the Eenzaamheid Fault marks the transition from Karoo rocks north of the fault, into Waterberg Group rocks south of the fault.
- The Waterberg Group sandstones generally have a lower salt content than the Karoo group (Dreyer Pers. comm, 2014). Accordingly it is possible that the salts from the rocks have leached into the groundwater, resulting in the higher EC values in Figure 2-7.

Anthropogenic causes can be attributed to the farm location (fly-ash dump for the Matimba Power Station) and the possibility of salts leaching from dumps into the farm boreholes. The boreholes are hosted within the Waterberg Group rocks in the shallow aquifer. The salts will enter the upper weathered aquifer during periods of high recharge and move through the unweathered aquifer. The boreholes drilled into the Waterberg Group have higher EC values and this is thought to be affected by the position of the boreholes that have been drilled into a dyke. A major contribution to this change is the location which is situated close to the ash dump and is contaminated by the leachate that is moving downward from the dump, compared to the boreholes drilled into the Karoo rocks.

There are some boreholes in the Karoo rocks that have a high EC. This does not specifically have to do with contamination, but with the depth of the borehole which has been noted at 420 m and situated south of the Daarby Fault, far from mine infrastructure. The water quality of the study area and the surrounding area is summarised in Figure 2-7.

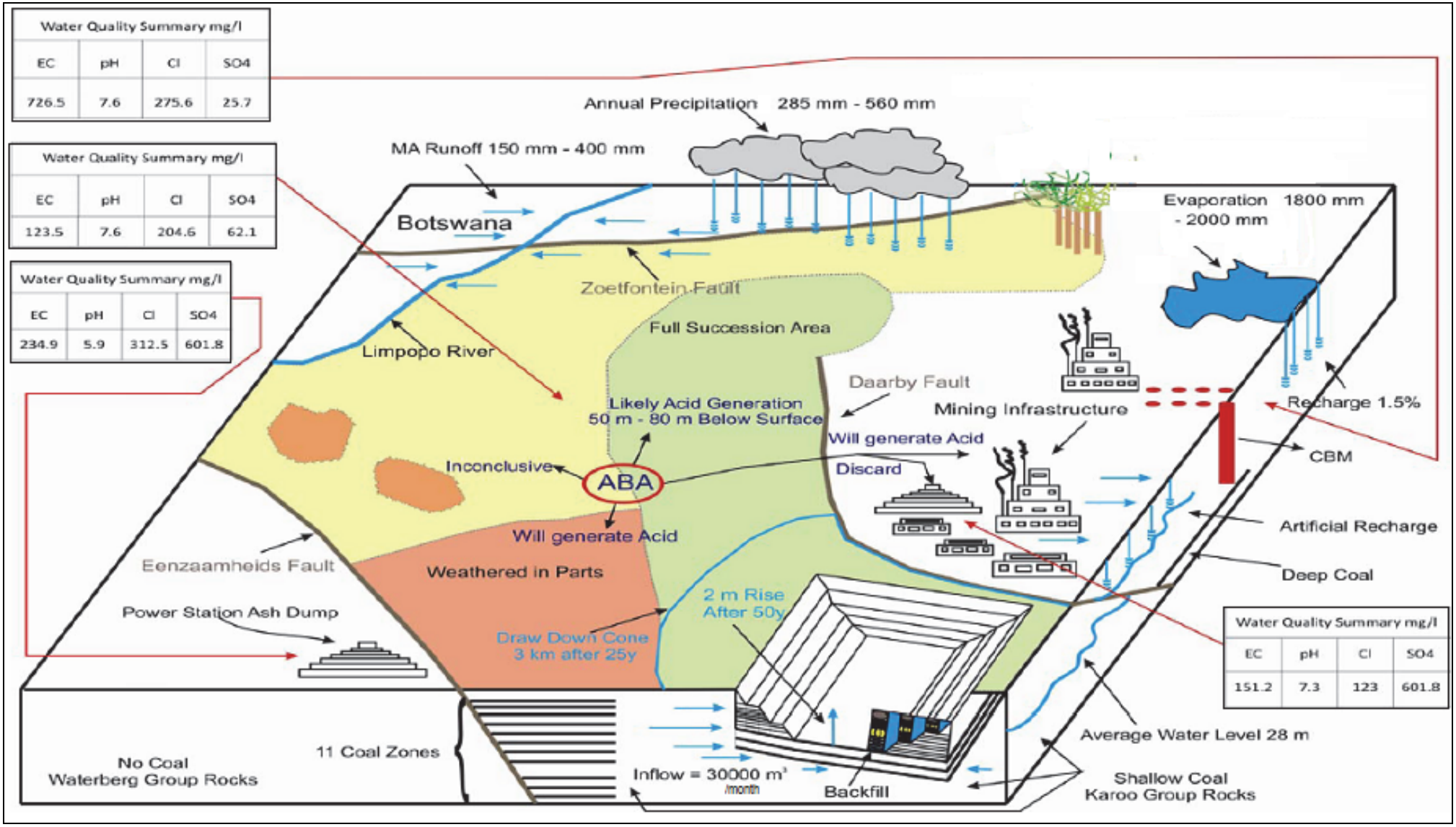

Figure 2-7: Summary of the water quality in the study and surrounding area (Modified from Bester, 2009)

3 Acid Base Accounting (ABA) Tests and Analysis

In order to assess the various acid and base producing potentials of the material sampled from various sections in the study area, ABA tests were performed. This consists of two parts of tests, static and kinetic. The static test provides a rough indication of the acid generation potentials of the various lithological units. The kinetic test is done over a period of 20 weeks and helps to establish which of the samples are prone to produce acid by exposing it to water and oxygen and to establish the rate of constituent leaching.

3.1 Introduction to static ABA

Acid-base accounting analyses (ABA) are according to Usher *et al.* (2002) a first-order classification procedure only, during which the acid-neutralising and acid-generating potential of rock samples are determined and the difference, also known as the net neutralising potential (NNP), can be calculated. Different methods of conducting ABA test work will lead to different sets of sample data for evaluation. The method only indicates the overall balance of acidification potential (AP) and neutralisation potential (NP) and is in its most basic form, merely a screening process. Accordingly, it provides no information on the speed (kinetic rate) at which acid generation or neutralisation will take place and due to limitations, ABA procedures are known as Static Procedures (Usher *et al.,* 2002). A given potential of a rock or coal sample to generate or neutralise acid is determined by its mineralogical composition. It is not only the quantitative mineralogical composition, but also includes individual mineral grain size, shape, texture, and spatial relationship with other grains in the rock (Usher *et al.,* 2002).

ABA can only yield a "worst case scenario" value for potential acid production and a "worst case", "most likely case", or "best case" value for potential neutralisation (Usher *et al.,* 2002). The neutralisation potential is a measurement of the sum of the total carbonates, alkaline earth's and bases available to neutralise acidity and therefore represents the most favourable condition.

The values resulting from these calculations, expressed as calcium carbonate equivalent, are compared in order to compute a net acid-producing or neutralising potential. According to Usher *et al.* (2002), "material exhibiting a net acid production potential of 5 tons/1000 tons of overburden material or more as calcium carbonate equivalent, is classed as toxic or potentially toxic". Studies have shown that "the application of the acid-base accounting methods to overburden handling and placement throughout the USA and Canada has generally been effective in eliminating or reducing adverse water quality impacts".

3.1.1 The Primary Advantages of ABA

- Short turn-around time for sample processing,
- Low cost,
- Relatively simple analytical procedures,
- Relatively simple interpretation of results (Usher *et al.,* 2002),

3.1.2 The Primary Disadvantages of ABA

- The method only predicts a maximum potential acidity and a maximum neutralisation capability, assuming complete acid/base consumption. According to Usher *et al.* (2002), the actual acid production and neutralisation release rates cannot be predicted in this manner, nor can the completeness of the reaction be assessed.
- ABA assumes that all the acid production from a rock can be attributable to iron disulphide minerals (predominantly pyrite) (Usher *et al.,* 2002).
- The measurement of NP utilises a hot acid extract to measure carbonates and bases.

3.1.3 Prediction Methods

It is believed that an accurate form of prediction offers the most cost-effective means of reducing the potential impact of AMD. These impacts that are being measured on the environment and in the mining sector as the costs associated with AMD can be prevented by allowing advanced planning for prevention and control (Usher *et al.,* 2002).

The objective of a prediction programme is to reduce uncertainty to a level at which potential risk and liability can be identified and effective extraction, waste handling and where necessary, mitigation and monitoring strategies, can be selected.

The scope of a prediction programme will depend on site-specific conditions and factors. Some programmes may comprise a few simple tests, in a relatively short period of time and with a modest budget. Others can involve extensive testing and analyses lasting several months to more than two years, with much higher costs.

The approach can include some or all of the following:

- Initial assessment and site reconnaissance.
- Sampling.
- Chemical, mineralogical and physical analyses.
- Short-term leaching tests.
- Geochemical static tests (ABA).
- Geochemical kinetic tests.
- Mathematical models.

With sufficient data the potentially higher accuracy of models and predictions can minimise the impact of acid generation in the mines. The IGS most commonly, uses the static peroxide method for ABA. This method is explained in more detail on the next page (Usher *et al.,* 2002).

3.1.4 Static Methods (Acid-Base Accounting)

Static methods are some of the more common tests generally used for ABA calculations. These are screening methods to determine the difference between the acid-generating capability and the acid-neutralising potential of a particular sample or set of samples.

Listed in Table 3-A are the most common procedures in static ABA testing.

Table 3-A: Most commonly used static ABA methods (Usher et al., 2002)

Paste pH	Static Net Acid Generation (NAG) procedure
Peroxide methods	BC Research Initial test
Sulphur content	BC Research Confirmation Test
Calculated NP	Sobek Neutralisation Potential method
Carbonate NP determination	Modified acid-base accounting procedures for neutralising potential
Lapakko neutralisation potential test procedure	COASTECH modified biological oxidation test
Net Carbonate Value (NCV) for acid-base accounting	

3.1.5 Peroxide Methods

Several tests using hydrogen peroxide as an oxidant for sulphide minerals exist for use in ABA calculations. The one that will be used for this study is the Net Acid Production (NAP), or Net Acid Generation (NAG) test. The NAP, or NAG test (Table 3-B), was developed to provide an alternative to acid-base accounting in order to predict acid rock drainage. The NAP test was used as it possesses the advantage of not requiring sulphur analysis and therefore has potential to be a quick method usable in the field if necessary. The NAP test can also provide an accurate quantitative assessment of acid-generating potential under controlled laboratory conditions.

Current work indicates that NAP test results correlate well with ABA, particularly when the net neutralisation potential values are relatively low and negative, which is the range in which greater certainty is required (Usher *et al.,* 2002). When the NNP values are negative, the NAP values tend to underestimate the acid-generating potential. This should however not seriously affect waste management decisions. The test relies on the ability of hydrogen peroxide to oxidise sulphides, such as pyrite, in a sample of mining waste to produce sulphuric acid.

The acid produced is simultaneously neutralised by carbonates and/or other acid-consuming minerals in the sample. At the end of the reaction, the final pH of slurry provides a qualitative indication of acid-generating potential. Titration of the slurry to determine its acid content, allows the calculation of the net acid produced by the peroxide digestion and a quantitative assessment of the acid-generating potential.

The pH recorded at the end of the H_2O_2 digestion step prior to titration, can provide a qualitative indication of the acid-generating potential.

Table 3-B: Interpretation of final NAG test pH (Usher et al., 2002)

Final pH in 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

Precaution should be exercised when interpreting NAP data in this way, since the pH values are dependent on the specific site lithology and mineralogy. Calibration with other tests and

analyses is therefore recommended if the test is to be used in this way. Caution should also be exercised when interpreting NAG test results for coal reject samples and other materials that may contain high levels of organic material (such as potentially acid sulphate soils, dredge sediments, and other lake or marine sediments).

All organic material must be completely oxidised, otherwise acid NAG results could be unrelated to sulphides. Several aliquots of H_2O_2 reagent may be added to the sample to break down organic acidity. Samples with a positive NAP value, high sulphur content and high ANC must be evaluated carefully (Usher *et al.,* 2002).

3.2 Introduction to Kinetic Tests

The composite samples from the discard plants that would be placed back into the pit were mixed according to density with various materials such as ash from power plants, interburden with the highest base potentials and overburden. In the event where the ABA could not predict with certainty if the sample would become acid (or not), kinetic tests were done. The kinetic cells consisted of samples that were inconclusive during ABA analyses. The kinetic cells that were ran included mixtures of the composites from beneficiation plants and different lithological units to assess possible ratios to optimize the current handling of waste material during and after mining operations.

Leachate tests were done on some samples to determine the accuracy of the sulphur percentage obtained from the ABA analyses. The methods used for each process during the determination of the potential acidity are summarised in Figure 3-1.

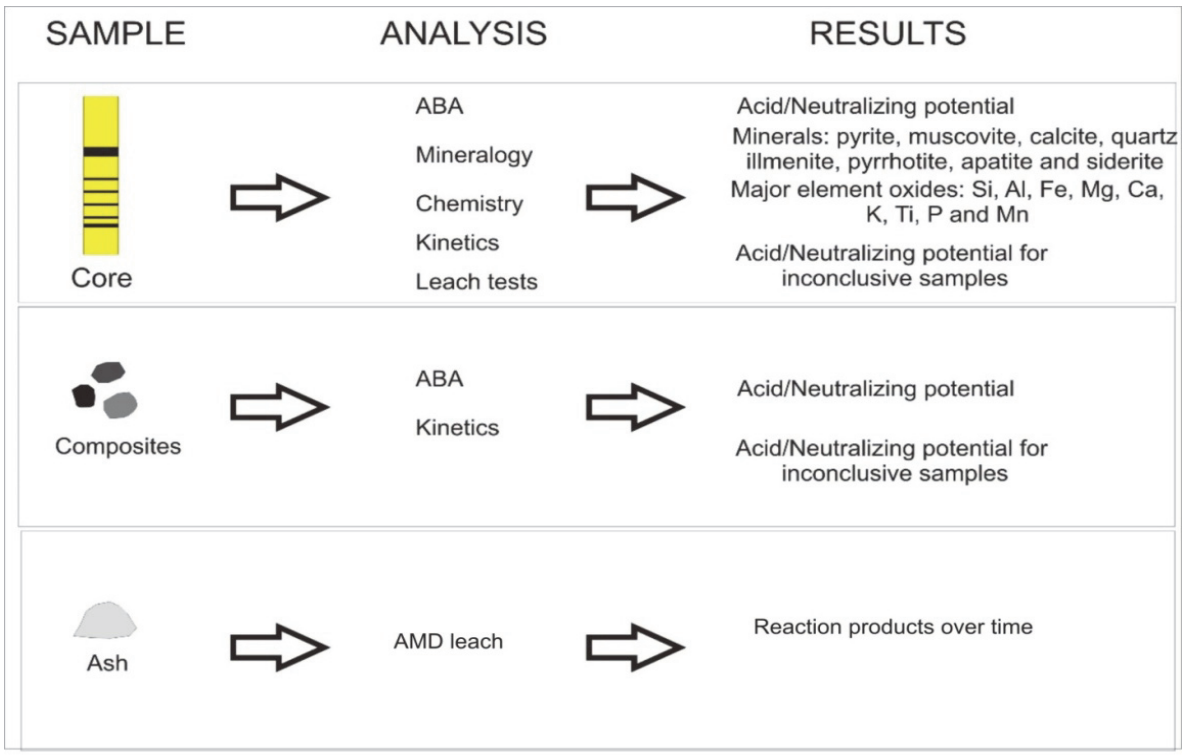

Figure 3-1: A flow chart of the methods used to determine the samples potential to produce acid

3.2.1 Laboratory Kinetic Tests

For material where the potential for acid generation is uncertain, kinetic test work is performed in an attempt to define acid generation characteristics. The term kinetic is used to describe a group of test work procedures wherein the acid generation (metal solubilisation and transport) characteristics of a sample are measured with respect to time. ABA methods are referred to as static, because measurements are made over a short and fixed period of time. Procedures are described below for humidity cells, which is one of the most commonly used methods of determining kinetic AMD characteristics of drill core, waste and other rock samples and tailings.

The main advantages of kinetic tests:

- Test methods are designed to simulate field conditions. (If pyrite oxidation rates and mechanisms can be better understood, it is possible that AMD can be stopped at the source so that complications downstream from mine sites will be eliminated (Jerz and Rimstidt, 2000).
- Reaction rates (kinetics) can be evaluated. Researchers such as Stromberg and Banwart (1999) have shown a good correlation between oxygen consumption and sulphate production in laboratory columns.
- Well-characterised test materials can be utilised.
- Leaching of overburden constituents other than acidity and alkalinity can be evaluated (Hunter, 1997)

The primary disadvantages associated with leaching tests are:

- Test time is lengthy; a typical run time is 20 weeks.
- Analysis is expensive.
- Long-term predictable capability of leaching tests is still uncertain.
- Data interpretation requires a more sophisticated review than the Acid-Base Accounting method (Hunter, 1997).

Currently the most popular kinetic test is the humidity cell test (Figure 3-2). The trend in humidity cell testing is much longer test times ranging from the ASTM suggested 20 week period to more than 2 years. The procedure is designed to mimic the conditions expected to occur in rehabilitated spoil or existing waste conditions. Samples are subjected to alternating water leaching and exposure to moist air. It has been indicated that fine-grained pyrite with a large surface area is much more reactive and more likely to produce acidity than coarse-grained pyritic material. It is suggested that Acid-Base Accounting be used as an initial screening test for overburden samples. Leaching tests will more accurately predict drainage quality (Hunter, 1997).

One of the major weaknesses of kinetic test interpretation is the lack of long-term data. Although tests are now generally run for significantly longer periods than in the recent past, the usual test duration of months or even 1 – 2 years, does not simulate the behaviour of a waste component in time frames often measured in years or tens of years. Assumptions, therefore, have to be made that the stability of concentrations and rates observed after a reasonable length of time of testing can be extrapolated into the future (Lawrence and Day, 1997).

Kinetic tests are carried out to determine the weathering characteristics of a sample as a function of time. For a proposed new mine, specific objectives for both the short-and long-term can include:

- Validation of static test results and classification.
- Determination of the rate of sulphide oxidation/acid generation.
- Determination of the rate of neutralisation depletion.
- Determination of the availability of NP.
- Time to the onset of AMD.
- Evaluation and selection of AMD control methods.
- Prediction of water quality.

Figure 3-2: An IGS humidity cell, left and an array of cells set up at the IGS, right

For an existing mine where AMD might already be a problem, some or all of the above objectives also apply. In addition, it may be necessary to add the following objectives to facilitate the selection of mitigation methods and for the development of a closure plan:

1. Evaluation of the extent of oxidation.
2. Evaluation of the extent of neutralisation.
3. Evaluation of stored reaction products within wastes (Dagenais and Poling, 1997; Lawrence and Day, 1997).

Kinetic tests typically involve subjecting a sample of the waste material to periodic leaching and analysis of the drainage. The most reliable test would be one that replicates exactly the actual field conditions. In practice this is not possible; not only because of the time factor, but also because it is impossible to simulate the physical, chemical, biological, meteorological and other factors associated with an actual dump, tailing impoundment or other mine component. With respect to the time factor, the difficult choice in designing, performing and interpreting a kinetic test is either to have a test which attempts to approximate actual field conditions, in which case the test will usually be of too short a duration, or to provide accelerated conditions, in which case the test might be unrealistic. In the former case, kinetic tests can often fail to demonstrate the onset of AMD or reach any steady state with respect to oxidation rates, neutralisation rates or water quality (Lawrence and Day, 1997).

3.3 Static ABA results

Acid base accounting was performed on samples to provide results for the Acid Potential (AP) and the Neutralising Potential (NP) of the various samples. From the results a summary of the closed NNP, NPR and the S% were given, which better explains NP-AP of the coal/rock samples. The results show that acid-neutralising potential exists for the analysed samples of different lithologies and successions. The ABACUS programme was used to draw the plots to better represent the results.

The straight line for the NPR versus the % Sulphide-S is seen in the majority of the figures. This phenomena is due to a zero base potential value for the sample.

3.3.1 Sasol

Static ABA tests were performed on 231 individual samples from Sasol. Sasol samples were located in the Full succession from the overburden, interburden and coal samples. Samples from this area were taken from the full succession and consist of rocks from the coal, interburden and overburden samples. Overburden samples consist of mudstone while interburden materials have coal, sandstone and shale samples.

3.3.1.1 Initial pH and final pH

The initial and final pH results are shown as a detailed table in Table 7-A. The majority of the results indicate a high risk for acid generation, with the final pH of most samples turning acidic upon complete oxidation. The minimum, maximum and the mean of the initial and final pH results of the Sasol samples are shown in Table 3-C.

Table 3-C: Statistics from the initial and final pH results of the Sasol samples

Sample	Parameter	Initial pH	Final pH
SASOL	Minimum	2.50	0.77
SASOL	Maximum	8.59	8.49
SASOL	Mean	6.93	3.11

It is important to differentiate between so called "**open**" and "**closed**" systems. The carbonate system is predominant in controlling the buffering intensity and neutralising capacity of natural waters, and represents a complex system involving the transfer of carbon among three phases: solid, liquid and gas. When $CO_{2(g)}$ is brought into contact with water, it will dissolve and form carbonic acid (H_2CO_3) until an equilibrium state is reached. Depending on the pH of the solution, the carbonic acid will tend to dissociate to hydrogen, bicarbonate (HCO_3) and carbonate (CO_3^{2-}) ions.

3.3.1.2 In an open system:

$FeS_2 + 2CaCO_3 + 3,75O_2 + 1.5H_2O \Leftrightarrow Fe(OH)_3 + 2SO_4^{2-} + 2Ca^{2+} + 2CO_2$ (carbon dioxide exsolves into the atmosphere)

Acidity produced from 1 mole of FeS_2 (64 g sulphur) is neutralised by 2 moles of $CaCO_3$ (200 g) or 1 g sulphur: 3.125 g $CaCO_3$ (Brady *et al.,* 1994).

3.3.1.3 In a closed system:

$FeS_2 + 2CaCO_3 + 3,75O_2 + 3,5H_2O \Leftrightarrow Fe(OH)_3 + 2SO_4^{2-} + 2Ca^{2+} + 2H_2CO_3$ (carbon dioxide dissolve in water).

H_2CO_3 reacts with carbonate in the following reaction:

$H_2CO_3 + CaCO_3 \Leftrightarrow Ca^{2+} + 2HCO_3^-$

A second reaction depicting the maximum calcium carbonate requirements for acid neutralisation in a closed system may therefore be written as:

$FeS_2 + 4CaCO_3 + 3,75O_2 + 3,5H_2O \Leftrightarrow Fe(OH)_3 + 2SO_4^{2-} + 4Ca^{2+} + 4HCO_3^-$ (Lloyd and Heathcote (1985), Cravotta *et al.* (1990).

In this reaction 1 mole of FeS_2 is neutralised by 4 moles of $CaCO_3$, which results in a mass ratio of 1 g pyrite: 6.25 g calcite. The application of the correct conceptual model is therefore of great importance in the interpretation of the results.

From the static tests done on the samples received from the Sasol mining area, it is clear that acid mine drainage will be produced once base potential has been exhausted. There is limited potential available to buffer the generated acid. The mineralogy confirms this hypothesis (Table 7-M). The Sasol samples also contained coal, whereas for the other regions the coal was removed by the mining companies for analyses.

The ABA analyses showed that the coal samples from the full, middle and partly weathered successions, along with mixtures of mudstone and coal, have the potential to generate acid. The sandstone samples have a higher potential of generating acid. Mudstone from the partly weathered areas showed an excess neutralising potential.

3.3.1.4 Coal and Interburden samples

Coal samples were taken from zones one to eleven, which represents the whole coal succession of the Waterberg coalfield. The samples in Table 7-A have an initial pH that is greater than 6 which indicates that the samples have not yet turned acidic in the field. However the samples showed a final pH that is less than 5.5, classifying the samples as having a medium to high risk of generating acid.

The majority of samples that consists of coal have an NNP that is inconclusive (-20 to 20 kg/tons $CaCO_3$) (Figure 3-3), while other samples have an NNP of a maximum of 121 kg/tons $CaCO_3$ which is an indication of an availability of excess neutralising minerals in the samples. Other samples have an NNP that is up to -360 kg/tons $CaCO_3$ which shows that the samples have a potential of producing acid upon oxidation.

Interburden samples (WGH) (Table 7-B) were taken from depths of 76m to 142m. These samples were collected from the Vryheid Formation (Middle Ecca) which consists mostly of medium to coarse grained sandstone, shale and siltstone. All the samples from the Interburden have a final pH of <2.4 which indicate that the samples have a higher risk of acid generation. Most of the samples have inconclusive, closed NNP results (-20 to 20 kg/tons $CaCO_3$) (Table 7-C). A neutralising potential exists in four samples that have a maximum closed NNP of 125 kg/tons $CaCO_3$. Some samples have a closed NNP value of -40.72 kg/tons $CaCO_3$ which underlines that the samples have a potential to be acidic generators.

3.3.1.5 Overburden samples

Overburden samples (W in Table 7-B) were taken from depths of 8 m to 24 m which lies above coal zone 11 of the Volksrust Formation. The majority of samples have a lower risk of acid generation falling into a final pH range 5.5 to 8.38 (Table 7-B). A few of the samples show a medium to high risk of acid generation based on the final pH between 2.5 to 4.98. These are samples that are located closest to the coal seams. Most of the samples have NNP values of between (-20 to 20 kg/tons $CaCO_3$) (Table 7-C) which are inconclusive and require further to be carried out. Other samples have the potential to be acid generators upon oxidation with a Closed NNP (between -20.34 and -124 kg/tons $CaCO_3$) and samples with access neutralising minerals with a NNP (25 to 71 kg/tons $CaCO_3$).

3.3.1.6 Summary of Sasol

Figure 3-4 and Figure 3-5 shows the NPR of all the Sasol samples that were analysed. Samples in Figure 3-4 show that some of the samples plot above the line of possible acidification and others plot below the ratio of 4:1 where acidification is unlikely to take place. The majority of the samples have a ratio of 1:1. For a sample to produce acid, 0.3% Sulphide-S is needed. Samples that are plotted in Figure 3-5, with a NPR less than 4 and more than 1, are the samples that contain low sulphides and low neutralising minerals. The samples are expected to turn acidic but just until the sulphide minerals are depleted. The majority of the samples (55%) pose a high risk of acid generation from the interburden and coal samples. A 35% low acid generating risk exists from interburden samples. The Vryheid Formation (Middle Ecca) consists of most samples that are acidic generators more than the Volksrust Formation, which contains more carbonaceous material.

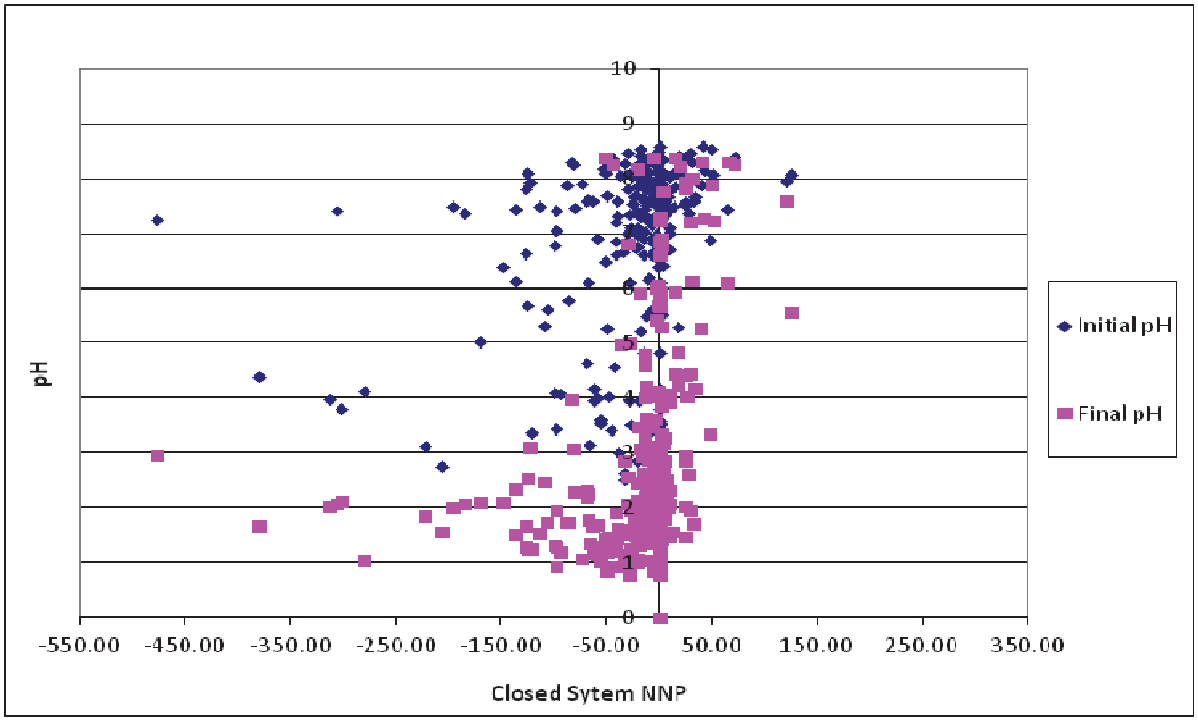

Figure 3-3: Closed NNP plotted versus initial and final pH for Sasol

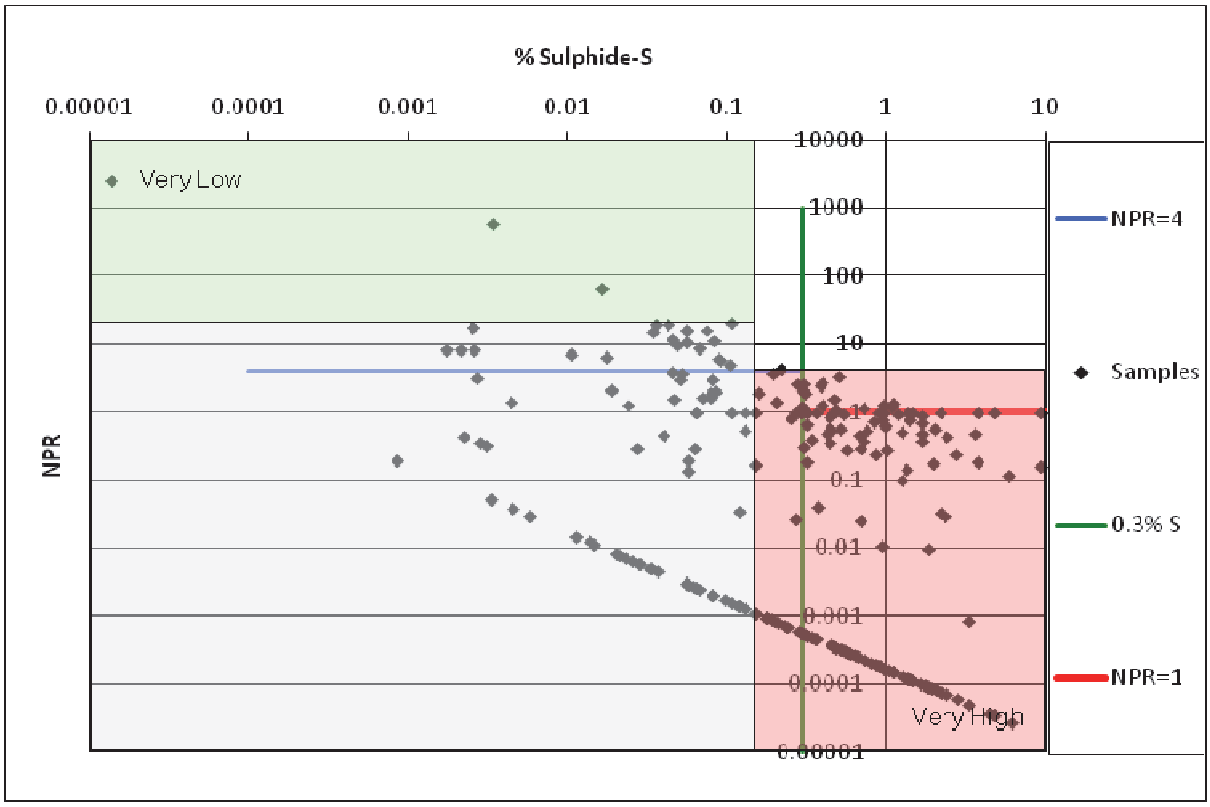

Figure 3-4: NPR versus % Sulphide-S for the Sasol samples tested

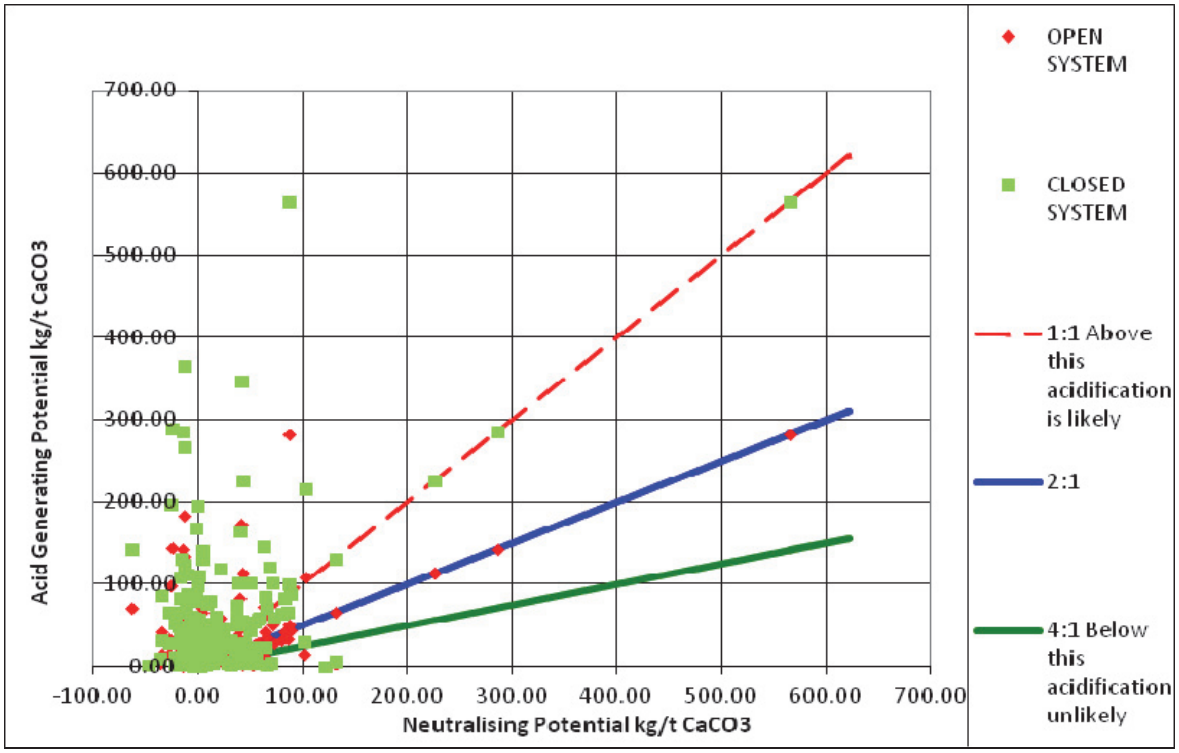

Figure 3-5: NP versus AP (NPR) for the Sasol samples tested

3.3.2 Resgen

A total of 153 samples from Resgen were collected and analysed from the farms Zoetfontein and Lisbon and a detailed table of the results can be seen in Table 7-C. Resgen samples were collected from the Middle Ecca and taken from various depths between 1 to 72 m (Table 7-C). The sample material included overburden and interburden.

3.3.2.1 Initial pH and Final pH

Samples with a medium to high risk of acid generation occur in almost equal proportions. Over 25% of the Resgen samples have an excess of acid potential which classifies the samples as having a higher risk for acid generation. Approximately 40% of the samples have a higher potential to neutralise acid. The remaining 35% have a medium risk to generate acid. The minimum, maximum and mean of the initial and final pH results are shown in Table 3-D. The initial pH of the samples varies between 4.60 and 9.03. The final pH of the samples varies mostly according to depth; samples that were taken from shallow depths between 1 to 25 m have a final pH that is above 5.5. The few samples at depths of 14 to 25 m have pH values below 3.5. Samples that were taken at greater depths between 31 to 72 m have a higher risk of acid generation. The higher risk of acid is associated with the abundance of sandstone found at greater depths in the Vryheid Formation, containing more of the mineral pyrite.

Table 3-D: Statistics from the initial and final (oxidised) pH results of the Resgen samples

Sample	Parameter	Initial pH	Final pH
RESGEN	Minimum	4.60	1.58
RESGEN	Maximum	9.03	8.56
RESGEN	Mean	7.71	4.55

The NNP for both closed and open systems is shown in a detailed table in Table 7-D. The negative values indicate acid production, while positive values indicate the samples with an acid neutralising (base) potential. The NNP (for a closed system) and the initial and final pH results are plotted in the graph, indicating that there is a wide distribution of acid and base potential (Figure 3-6). The closed and open NNP for most of the samples ranges between (-20 to 20 kg/tons CaCO3) which requires further tests to be carried out as the results are inconclusive. A few of the samples have an excess of neutralising minerals with a closed NNP and results that are between (21 to 57 kg/tons $CaCO_3$). Only three samples have a Closed NNP (Figure 3-17) (-65 to -55 kg/tons $CaCO_3$) and are classified as samples that contain enough sulphide minerals to produce acid.

The percentage sulphur (% Sulphide-S) determined in the samples are plotted against the Neutralising Potential Ratio (NPR) and presented in Table 7-D. Figure 3-17 indicates a small risk of acid production with a high base potential, when compared to samples from Sasol. Some of the samples have less than 0.3% Sulphide –S, this amount is not sufficient to cause the samples to generate acid. The AP vs. NP (NPR) for both closed and open systems is illustrated in Figure 3-18. The majority of the samples exhibit an AP-NP ratio of 4:1. This classifies the samples as unlikely to become acidic. A few samples have a ratio of 1:1 indicating the likelihood of producing acid

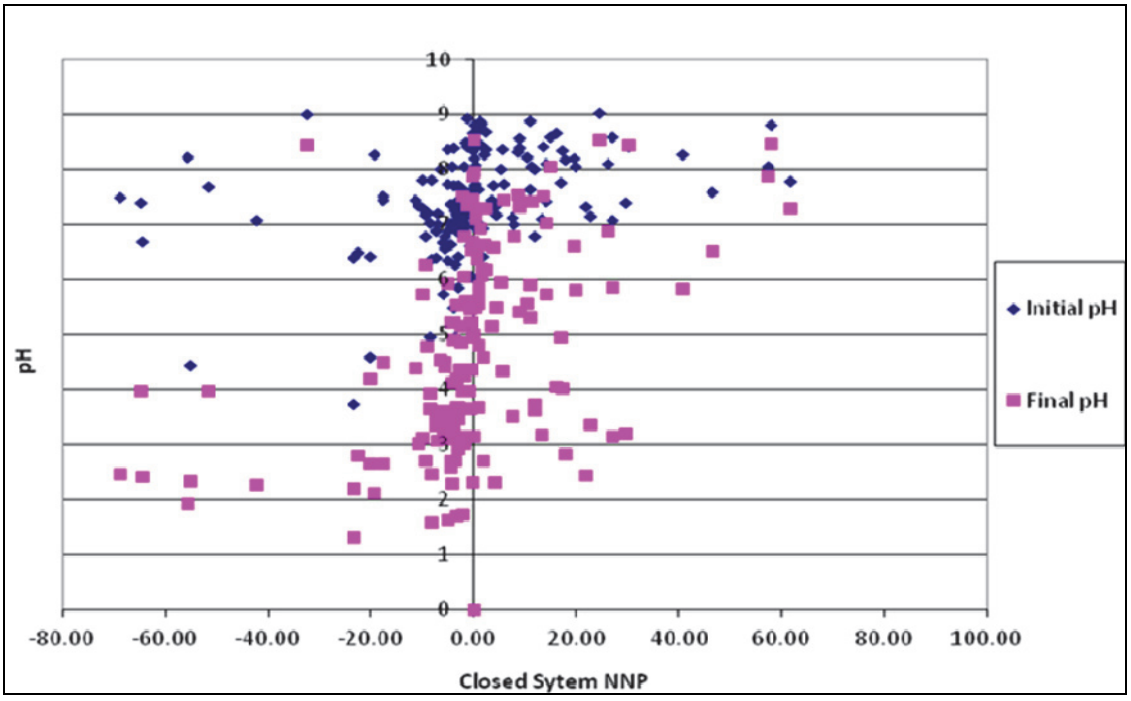

Figure 3-6: NNP versus initial and final pH for Resgen for a closed system

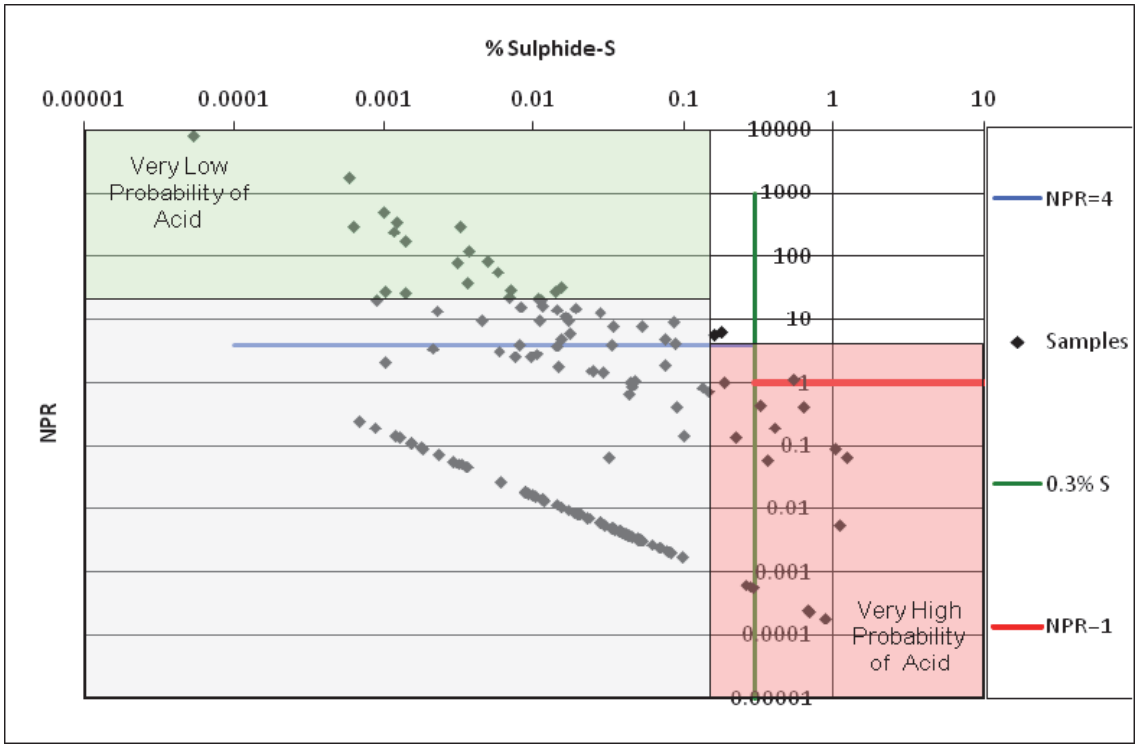

Figure 3-7: NPR versus % S for Resgen samples tested

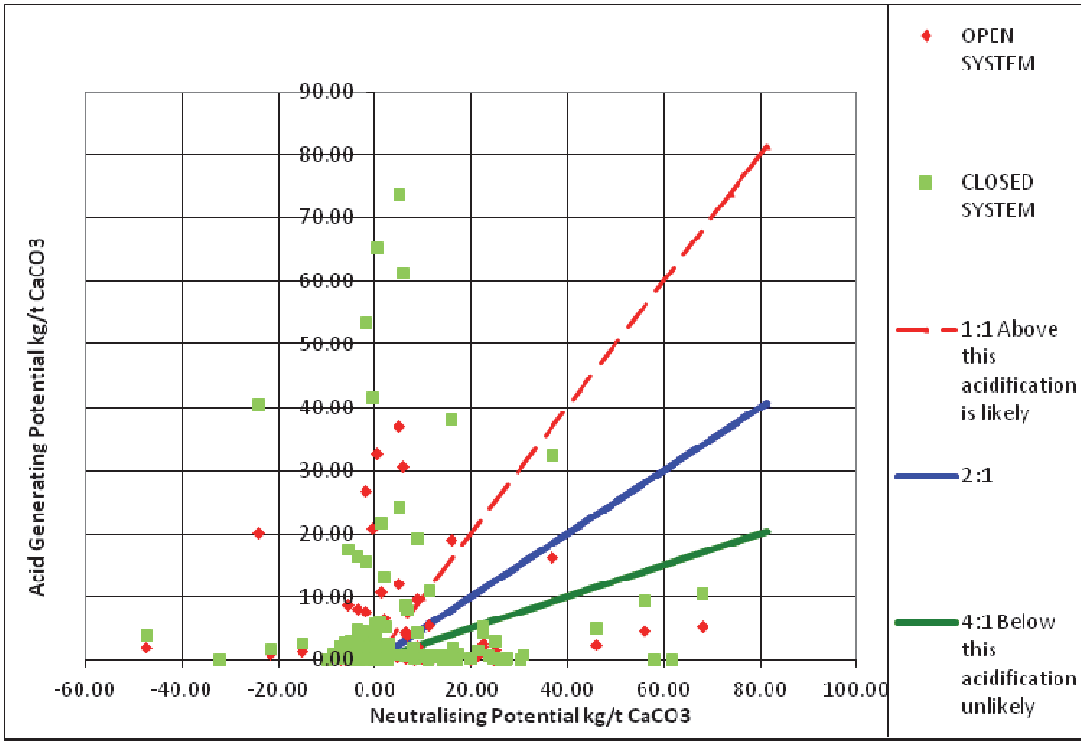

Figure 3-8: NPR (NP versus AP) for the Resgen samples

The ABA results indicated that the calcrete, mudstone and shale samples from Resgen had both a neutralizing, and acid generating potential. The sandstone samples showed inconclusive data which categorises the material as either having an acid or neutralizing potential. Mixtures of shale with mudstone and sandstone showed the potential to produce acid.

3.3.3 Sekoko

The samples collected from Sekoko comprise overburden and interburden selected from drilling cores taken from the Middle Ecca. Static ABA tests were performed on 41 individual samples from Sekoko. The initial and final pH results are shown as a detailed table in Table 7-E. Sampling took place from various depths between 23 m and 141 m and from the areas which are partly weathered at 27 to 61 m.

3.3.3.1 Initial pH and Final pH of the samples

Majority of the samples have an initial pH that is above 6. There in an exception for one sample with a pH of 4.88. The minimum, maximum and mean of the initial and final pH results for the Sekoko samples are shown in Table 3-E. The lowest final pH value for the samples is at 1.79. The high pH value above 6, have a lower risk to generate acid. Some samples show a high risk to generate acid than to neutralise. Over 50% of the Sekoko samples have an excess of acid potential and are classified as a high acid generation risk. About 40% of the samples have a higher base potential. The remaining samples are inconclusive and require further testing.

Table 3-E: Statistics of the initial and final pH results from the Sekoko samples

Sample	Parameter	Initial pH	Final pH
SEKOKO	Minimum	4.88	1.79
SEKOKO	Maximum	7.79	6.60
SEKOKO	Mean	6.70	3.52

The NNP for both closed and open systems is shown as a detailed table in Table 7-F. The NNP (for a closed system), the initial and final pH results indicate a few samples have a limited neutralizing potential (Figure 3-9).

Figure 3-10, shows the ratio of AP vs. NP for the open and closed system where most of the samples plot above NPR 1:1. The samples have the likelihood of turning acidic upon oxidation. A few samples have Sulphide –S values less than 0.3%. The Sekoko samples taken from the Middle Ecca consisted of medium to coarse grained sandstone and in most cases contained pyrite mineral. The % Sulphide-S against the NPR (Figure 3-10) indicated a limited quantity of samples that have a high risk to produce acid. The NPR in Figure 3-11 indicates the limited base potential of some of the samples. The ABA results for sandstone and mudstone samples indicated an acid producing potential.

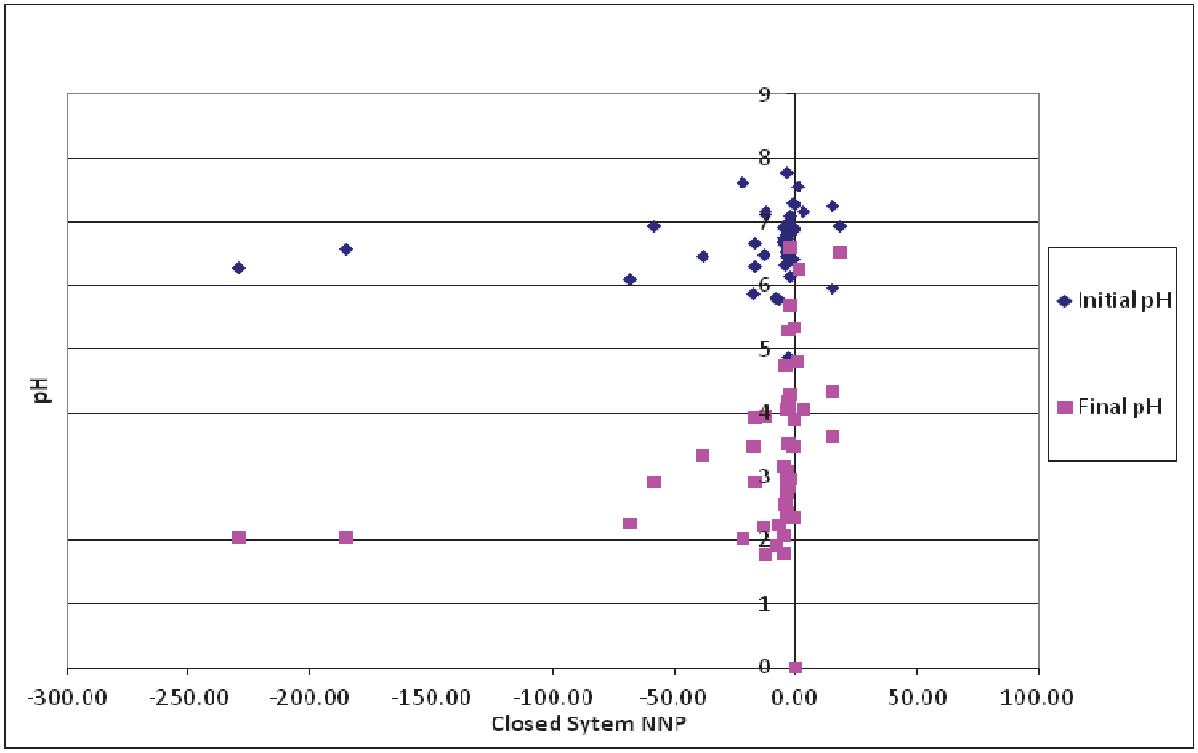

Figure 3-9: NNP (closed) versus initial and final pH for Sekoko

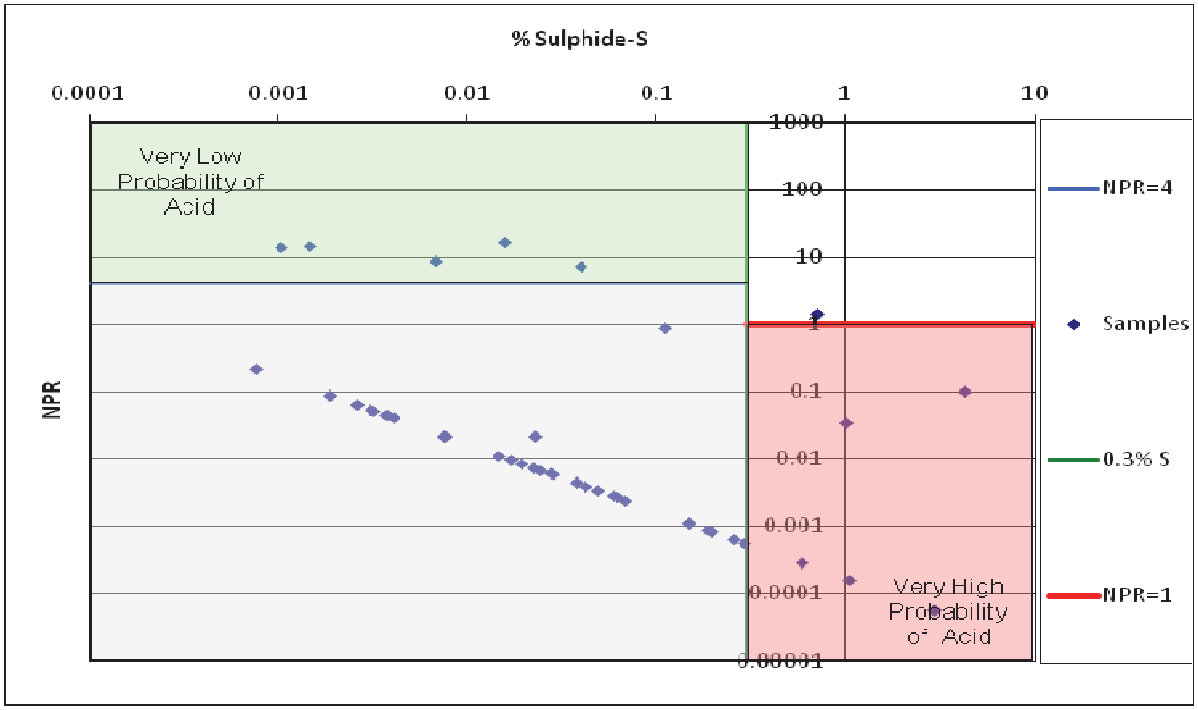

Figure 3-10: NPR versus %S for Sekoko

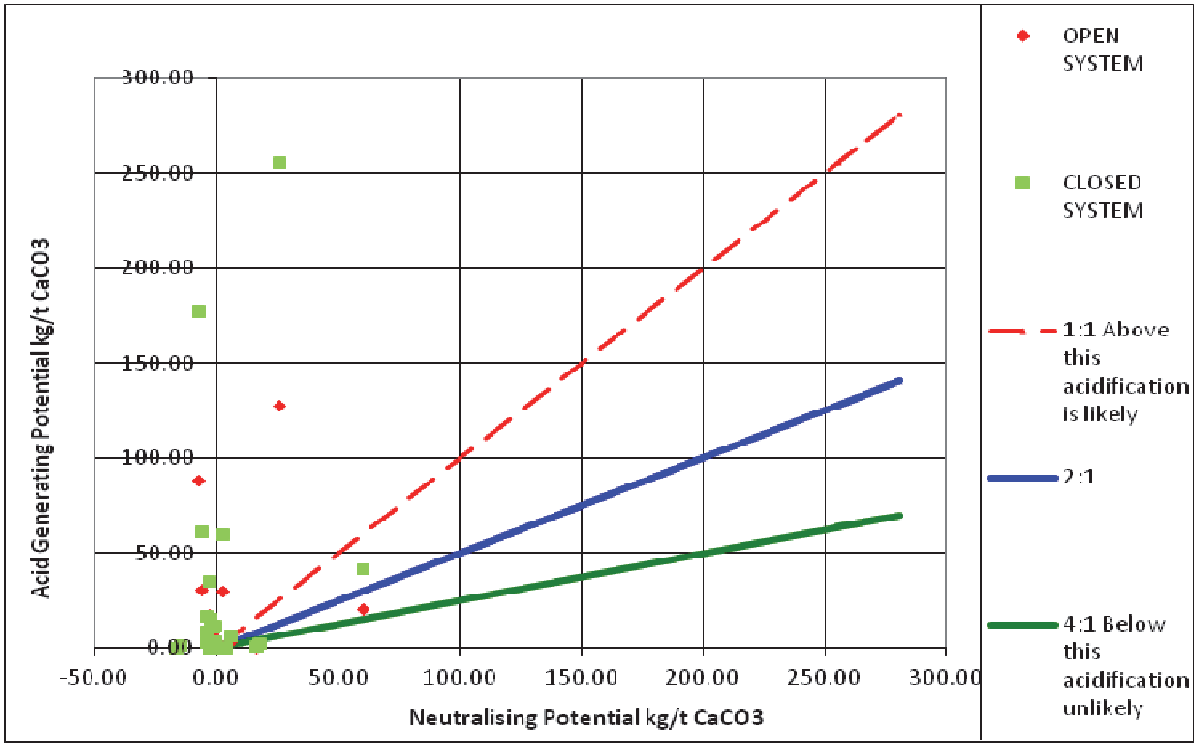

Figure 3-11: NPR versus Sulphide for Sekoko

3.3.4 Grootegeluk

Static ABA tests were performed on 292 Grootegeluk overburden samples taken from different boreholes. Overburden samples from Grootegeluk were collected from the three differently geological regions, based on weathering of the Ecca. The initial and final pH results are shown as a detailed table in Table 7-G.

3.3.4.1 Initial pH and Final pH of the samples

The initial pH of the samples is >6.6. The majority of the samples have a low risk to generate acid, with final pH values between 5.9 and 8.47. Only four samples show a medium acid risk with a final pH of 3.6 to 5.29. Over 50% of the Grootegeluk samples have an excess base potential. Approximately 25% of the samples have a high acid potential. The remaining 25% have a medium risk to generate acid. The minimum, maximum and mean of the initial and final pH results from the Grootegeluk samples are shown in Table 3-F.

Table 3-F: Statistics of the initial and final pH results from the Grootegeluk samples

Sample	Parameter	Initial pH	Final pH
GROOTEGELUK	Minimum	6.37	2.23
GROOTEGELUK	Maximum	8.26	6.26
GROOTEGELUK	Mean	7.49	4.88

The NNP for both closed and open systems is shown as a detailed table in Table 7-G. Over 35% of the results show an NNP range from -20 to 20 kg/tons $CaCO_3$, this indicates the inconclusive nature of the samples. Other samples have an NNP value (21 to 310 kg/tons CaCO3) that

shows the samples have an access in neutralising potential (Figure 3-12). Minerals with a neutralisation potential in the Waterberg Coalfield from the Karoo Supergroup have been identified as calcite and dolomite/ankerite.

The NPR for both closed and open systems is shown in Figure 3-13. The majority of the samples exhibit an AP-NP ratio of 4:1; this indicates the unlikelihood for the samples to become acidic. A few samples with a ratio of 1:1 highlight the likelihood of samples to generate acid. Figure 3-13 shows the majority of the samples have less than 0.3% Sulphide –S. This is a small amount and would not be sufficient to cause the generation of acid. The overburden samples from Grootegeluk consist of more neutralising than acid producing minerals. The NPR results of the Grootegeluk samples are shown as a detailed table in Table 7-H. The overburden samples from Grootegeluk showed the highest base potentials. The NPR results are shown in Figure 3-14.

The ABA analyses of clay, shale and sandstone samples from the partly weathered and full successions indicated neutralising potential. Shale samples from the full succession on the other hand, have strong base producing potential. The samples taken close to the coal layers all have a strong acid generating potential.

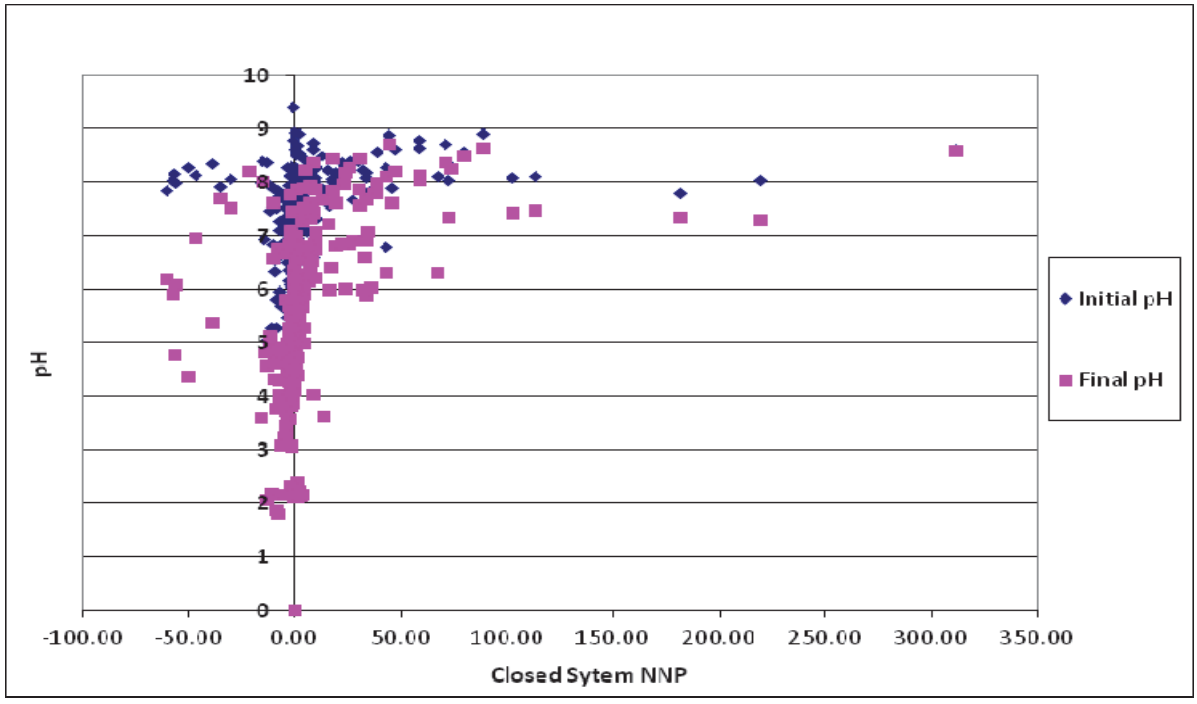

Figure 3-12: NNP (closed) versus initial and final pH for Grootegeluk

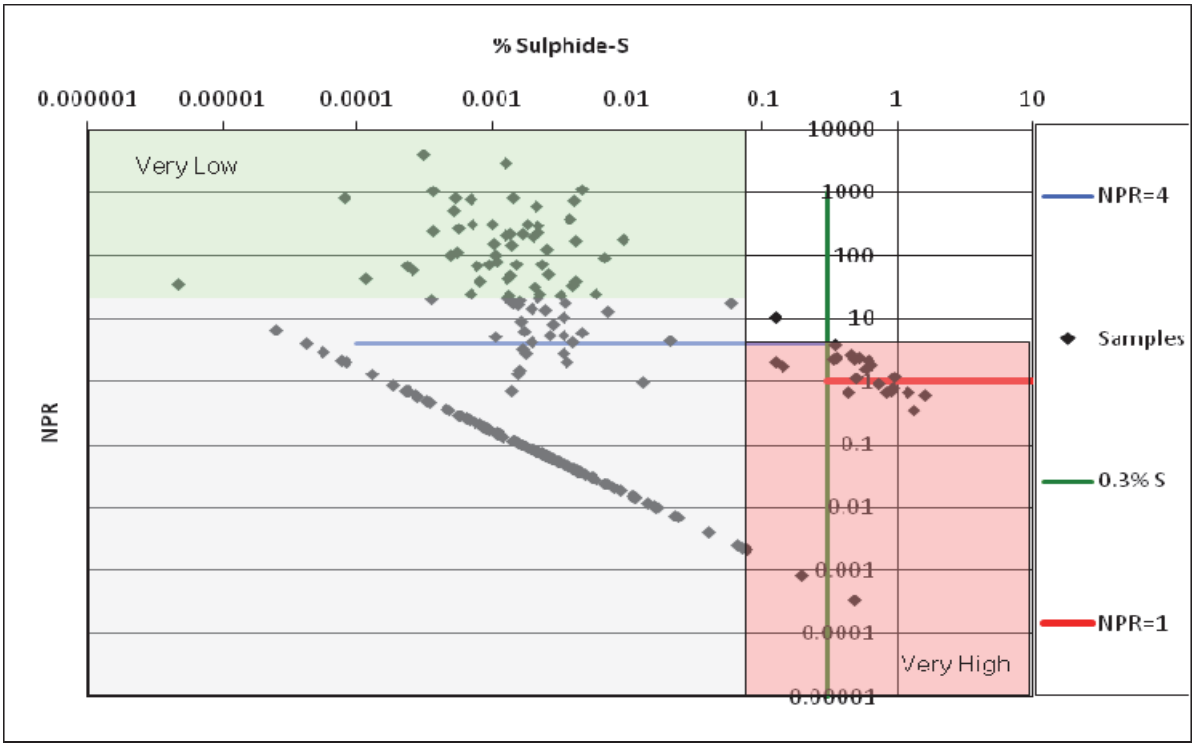

Figure 3-13: NPR versus %S for Grootegeluk

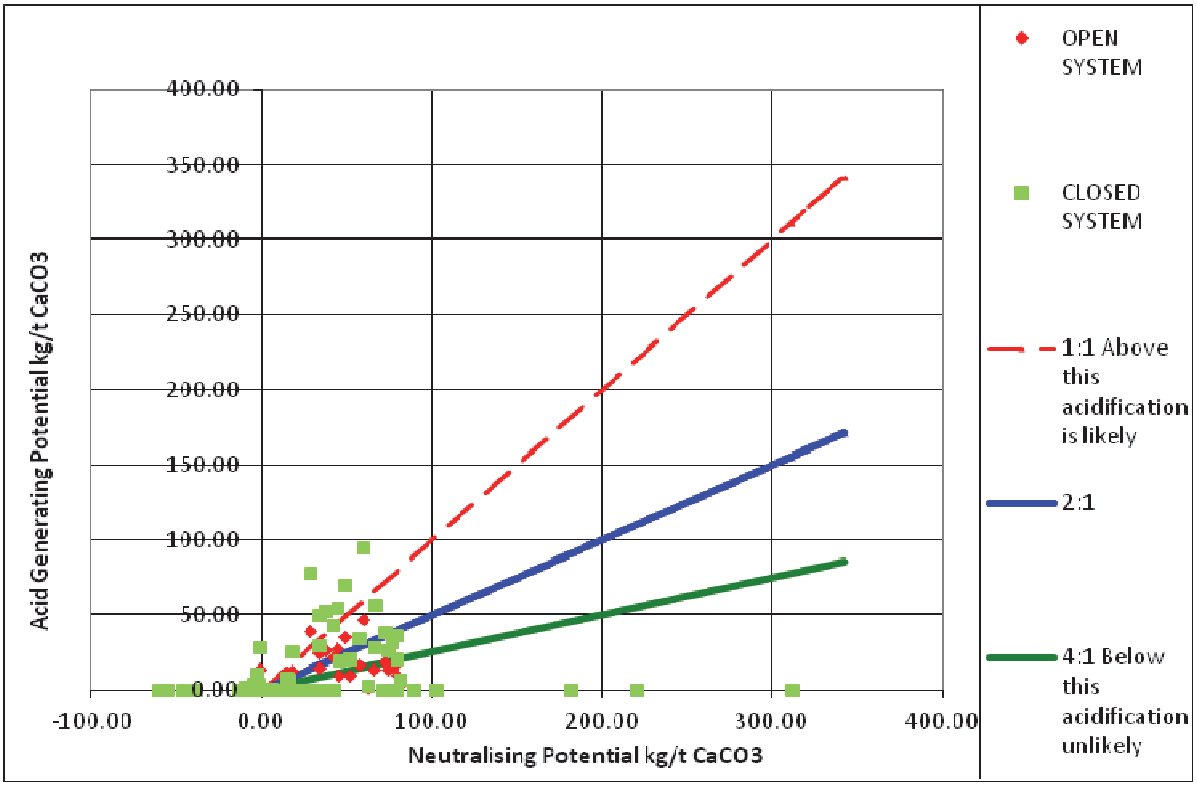

Figure 3-14: NPR (AP versus NP) for Grootegeluk

3.3.5 Composite samples

Static ABA tests were performed on 119 Composite samples, taken from different fractions of the processing plant discard. Only 29 samples were selected and presented in Table 7-I and Table 7-J. The samples selected for Leco tests were selected to represent the composite

material. The fractions consist of float and sink densities range between D1.80-S2.20 and D2.10-S2.20 taken from different zones 1 to 10. Table 7-O gives an indication of SO_4 values after complete oxidation zones 1, 2 and 3 from the Middle Ecca have the highest average of SO_4 which is a phenomena that was noted throughout the analysis in other areas of study.

3.3.5.1 Initial pH and Final pH of the samples

The initial and final pH results indicate that all the samples have a very high risk for acid generation. Approximately 95% of the samples have a higher acid potential. The remaining 5% have a medium risk to generate acid. The minimum, maximum and mean of the initial and the final pH results from the Composite samples are shown in Table 3-G. Samples with higher densities D2.10-S2.20 appear to have lower final pH values than lower density D1.90-S2.20 samples.

Table 3-G: Statistics of the initial and final pH results from the Composite samples

Sample	Parameter	Initial pH	Final pH
Composite	Minimum	3.27	1.57
Composite	Maximum	7.18	5.46
Composite	Mean	6.70	2.36

The NNP for both closed and open systems indicates that negative values indicate acid mine production, while positive values will indicate samples with acid neutralising (base) potential. Only 5% of the results have a NNP range of -20 to 20 kg/tons $CaCO_3$, where the sample can either be acidic or remain neutral (Usher *et al.*, 2003). The majority of the samples have a NNP of more than -50 kg/tons $CaCO_3$ which is indicative of the presence of excess acid minerals. The NNP (for a closed system) and the initial and final pH results are plotted in a graph, indicating the high acid generating potential of the samples (Figure 3-15).

The percentage sulphur (% Sulphide-S) determined in the samples is plotted against the Neutralising Potential Ratio (NPR) (Figure 3-16). The graph shown in Figure 3-16 indicates the majority of the samples have an acid generating potential with very high sulphur content.

The NPR is additionally indicated in a plot of NPR (NP/AP) graph (Figure 3-17). All the samples submitted for ABA analyses have high acid generating potentials.

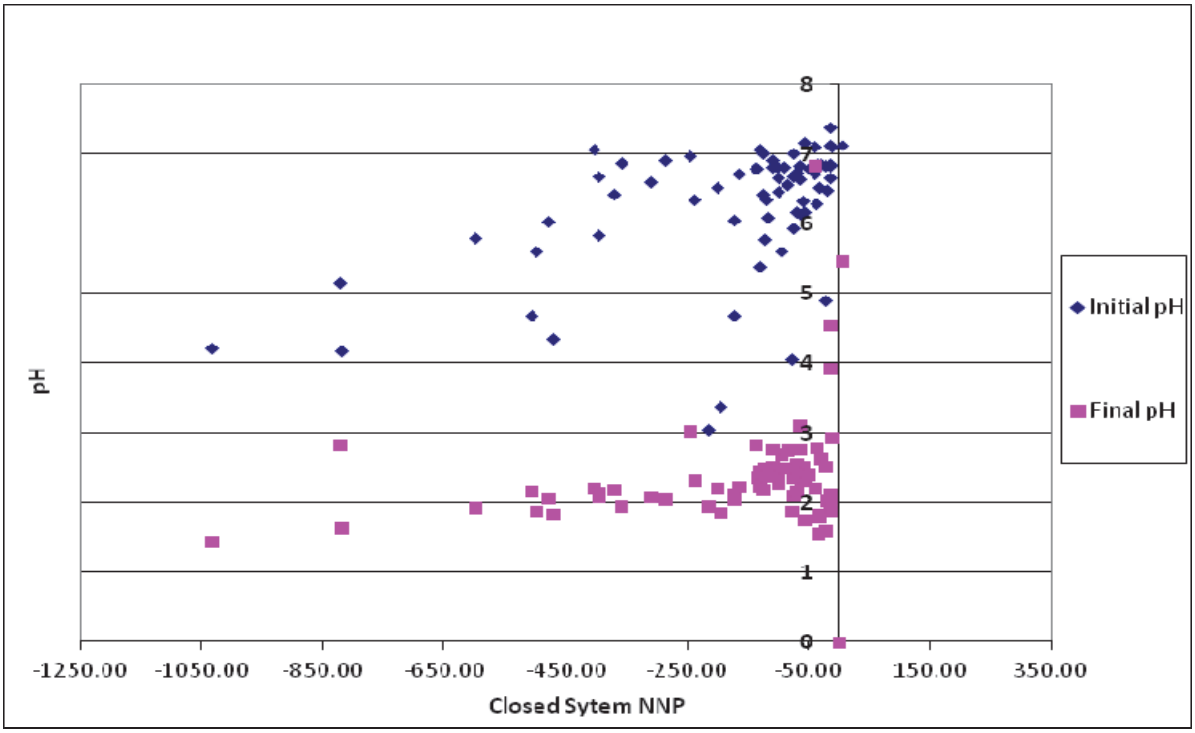

Figure 3-15: NNP (closed) versus initial and final pH for Composite samples

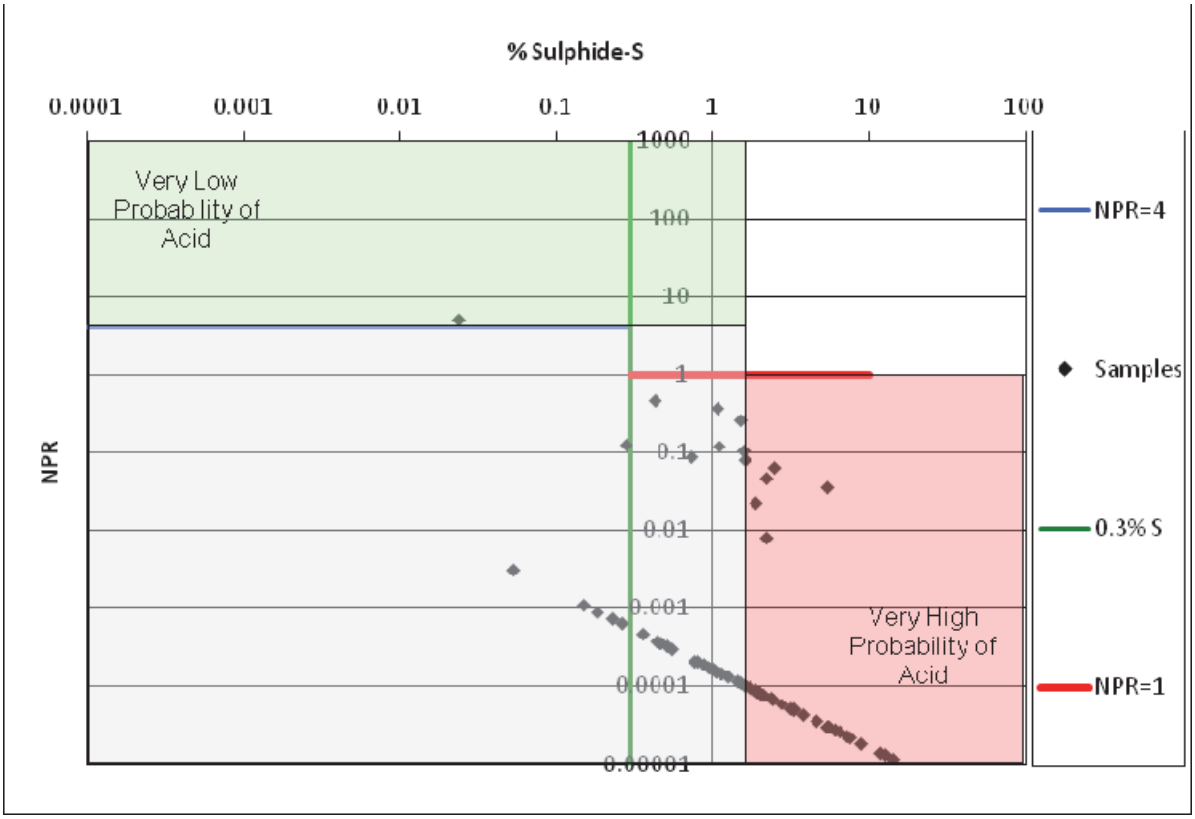

Figure 3-16: NPR versus %S for Composite samples

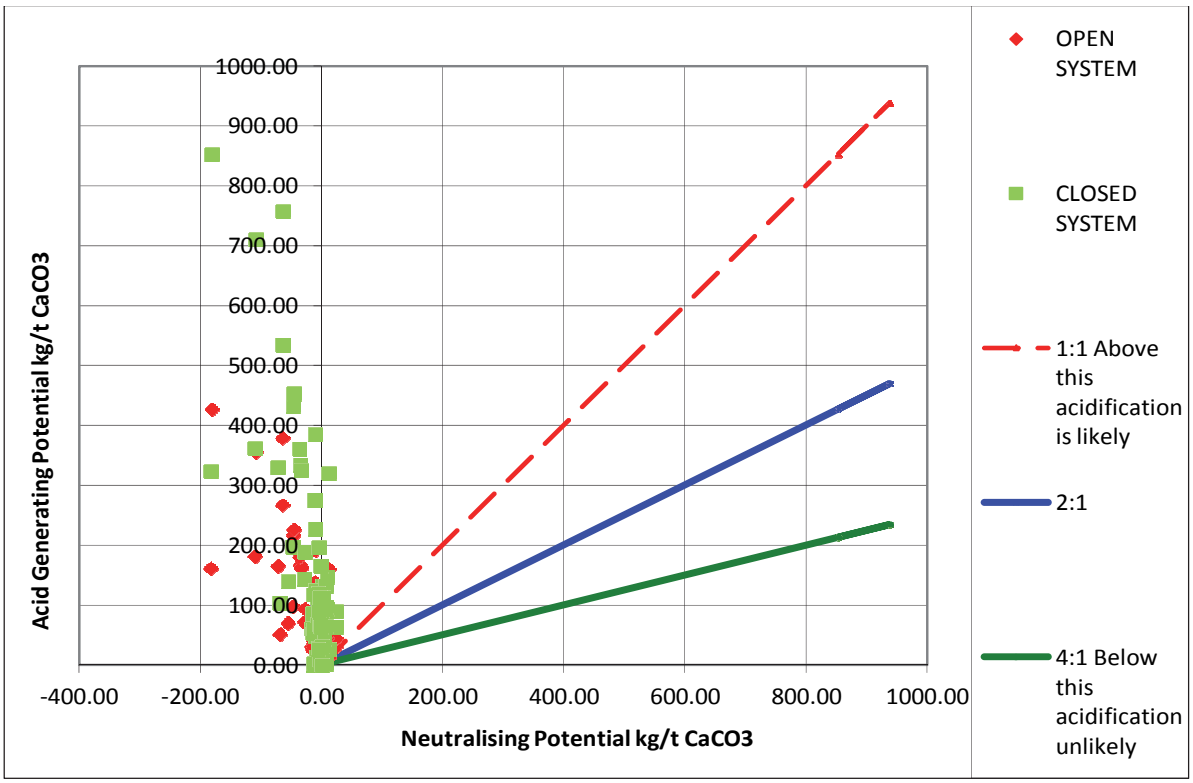

Figure 3-17: NPR (AP versus NP) for Composite samples

3.4 Comparison

The majority of the samples from Sasol are classified as having a NPR of less than 1, implying that the samples have a high potential for acid generation. The difference in NPR is noticed with the Resgen samples where the NPR is 4, which classifies the samples as having a low probability of acid generation. The Resgen samples also have a low sulphide percentage (less than 0.3) which is too low to sustain acid generation. The Sekoko samples show a different trend in this regard as some samples indicate a high probability of acid generation, while others indicate a low probability of acid generation. Samples from Grootegeluk have a NPR of 4, which classifies the samples as having a low probability of acid generation. The composite samples predominantly consisting of processing plant discard have a NPR of less than 1, indicative of a high potential to produce acid.

The static ABA tests are divided into boreholes from different geological areas, namely the full succession, partly weathered and weathered down to the Middle Ecca. The sampled intervals are shown as geological borehole logs where tests have been conducted and it is indicated adjacent to the log, specifying the result of the test and the sample name (Figure 3-18 to Figure 3-22). The samples subjected to testing from the full geological succession, are summarised in Figure 3-18 and Figure 3-19. The partly weathered geological succession, are summarised in Figure 3-20 and Figure 3-21 and the Middle Ecca geological succession in Figure 3-22.

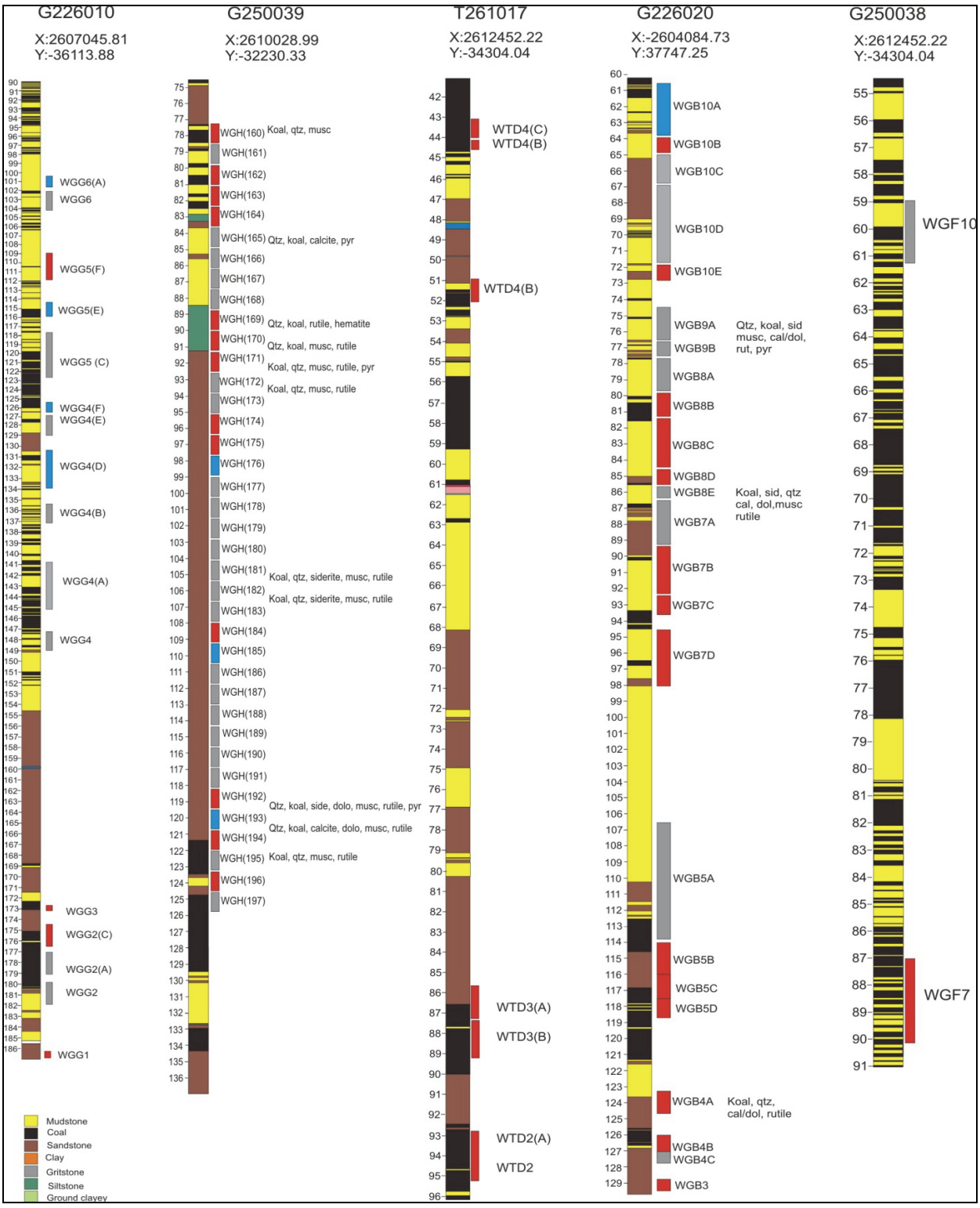

Figure 3-18: Full successions for Sasol. *The sampled intervals are indicated directly next to the borehole profiles with the acid generating potentials, red - acid, blue - neutralizing and grey- inconclusive results. Minerals found within the samples are also indicated where applicable.*

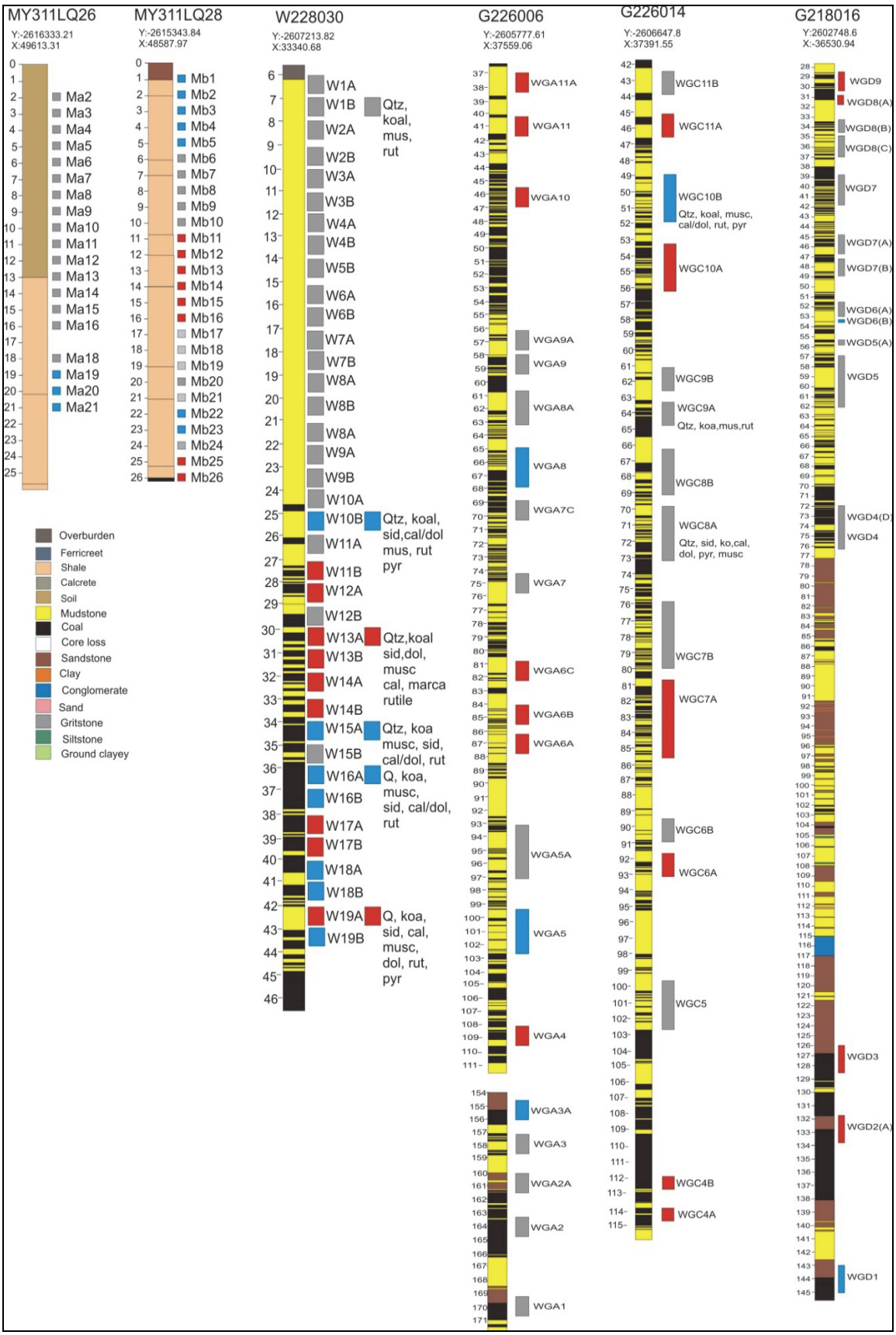

Figure 3-19: Full successions for Sasol and Exxaro. The sampled intervals are indicated directly next to the borehole profiles with the acid generating potentials, red - acid, blue - neutralizing and grey - inconclusive results. Minerals found within the samples are also indicated where applicable.

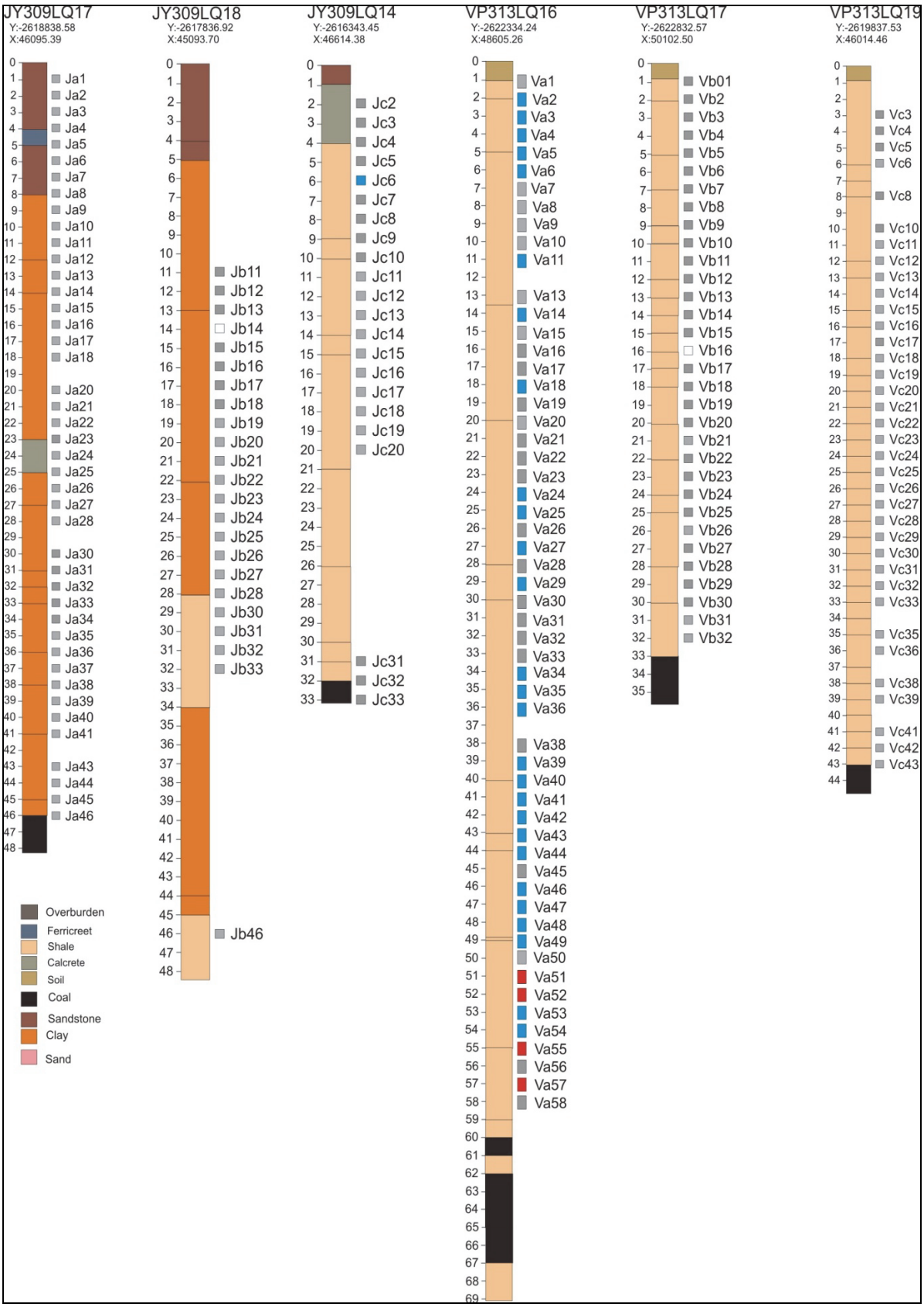

Figure 3-20: Partly weathered successions for Exxaro. The sampled intervals are indicated directly next to the borehole profiles with the acid generating potentials, red - acid, blue - neutralizing and grey - inconclusive results. Minerals found within the samples are also indicated where applicable

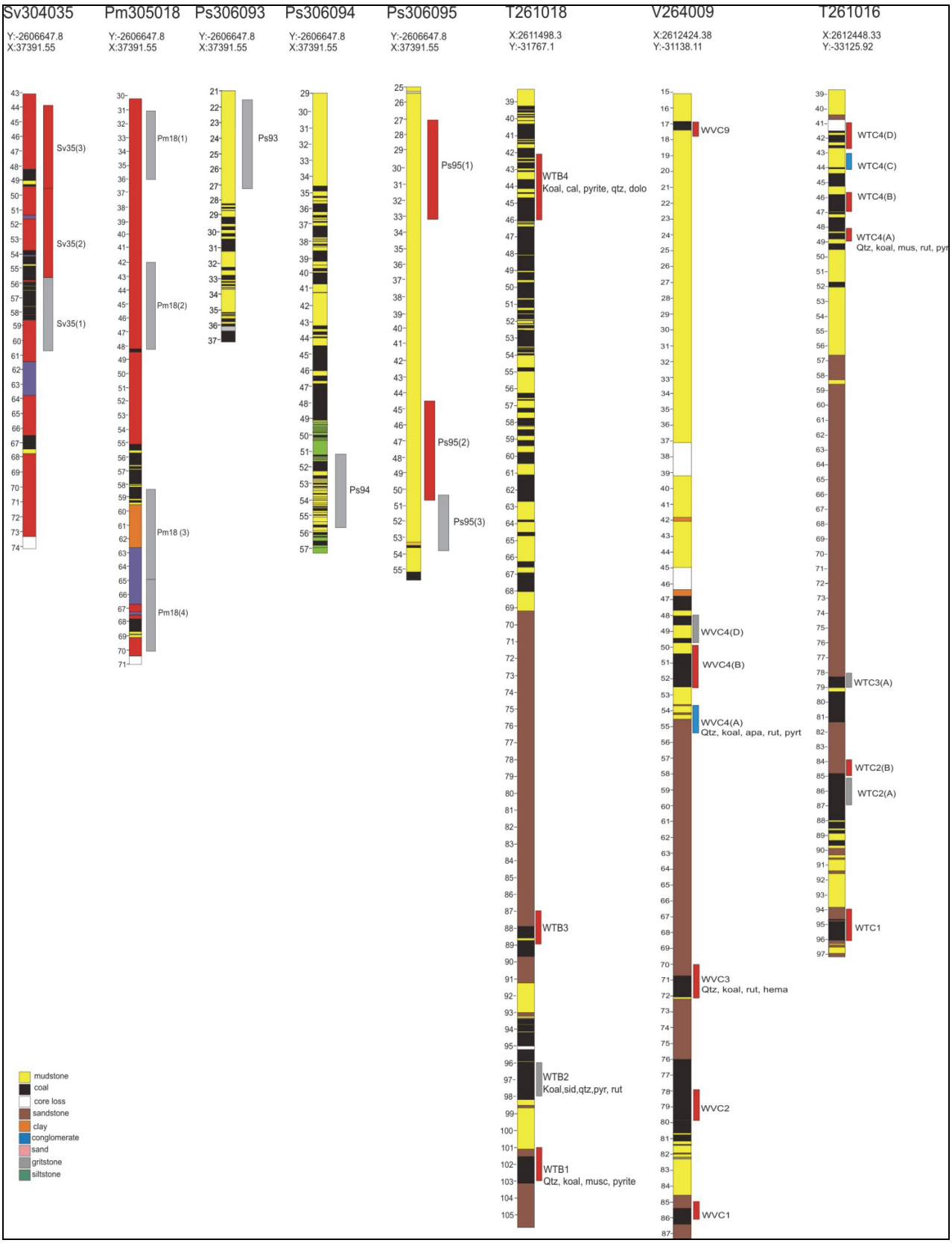

Figure 3-21: Partly weathered successions for Sasol and Sekoko. The sampled intervals are indicated directly next to the borehole profiles with the acid generating potentials, red - acid, blue - neutralizing and grey - inconclusive results. Minerals found within the samples are also indicated where applicable.

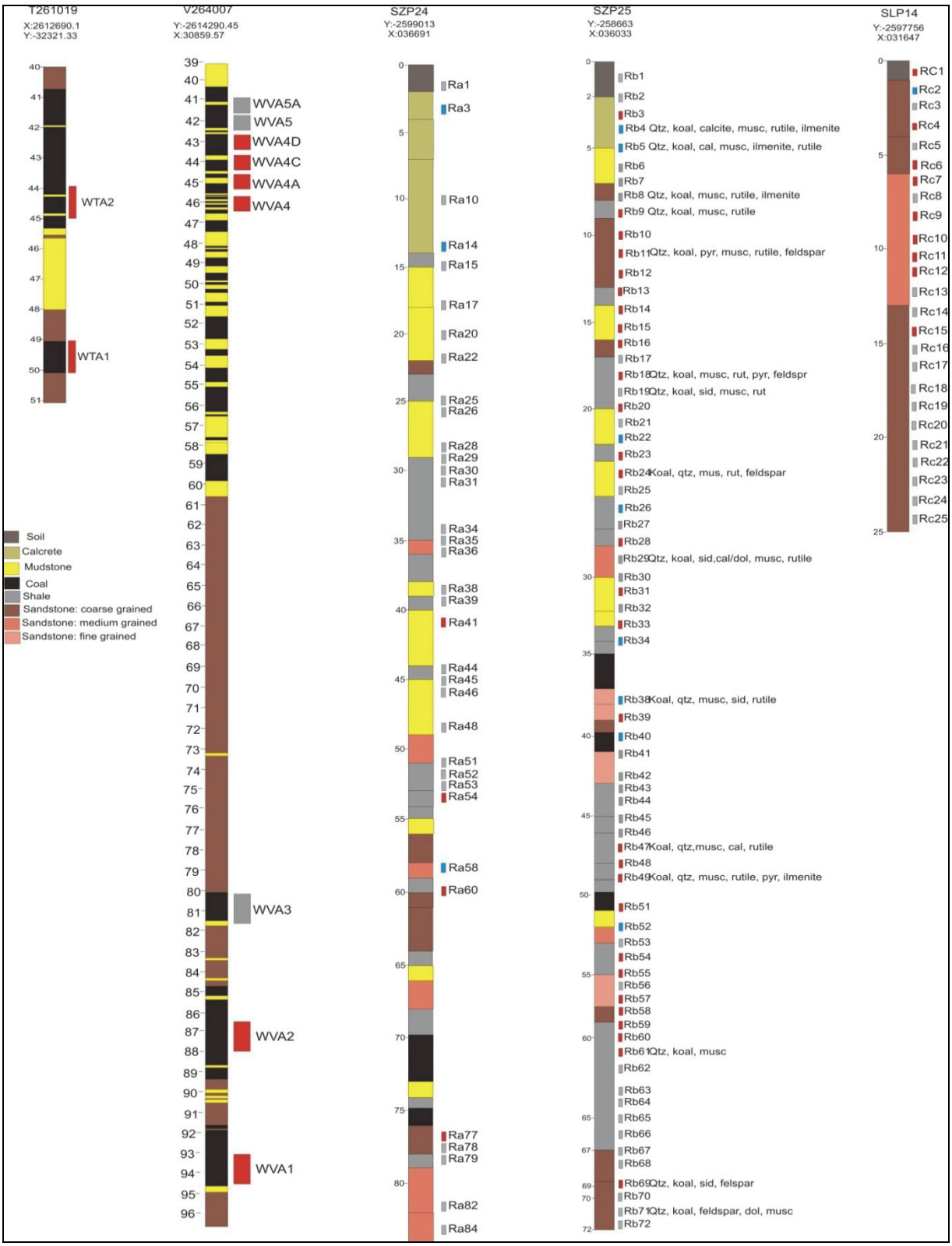

Figure 3-22: Weathered down to middle Ecca successions for Sasol and Resgen. The sampled intervals are indicated directly next to the borehole profiles with the acid generating potentials, red - acid, blue - neutralizing and grey - inconclusive results. Minerals found within the samples are also indicated where applicable.

3.5 Leach tests

Acidity is only a single aspect to be considered when gauging the potential for acid generation. Others that provide important information in terms of possible impacts include the quantity and nature of elements released by water solubilisation, oxidation and an acidic environment.

Coal mines associated with Acid Rock Drainage (ARD) usually have lithologies that include high concentrations of sulphate, aluminium, manganese and iron. Additional elements include calcium, potassium, magnesium and sodium. The major contributors to the acidic drainage are ferrous and ferric Iron (Fe^{+2}; Fe^{+3}), aluminium and manganese, as well as free hydrogen ions. The element abundance in ARD derived from different minerals like zinc and cadmium result from the dissolution of sphalerite. Calcium and sulphate are derived from secondary gypsum dissolution and the weathering of calcite and pyrite (Nordstrom and McCleskey, 2006).

A detailed chemical analysis was done on all the samples subjected to the static ABA tests. Elements included: Al, Ba, Ca, Cd, Co, Cu, Cr, Fe, K, Mg, Mn, Na, Ni, Pb, S, Sb, Sr and Zn. The leachate characteristics of the rock and coal samples mimic conditions in an initial pH, after oxidation has taken place and in an acidic environment.

3.5.1 Sasol leach

The leachate characteristic of the samples indicates the changes in a neutral to an acidic environment. The results illustrate the effect that lowering of the pH would have on interburden and coal samples. It also emphasises that there is an increase in heavy metal concentrations.

The release of the constituents as a function of pH is shown in Figure 3-23 to Figure 3-27. Potassium and sodium goes into solution independent of the pH condition (Figure 3-23). The carbonate minerals have a buffer potential which would allow the pH to increase. This is associated with the release in solution of carbonates (Figure 3-23) which continue to increase until depleted from the system.

Sulphate and iron (Figure 3-24) exhibit an associated rise; this may be as a result of the presence of the sulphide mineral pyrite. Sulphate (Figure 3-24) has the highest concentration when compared with other heavy metals, which increases as the pH decreases. The high concentrations of sulphate in the coal and interburden sandstone samples are attributed to the presence of the mineral pyrite. In Figure 3-25 cadmium, chromium, copper and manganese also shows an increase when the pH is lowered, at smaller increments (the concentration reaches up to 0.1 kg/tons). Aluminium becomes soluble with the lowering of the pH. The presence of calcium which is derived from the weathering of carbonate minerals continues to increase and will continue in this manner until it is depleted from the system.

Lead, zinc (Figure 3-26) and nickel show similar behaviour; the metals show a constant trend in concentration between the pH 6 and 8 (± 1.0 kg/tons). As the pH is lowered (below 5.5), the metal concentration rises from 1.0 to 10.0 kg/tons. Antimony (Figure 3-26) is available in lower concentration than strontium, lead, and zinc between pH values of 5.5 to 8. As the pH decreases; copper becomes more soluble, this is also applicable to cobalt.

Similar results were obtained for the other samples subjected to an acidic environment. It is thus important to screen the samples with base potentials carefully, since these samples can pose a higher environmental risk when subjected to an acidic environment (ARD). It is explained by Figure 3-27, where mining samples were subjected to the paste pH leach (water) and by oxidising the sample thereafter subjecting the sample to an acidic environment. The solution of heavy metals for the different environments is illustrated in Figure 3-27. The heavy metal concentrations become more soluble with a decrease in pH.

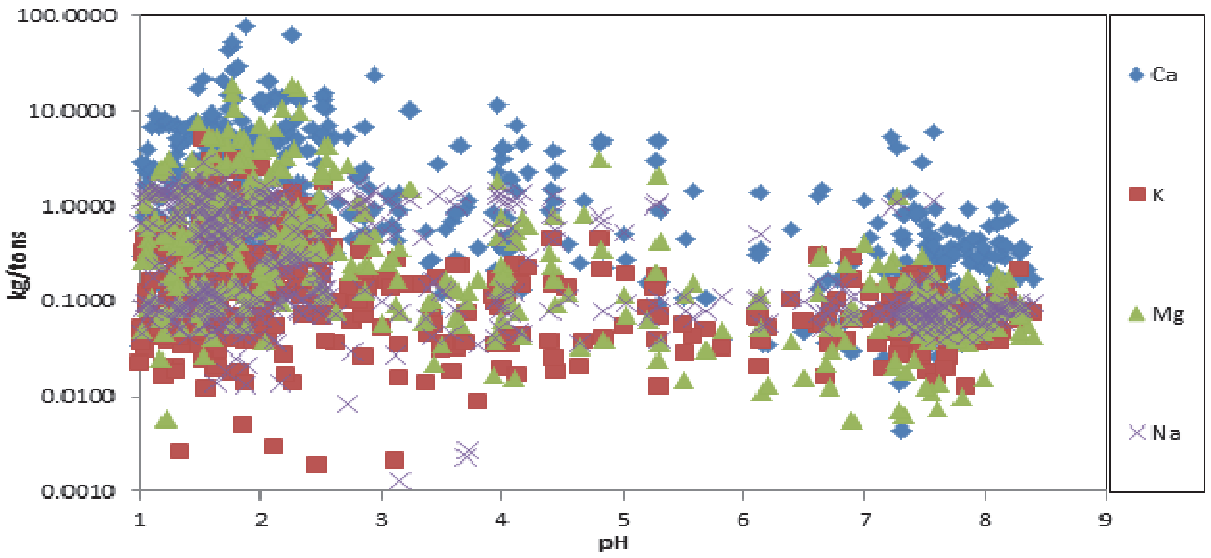

Figure 3-23: Release of Ca, K, Mg and Na as function of pH for Sasol samples. Ca and K show a strong pH dependance, for low pH values the concentrations for these elements are significantly increased.

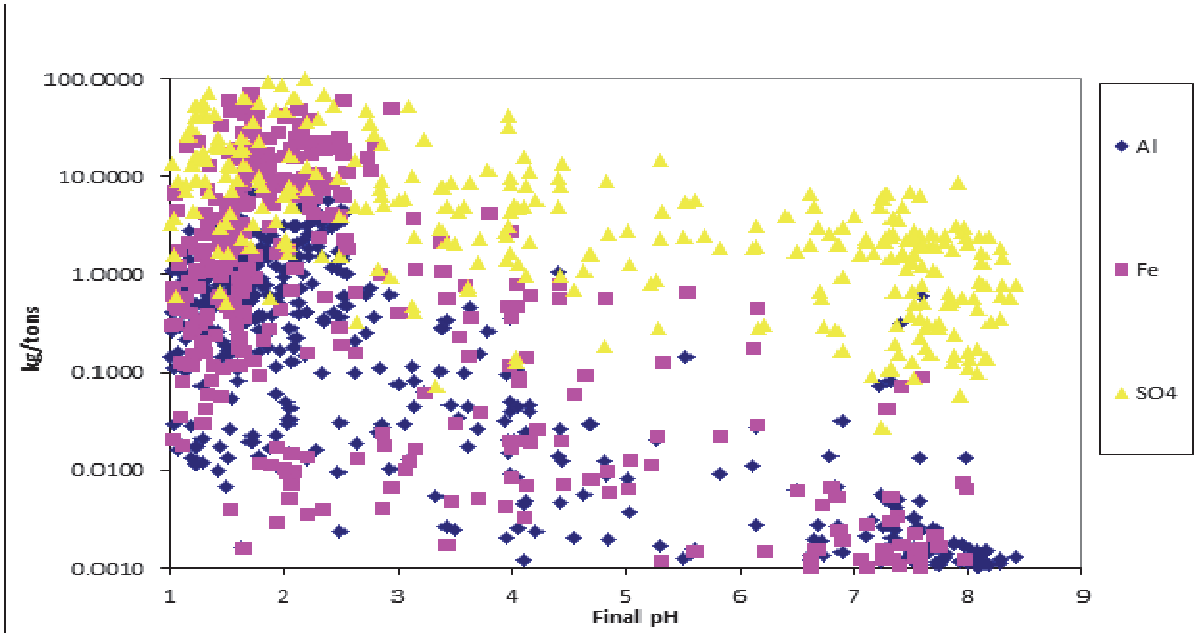

Figure 3-24: Release of Al, Fe and SO_4 in various pH conditions for Sasol samples. Al and Fe have a positive trend with a decrease in pH.

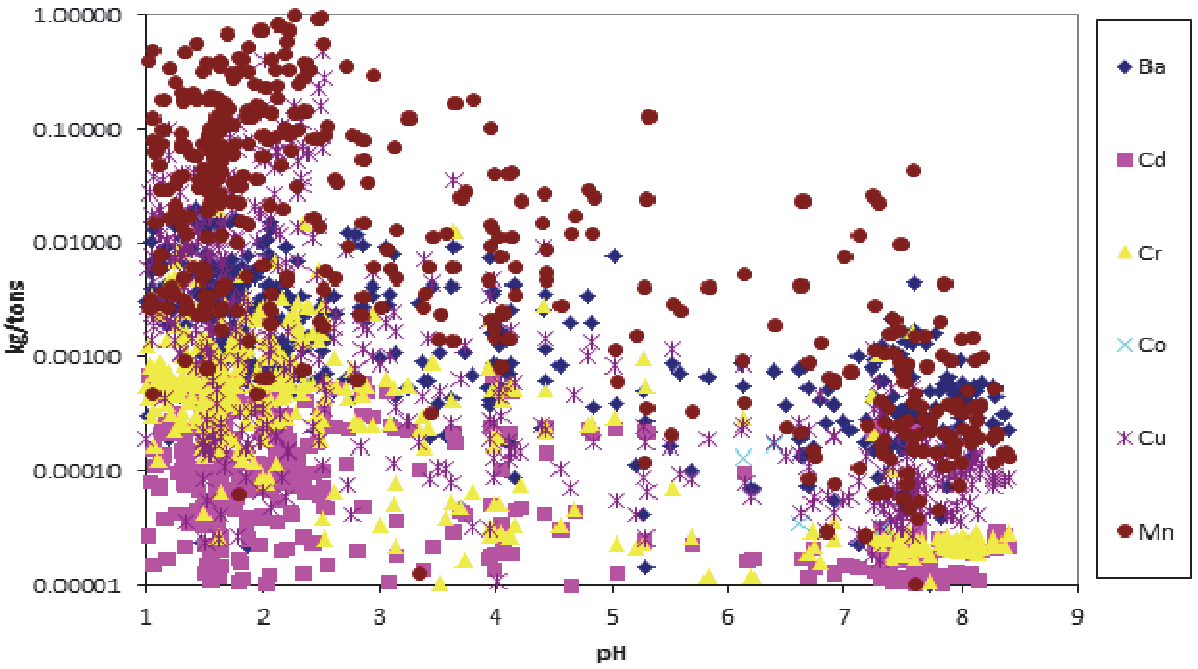

Figure 3-25: Sasal samples with element concentrations that are pH dependant.

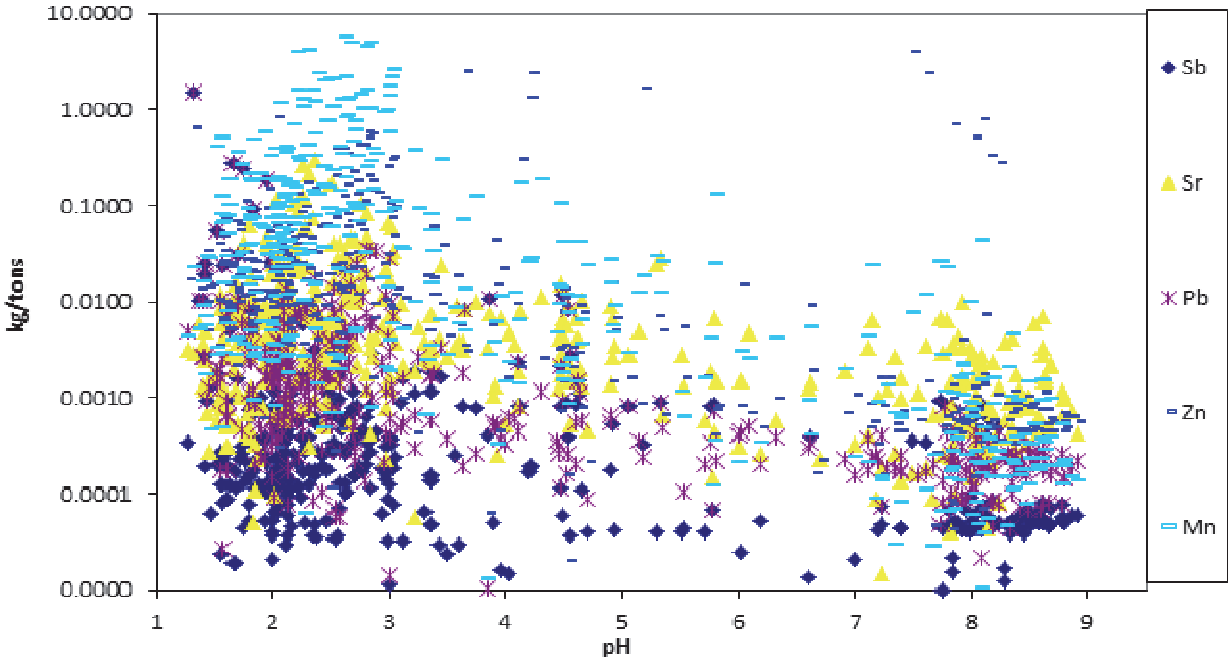

Figure 3-26: Release of Sb, Sr, Pb and Zn as function of pH for samples from Sasol. The Zn concentration shows a steep increase at lower pH values.

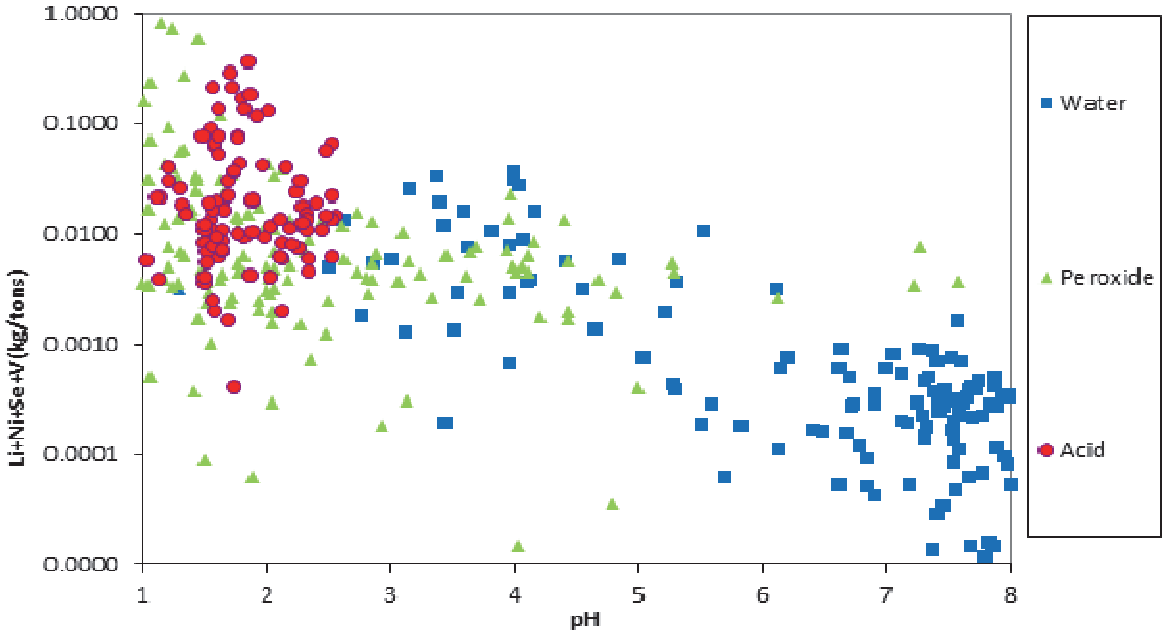

Figure 3-27: Total metal concentrations in solution for different media from Sasol samples indicating a pH dependance.

3.5.2 Resgen leach

The results consist of constituent concentrations leached at low to high pH values. The leachate characteristics of interburden such as mudstone, sandstone and calcrete samples have been observed after oxidation, and were compared to final pH values. The results of the leachate tests indicated that over a wide pH range the constituent concentrations stays relatively the same.

The Resgen interburden and overburden samples were analysed and the release of constituents is shown in Figure 3-28 to Figure 3-32. The analysed samples contained minerals with acid buffering capabilities such as carbonate minerals which is indicated by the release of calcium and magnesium (Figure 3-28). The presence of carbonate in solution (Figure 3-28) results in the increase in pH of the system. Sodium and potassium goes into solution similarly in different pH environments.

Iron and sulphate (Figure 3-29) shows an increase in concentration at lower pH values this is associated with the presence of pyrite, the sulphide mineral. Cadmium and chromium (Figure 3-30) show concentration increases as the pH is lowered. The decrease in pH leads to the dissolution of copper. Cadmium exists in small concentrations when compared to manganese and barium. Copper (Figure 3-30) is present in lower concentrations at a pH of 5.5 to 9. There is a similar increase in strontium, antimony, lead and zinc concentrations with a decrease in pH (Figure 3-31). These metals show a constant trend in concentration between the pH 6 and 8 (+/- 0.0001 kg/tons). As the pH decreases below 5.5, the constituent concentration rises. Figure 3-32 shows the nickel in solution, the quantities of nickel increase for an acidic environment. Nickel is thus released more readily in a lowered or acidic environment compared to higher pH values.

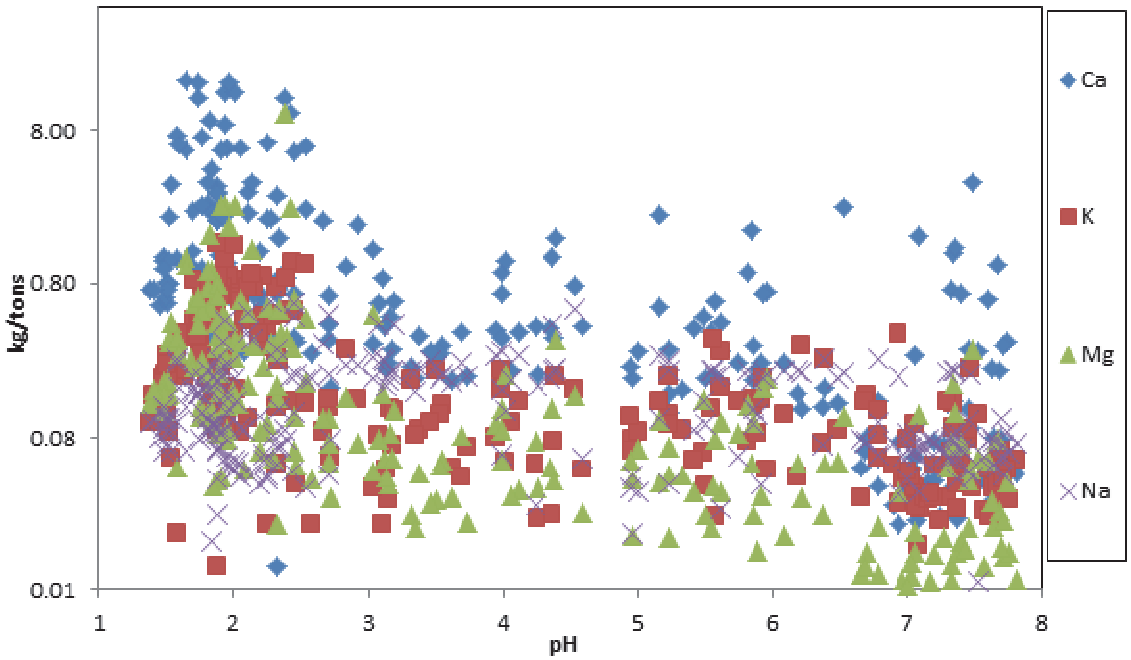

Figure 3-28: Release of major elements for Resgen samples as function of pH. Ca and Mg concentrarions show the pH denpendancy for the samples.

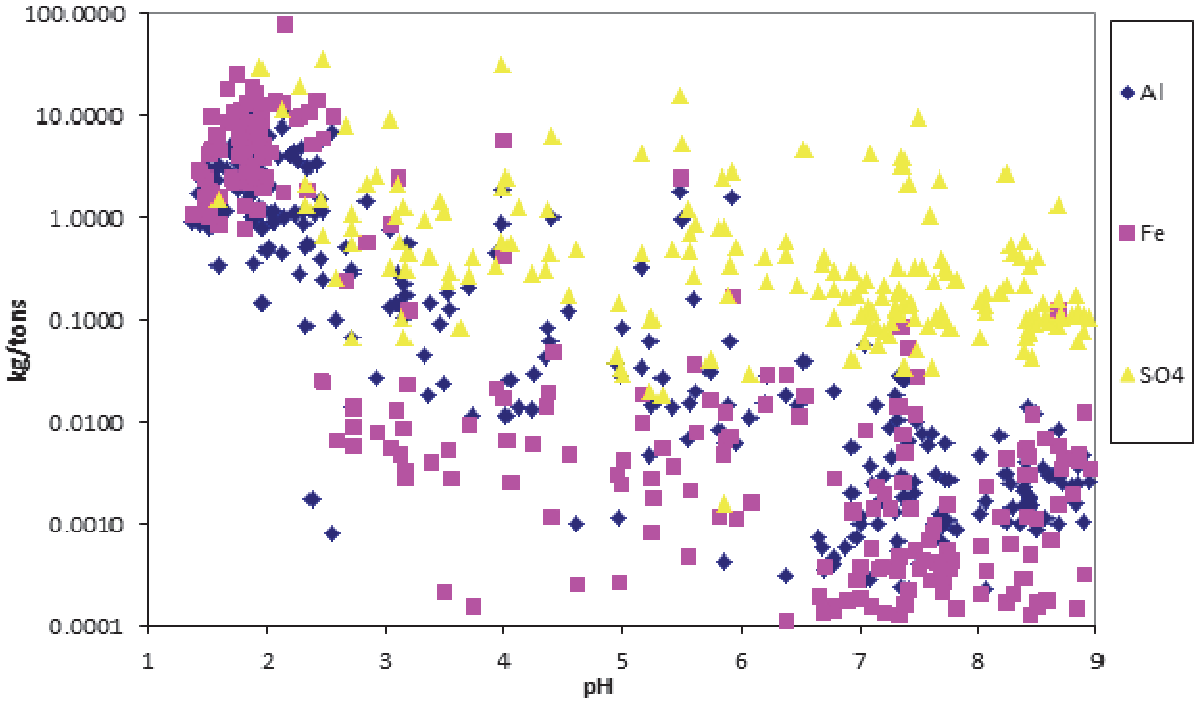

Figure 3-29: Increase of constituents at different pH conditions for samples from Resgen. The distribution of Fe and Al concentrations is increased with a decrease in pH.

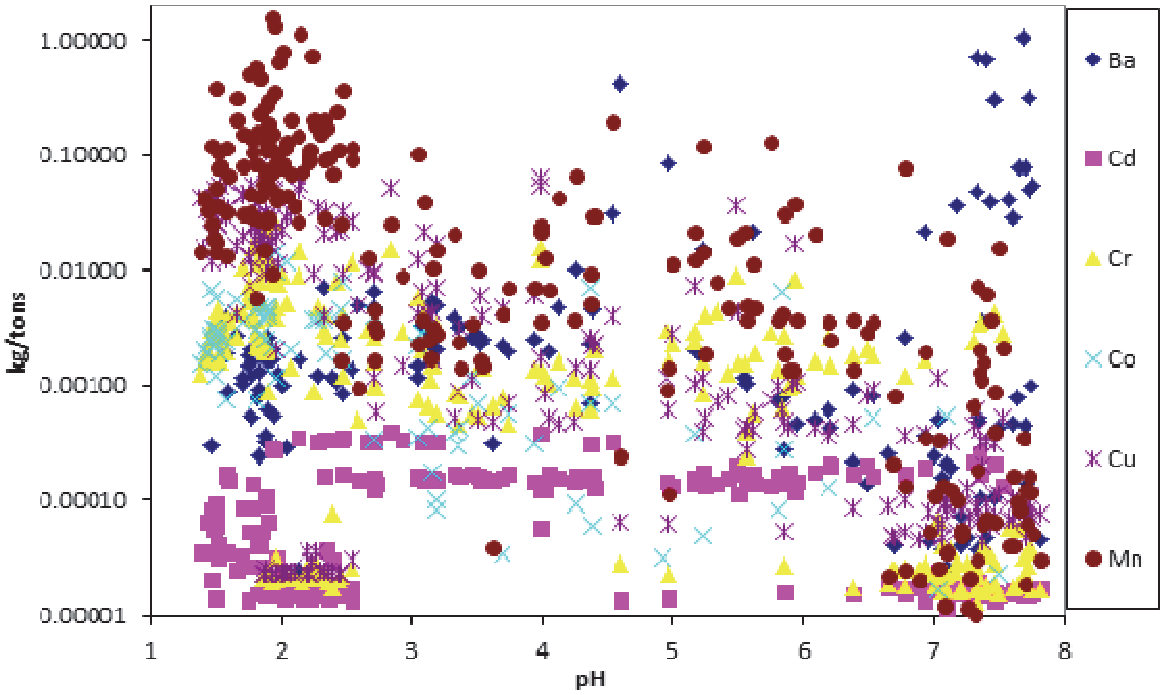

Figure 3-30: Resgen samples with pH depentant elements. The concentration changes for Mn and Cu at lower pH values are significant, with little to no change in Cd concentrations.

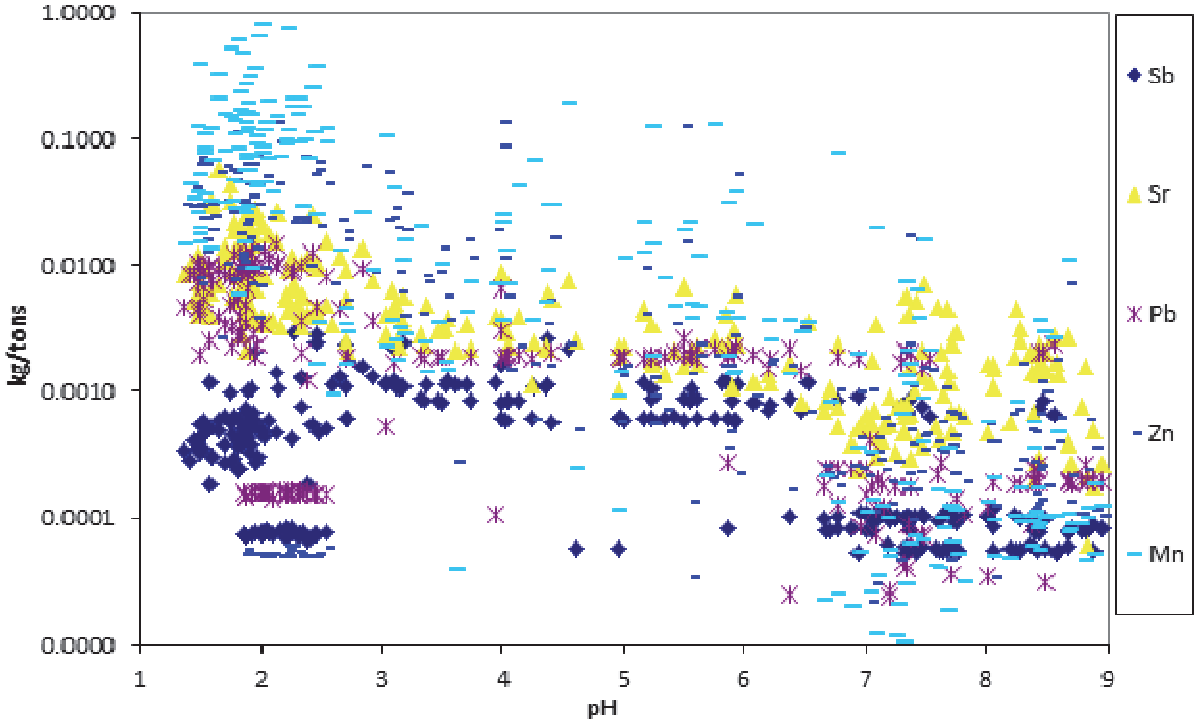

Figure 3-31: Release of Sb, Sn, Sr, Pb and Zn as function of pH for Resgen samples. There are no noteworthy changes in the concentrations at different pH values but a slight negative trend is observed towards higher pH values.

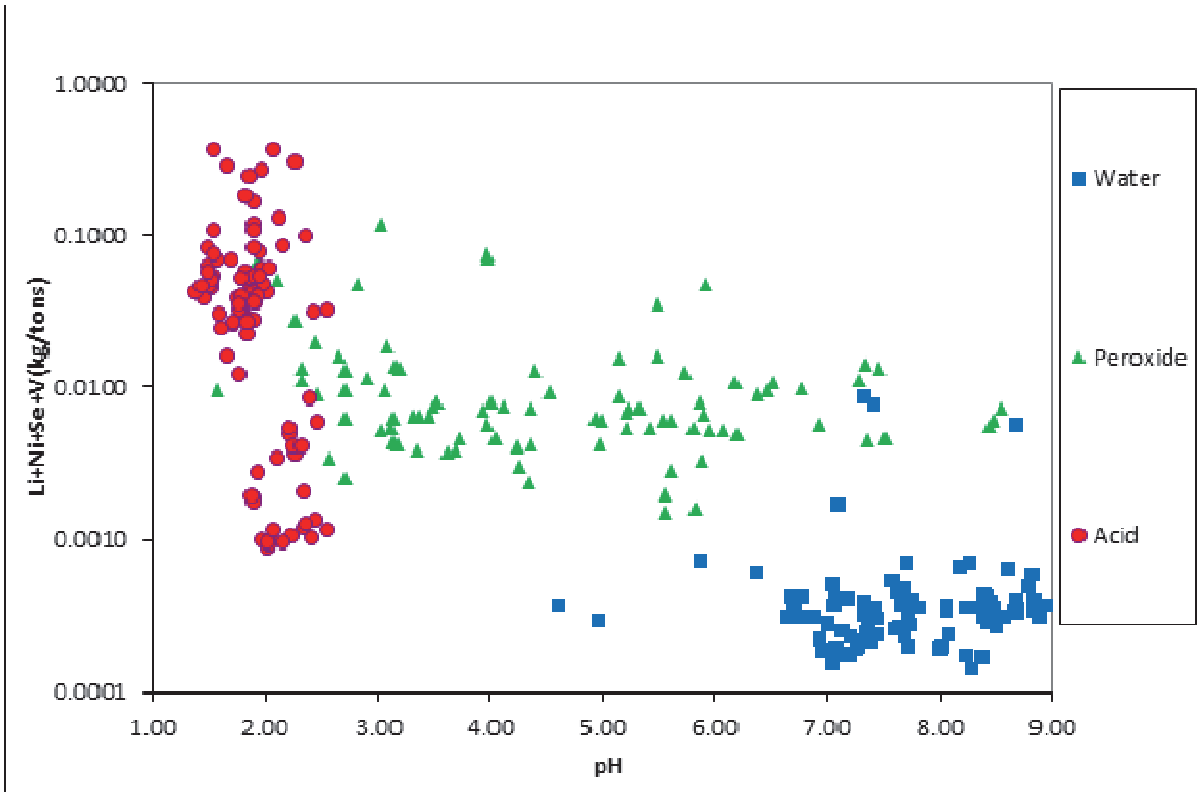

Figure 3-32: Total metal concentrations in solution at various pH environments from Resgen samples.

3.5.3 Grootegeluk leach

The samples from Grootegeluk consist of overburden material. The static ABA showed the overburden material had a high acid neutralising potential more than acid producing potential.

The constituent concentrations show an increase when plotted against the final pH (Figure 3-33 to Figure 3-37) where the pH decreased due to oxidation of pyrite. The leachate results from the Grootegeluk samples indicated a clustering trend that appears to be specific for pH values between 1.5 and 2.5. This clustering effect of the overburden material shows the sensitivity the system has at different pH values. Most metal constituent concentrations illustrate similar behaviour with a decrease in pH.

Figure 3-34 shows the constituent concentration of iron and sulphate which goes into solution an increase in concentration is noticed. The rise of these two metals is associated with the presence of the sulphide mineral pyrite which is ten times lower than other areas of analysis but still considerably more than the other metal concentrations. The constituent concentrations become more soluble as the pH decreases. The difference is in the concentration of sulphate which is ten times lower than the other areas of analysis. Copper, chromium, cobalt and manganese (Figure 3-35) go into solution with a decrease in pH.

The dissolution concentrations for lead, zinc and strontium were higher than that of antimony (Figure 3-36). The metals in solution increase with a decrease in pH values (Figure 3-37).

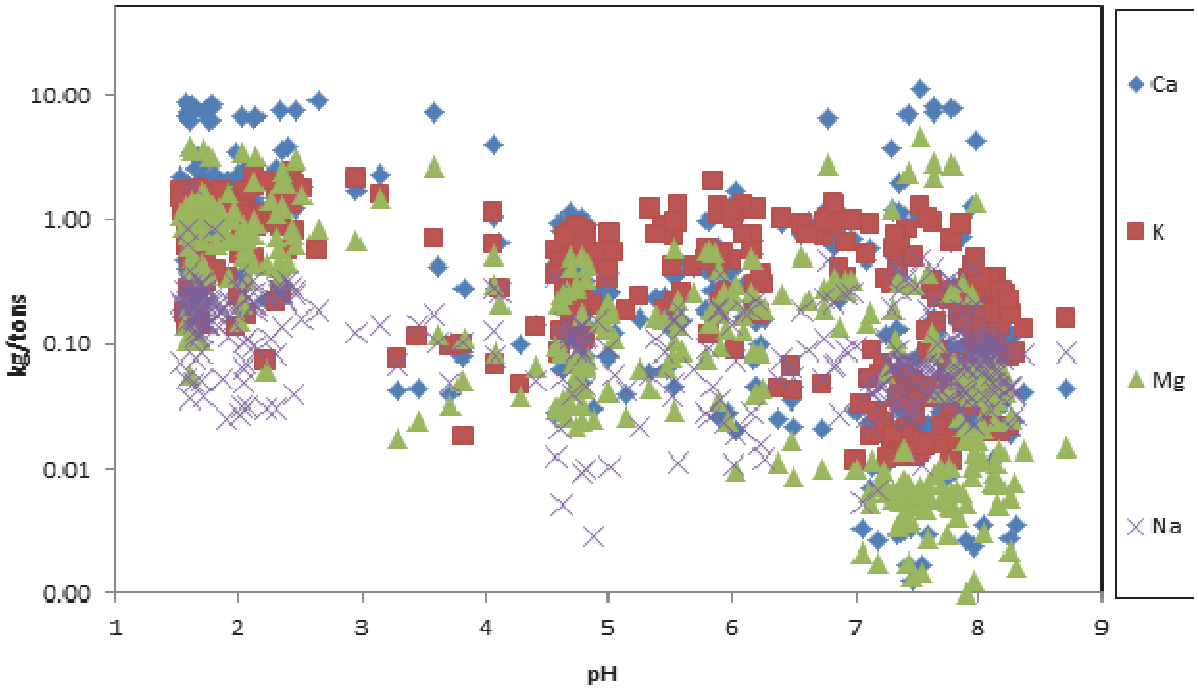

Figure 3-33: Ca, K, Mg and Na concentrations as function of pH for samples from Grootegeluk. There is a clustering of major elements at pH values between 0.5-2.5 and 3-4. Ca and Mg concentrations are affected at different pH values.

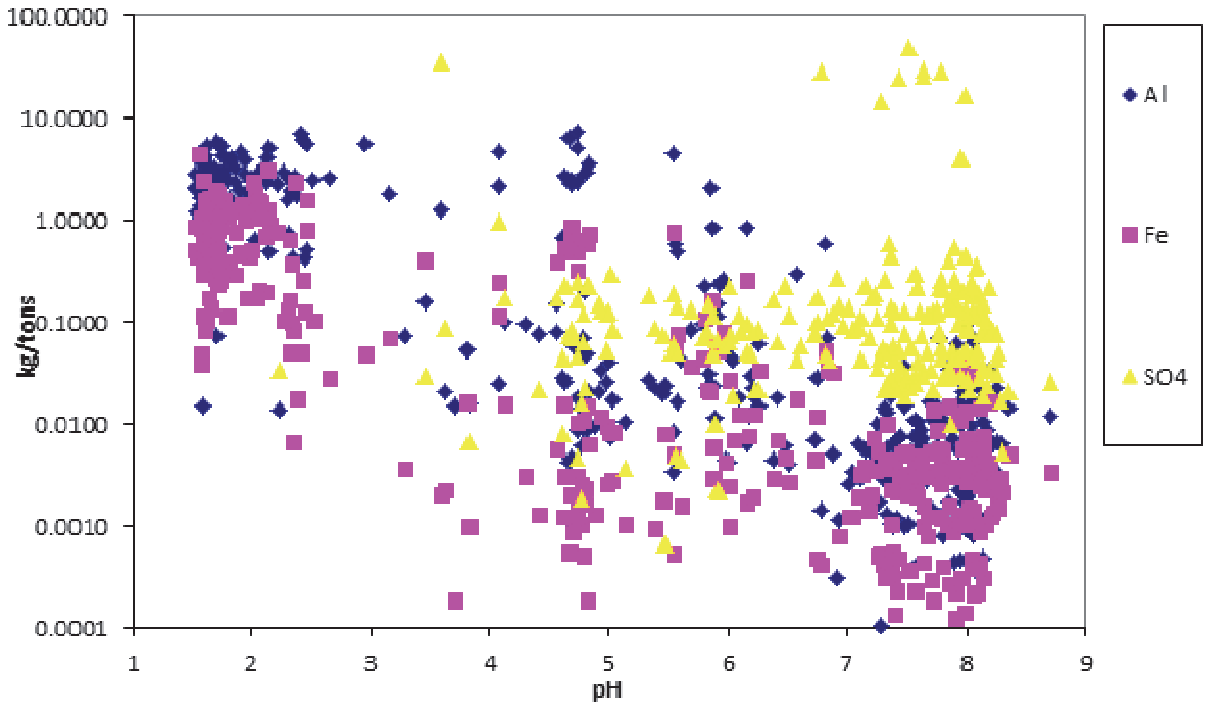

Figure 3-34: Release of Al, Fe and SO_4 in various pH conditions for Grootegeluk samples. Fe and Al are pH dependant as is show by the negative trends towards the higher pH.

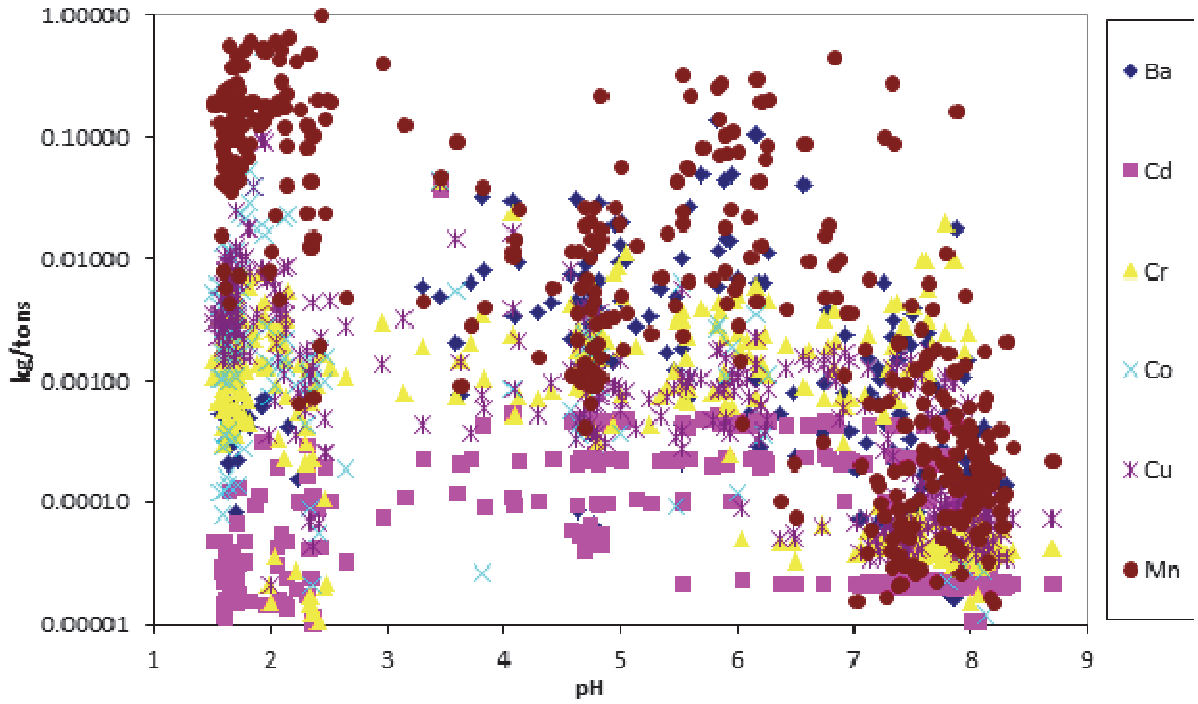

Figure 3-35: Release of Cd, Cr, Cu, Co, Ba and Mn for Grootegeluk samples at different pH

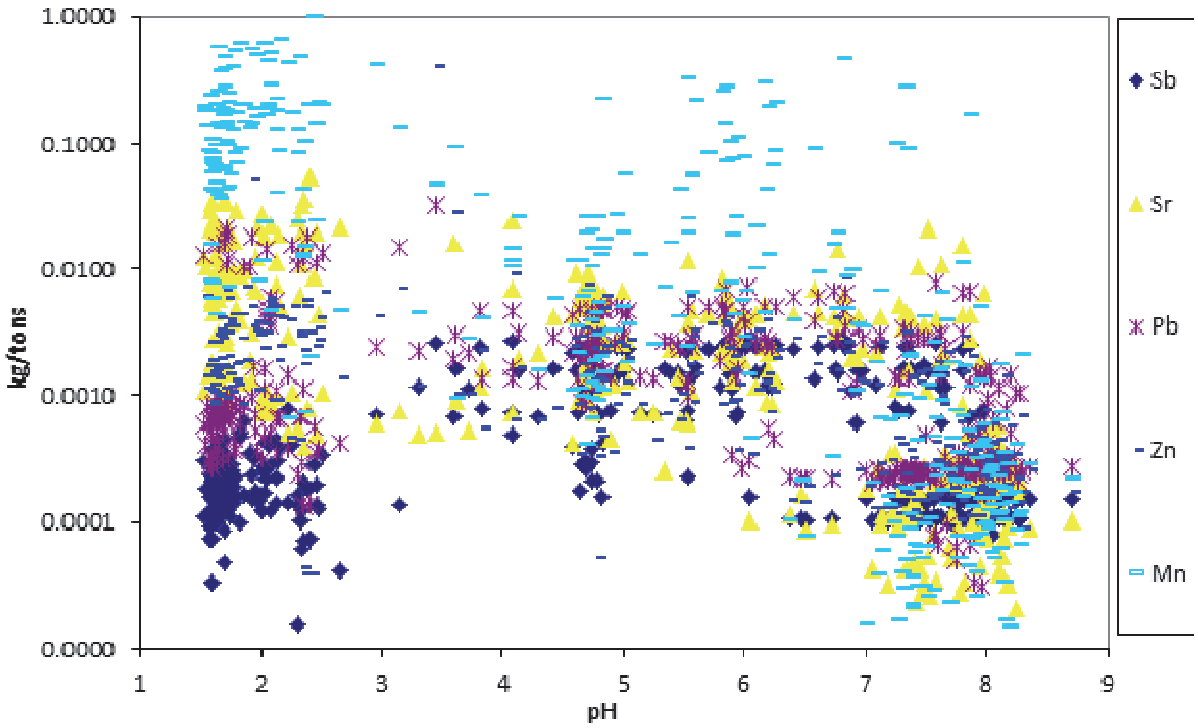

Figure 3-36: Grootegeluk samples show a clustering at lower pH values, with no significant changes in concentrations.

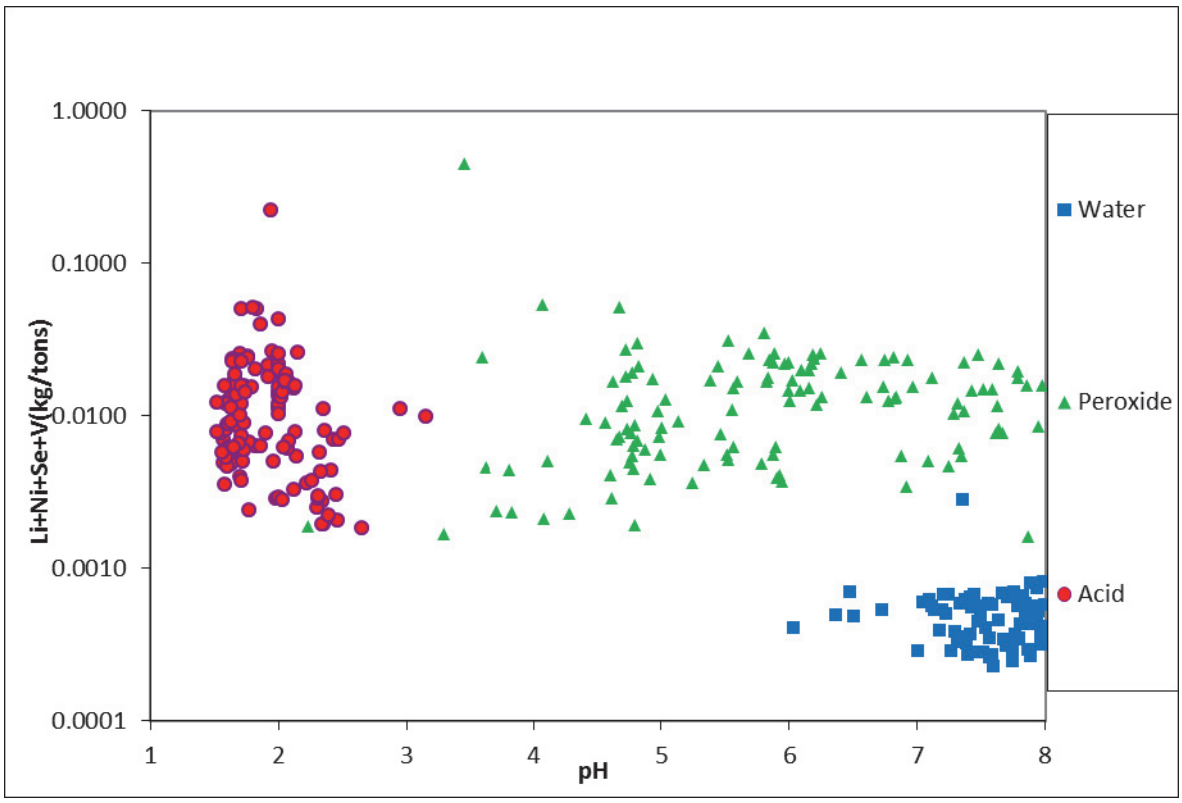

Figure 3-37: Total metals in solution from Grootegeluk as a function of pH

3.5.4 Sekoko leach

The results consist of constituents leached at different pHs plotted in Figure 3-38 to Figure 3-42. Sekoko samples consisted of interburden samples that were taken from the Middle Ecca with the coal removed.

Calcium/magnesium carbonate minerals (Figure 3-38) have a neutralising potential that can cause an increase in pH. The pH will decrease after the buffer capacity of the carbonate minerals are depleted from the system.

The sulphide mineral pyrite which is known for its role as an acid producing mineral is positively identified within the samples. This is due to the association of constituent concentrations with iron and sulphate that increases at low pH values Figure 3-39. Cadmium, Cobalt, Chromium and Barium concentrations increased as the pH decreased (Figure 3-40). Lead and Zinc (Figure 3-41) exists in small quantities when compared to other constituent concentrations but still dominantly follow the same trend as other metals. These constituents go into solution with a decrease in pH. Figure 3-42 shows the total constitute concentrations in solution as a function of pH.

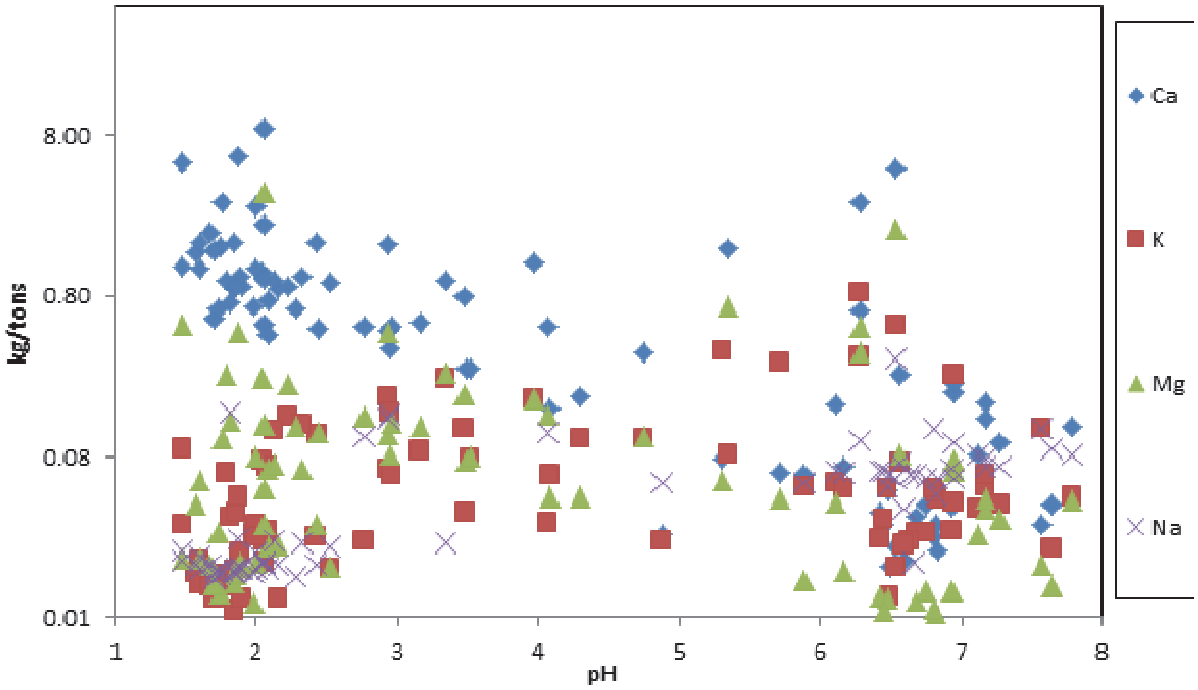

Figure 3-38: The concentration distribution for Ca, K, Mg and Na for Sekoko samples. Mg and Ca show pH depandancy as a function of various pH values.

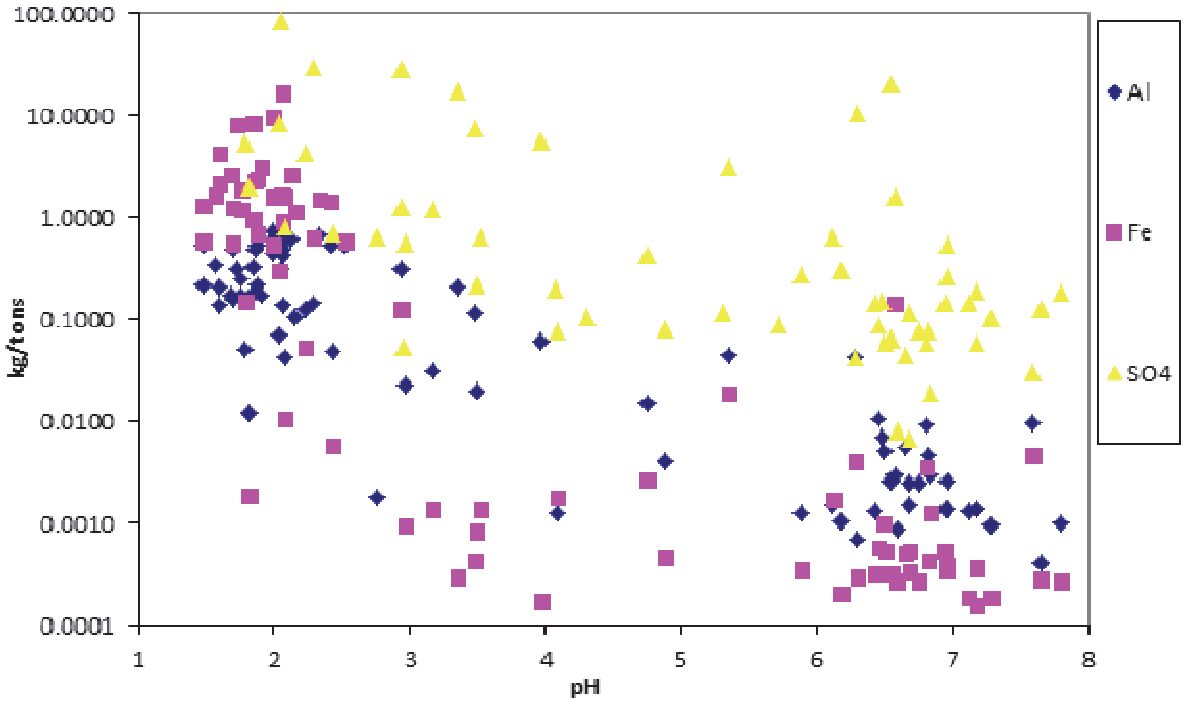

Figure 3-39: Release of Al, Fe and SO_4 in various pH conditions for samples from Sekoko. There is a negative trend for Al and Fe towards higher pH conditions. The highest concentration changes are observed at extreme low and high pH values.

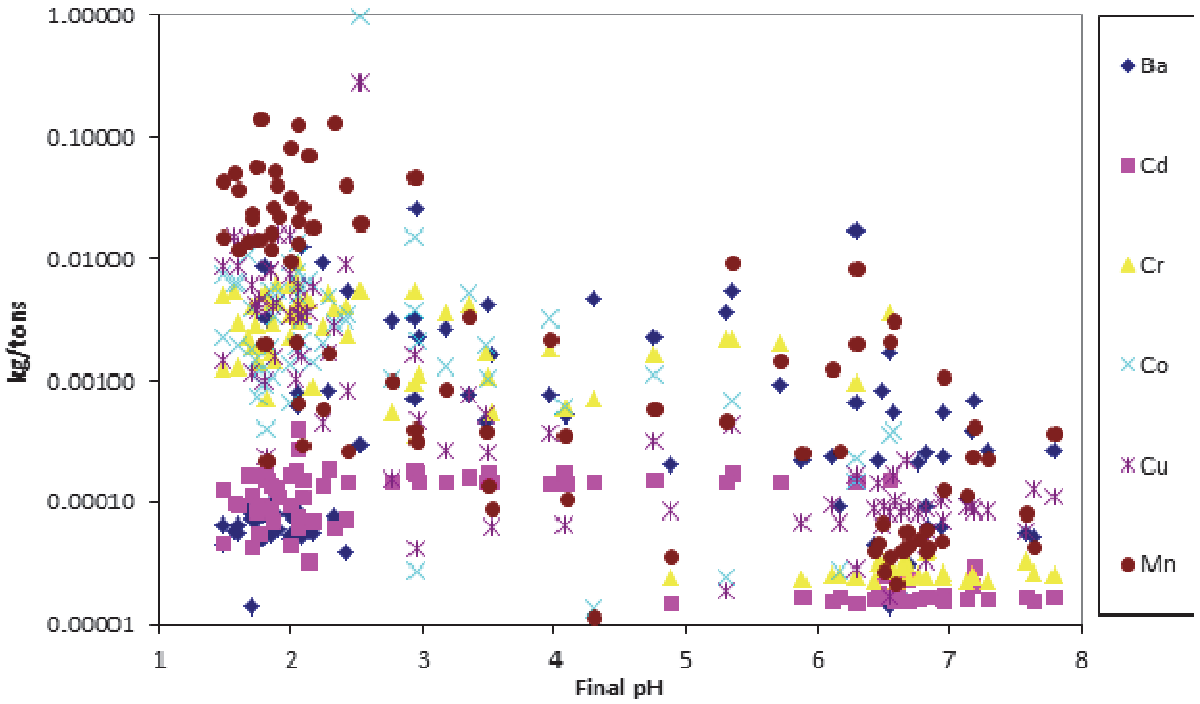

Figure 3-40: Sekoko samples with a pH denpendance. The most noteworthy concentration changes is seen for Mn with a considerable decrease in Cr concnetration at higher pH condditions.

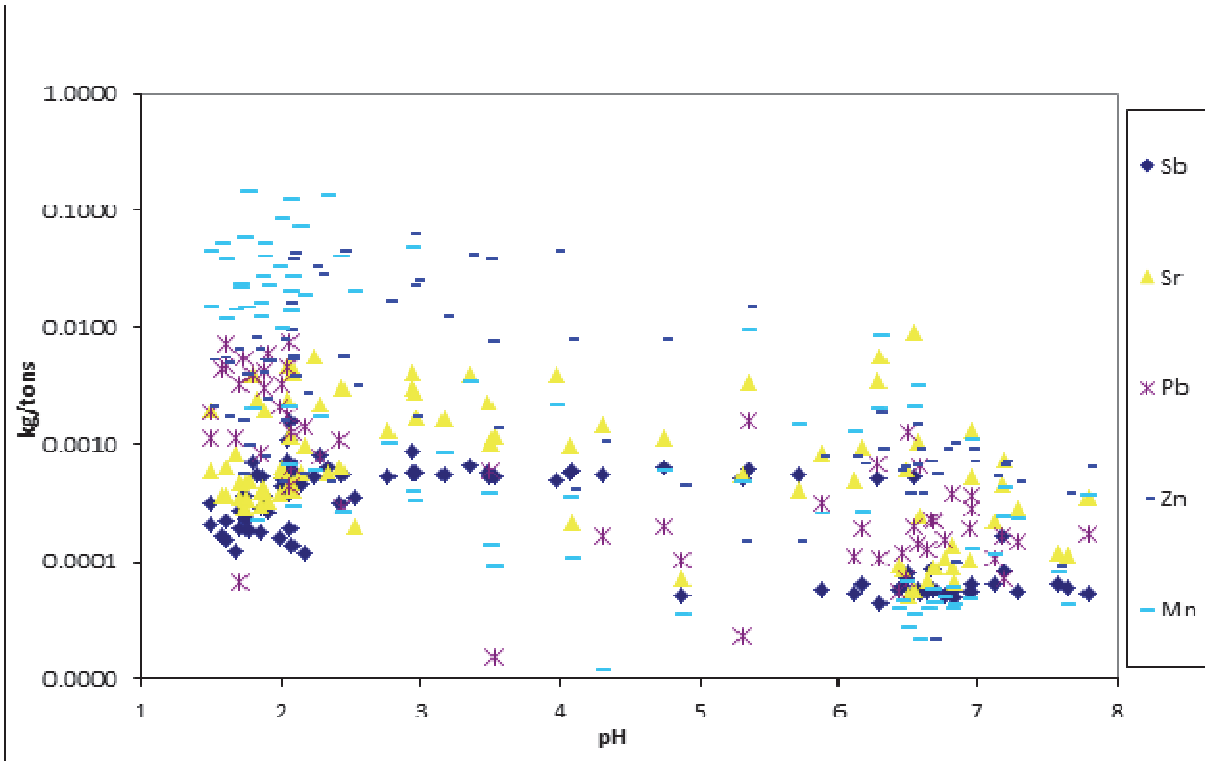

Figure 3-41: Release of metal concnetrations in Sekoko samples for different pH conditions. The concentrations show an overall negative tend towards higher ph values with no significant concentration changes.

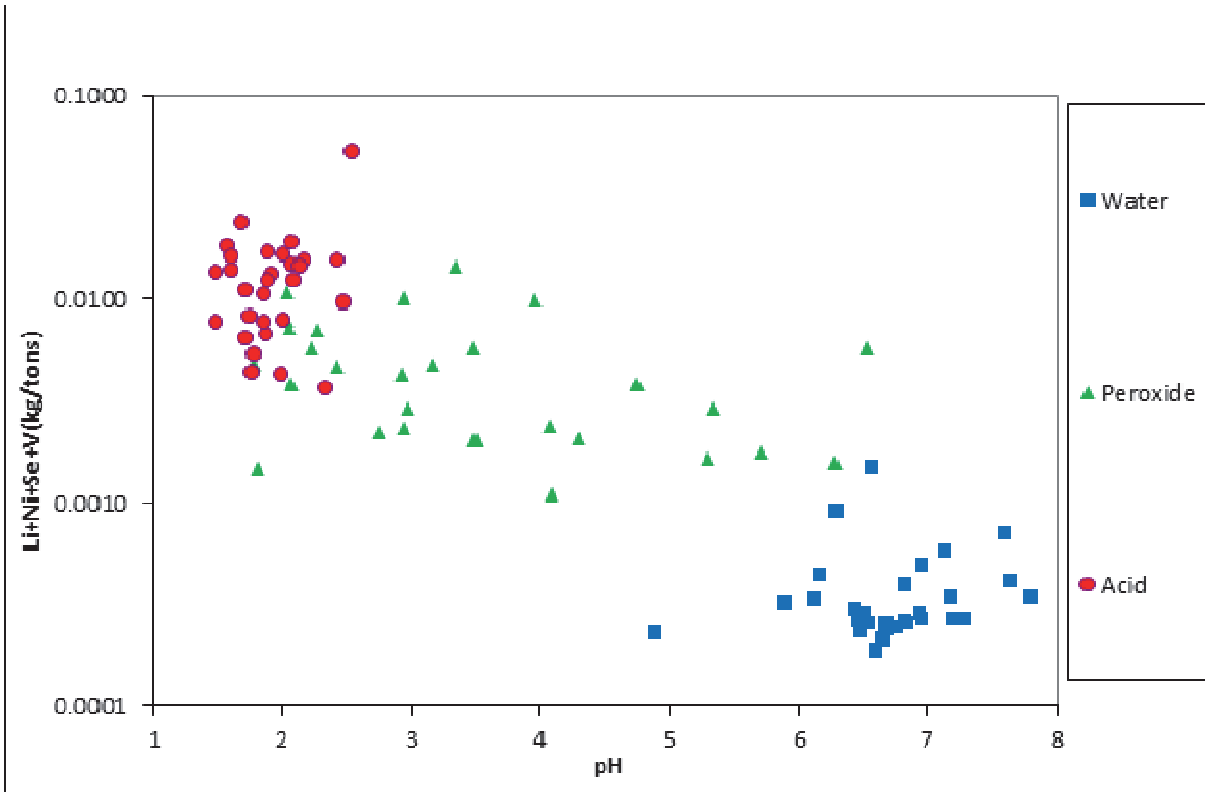

Figure 3-42: Sekoko samples of varoius media as a function of pH

3.5.5 Composite leach

The results of the composite samples show erratic scatter patterns for the metal species plotted in Figure 3-43 to Figure 3-47. The metal species within plant discards which are liberated at high and low values include aluminium, barium, sodium, nickel, copper and iron.

Calcium/magnesium (*Figure 3-43*) come from weathering of carbonate minerals that increase the pH of the system until it is depleted from it and the pH will decrease. Sulphate and iron (Figure 3-44) show an increase in concentration associated with the presence of the of the sulphide mineral pyrite.

At a pH of 4 to 7, copper (*Figure 3-45*) is available in lower concentration than Pb and Zn (Figure 3-46). As the pH decreases; copper becomes more soluble, this is also observed for cobalt concentrations. Figure 3-47 gives leachate results for nickel in a neutral to acidic environment. The results show that the solubility and so the nickel concentration increases in an acidic environment.

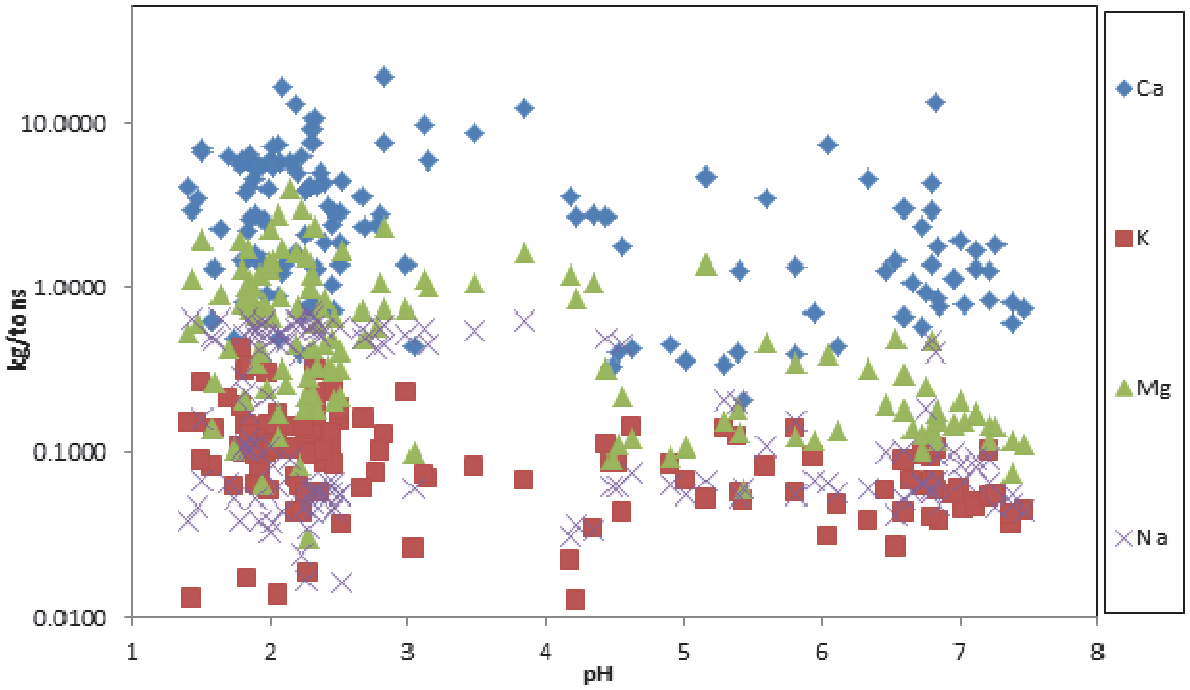

Figure 3-43: Composite samples for major elements. Between the pH of 1-3 there is a clustering of various concentrations. The high Ca concentrations show significant pH depandancy.

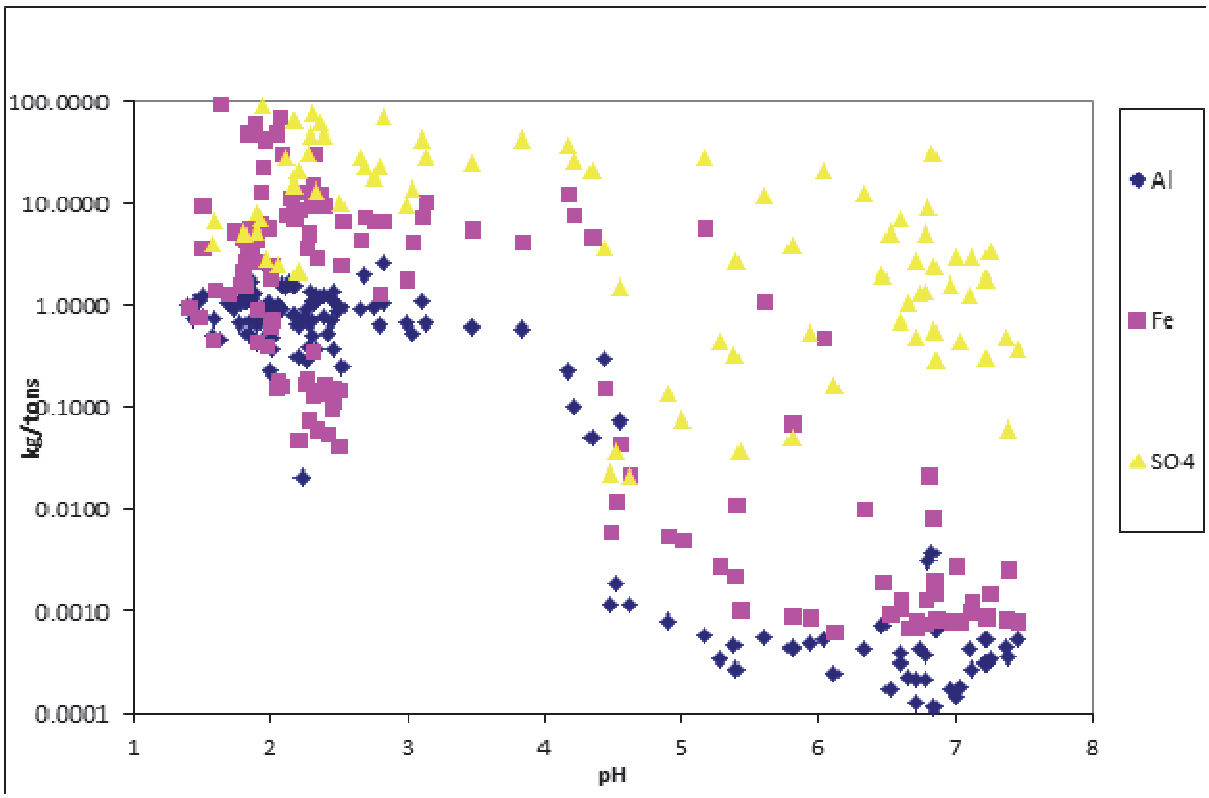

Figure 3-44: Release of Al, Fe and SO_4 as function of pH for Composite samples. A negative trend towards higher pH conditions.There are striking concentration changes for both Al and Fe.

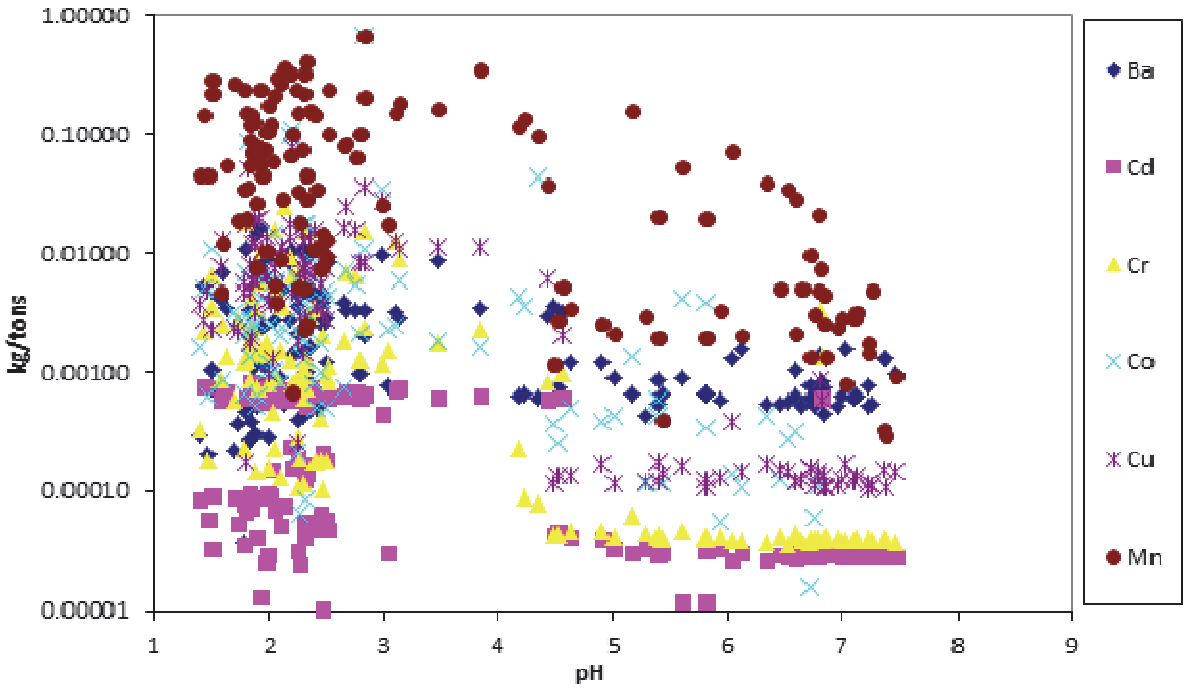

Figure 3-45: Elemental concentrations for Composite samples at differnet pH condtitions. There are slight concentration changes but none noteworthy.

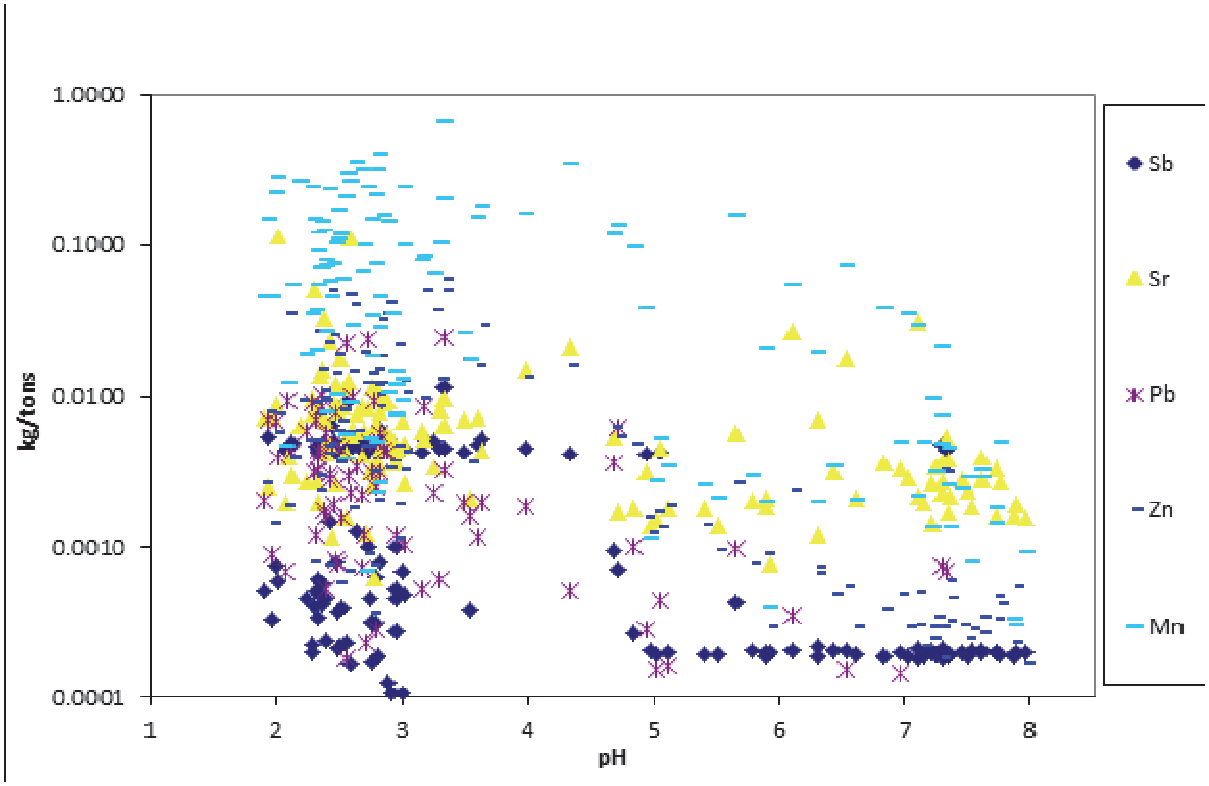

Figure 3-46: Composite samples with a pH dependancy. There is a negative trend towards a higher pH for all the concentrations.

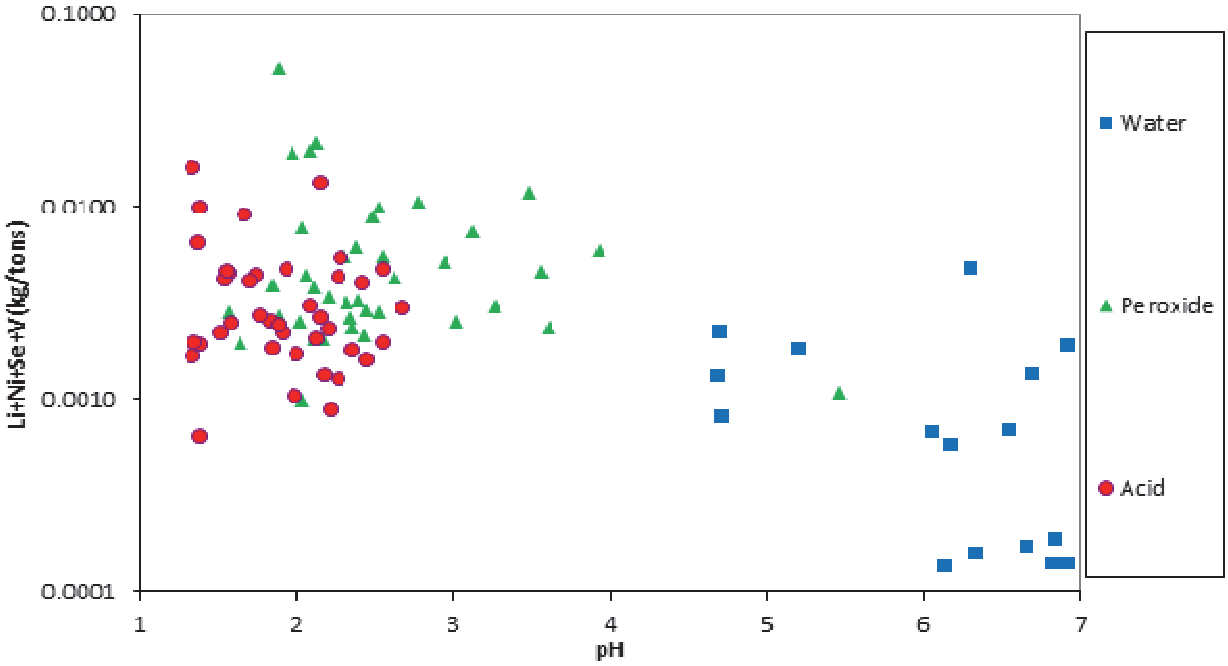

Figure 3-47: Total metal concentrations in solution for Composite samples at various pH conditions

3.5.6 Summary of analytes

- Sulphate has the highest concentration when compared with other constituents, and increases as the pH decreases; the high concentration are associated the presence of pyrite in coal and interburden sandstone samples.
- The concentrations of the lead, nickel and zinc are higher when compared to the rest of the metal concentrations. The dissolution of these elements increases in an acidic environment, and are similar to the various sample locations.
- Areas where more overburden samples were analysed show lower quantities of iron and sulphate which is due to lesser sulphide minerals that are present within the mudstones, shales and calcrete samples.
- Carbonate concentration increase the pH of the system for acidic environments. The carbonate minerals will eventually be depleted from the system and depending on the environment and the amount of acidic minerals present the pH will decrease or stay neutral.
- Sodium ranges from low to intermediate levels; the higher sodium levels often coincide with high pH-levels, suggesting the presence of sodium carbonate species.

3.6 Leco versus peroxide Sulphur

Different samples were analysed additionally by the Leco method to determine the total percentage sulphur in the sample, by using a Leco sulphur analyser. The sample (0.01 to 0.1 g) is heated to approximately 1350°C in an induction furnace while passing a stream of oxygen through the sample. Sulphur dioxide released from the sample is measured by an IR detection system and the Total Sulphur result is provided.

The results obtained are plotted in Figure 3-48 indicating that with the Leco, total % Sulphur are slightly higher than that obtained with the peroxide sulphur method. This is mainly in the very high sulphur range samples (4-8%). In the lower ranges, there is a variety in both methods.

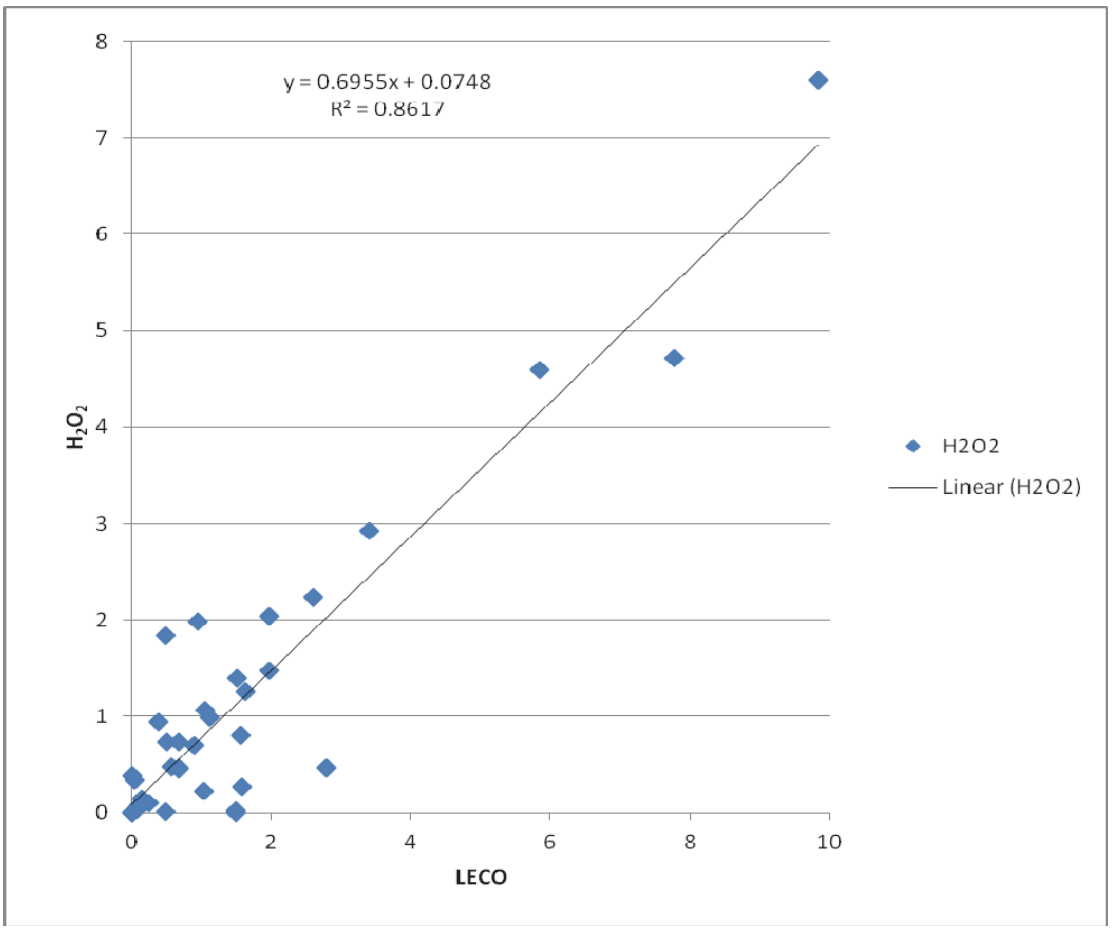

Figure 3-48: Leco S versus Peroxide S

There is a difference for the two methods but it is still useful to use the peroxide sulphur values as prediction methods for acid potentials of samples.

3.7 Mineralogy

Based on the static ABA results, X-ray diffraction (XRD) and X-ray fluorescence (XRF) analyses were done. XRF is a semi-quantitative whole rock analyses used mainly to identify the chemical compositions of major and trace elements from selected samples. XRD is a quantitative method that identifies the minerals present within the samples. A complete list of samples that were selected for analysis is given in Table 7-M. Sample preparation requires material to be crushed, milled and made into fusion disks and pellets. The major elements are determined as oxides in wt%.

In total 50 samples were subjected to XRD and XRF analyses. The analyses determined the mineral and elemental chemistry. A full list of the results can be seen in Table 7-K, Table 7-L and Table 7-M.

The samples with a neutralising capacity mainly contained minerals calcite and ankerite/dolomite. This is due to the carbonate content within the mineral chemistry. Pyrite is the dominant mineral in the acidifying samples. The mineral chemistry of pyrite contains iron and sulphide elements that under favourable conditions contribute to the production of acidic waters.

There is a difference in the mineral distribution for the three successions over the various lithologies. The different minerals found in the mudstones are shown in Table 3-H.

Table 3-H:The mineral distributions found in mudstones of the different successions.

Minerals	Full succession	Partly weathered	Middle Ecca
Quartz	■	■	■
Kaolinite	■	■	■
Siderite	■		
Calcite	■	■	
Muscovite	■	■	■
Rutile	■	■	■
Pyrite	■	■	
Marcasite	■		
Hematite	■		
Apatite		■	
Pyrrothite		■	
Feldspar			■

The mudstones have both neutralising and acid generating potentials which are associated with their mineral chemistry. The mineral chemistry for the sandstones from the three successions appears to be relatively similar with minor exceptions for hematite, ilmenite and feldspar (Table 3-I).

Table 3-I: The mineral distributions found in sandstones of the different successions

Minerals	Full succession	Partly weathered	Middle Ecca
Quartz	■	■	■
Kaolinite	■	■	■
Siderite	■	■	■
Muscovite	■	■	■
Rutile	■	■	■
Pyrite	■	■	■
Hematite		■	
Ilmenite			■
Feldspar			■

On average the samples acidifying and those with a base potential, contain similar concentrations of SiO_2. The major difference is between the CaO and MgO of the samples with a base potential to 50% less in the samples acidifying.

3.8 Kinetic ABA tests

Kinetic tests determine the weathering characteristics of a sample as a function of time. Kinetic tests typically involve subjecting a sample of the waste material to periodic leaching and analysis of the drainage. The most popular kinetic test is the humidity cell test. Humidity cells use a sample size of about 1 – 15kg and have much longer testing times. Samples are subjected to alternating water leaching and are exposed to moist air. This method is used as an initial screening test for overburden samples. The leaching tests predict the drainage quality of the samples more accurately.

Where the potential of acid generation is uncertain, kinetic test work is performed to attempt to define acid generation characteristics. The term kinetic is used to describe a group of test work procedures wherein the acid generation (and metal solubilisation and transport) characteristics of a sample are measured with respect to time.

Samples for kinetic testing were selected based on the results from the static ABA tests. The kinetic tests are intended to mimic the physicochemical processes of weathering found at mining sites, usually at an accelerated rate. These tests require more time and are considerably more expensive than static tests (US EPA, 1994). The samples were chosen to be representative of the lithologies present in the study area. The leachate was analysed for pH, conductivity, sulphate, acidity and alkalinity. The analyses are used to confirm the AMD risk associated with a range of ABA values linked to the specific lithologies. Based on the static and kinetic ABA data a useful handling plan for the material from the mining and processing area can be developed.

A total of 68 samples were tested to determine the acid generating potential. The samples consisted of overburden, interburden and composite plant discards. Table 7-N includes a detailed table of the samples selected for kinetic ABA tests.

Bromide was detected in the composite samples. This was due to laboratory methods applied to the material afterwards and is not applied on-site.

3.8.1 Full succession samples

The first parameter to consider is pH, since this will provide an indication of the onset of acidification (Figure 3-49 and Figure 3-50). Some of the cells from this area had initial pH values that were already acidic. Of interest too is the fact that these cells are cells with excess acid potential (AP) over neutralising potential (NP). From an acid generation point of view, these results tie in well. The other pH values were initially neutral and remained neutral throughout the testing, while a few samples went from neutral to acidic over the testing period.

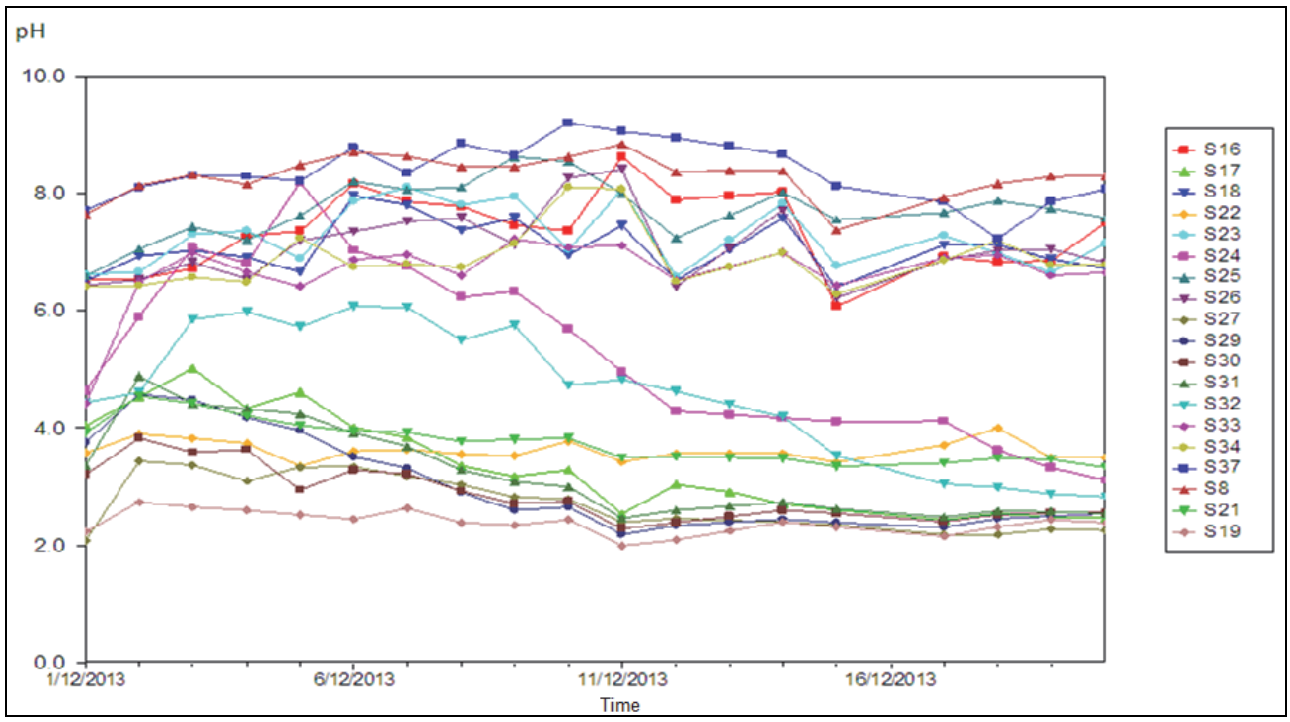

Figure 3-49: pH values from the humidity cells for the full succession 1 samples

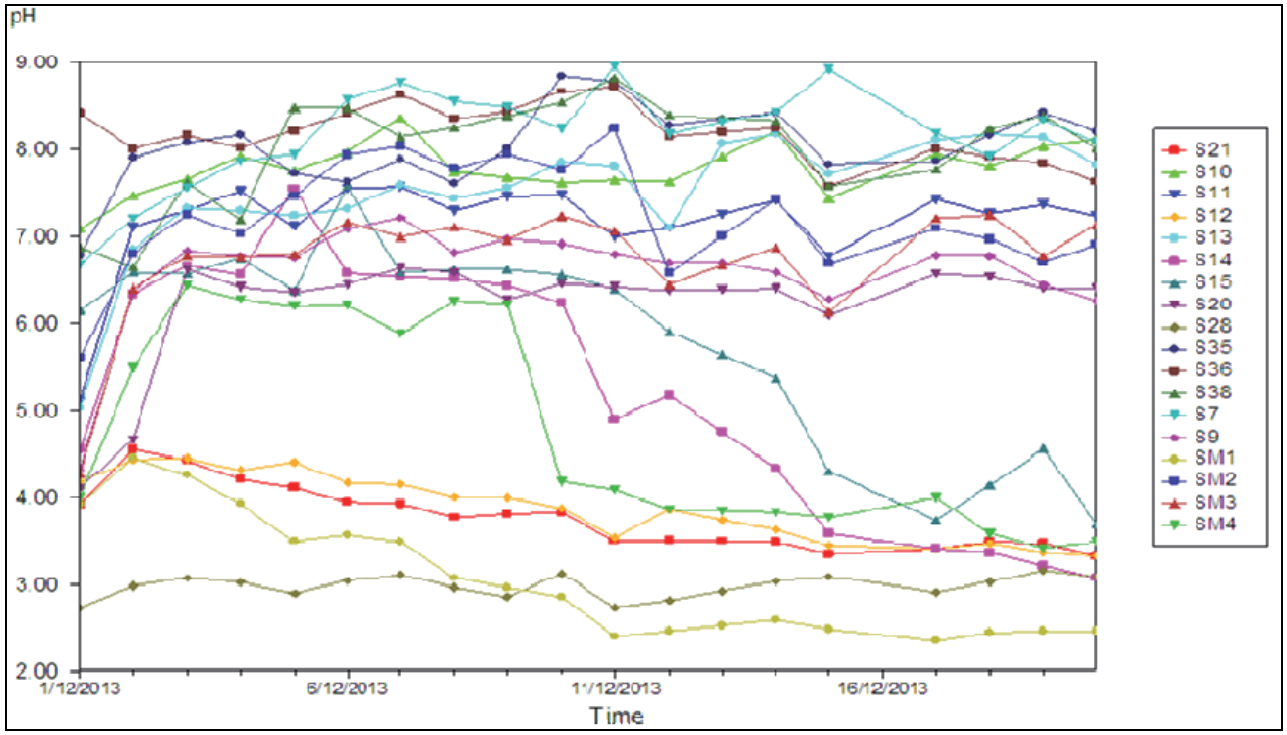

Figure 3-50: pH values from the humidity cells for the full succession 2 samples

Sulphate is the next important parameter to consider (Figure 3-51). Inspection of the sulphate values shows a sharp decline in values of some samples over the first few weeks as oxidised products are flushed out. This suggests those sulphide oxidations that occur prior-kinetic testing, were flushed out (Figure 3-51). The high SO_4 values at the beginning of the test work suggest that some oxidation occurred in the samples prior to initiation of the kinetic cell test, supported by the low pH value. The drop in pH over time with the production of sulphate is clearly

illustrated in Figure 3-52 for sample S24 where the pH dropped with the sulphate production versus GM4, where the pH stayed neutral for the duration of the test and the very low and decrease in sulphate production.

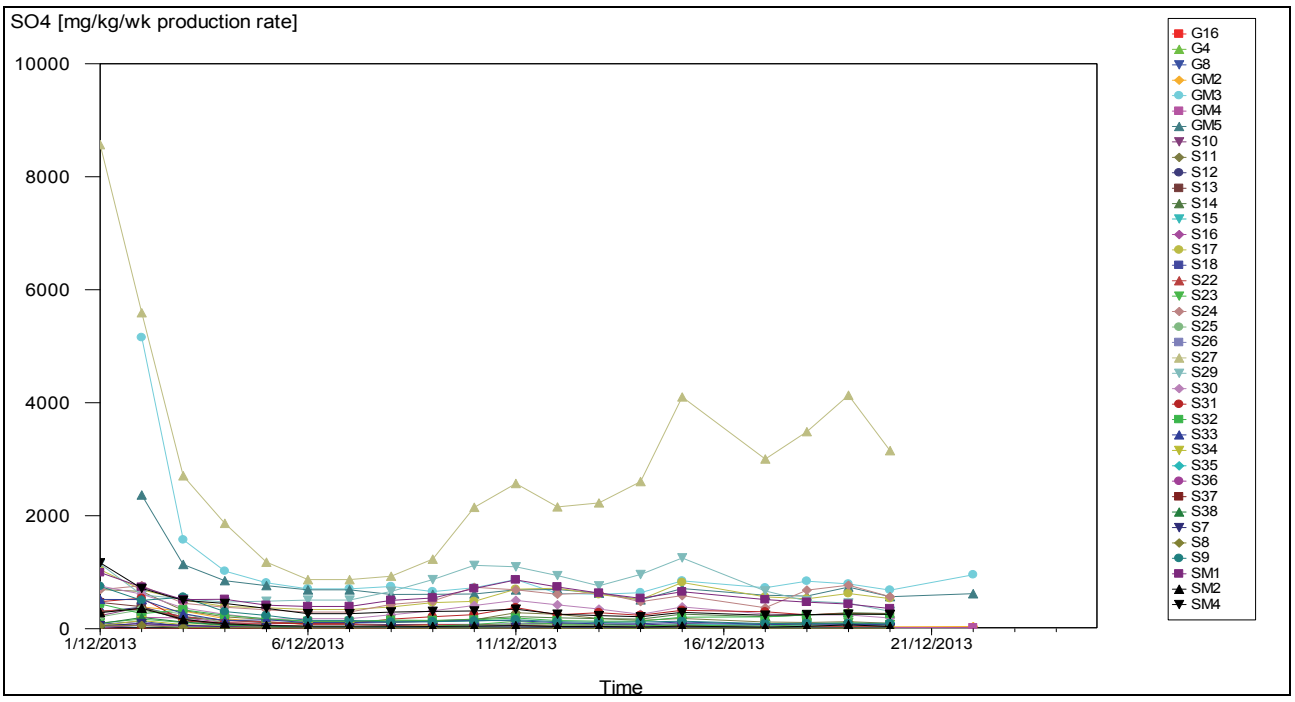

Figure 3-51: Humidity cell Sulphate results for the full succession samples

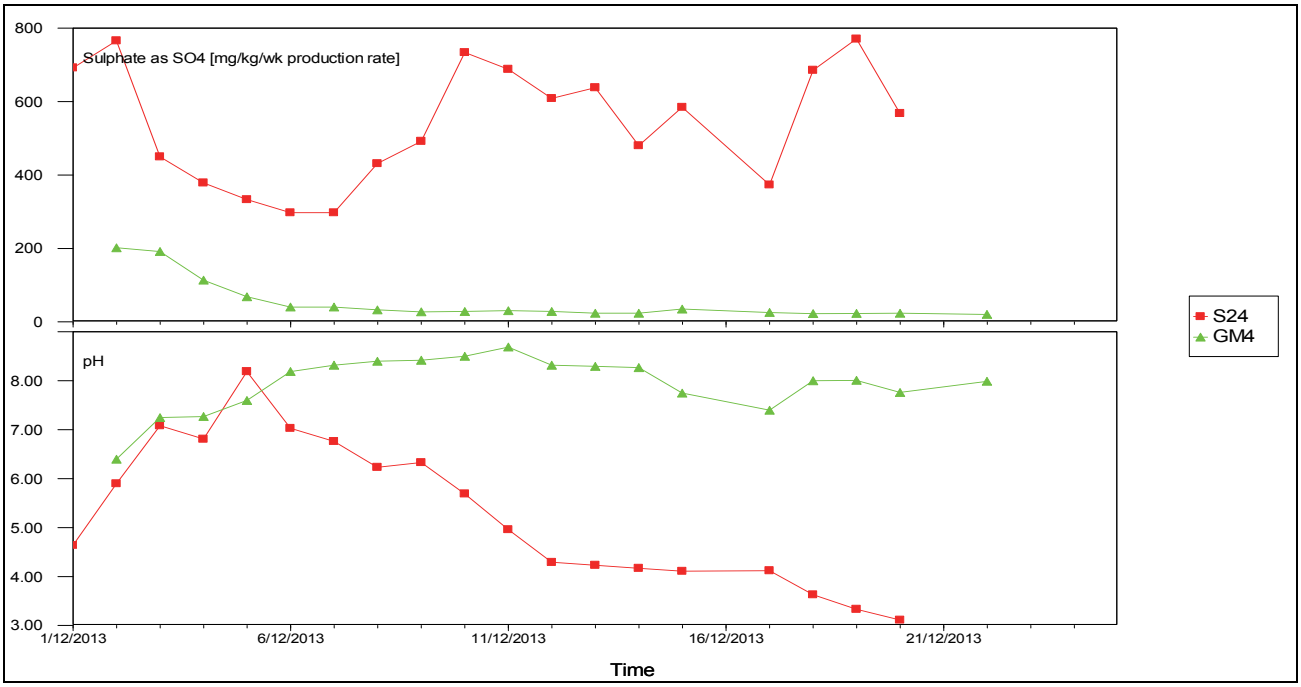

Figure 3-52: pH and Sulphate results for a full succession sample

The cumulative mass of sulphate produced clearly shows how the samples acidify (Figure 3-53 and Figure 3-54). The cumulative plot shows how the production flattens over the course of the testing.

This is typically what is expected at the mines when they fill up as well, due to initial oxidation on the outside surface of the material. The gradient of the curve provides an indication of the relative rates of sulphide production. The graphs for sulphate and iron indicated that the liberation of the two elements coincide, which is associated with the oxidation of pyrite (Figure 3-55).

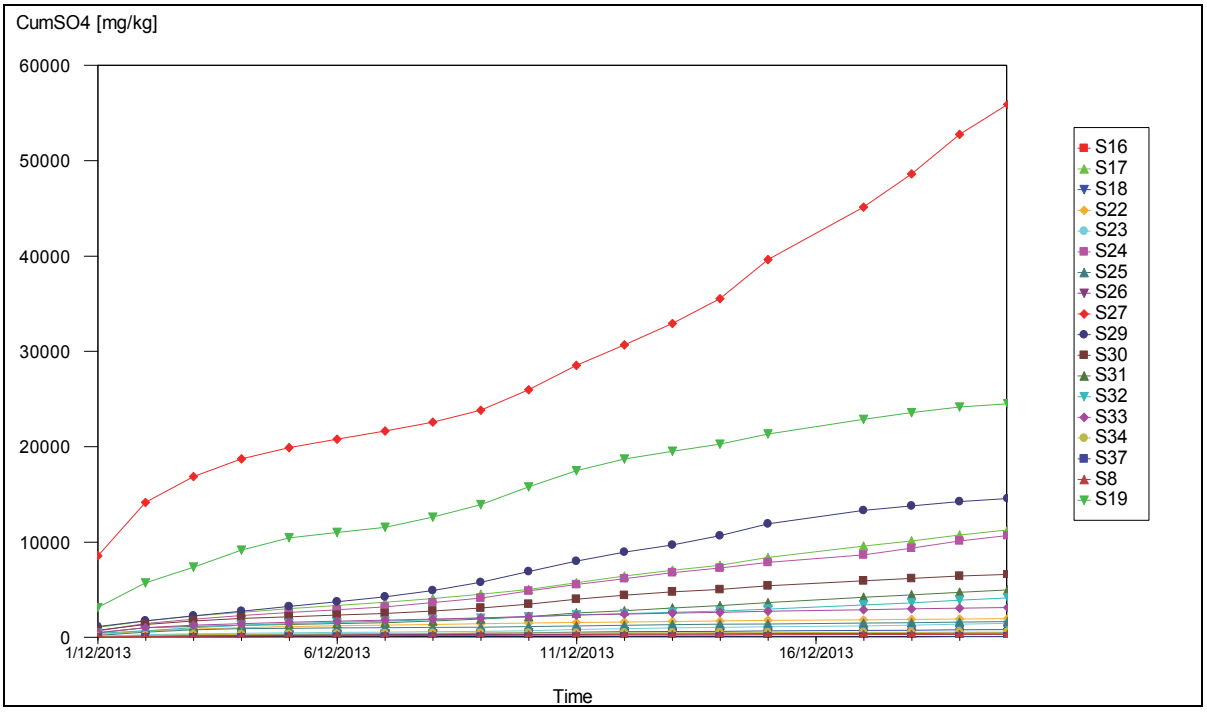

Figure 3-53: Cumulative Sulphate production for full succession 1 cell

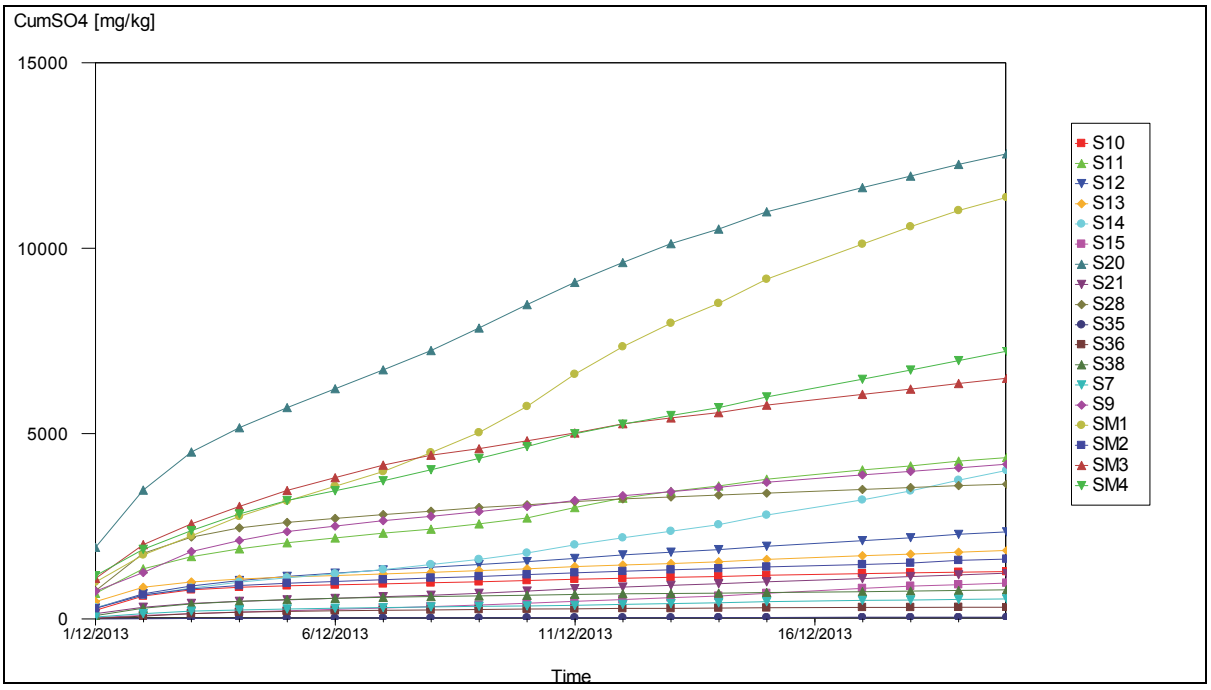

Figure 3-54: Cumulative Sulphate production for full succession 2 samplesl

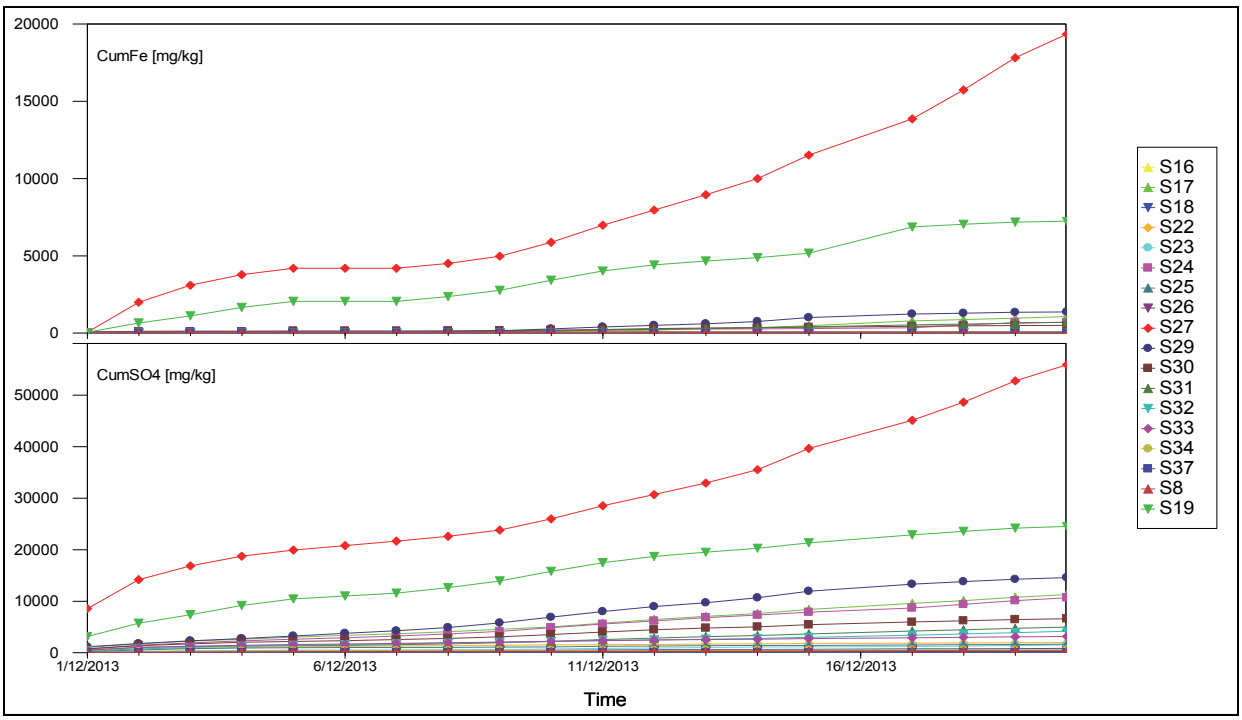

Figure 3-55: Sulphate and Iron production for samples from the Full succession

The nature of each humidity cell's leachate and the evolution thereof can be visualised effectively using the trilinear Durov diagram (Figure 3-56). The distinct grouping of each cell is evident, as is the fact that the electrical conductivity (EC) is driven by the relative sulphate/calcium/magnesium enrichment with respect to bicarbonate, and also to a lesser degree the sodium being leached.

The results for the humidity cells indicate the migration of the chemical composition within each cell. Over time the elements are leached from the system and show the migration pattern observed in Figure 3-56. Not all the full succession samples are plotted, but similar graphs are obtained with the rest of the samples.

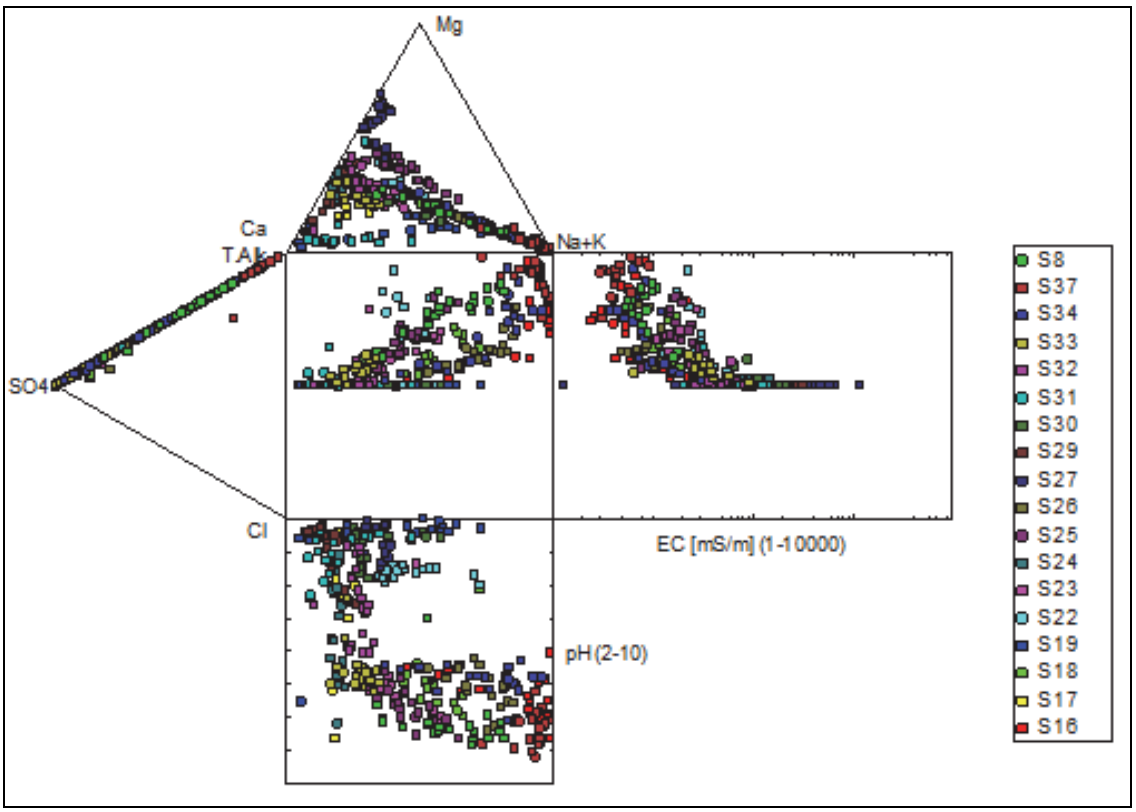

Figure 3-56: Durov diagram indicating chemical composition migration for some full succession samples

The leaching of Calcium from the humidity cells are illustrated in Figure 3-57. The liberation of the calcium will coincide with the depletion of the neutralising potential of the samples (Figure 3-57). As calcium is leached from the sample the NP decreases, lowering the buffer capacity the sample would have.

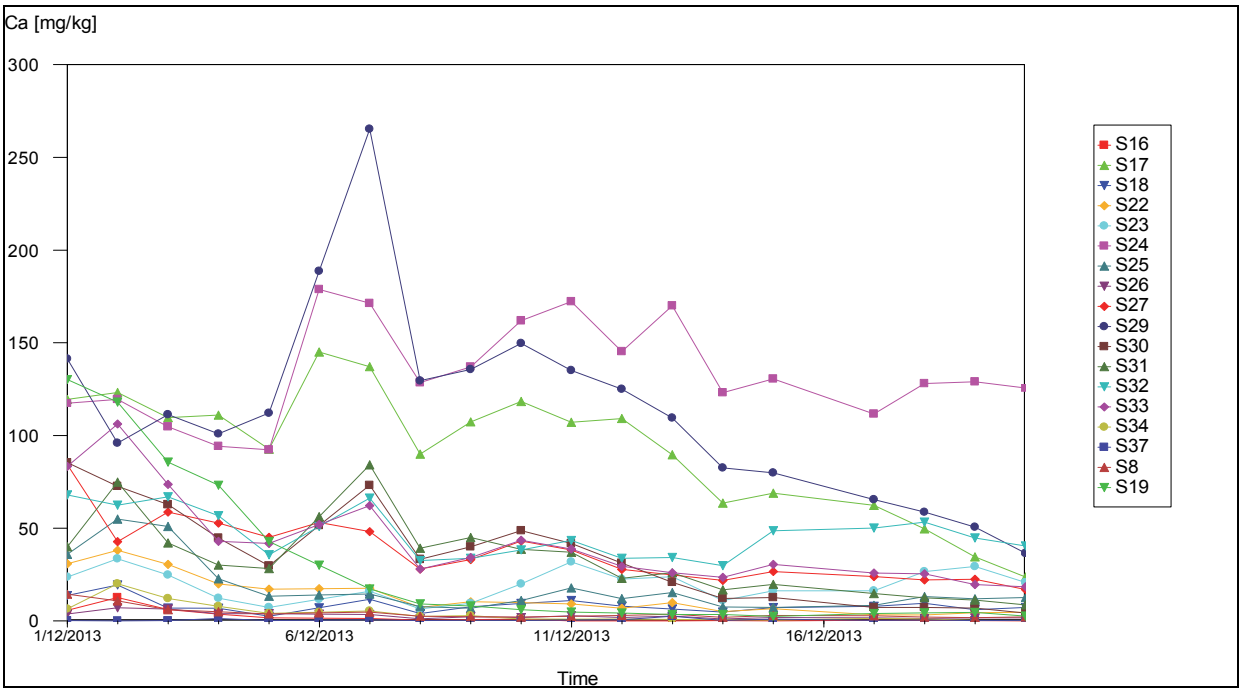

Figure 3-57: Leaching of calcium from the full succession cells

The cumulative salt load liberated from the cells over the time is plotted in Figure 3-58. Iron and sulphate are the major contributors to the total dissolved solids (TDS) for the high valued samples, which is mainly due to the oxidation process. The TDS will be liberated into the environment, causing higher salt values in streams and groundwater.

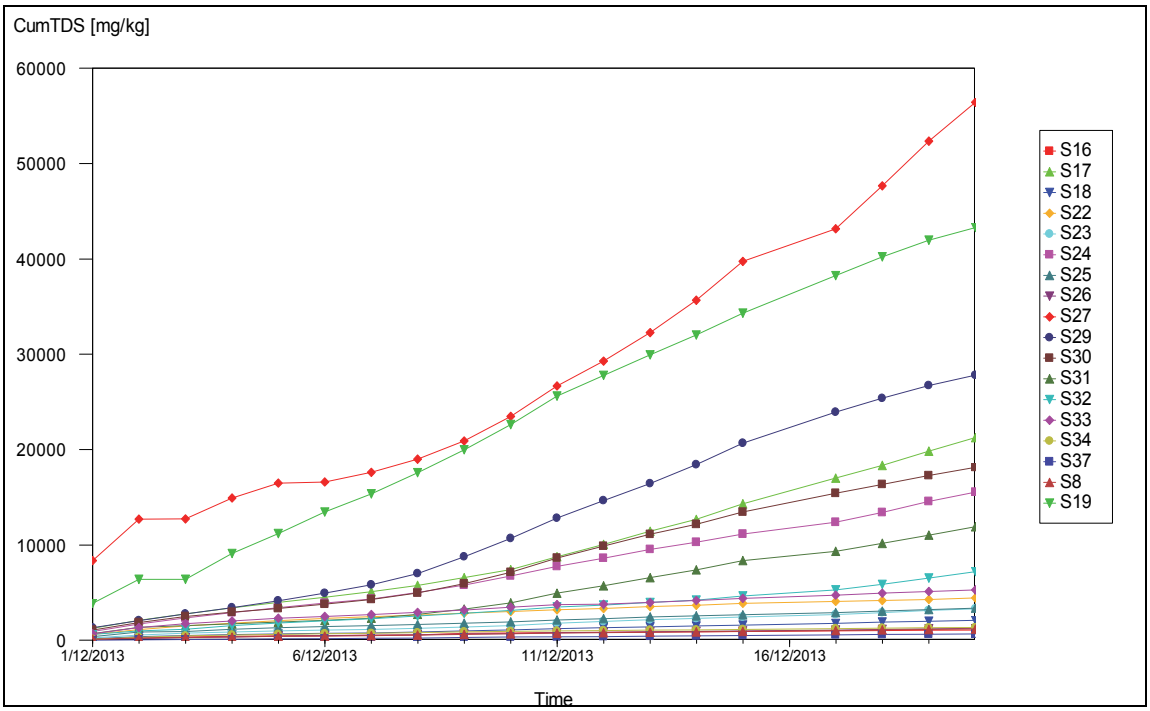

Figure 3-58: Cumulative TDS (full succession cells)

3.8.2 Middle Ecca samples

Only a few samples were selected from the Middle Ecca. The pH and sulphate values of the Middle Ecca are provided in Figure 3-59. These two parameters will provide an indication of the onset of acidification.

The pH results from the Middle Ecca samples remained approximately neutral and increased slightly over the 20 weeks testing time. The high sulphate values at the beginning of the tests are those that go into solution and are not mainly due to oxidation since the pH of the samples stayed neutral (Figure 3-59).

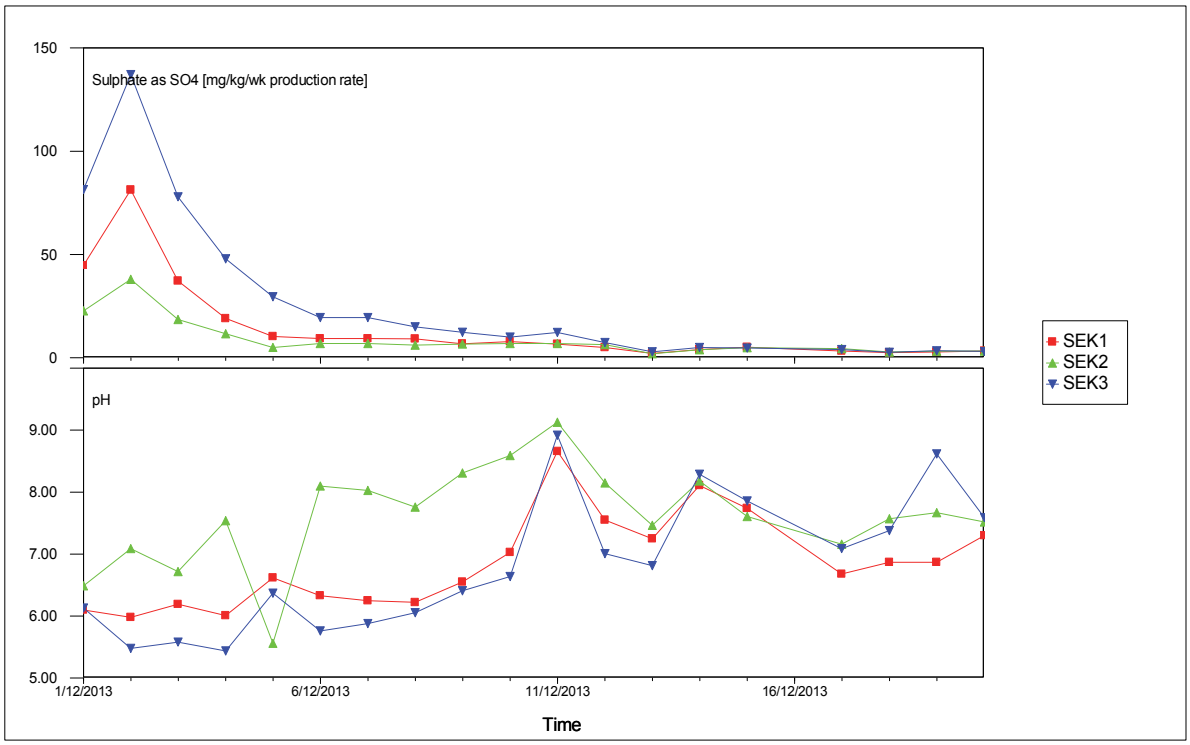

Figure 3-59: Sulphate and pH values over time for the Middle Ecca samples

The kinetic results obtained in the time frame of this experiment coincides with the results obtained with the static ABA. This occurred even though the acidic pH values of the final static pH results were not obtained over the time of the experiment, confirming the contribution of surface area to the reaction rate (Figure 3-59). The total salts liberated by the Middle Ecca Formations are much lower than that of the other succession samples tested. The oxidation of iron and sulphate better explains the elevations in TDS for Figure 3-60; this trend over time is typical for pyrite.

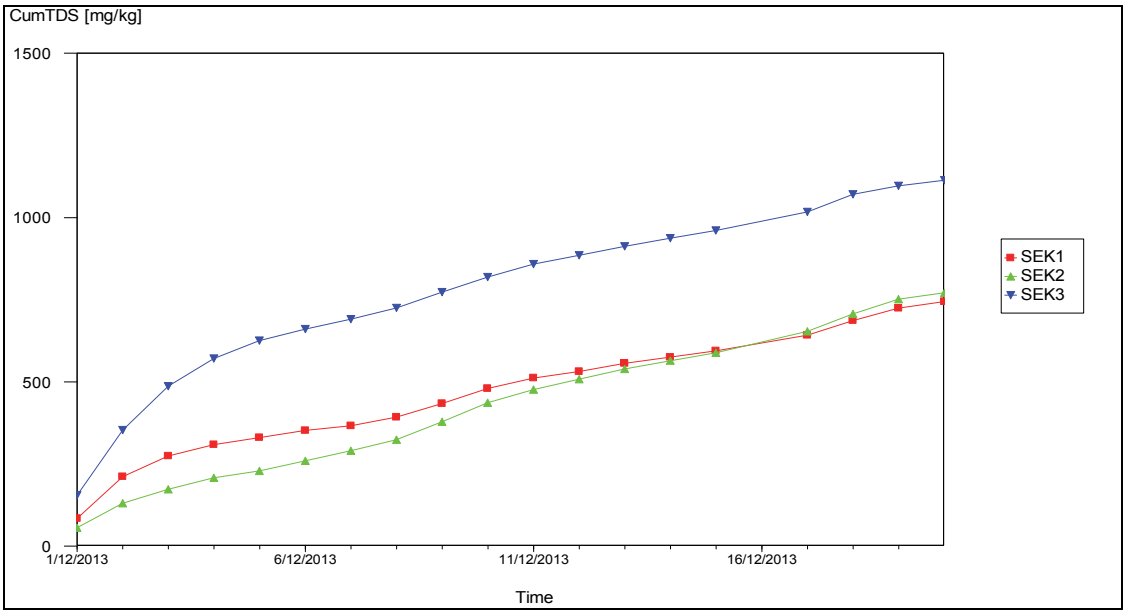

Figure 3-60: Cumulative TDS values over time for the Middle Ecca samples

3.8.3 Partly weathered samples

All the partly weathered samples retained their initial pH values at the start of the kinetic testing with small variations. No samples changed from their neutral pH to acidic (Figure 3-61). These samples would be ideal to use as their chemical characteristic doesn't change over time.

The liberated sulphate values are plotted in Figure 3-62. The sample with the lowest pH (S19), released the highest sulphate values. There appears to be two liberations for the sulphate within the sample. The first liberation of the sulphate can be from oxidation products already present, because of oxidation of the sample prior to the test. The second liberation is most likely due to the fresh oxidation of species in the sample. The pH and sulphate values for the acidic samples are plotted in Figure 3-63.

The cumulative plot indicates how the production flattens over the course of testing (Figure 3-64). This is not true for all of the samples. The cumulative plot shows an increase in sulphate over time. At this low acidic pH, it is assumed that the process would be self-sustaining and would continue to produce sulphate.

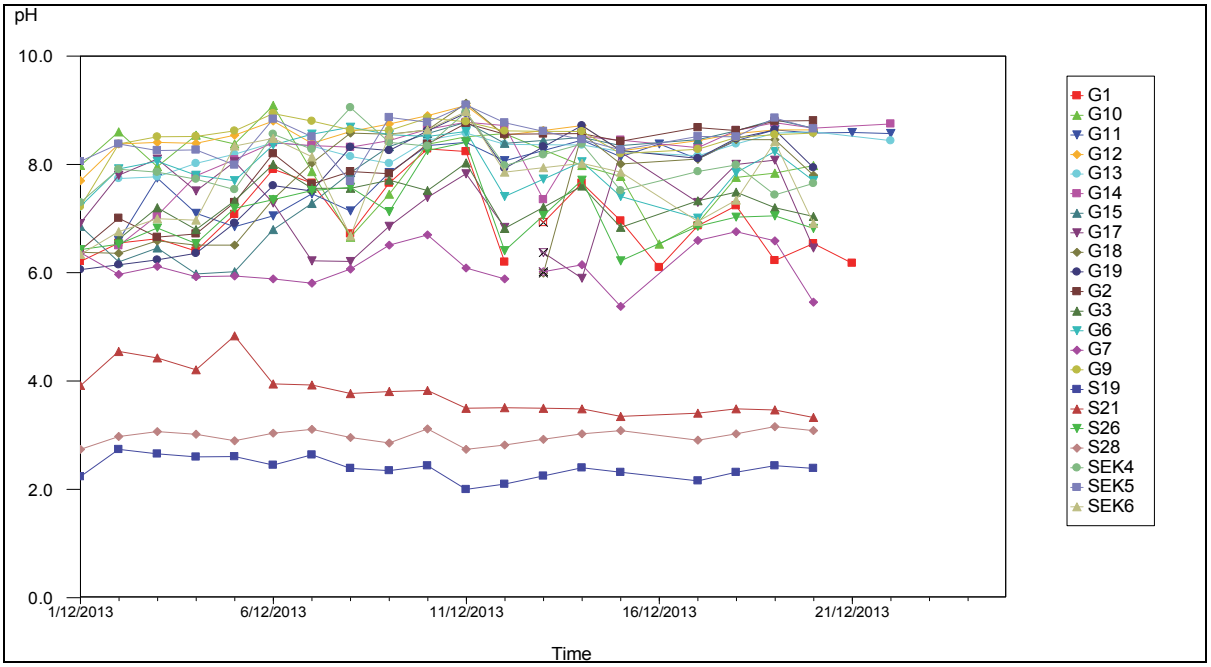

Figure 3-61: pH values over time for the Partly Weathered samples

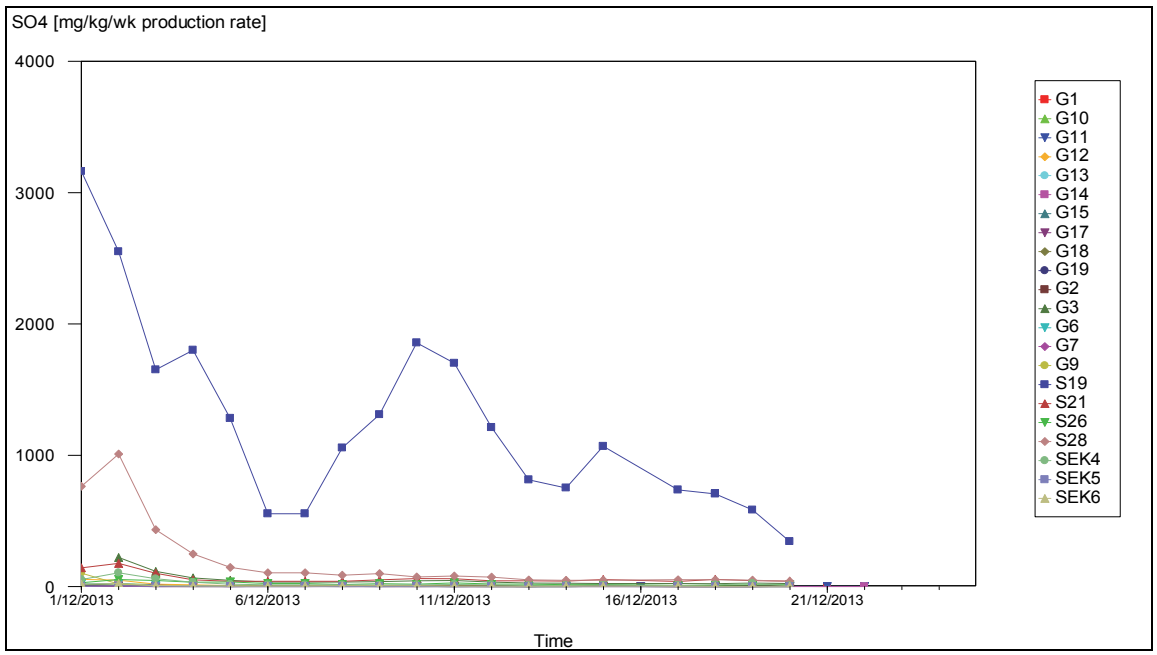

Figure 3-62: Sulphate values for the Partly Weathered samples

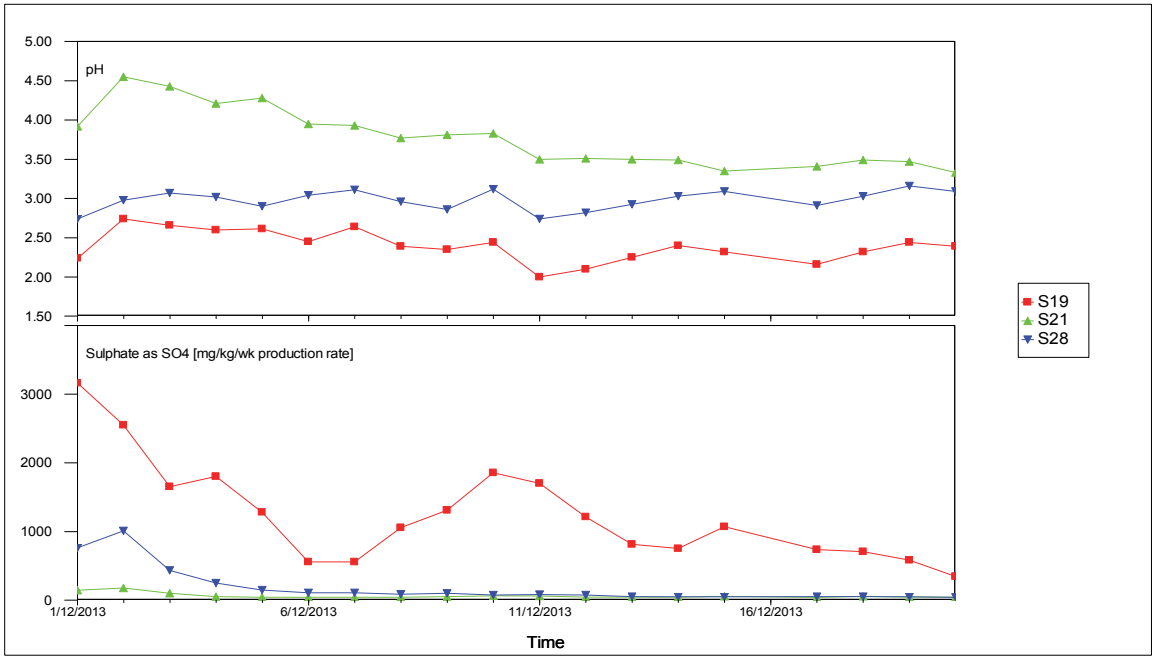

Figure 3-63: pH and sulphate values for the Partly Weathered samples

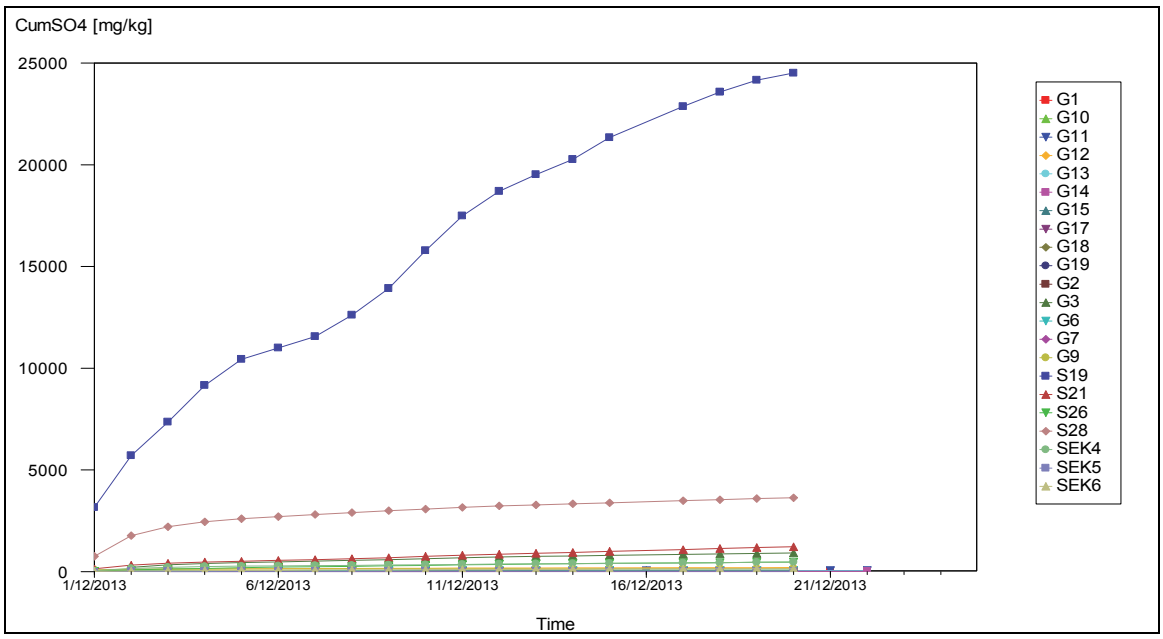

Figure 3-64: Cumulative sulphate values for the Partly Weathered samples

The cumulative plot of Iron and Sulphate is shown in Figure 3-65. There is a clear correlation for iron and sulphate within the samples. The high values are due to the contribution of pyrite minerals within the sampled material.

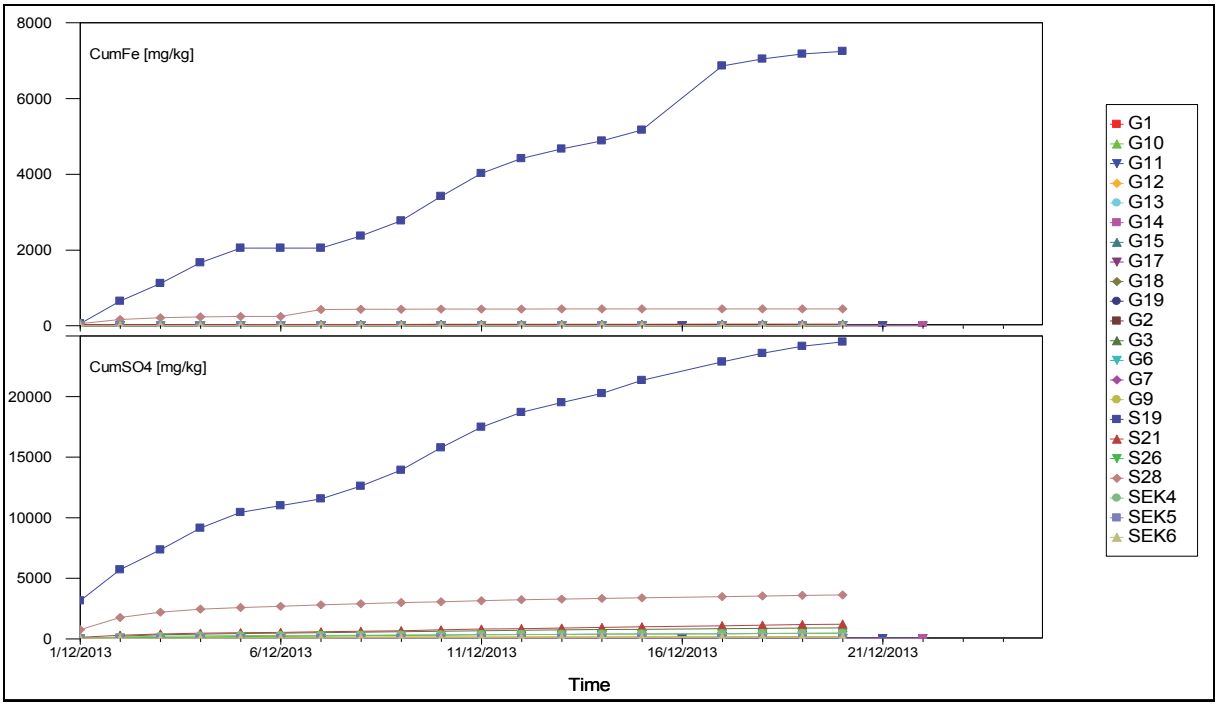

Figure 3-65: Cumulative sulphate and iron values for the Partly Weathered samples

The nature of each humidity cell's leachate and the evolution thereof can be visualised using the Durov diagram (Figure 3-66). The distinct grouping of each cell is evident, as is the fact that the electrical conductivity (EC) is driven by the relative sulphate/calcium/magnesium enrichment with respect to bicarbonate and also to a lesser degree the sodium being leached.

The cumulative salt load liberated from the cells over the time is plotted in *Figure 3-67*. Iron and sulphate are the major contributors to the total dissolved solids (TDS) in the samples with the high values, which are mainly due to the oxidation process. The elements that are dissolved are liberated into the environment. This increases the amount of dissolved solids (salt) that end up in the groundwater and streams. The total liberation of salts from the exposed rock or sample is clearly seen over time. The results from the kinetic testing are in line with that of the static ABA.

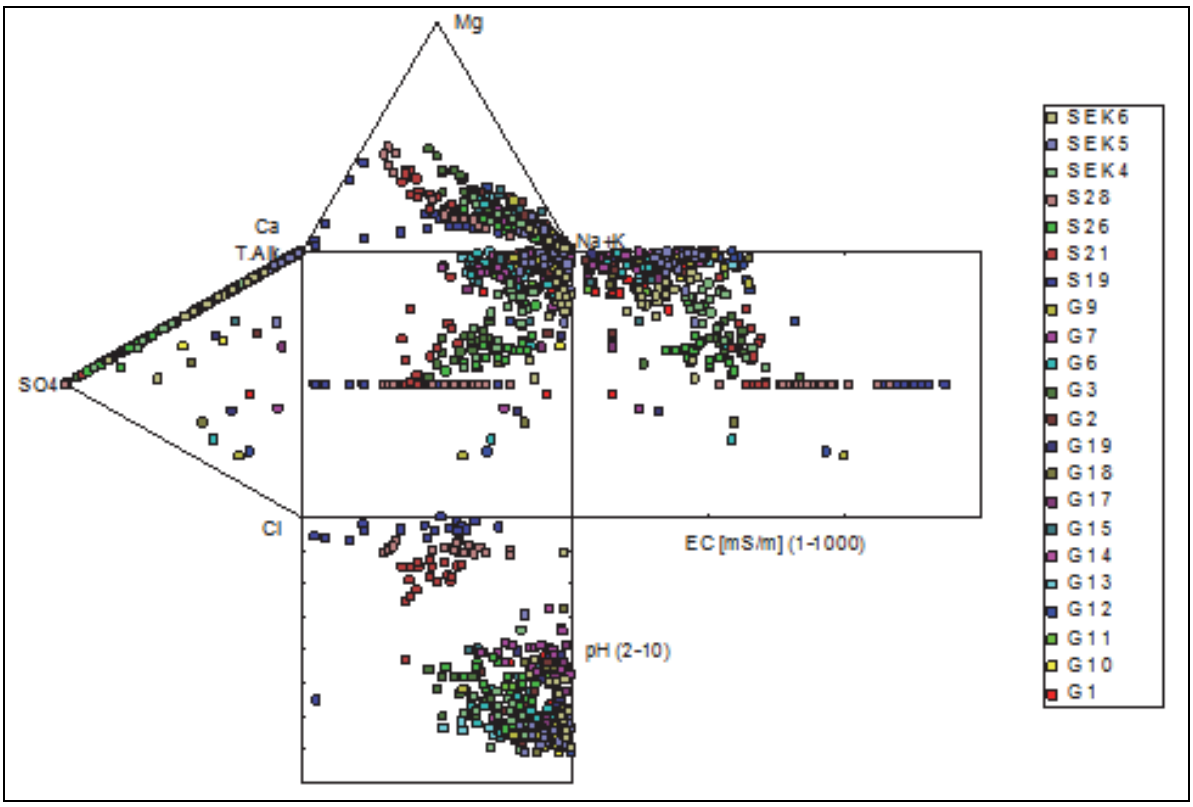

Figure 3-66: Durov diagram (Partly weathered)

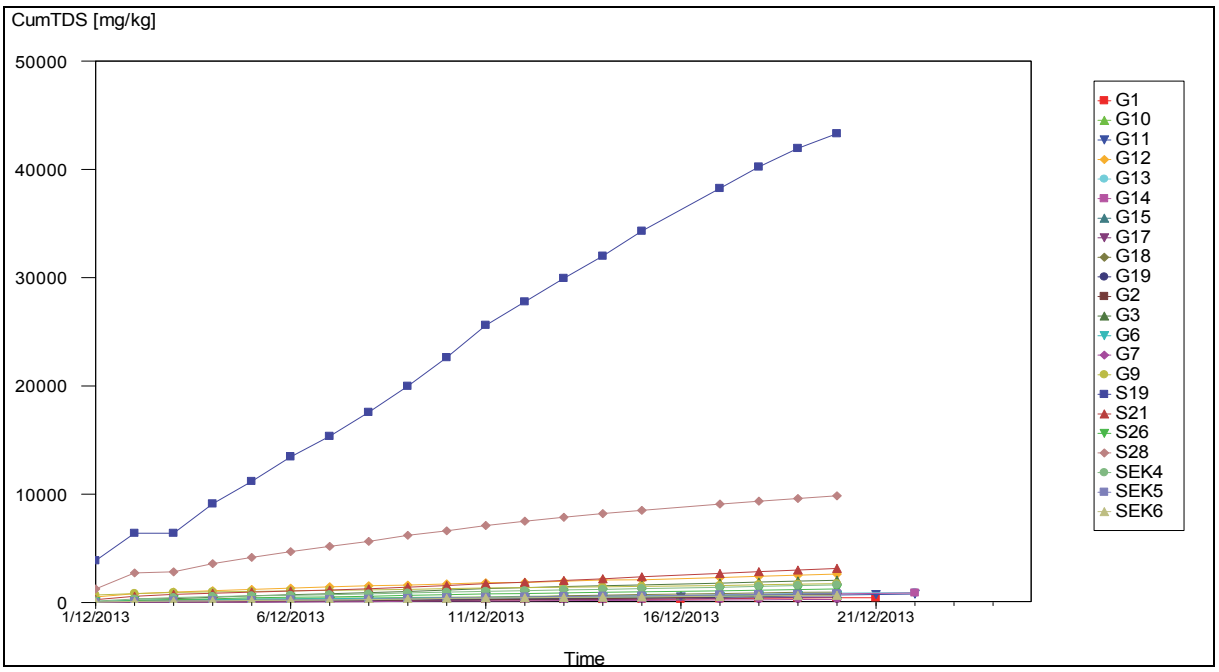

Figure 3-67: Cumulative TDS values for the Partly Weathered samples

3.8.4 Combination samples

Eleven kinetic cells were run with a combination of samples selected from the static ABA results. All samples were combined in a ratio of 1:1, while one sample (sample SM2) was comprised of 25% of each of the contributing sample. The combined samples' pH, calcium and sulphate values are shown in Figure 3-68.

The result showed a slight increase in calcium over time, and also explains the decrease of sulphate as the calcium probably acts as a buffer within the samples. The pH for the majority of the samples stays at relatively neutral values with two exceptions SM1 and SM4. The slight increase in pH is due to the liberation of calcium. This is seen in sample SM4 where calcium is released the pH increased and as soon as the calcium is removed the pH decreased to the initial acidic value.

The iron and sulphate graphs, clearly indicate that acidification of the samples are in most cases linked to pyrite oxidation (Figure 3-69).

The cumulative TDS for the combined kinetic cells are plotted in Figure 3-70. There is an increase in TDS over time, which indicates that the samples have a high salt load. These salts can be released if exposed to rain. The rain would leach salt from the material over time.

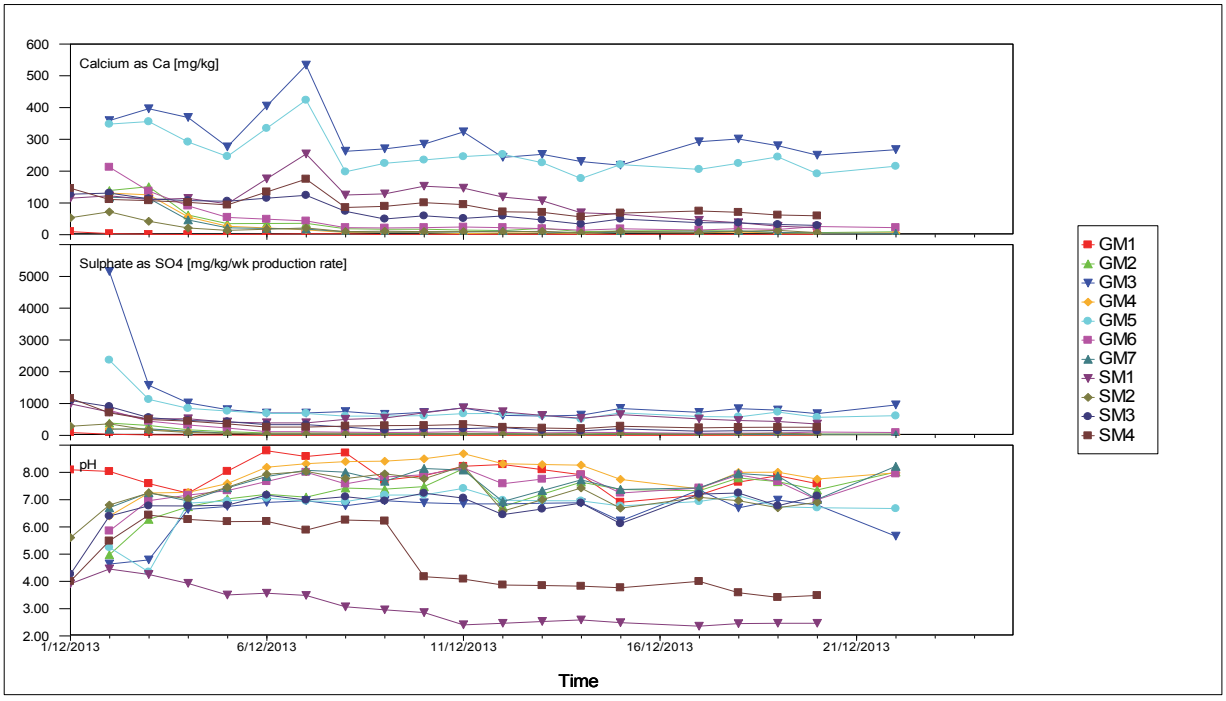

Figure 3-68*: pH, Calcium and Sulphate values for the combined/mixtures cells*

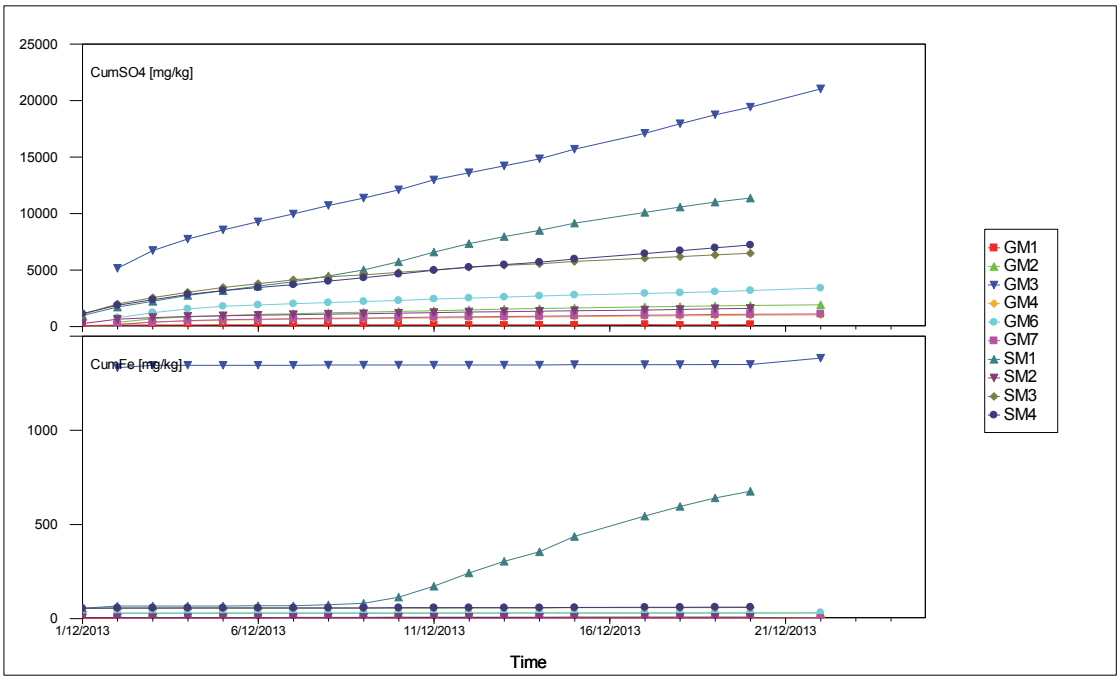

Figure 3-69: Iron and Sulphate values for the combined cells

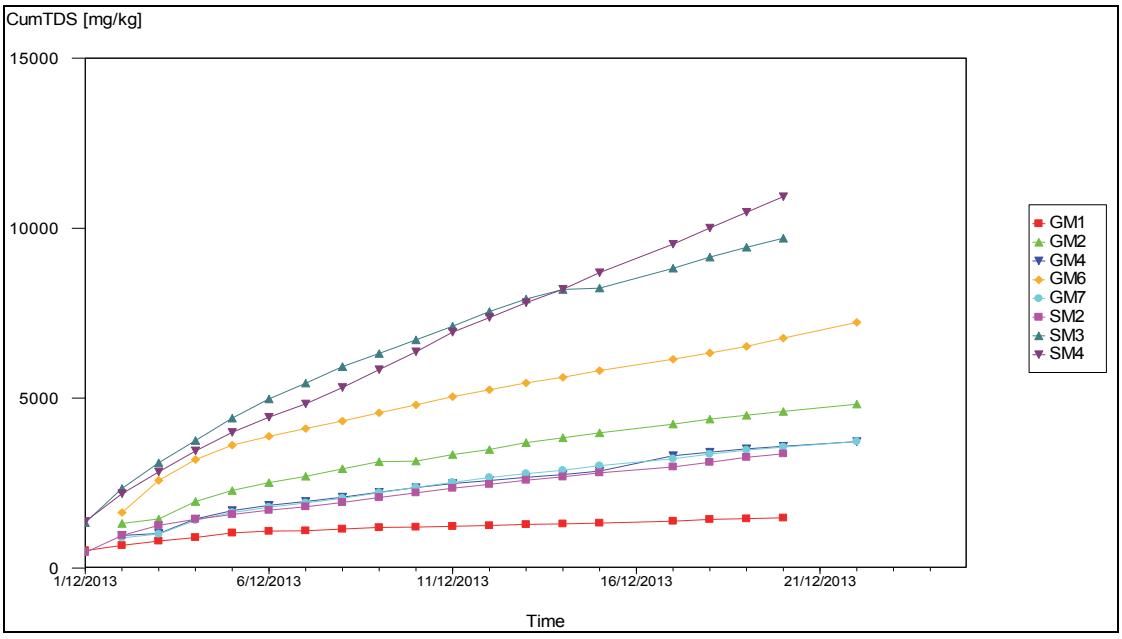

Figure 3-70: Cumulative TDS values for the combined cells

The remaining percentage sulphur for all the humidity cells (except the combination cells) are sho*wn* in Figure 3-71, Figure 3-72 and Figure 3-73. The remaining sulphur plot indicates that even if the humidity cells have a low acid potential, they still contain a high percentage of the original sulphur in the humidity cell after leaching. The remaining sulphur in the humidity cells with a high acid potential show that up to 25% of the sulphur has been leached from the humidity cells over the 20 weeks of kinetic testing.

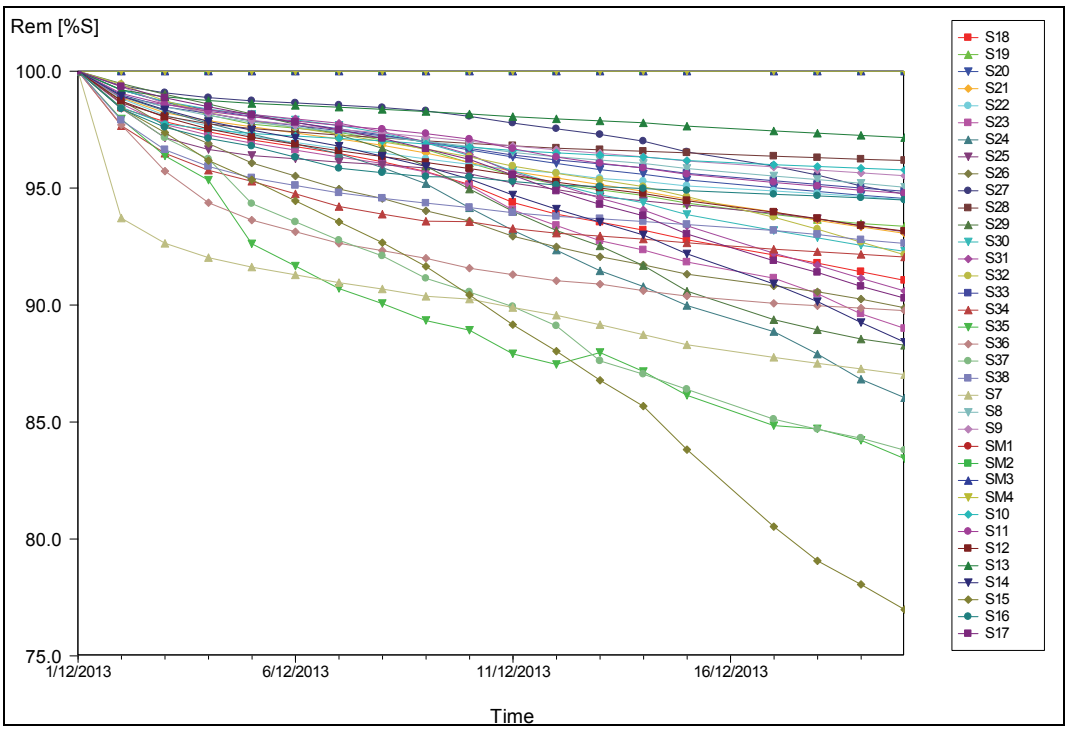

Figure 3-71: Remaining % S for the full succession

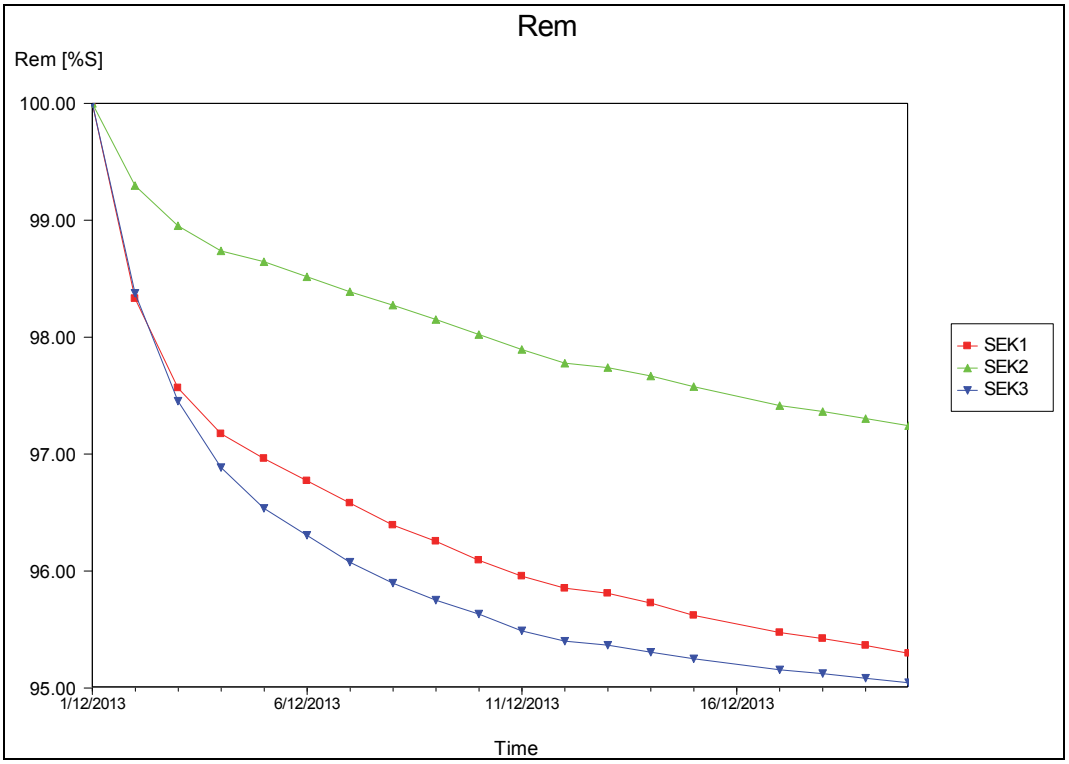

Figure 3-72: Remaining % S for the Middle Ecca succession

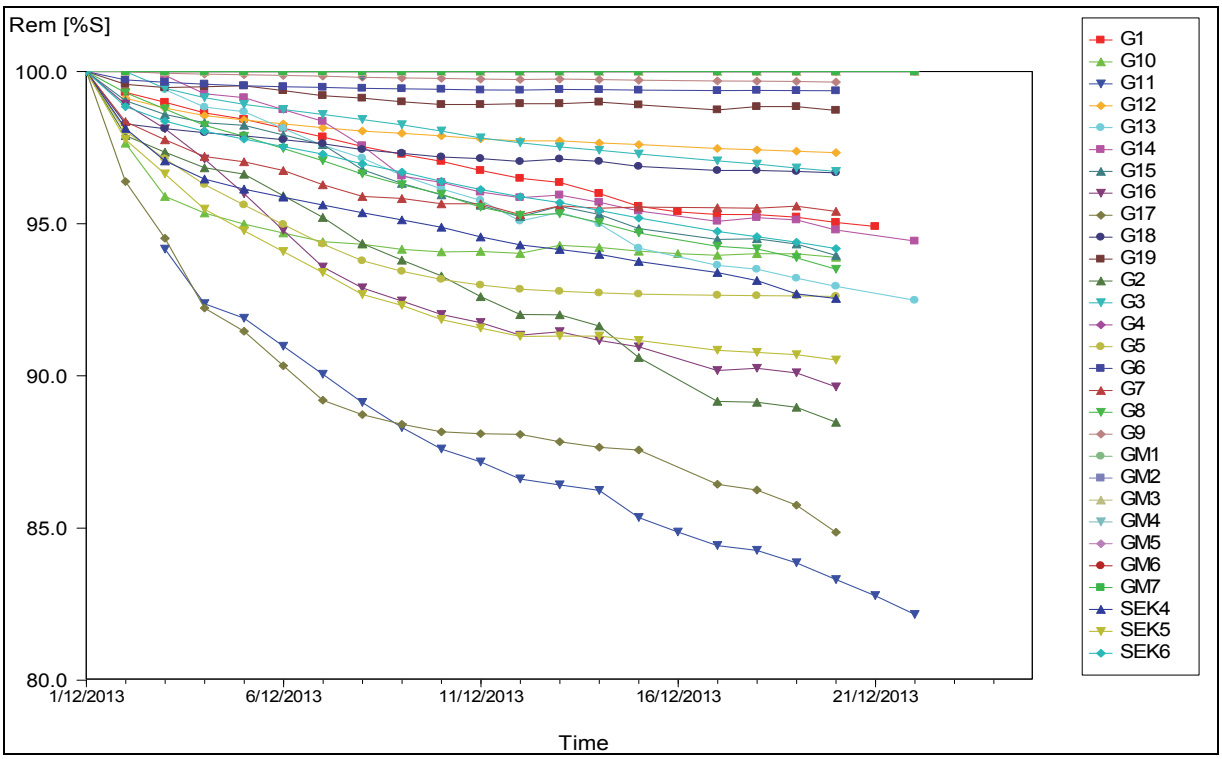

Figure 3-73: Remaining % S for the partly weathered successions

The remaining percentage NP (alkalinity) for the cells correlates with the pH of the samples. The alkalinity in Figure 3-74 shows with a decrease in pH (<4.5), there is no NP left in the sample.

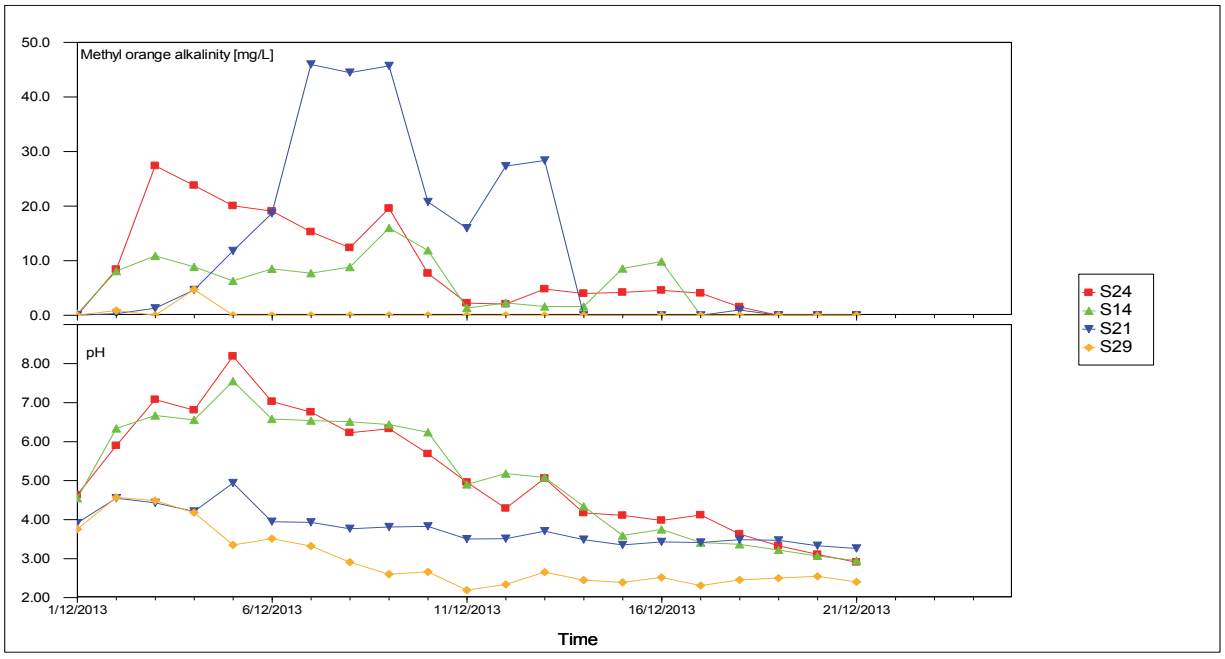

Figure 3-74: pH and alkalinity relationship

In most cases, the kinetic data confirmed what was obtained with the static ABA tests. In some cases the kinetic cell results (after 20 weeks) did not completely correlate with the static ABA results due to a time constrain (many authors recommend kinetic/humidity cells to run for longer than 20 weeks). The effects of pulverising include more sample area exposed that can react

compared to slower or incomplete reactions. The total salt (TDS) released from exposed rock into the environment can be seen from the cumulative TDS values plotted over time. The exact onset of when ARD will start an exactly how long it will take cannot be predicted. Of importance is to know the geological units, mainly interburden and plant discards, that can produce ARD and that the samples are handled accordingly with the goal in mind to minimise the ARD and the effect on the environment.

3.9 Overall summary of results

3.9.1 Overburden

The ABA analyses indicated a dominantly neutralising potential for overburden samples, as well as an acidic potential for the shale units on top of the coal. The samples that did not show a clear distinction were subjected to further kinetic tests. The samples that were analysed over a period of 20 weeks indicated non-acid producing potentials and some with neutralising potentials.

The pH provides an indication of the onset of acidification (Figure 3-75). The initial pH values from the overburden samples were neutral to start with and remained neutral throughout the testing. The sulphate values shows a decline over the first week as the oxidised products are removed from the system (Figure 3-76). This suggests that the sulphide oxidation occurred prior to kinetic testing. Figure 3-77 shows the sulphate concentrations when the high values are removed to show the range of the overburden samples.

The cumulative mass of sulphate produced, indicated that the overburden samples do not continue to produce sulphate, but rather reaches a constant rate where sulphide is produced (Figure 3-78). The cumulative plot shows how this flattens over the course of the testing time to provide a better spread of production rates.

During the kinetic tests, the results for calcium and alkalinity were relatively high (Figure 3-79). The relatively low calcium values indicate that carbonates are immediately available and demonstrate the balance between the released alkalinity and the acidity generated. If the balance between the alkalinity and the acidity stays positive, the system will not acidify.

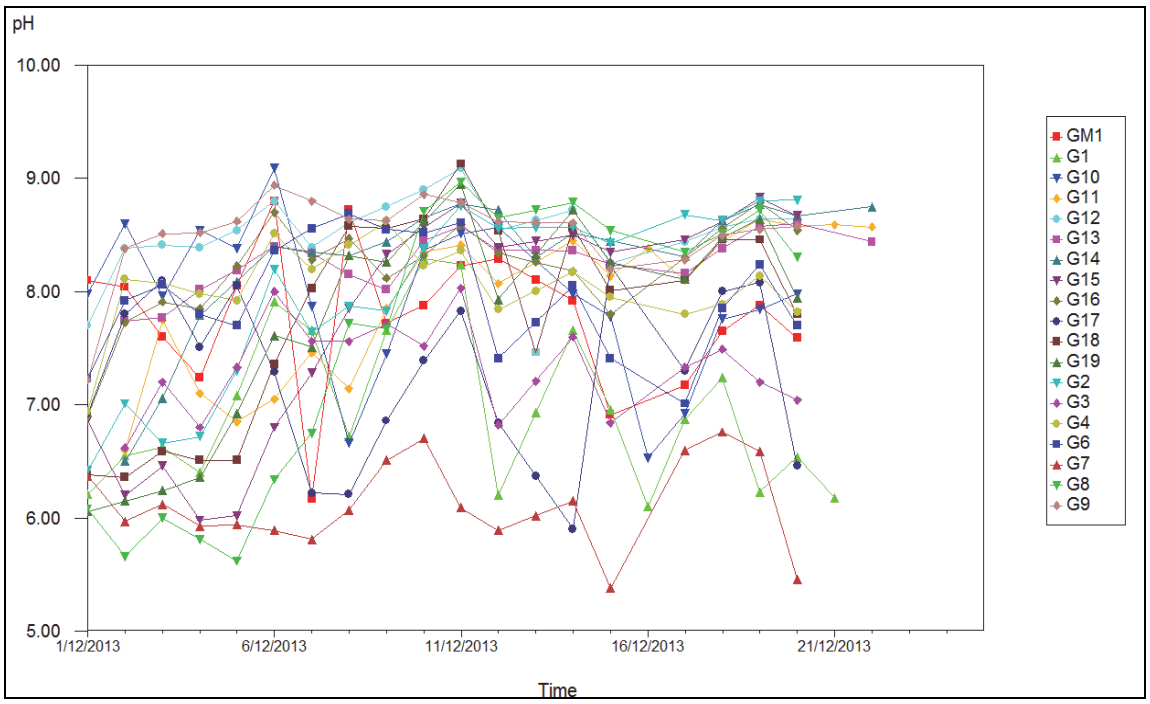

Figure 3-75: The pH values from the humidity cells for overburden material

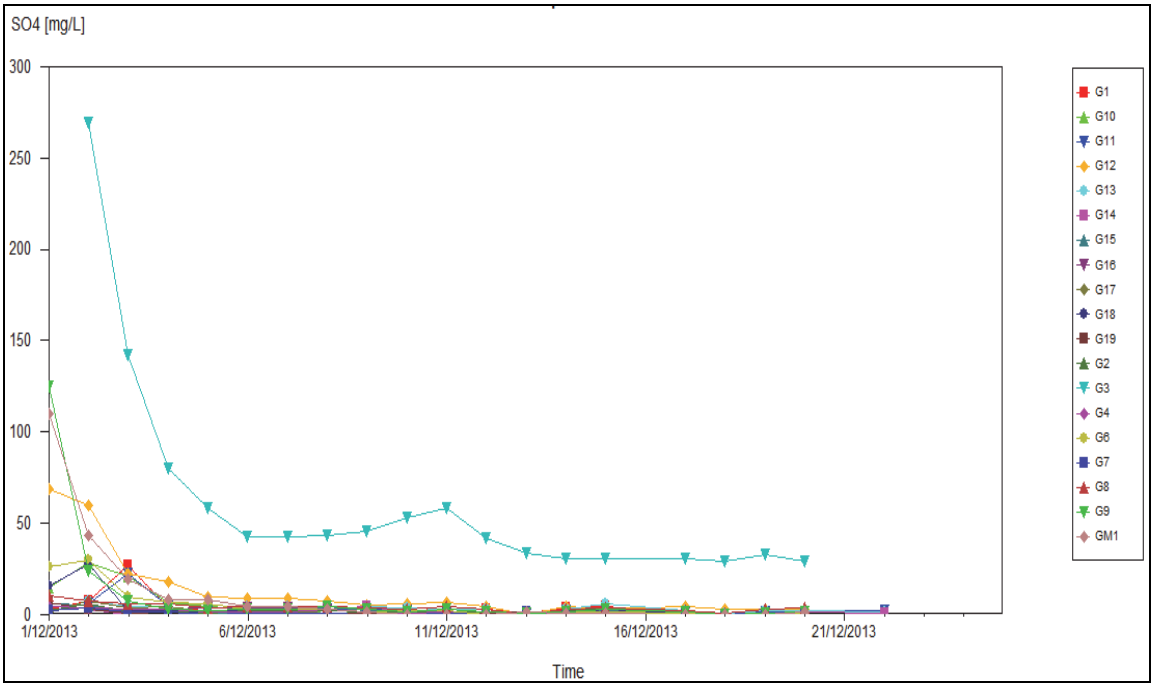

Figure 3-76: The sulphate values from the humidity cells for overburden material

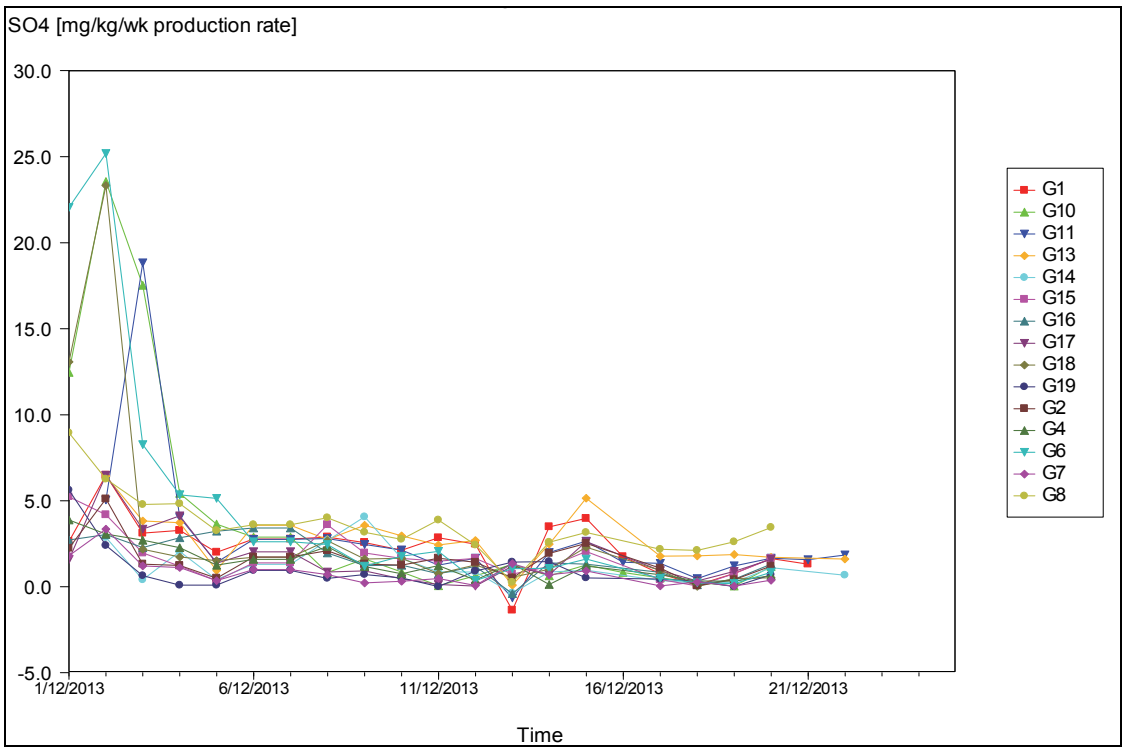

Figure 3-77: The enlarged sulphate values from the humidity cells for overburden material

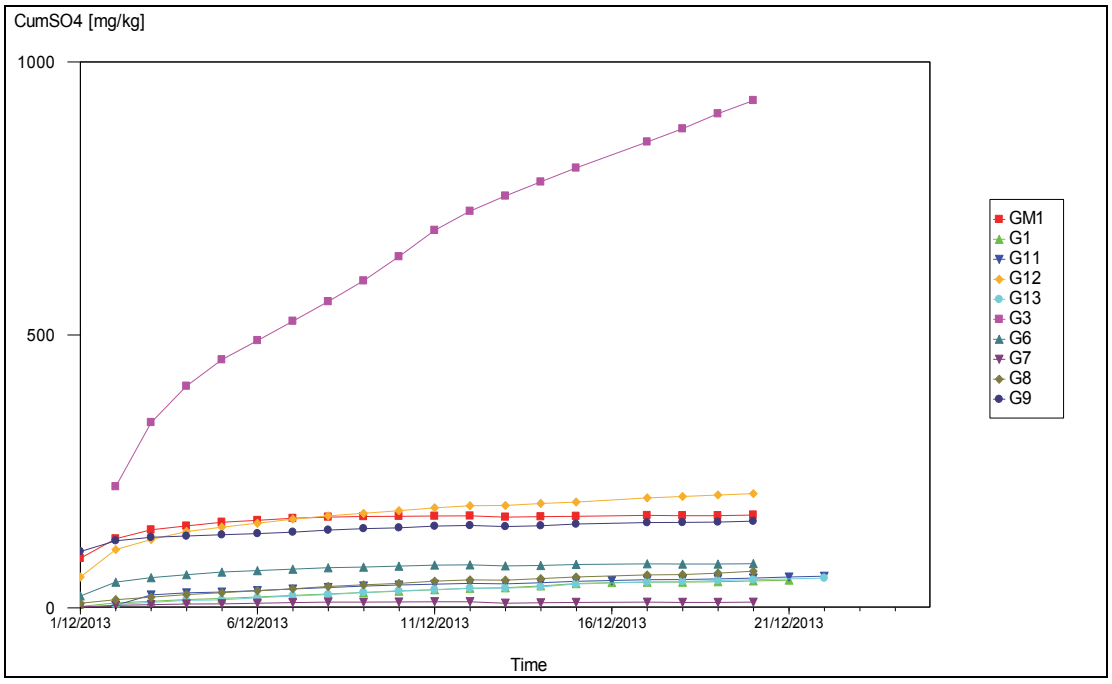

Figure 3-78: Cumulative sulphate production (mg/kg) from humidity cells for overburden material.

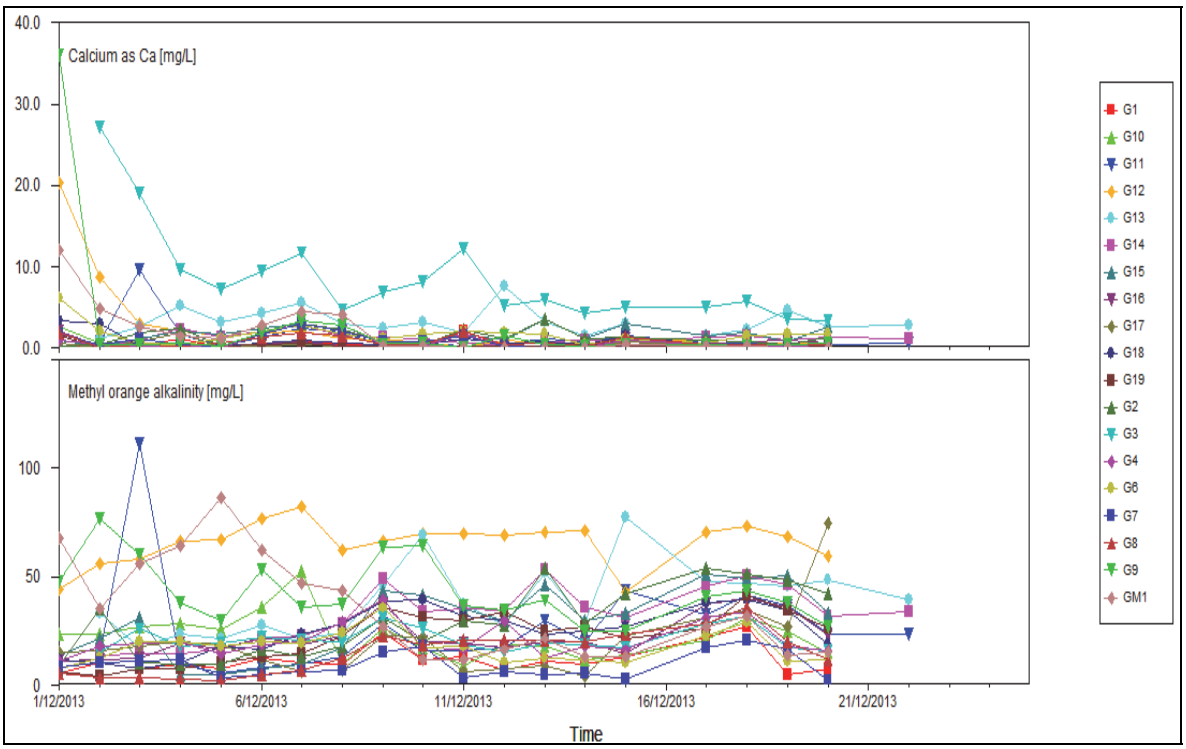

Figure 3-79: The Ca and alkalinity values from humidity cells for overburden material

3.9.2 Interburden

The ABA analyses showed that the analysed interburden samples contained both acidic and neutralising potentials. Interburden and mixtures of acidic and neutralising interburden was selected to run kinetic tests on. The purpose was to show the extent to which acid producing interburden, mixed with a neutralising component, could reduce the acidic nature of the samples.

Mudstone, shale and calcrete layers indicated a neutralising potential, while sandstone had a relatively high acid generating potential. The initial pH values for the interburden samples were both acidic and neutral. The acidic pH values stayed acidic, whilst some of the neutral pH values remained neutral and others became acidic (*Figure 3-80*). The kinetic samples S14, S15, S24, S32 and SM2 consisted of mudstone, sandstone and siltstone (Table 3-J).

Table 3-J: The kinetic tests that became acidic from initially neutral pH values

Kinetic sample	Sample name	Lithology
S14	WGH 170	Sandstone
S15	WGH 192	Sandstone
S24	WGD2 (A)	Sandstone/coal
S32	WGB4 (B)	Mudstone/sandstone
SM2	WGG2+WGG4(D)+WGG4(F) +WGG6(A)	Mudstone and sandstone

The sulphate values show a slight decline over the first few weeks of testing, with a gradual increase for the remainder of the test. The slight increase is due to the oxidised products being flushed from the system (Figure 3-81). The gradual increase of the interburden samples suggests sulphide oxidation occurred during the kinetic testing.

The cumulative mass of sulphate produced, showed that the interburden samples continue to produce sulphate and did not appear to reach a constant rate of sulphate production (Figure 3-82). The cumulative plot demonstrates the increase in relative rates of sulphate production over the course of the testing time. With prolonged exposure the system would acidify as sulphate is released into the system.

Calcium and alkalinity results showed high calcium values, with relatively low alkalinity for the interburden material (Figure 3-83). The high calcium values indicate the availability of carbonates, whereas in this case the carbonates are not immediately available.

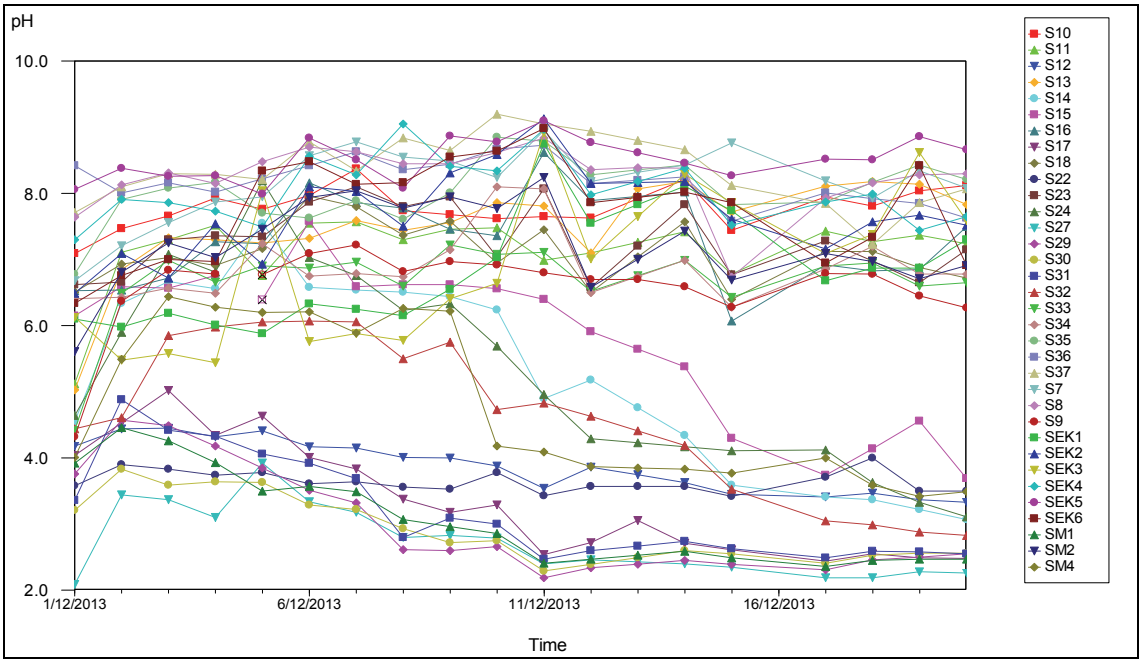

Figure 3-80: The pH values from the humidity cells for interburden material

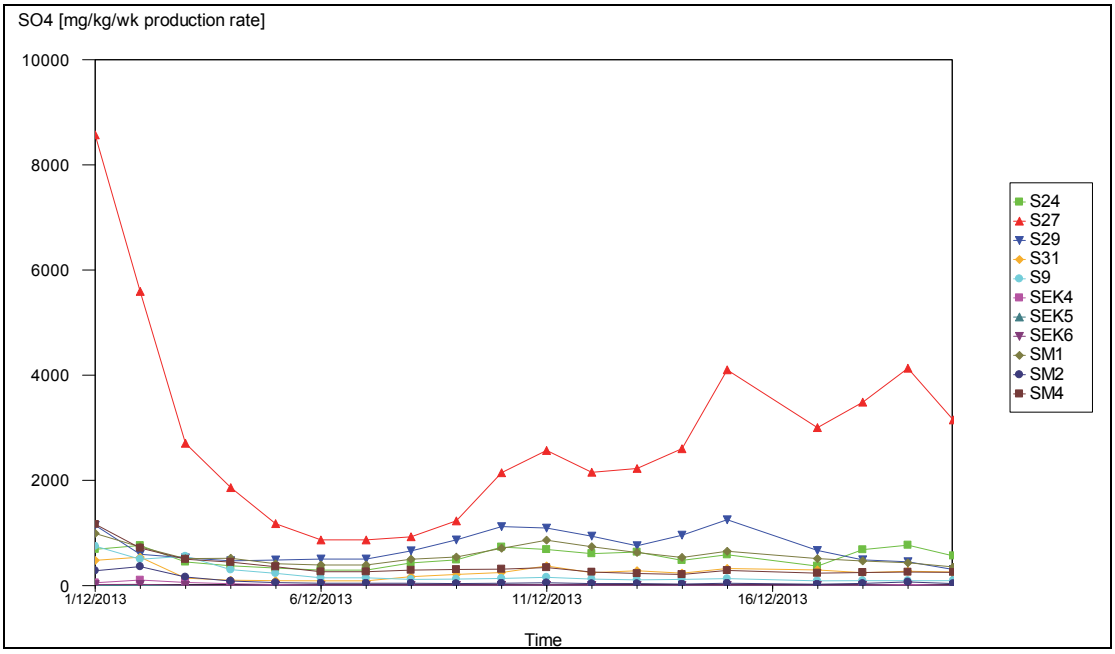

Figure 3-81: The sulphate values from the humidity cells for interburden material

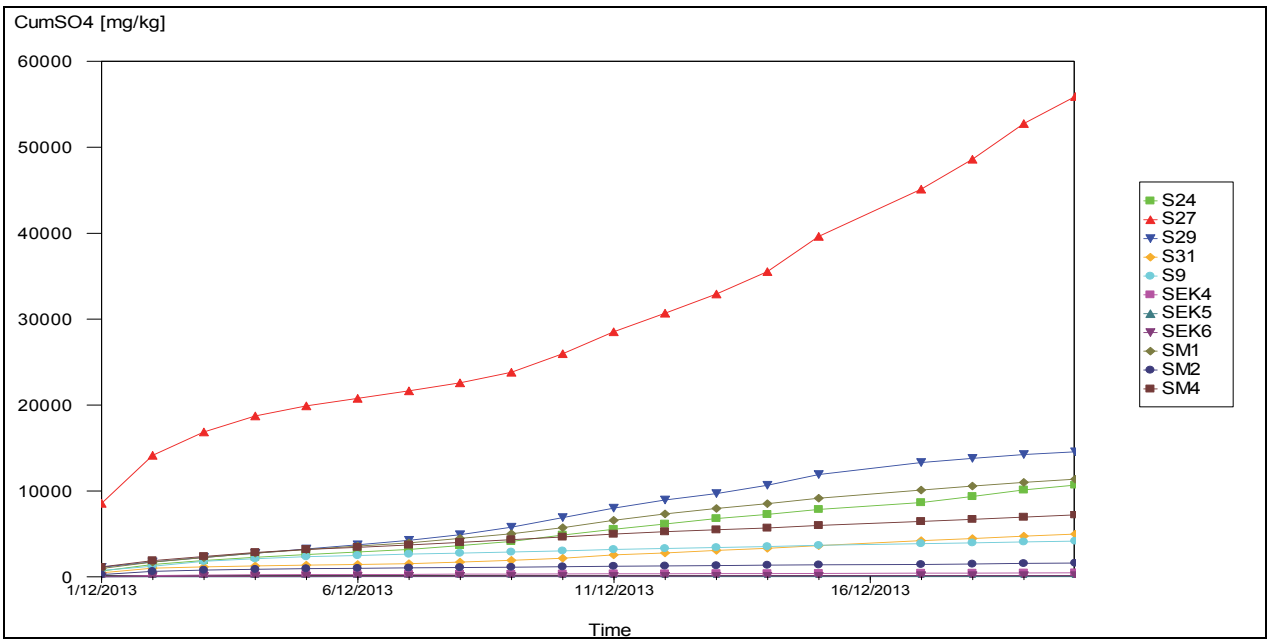

Figure 3-82: Cumulative sulphate production (mg/kg) from humidity cells for interburden material

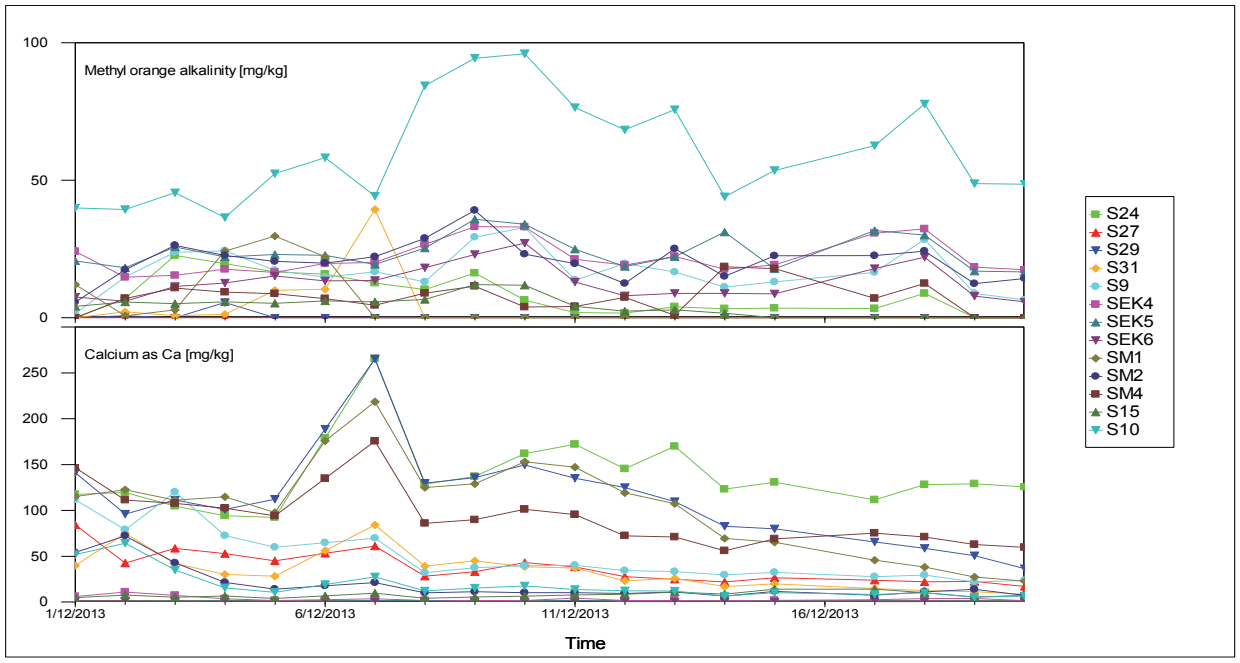

Figure 3-83: The calcium and alkalinity values from humidity cells for interburden material

3.9.3 Plant discards/composites

The plant discards consist of unwanted material that remains after coal separation, also known as composite samples. The different density composite samples were analysed and indicated that they all have a high potential to produce acid.

3.9.4 Mixed overburden, interburden and discards

The overburden and interburden have already been mentioned as neutralising and acidic, respectively. A combination (predetermined mixture ratio) of overburden, interburden and

composites, can potentially reduce the risk of acid generation within the pit. Kinetic tests on mixtures of overburden, interburden and composite material showed that the acidic nature of the samples were reduced. In the event that the buffer potential of the mixed overburden and interburden fail to reduce the acid generation and the exposure to oxygen in the presence of water, the acid generating process will be accelerated. All the samples were mixed in a 50:50% ratio except for sample SM2 which consisted of 25% of each sample.

The initial pH values of the samples were acidic, but after testing was completed the samples became neutral due to the overall effect of mixing overburden, interburden and composite material (Figure 3-84). The decrease in pH for samples GM3 shows the limited buffer capacity this mixture would have, initially increasing the pH and after the buffer capacity is not adequate enough the pH would decrease.

The slight sulphate decline in samples GM2-GM7 at the initiation of kinetic testing suggests the oxidised products were leached from the system (Figure 3-85). The cumulative mass of sulphate produced, indicates that the overburden, interburden and composite samples all continued to produce sulphate over the course of the test (Figure 3-86). The gradient of the curve provides an indication of the relative sulphate production rates, showing that the initially high sulphate production continues to increase over time.

Calcium and alkalinity results showed that there were relatively low amounts of alkalinity released into the surroundings (Figure 3-87). Although the carbonates are not immediately released, the balance between the acid generated and the released alkalinity stays positive. If the balance is influenced negatively, acid would start to generate from these materials and infiltrate to the bottom of the pit and eventually into the groundwater system.

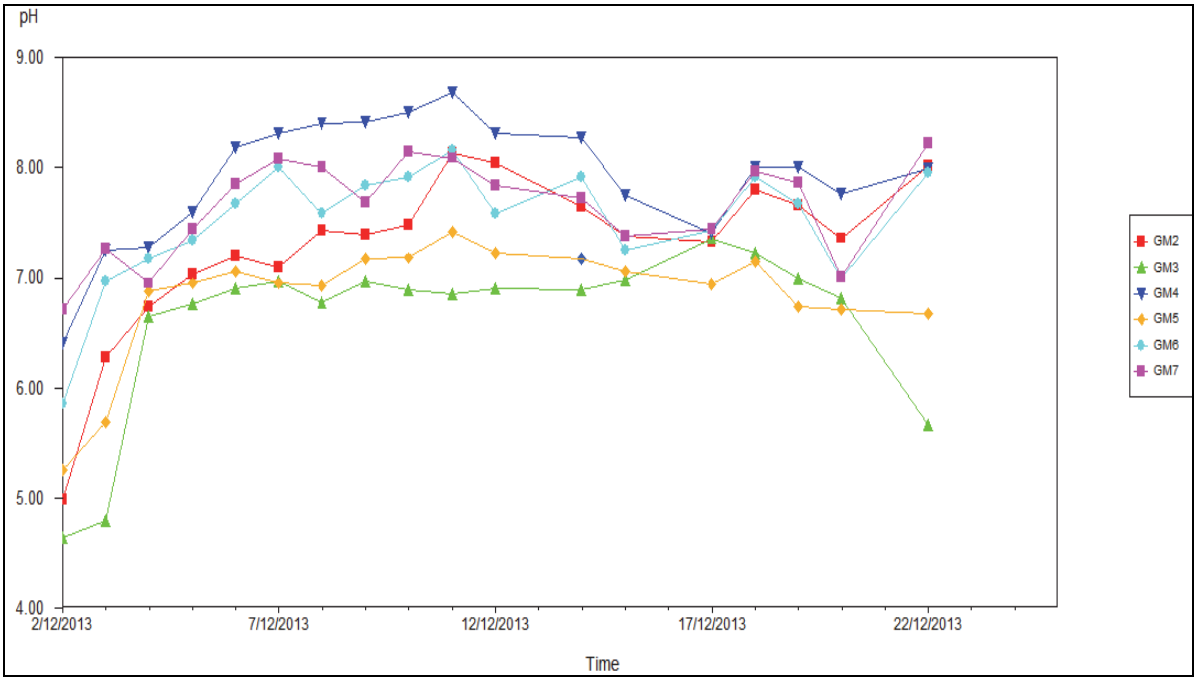

Figure 3-84: The pH values from the humidity cells for overburden, interburden and composite material

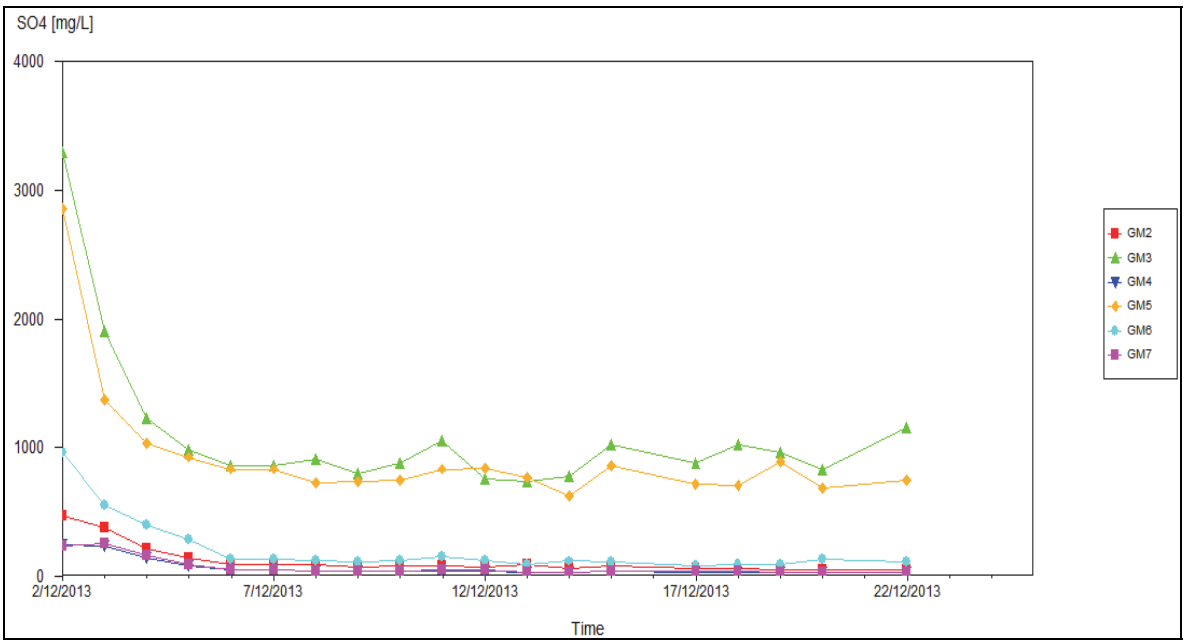

Figure 3-85: The sulphate values from the humidity cells for overburden, interburden and composite material.

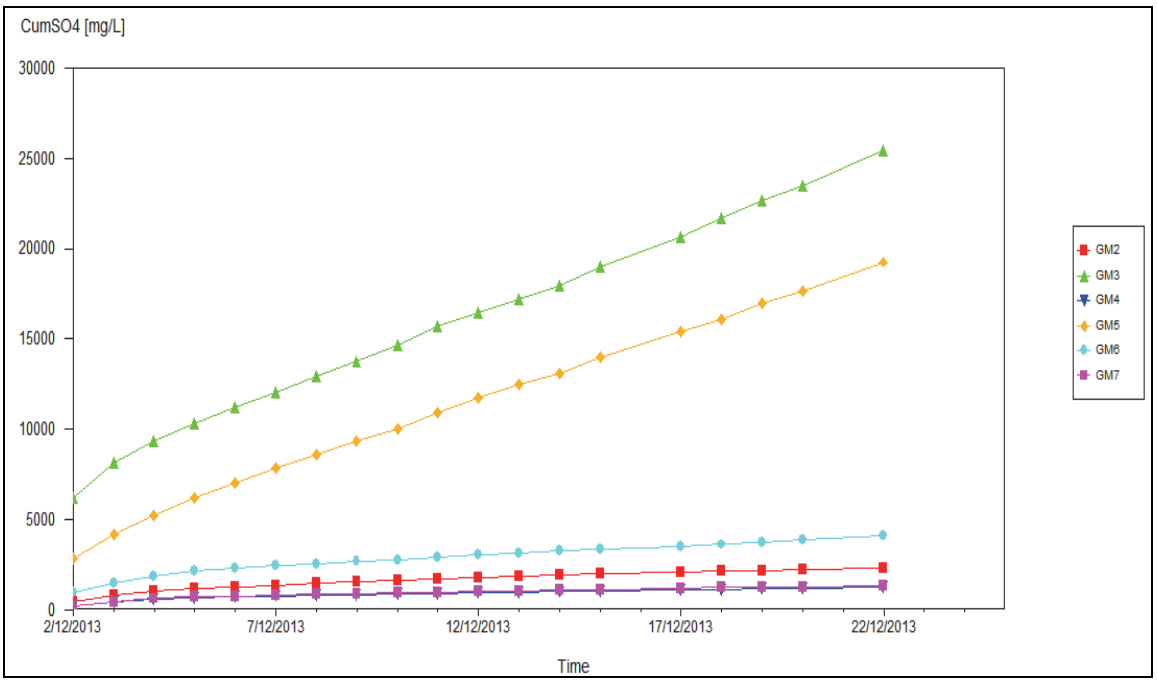

Figure 3-86: Cumulative sulphate production (mg/kg) from humidity cells for overburden, interburden and composite material.

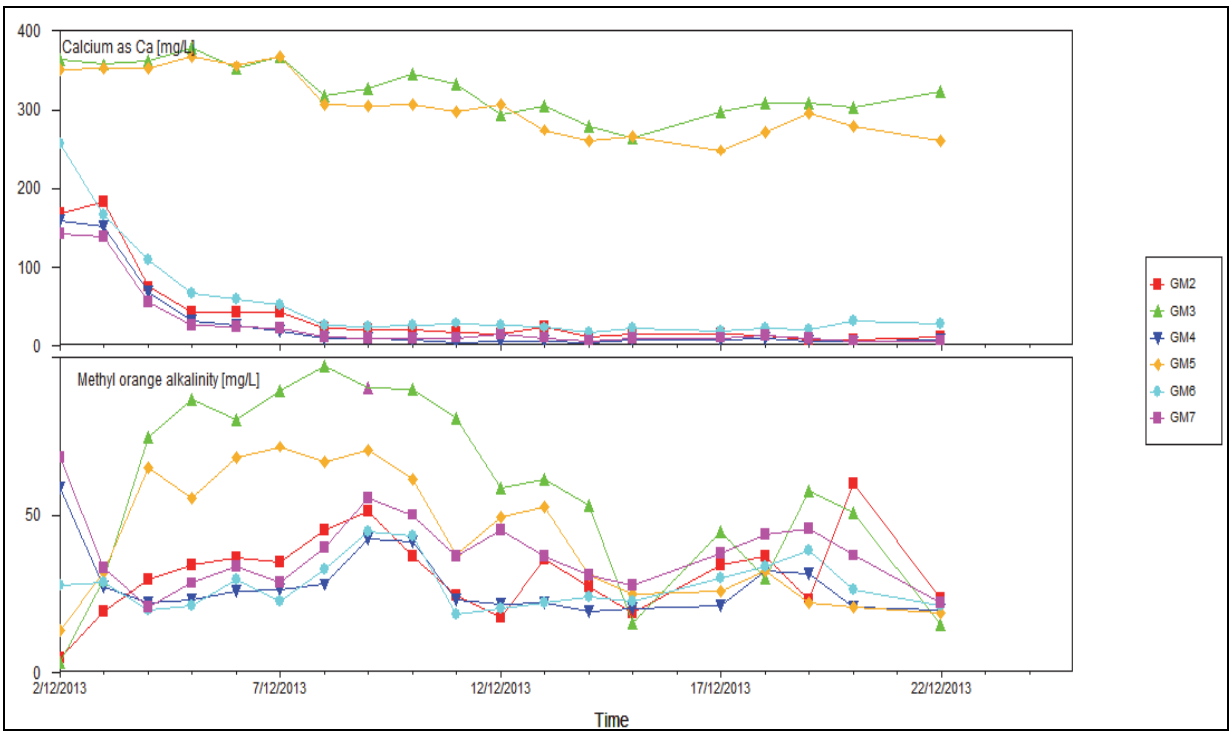

Figure 3-87: The calcium and alkalinity values from humidity cells for overburden, interburden and composite material.

Three samples with a base potential and the other an acid potential, were combined (50% each) and a kinetic cell were run for this combination (Figure 3-88). In addition these samples (S33 and S29) were individually analysed. The result of the combination (SM4) cell indicated that for the period of testing, the base potential was leached and the mixed/combined sample leachate became acidic.

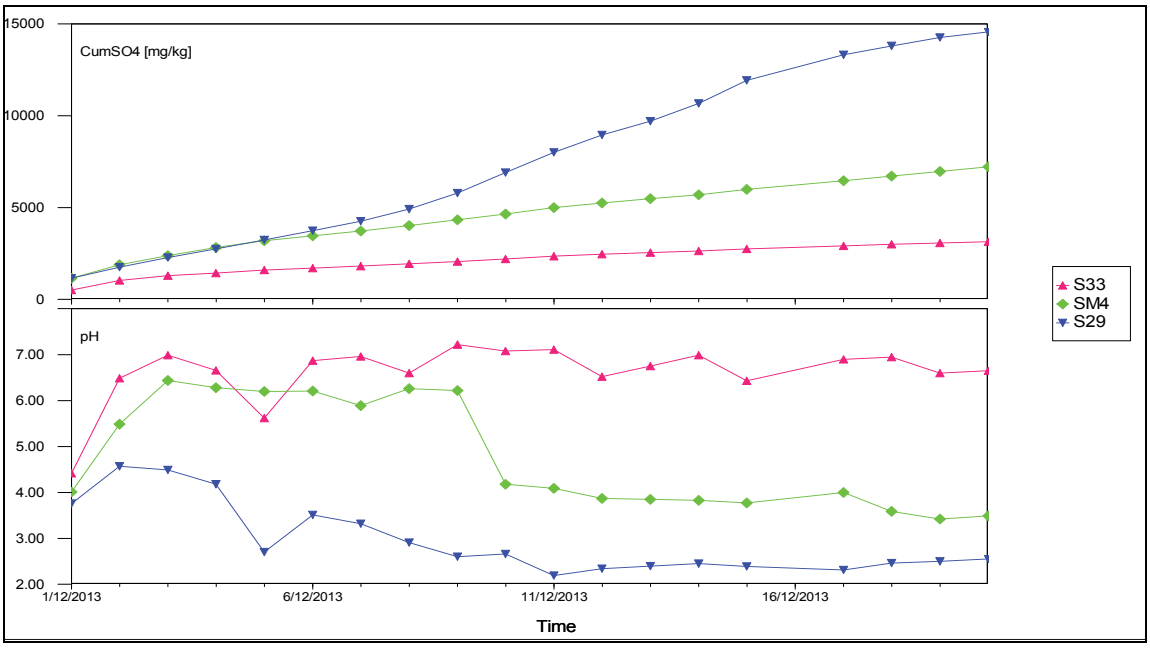

Figure 3-88: Cumulative sulphate production and pH for the combination humidity cells

3.9.5 Interburden and ash

Ash in general has a high neutralising potential. The analysed ash samples from the Matimba Power Station had pH values that ranged from 9.30 to 10.91. The alkalinity component and the addition of any acid generating material would reduce the risk of acid generation. The alkalinity of the ash samples were between 0.124 kg/tons and 0.208 kg/tons. If ash however becomes acidic it can mobilise heavy metals into the natural system and can become harmful.

During kinetic testing, four samples turned highly acidic (S17, S19, S27 and S29). The leachate from these samples were mixed and analysed. The initial pH of the mixture was 2.41. The fresh ash sampled from Matimba Power Station were weighed into 5 g, 10 g, 20 g and 50 g quantities and added to 100 ml of the leachate mixture (Table 3-K). The purpose of this was to determine what effect different ratios of ash would have on the acidic leachate over time.

Table 3-K: The different time intervals for leachate and ash mixtures

Time (hours)	1		24		48	
Mass (g)	**Initial pH**	**Final pH**	**Initial pH**	**Final pH**	**Initial pH**	**Final pH**
5	2.41	3.01	2.41	2.98	2.41	3.36
10	2.41	4.06	2.41	4.08	2.41	3.92
20	2.41	4.84	2.41	5.35	2.41	4.87
50	2.41	6.19	2.41	6.47	2.41	7.99

The experiment conducted on the interburden leachate and ash demonstrated the reduction potential ash has for acidic water (Figure 3-89). The ash samples for 5 g, 10 g and 20 g were mixed with acidic pH values. The 50 g ash samples increased the acidic mixture by more than four times from the initial level of 2.41. In Figure 3-89 the limited alkalinity of ash is also shown. The ratio of acidic water to ash is very important as the ash has a limited alkalinity. This is seen for the 10 g and 20 g samples.

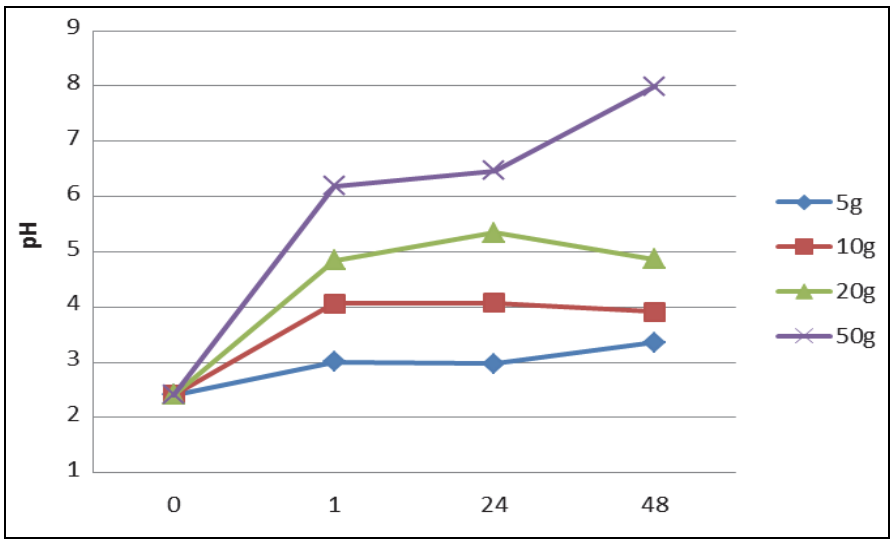

Figure 3-89: pH values for the interburden and ash mixture over time

3.9.6 Application of results to lithology units

The ABA and kinetic tests highlighted the lithological units that are prone to turn acidic or poses a neutralising potential. A summary of the geological logs, the minerals within the units as well as their acid and neutralising potential, are indicated in Figure 3-90. The different potentials are discussed according to the classification of Bester (2009) and Dreyer (1998), into partly weathered, Middle Ecca and full successions.

3.9.6.1 Partly weathered successions

The geological units with a dominant base potential above the coal units included calcrete, mudstone, shale and sandstone. These units typically consist of quartz, kaolinite, muscovite, calcite, dolomite, rutile and feldspar (Figure 3-90) and tabled in Table 7-M.

The units that showed an acidic nature were mostly the coal samples, as well as the sandstone found underneath the coal layers. In the sandstone samples the quartz, kaolinite, pyrite, muscovite, ilmenite and rutile minerals were positively identified (Figure 3-90).

3.9.6.2 Middle Ecca successions

The geological units analysed from this succession revealed more acid producing sections than of the partly weathered successions. The geological units that were prone to become acidic were shale, mudstone and both coarse and medium grained sandstone. The units predominantly contain quartz, kaolinite, pyrite, muscovite, rutile, ilmenite and feldspar (Figure 3-90).

The fine grained sandstone, calcrete and soil all indicated a neutralising potential. The main minerals identified within these geological units were quartz, kaolinite, muscovite, siderite, calcite, dolomite and rutile (Figure 3-90).

3.9.6.3 Full successions

The dominant geological units that have an acid producing potential were the sandstone and the coal units. These units consist of quartz, kaolinite, muscovite, pyrite, siderite and rutile (Figure 3-90).

The mudstone and shale units all showed a neutralising potential and the minerals identified within these units included quartz, kaolinite, muscovite, pyrite, hematite, marcasite and calcite (Figure 3-90).

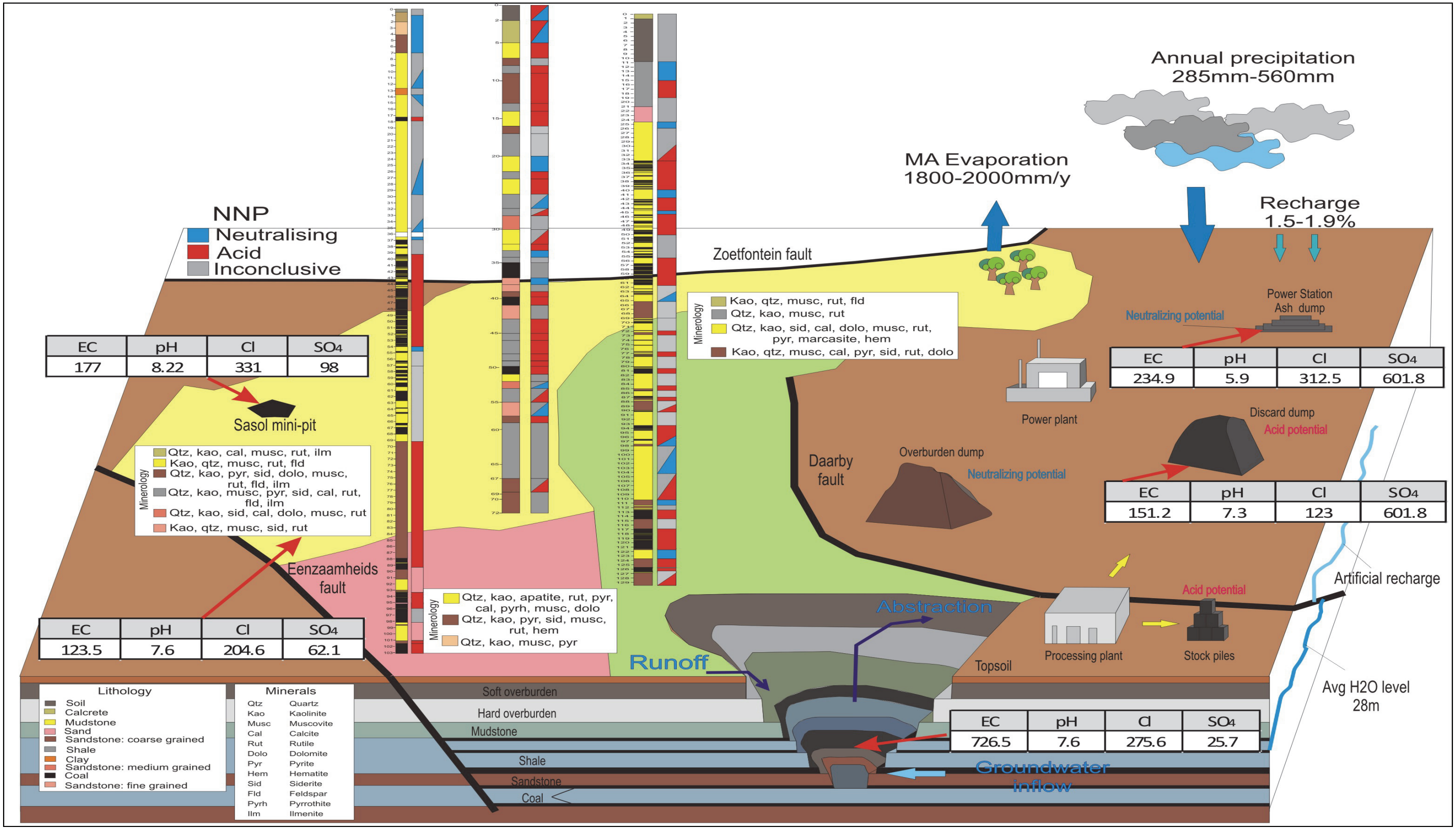

Figure 3-90: Summary of the acid and neutralising potential of the various contributing factors over the extent of the study area.

4 Spoils Management

Discards are generated during mining operations when coal is extracted from intermittent rock waste. Spoils consist of mined overburden and noneconomic mineral deposits removed during mining operations. The composition of spoils vary greatly depending on the area, depth and lithology where mined. The amount and type of waste generation is a direct result of the method used during the mining process namely surface open cast, underground mining and blasting or continuous mining. Backfilling methods must in general fit in with the mine design. The type of backfill that is going to be used is also usually identified during the design stages.

There is a need to dispose large amounts of colliery waste or spoil in such a manner that the least amount of damage is done to the surrounding environment. About 80% of waste is dry or solid spoil and usually tipped on site close to the pit head. The other form of waste generated is a wet by-product during the washing of the coal. This requires a different method of disposal and in some countries they make use of lagooning. The main environmental effects of these processes include visual intrusion, loss of land, noise and dust from vehicle movement during tipping of dry waste, and potential water pollution. The various activities have an immediate visible effect on the local area but the effect can be much deeper.

Extraction, beneficiation and processing of metals and industrial mineral ores produce mining wastes. Waste can be divided into categories which include:

- Waste rock, when material is moved to gain access to ore and excludes any material that is used during reclamation.
- Tailings, usually in a slurry form, from beneficiation processes.
- Mine water, water that infiltrates mines during extraction including groundwater or precipitation.
- Processing waste, residuals after beneficiation process, such as smelting and electrolytic refining operations.

Placement of backfill is one of the tools used in managing voids created during mining processes and reduces the cost and impact of a separate waste disposal site or process (Ward *et al*., 2006). Backfilling may be done by hydraulic or pneumatic techniques, using a variety of materials including run of mine waste rock, milled tailings, or other materials, and may include the use of cement or other modifiers to increase strength. It may also have a favourable effect on the environment by addressing water quality impacts (such as from acid drainage), reducing waste rock disposal requirements and ground fissuring, and increasing long-term strata stability as well as providing roof support.

4.1 Current backfilling method in the study area

At Grootegeluk the set objectives determine the backfilling method. These objectives include the minimal risk of spontaneous combustion, minimal cost and maximum safety conditions. The backfilling entails the compartmentalising of waste and overburden. The first-year compartments required the construction of an eastern sealing wall using sandstone from bench 10 (45m thick). After the construction of the 11m high wall, the reactive inter-burden material from benches 7A and 8 were backfilled from the north-eastern corner (Figure 4-1). Material placement is very

important and cannot be mixed during the off-loading of spoils. The contact area is isolated by inert material from either overburden or bench 10 (sandstone) in order to lower the risk of transferring spontaneous combustion to the pit's high walls.

A total of 14 benches are present, and benches 1, 7 and 9 are sub-divided into 1A, 1B, 7B, 9A and 9B. The bottom of the eastern part of the pit is used for a water dam and is utilised as an industrial-water recycling system. The northern part of the dam (sediment dam) clarifies the water from the plant. Next to the water dam (toward the west) is a backfilling dump. The third-year compartment is progressing with the sealing layer visible in the back of the compartment's advance (Adamski, 2003). The compaction of the sealing layer is due to mining equipment travelling on the backfilled compartments.

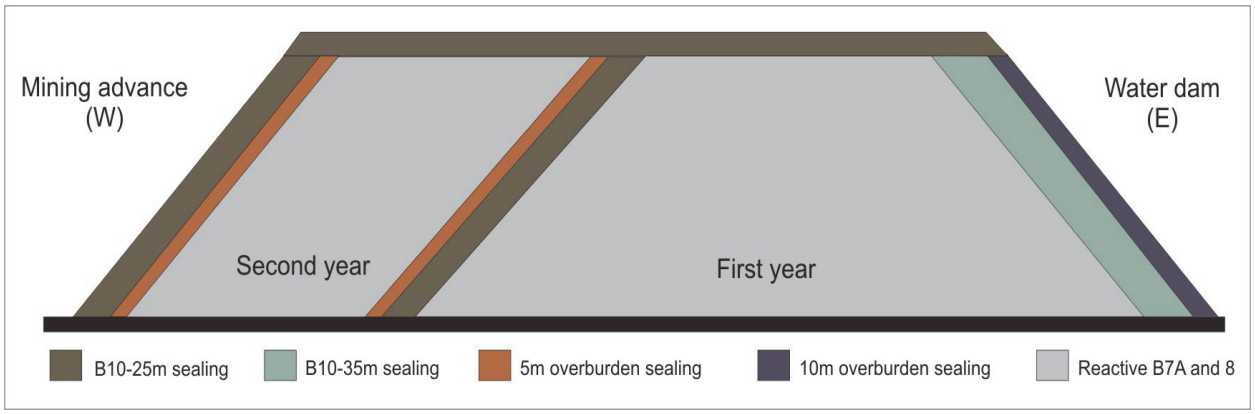

Figure 4-1: Backfilling advance at the Grootegeluk mine (redrawn from Adamski, 2003)

4.2 Investigated scenarios for handling of spoils

The scenarios suggested in this section focus on the benches removed during coal mining. The material removed from the GCM includes overburden, interburden and processing plant discard. The ABA and kinetic tests highlighted the lithological units that are prone to turn acidic or poses a neutralising potential. These findings helped to formulate different spoils management scenarios as the problematic units were identified. In order to have a full understanding of the various impacts the different geological units can have on the surrounding area of this study, different scenarios are discussed. The different pH ranges are indicted on the figures included for the various scenarios.

The various scenarios focus mainly of co-disposal and blending, where sulphide rich waste is blended, co-disposed or both with alkaline material. Co-disposal requires the mixing of fine and coarse grained material, and blending entails the addition of alkaline material to such an extent to neutralize the acid potential of the discard. Alkaline material ensures that the metals are immobile permanently by converting them into soluble minerals such as sulphates, carbonates and hydroxides. The scenarios all refer to the backfilling method currently used at the Grootegeluk Colliery.

4.2.1 Scenario 1 – Overburden

The ABA analyses showed a predominantly neutralising potential for overburden samples as well as an acidic potential for the shale units near the coal. The samples that did not show a

clear distinction was further tested by kinetic testing. The samples that were analysed over the 20 weeks of testing indicated non-acid producing potentials and some samples with neutralising potentials.

The pH provides an indication of the onset of acidification. The initial pH values from the overburden samples were neutral to start with and remained neutral throughout the testing. The sulphate values show a decline over the first weeks as the oxidised products are flushed from the system. The relatively low calcium values indicate that carbonates are immediately available and show the balance between the released alkalinity and the acidity generated. If the balance between the alkalinity and the acidity stays positive the system will not acidify.

Backfilling with overburden directly into the opencast pit would not acidify, but rather neutralise the surrounding area (Figure 4-2). The groundwater system would not be influenced in a negative way. In the event of heavy rain and infiltration, no acid would be produced nor be introduced into the system. The extent of the pit is unfortunately so large (100 m below surface) that the amount of overburden material available would not fill the entire pit. Overburden would be the ideal backfilling material to use because of its buffering potential.

The thick overburden layer would increase the path length for oxygen diffusion to the reactive layers within the pit that is being backfilled. The fine grained cover layer has a higher degree of moisture retention and would be easily evaporated in drier seasons. The high moisture retention also ensures a high level of pore water saturation and reduces the rate of oxygen diffusion.

The pit can be filled with water to the compacted overburden, but this will require the construction of water pipes and channels into the pit from the river and can become costly. The addition of water into the pit will only be advised if some of the exposed mined benches have a high acid generating potential. The amount of overburden available is too little to fill the entire void of the pit and in most cases the overburden material is saved for rehabilitation after mine closure.

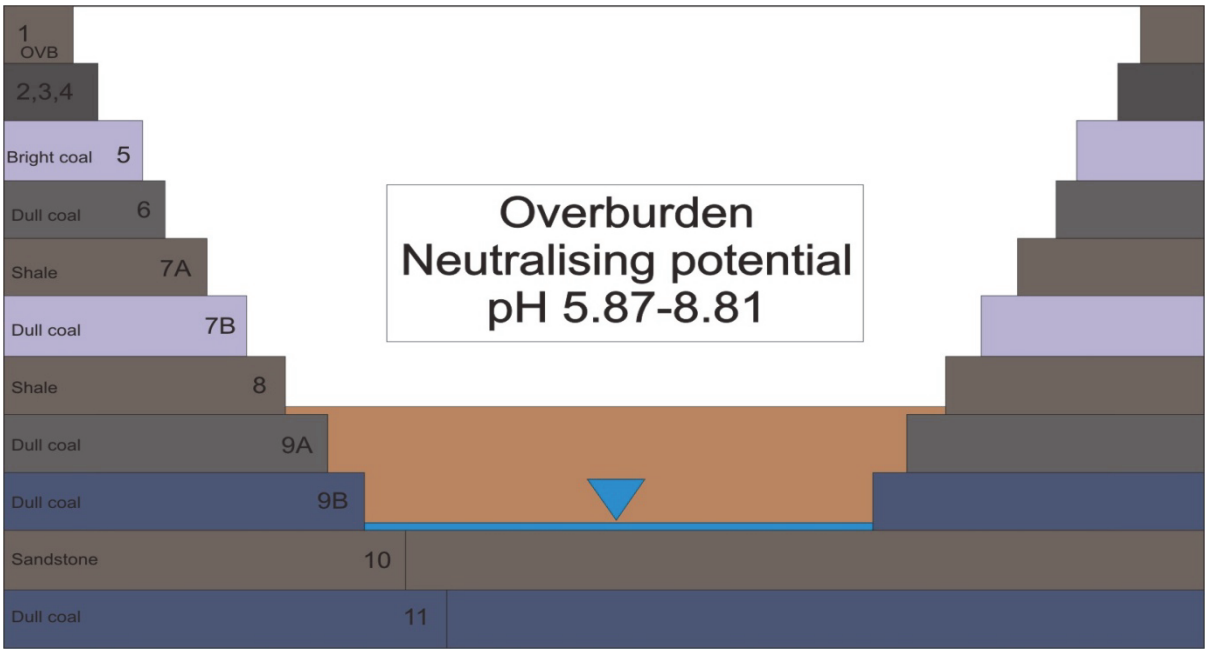

Figure 4-2: Schematic representation where opencast pit is filled with overburden (ovb) material

4.2.2 Scenario 2 – Interburden

The ABA analyses showed that the interburden samples analysed contained both acidic and neutralising potentials. Interburden and mixtures of acidic and neutralising interburden were selected for kinetic tests. The purpose was to determine the extent that acid producing interburden, mixed with a neutralising component, would have to reduce the acidic nature of the sample. Mudstone, shale and calcrete layers showed a neutralising potential, while sandstone had a relatively high acid generating potential.

The initial pH values for the interburden samples as mentioned are both acidic and neutral. The acidic pH values stayed acidic, whilst some of the neutral pH values remained neutral and some turned acidic. The kinetic samples S14, S15, S24, S32 and SM2 consist of mudstone, sandstone and siltstone. The sulphate values show a slight decline over the first weeks, with a gradual increase for the remainder of the test. The slight increase is due to the oxidised products leaving or being flushed from the system. Calcium and alkalinity results showed high calcium values with relatively low alkalinity for the interburden material.

Backfilling with only interburden has a high possibility of acid production that would reach the groundwater system (Figure 4-3). In favourable conditions (exposed to oxygen and water), the interburden would generate acid over a longer period of time. The quantity and quality of the interburden material is not suitable to use as filler alone in the pit.

The removal of large quantities of coal results in less material to fill the pit with. In the event that the interburden would not be enough to fill the pit, a compacted layer of topsoil or overburden can be placed above the interburden. The overburden acts as a buffer with a neutralising potential.

The overburden cover would increase the path length for oxygen diffusion to the reactive material in the pit and the mixed interburden material. The fine grained cover layer overlaying the coarse grained interburden will have a higher degree of moisture retention I the upper part of the cover layer. This ensures a high level of pore water saturation and a lower rate of oxygen diffusion.

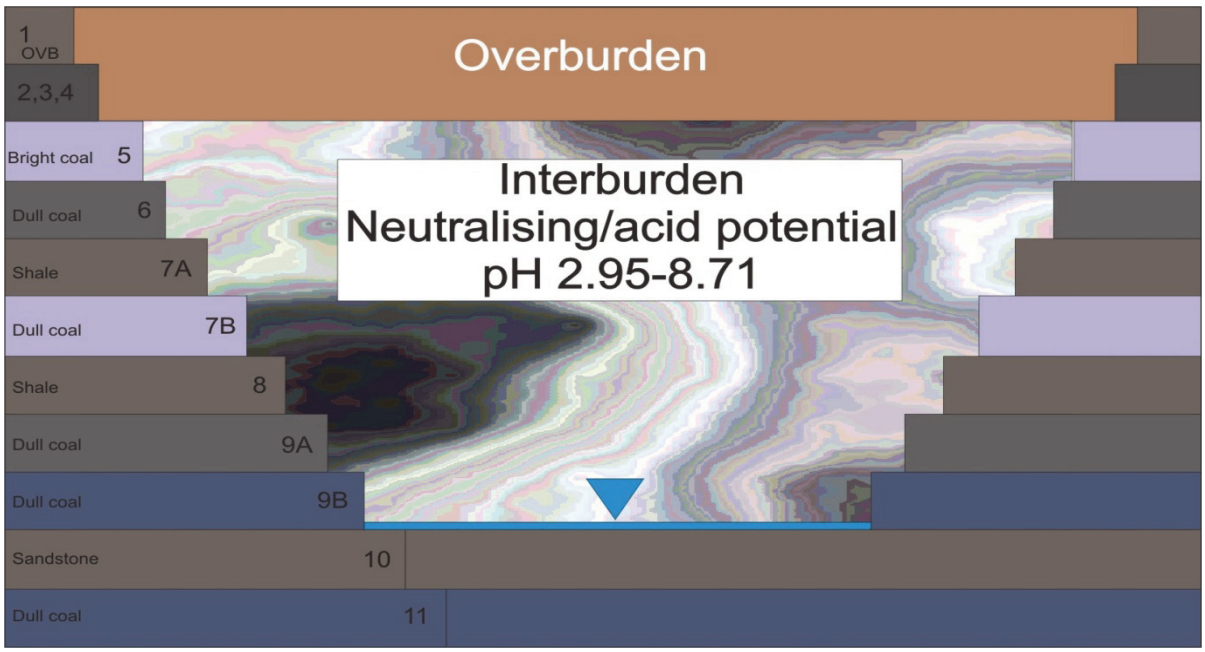

Figure 4-3: Schematic representation where opencast pit is filled with interburden material

4.2.3 Scenario 3 – Plant discards/composites

Plant discards consist of the unwanted material that remains after coal separation, also known as composite samples. The different density composite samples were analysed and indicated that they all have a high potential to produce acid.

The main risks associated with discard are the sulphide potential that leads to the generation of acid upon exposure to oxygen and moisture. There is a risk for metals to mobilise in surface or groundwater when they are liberated in acidic conditions. There can also be contaminant influx due to precipitation, creating runoff from discard storage piles.

Backfilling with composite or discard material would influence the groundwater system in a negative way, especially if the discards are exposed to favourable conditions (oxidation and water). The best way to decrease the risk would be to immediately fill the pit with water (Figure 4-4). The water can be piped or channelled from the river, but this can become costly. Water reduces the exposure of the composite material to the combination of oxygen and occasional water, which are the two main factors that activate acid generation. The composite material also has the potential to spontaneously combust when in contact with oxygen. The water in the pit with the discard increases the pore water saturation, reducing the rate of oxygen diffusion to the combustible material.

It should be mentioned that to channel water is costly and regarded as not feasible. Although the immediate fill using water would reduce the spontaneous combustion of waste material, it cannot be the best solution for managing discard.

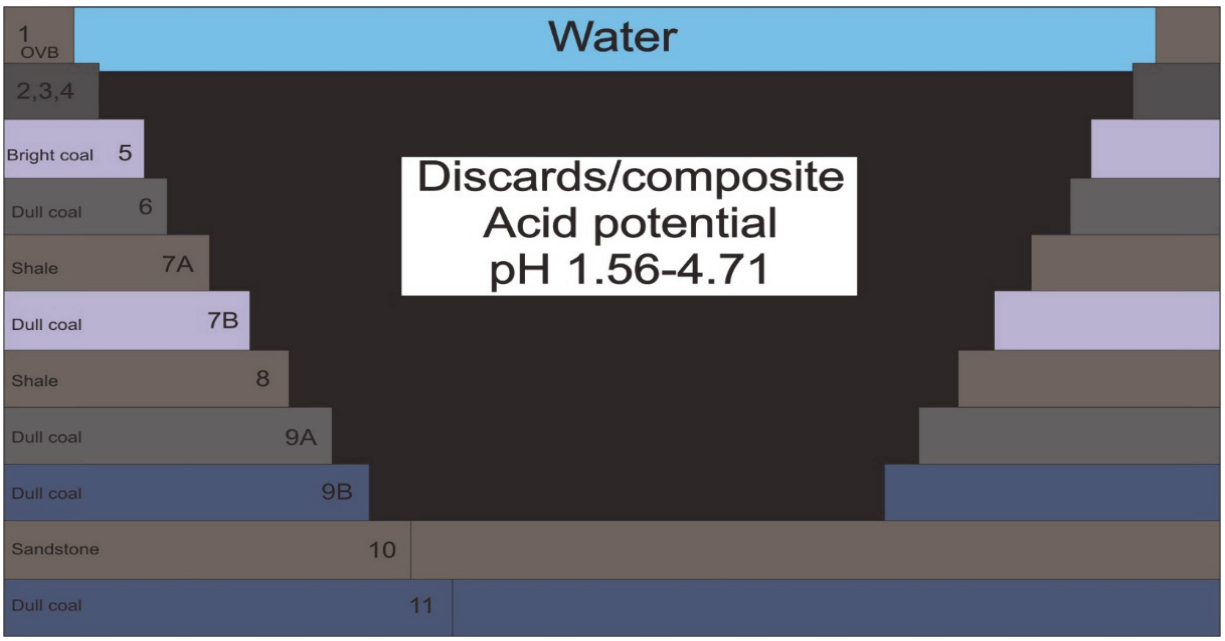

Figure 4-4: Schematic representation where opencast pit is filled with composite material

4.2.4 Scenario 4 – Mixed overburden, interburden and discards/composites

The overburden and interburden have already been mentioned, as neutralising and acidic, respectively. A suitable ratio of overburden, interburden and composite material will have a positive effect on the surroundings after they are placed back into the pit. Acid generation from these materials will be neutralised in the pit in the event that they are exposed to favourable conditions. Kinetic tests on mixtures of overburden, interburden and composite material confirmed that the acidic nature of the samples could be reduced. In the event that the buffer potential of the mixed overburden and interburden failed to reduce acid generation, exposure to oxygen and water would accelerate the acid generating process.

The initial pH values of the samples were acidic and after the testing was completed, turned neutral for the overburden and interburden mixed with the composite material. The slight sulphate decline in samples GM2-GM7 at the initiation of kinetic testing, suggests the oxidised products are being flushed from the system. Calcium and alkalinity results show the relatively low values of alkalinity released into the surroundings.

As a consequence, backfilling with the correct mixture of overburden, interburden and composite material would create a balance between the highly acidic and neutralising potentials (Figure 4-5). If the backfill material was exposed to favourable conditions, the pH and acid production will be insignificant.

This scenario does not have enough data to propose how long the system would buffer itself. It is recommended to run the humidity cells for longer to have an estimation of the extent of the buffer capacity or neutralising potential. The most important aspects observed from the humidity cells are that blending the material does have a positive effect on the system in reducing the acid generating potential.

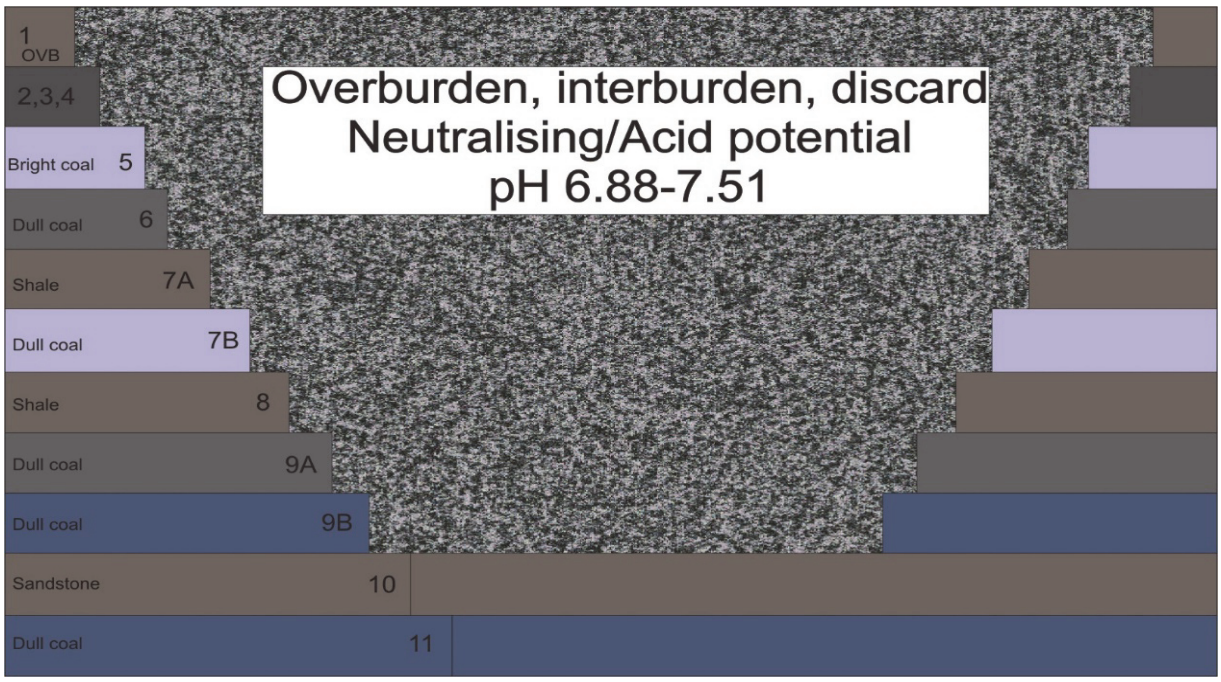

Figure 4-5: Schematic representation where opencast pit is filled with overburden, interburden and composite material

4.2.5 Scenario 5 – Interburden and ash

The analysed ash samples from the Matimba Power Station had pH values that ranged between 9.30- 10.91. The alkalinity component and the addition of any acid generating material reduce the risk of acid generation. If fly ash becomes acidic it unfortunately mobilises heavy metals into the natural system and can become a risk in this regard.

Fly ash from coal-fired power stations is one of a number of materials that may be used in mine backfill (Ward *et al*., 2006); others include waste rock such as overburden, natural sands or gravels and coarse or fine reject materials from preparation plants. Fly ash that comes into contact with acid mine drainage will increase the pH of the mine water. Ash can be mixed with acidic water to neutralise it, and co-disposed in an appropriate manner.

The co-disposal of interburden and ash material will result in an excess of neutralising potential. The material properties of interburden, with both an acid and neutralising potential, would not lead to acid production due to the high neutralising potential of the fly ash material. If fly ash was intermittently layered in between samples prone to produce acid, it would positively affect the surrounding area and neutralise any acidic threat to the system.

The best option would be to co-dispose fly ash and interburden into layers and cover it with a layer of compacted fly ash (Figure 4-6). The compacted fly ash top layer will act as a seepage reducer, and in the event that water managed to seep in, it would not produce acid. The long term effect of fly ash cannot be stated with certainty other than that it has a high neutralising potential and can be co-disposed with acidic material to reduce an acid generating potential. The acid producing spoils can also be buried on-site with fly ash or other neutralising material surrounding it. For underground mines ash can be introduced as a low-permeability fill or grout within the voids, fractures, subsurface openings and to reduce the contact of acid generating rocks to water and air.

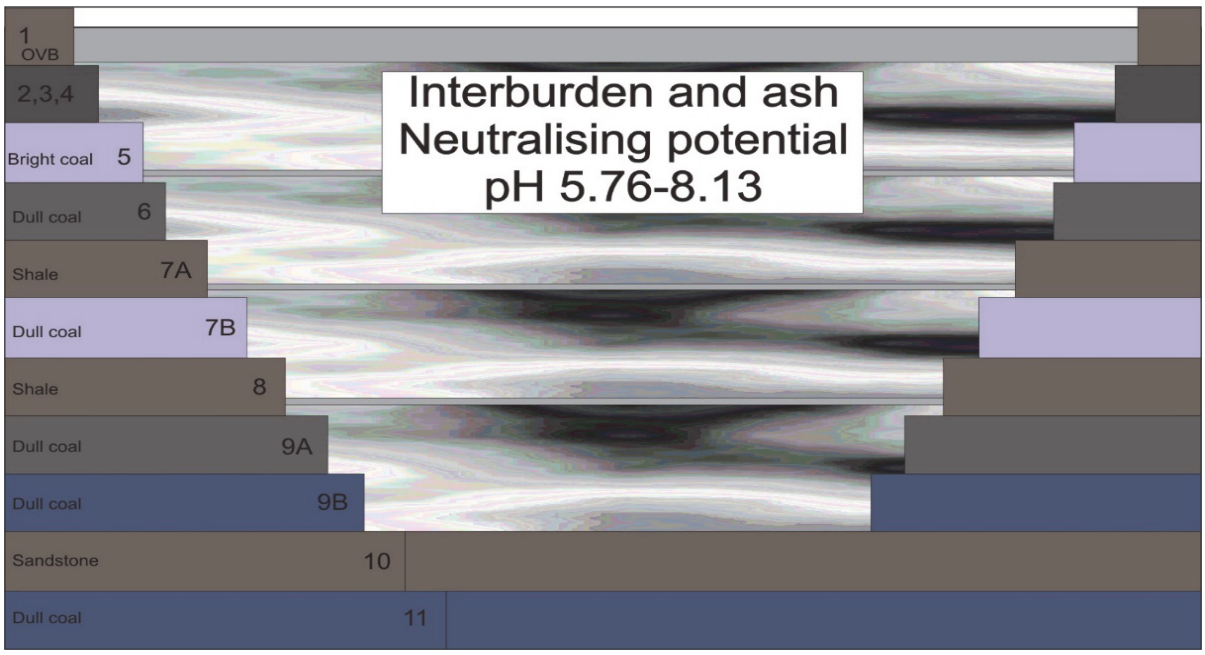

Figure 4-6: Schematic representation where opencast pit is filled with interburden and fly ash material.

4.3 Proposed handling of spoils

Based on the investigated scenarios, the mixture and/or layering of a combination of material would be recommended. The layered option proposed by Adamski (2003) which is the current means of backfilling at Grootegeluk Mine, has the lowest long-term environmental risk for water impact. It reduces ARD rates and leaches alkalinity into underlying acid generating discard material.

The backfilling method scenarios investigated are based on the current method applied at the Grootegeluk Colliery. From these scenarios, two types of backfilling for fly ash and different discard should be considered and possibly implemented in the mining industry. The types of systems for backfilling are discussed as two options, one in the event prior to disposal and the other as the disposal of waste in layers. Either Option 1 or 2 can be implemented depending on the economic motivation or viability of each option.

The design objectives for any backfill pit cover should include the following:

- Reduce the ingress of atmospheric oxygen to the underlying waste material to the minimum acceptable level
- Reduce entry of meteoric water to the underlying waste material to less than 5% of annual precipitation at the site
- Provide a medium for establishing a sustainable vegetation cover that is consistent with the final land use of the area.

The first two objectives can be easily achieved by incorporating a layer of fine-textured material in the cover system (MEND, 2004). The objective is to utilize the capillary barrier concept to help maintain near saturation within the fine-textured layer. This would additionally help to lower the

ingress of oxygen by reducing the oxygen diffusion rate. The fine-textured layer has a low hydraulic conductivity. The low conductivity and the low capillary barrier would control the percolation to the underlying waste material. This is the ideal design that relates to the layered co-disposal for discards and ash. If ash is deemed not suitable to use an alternative would be clay. Clay, when compacted, has a saturated hydraulic conductivity of 10^{-8} cm/s (Ayres *et al*., 2012). Skousen *et al.* (1997) analysed various fly ash material to determine the relative hydraulic conductivity of ash between 10^{-5} or 10^{-6} cm/s.

It is recommended that a small scale field test be done before and after ash is backfilled into the pit. This would give a much better idea and understanding of what can and would happen in the specific study area. Additionally geochemical modelling is recommended for further work in order to assess the amount of salt loads and chemical interaction between the various backfilled materials within the pit.

4.3.1 Blending of material prior to disposal into the pit (Option 1)

This option utilises the conveyor belt from the power plant that will discharge ash onto overland conveyors from the mine discard dump transfer station entering the pit. Mixing the fly ash and discard will occur through the transfer stations up to the stacker. Material is initially mixed with already existing equipment, therefore avoiding additional costs for building the required conveyor belts. One major factor influencing this option would be the availability of fly ash and discard.

The combination of fly ash and discard has a higher degree of water retention in the mixture than discard material alone would have. Fly ash prohibits the spontaneous combustion of discard by limiting the oxidation potentials. Fly ash also dilutes the reactive portion of the discard backfill.

4.3.2 Disposal of waste in layers (Option 2)

This option uses the power station fly ash and transfers it onto in-pit conveyors for the initial deposition of an ash layer. This initial fly ash layer would act as a wedge that can be covered with interburden material with the fly ash, and interburden acting as a seal. A layer of discard can then be placed above the already backfilled material, until enough discard is placed into the pit to start depositing fly ash above the pit water. With this option, the fly ash will be deposited above the expected pit groundwater level after recovery. The fly ash disposal rates will directly affect the volume of fly ash that will initially be deposited into the bottom of the pit as well as the thicknesses of the layers. The last ash cover can only be done if the discard has reached the height of the pit. This layer option is therefore strongly affected by the coal processing plant that will produce the discard material.

4.4 Effects of backfill material

This section proposes the different factors that could potentially affect the groundwater system, by illustrating the different water movement paths within backfilled material. There are various factors that contribute to the pit water. These include direct rainfall recharge, runoff from backfill materials, working face and active mining area, groundwater inflow from the surrounding

environment and any mine water pumped to the opencast mine. These factors are shown in Figure 4-7.

The closure phase of mining will re-fill the pit with water to reduce the head difference between the surrounding groundwater table and in-pit water level, and thus lower the inflow rates over time. The recharge within backfill material occurs as unsaturated flow and is majorly dependant on the material properties. The hydraulic conductivity of the backfill material would be higher than the original solid material that was removed.

The water that accumulates in the opencast pit is typically hydraulically linked to the groundwater system in the surrounding environment. The regional groundwater gradients will control the groundwater system of the surrounding area.

Recharge rates through the backfilled area is expected to be relatively low. The reason for this is due to the behaviour of the backfilled material and the cover layers. The combination of the backfill and cover material acts as a store and release process for water entering into the system.

Seepage through the backfilled material will be influenced by the moisture present in the material and the different layers it intersects as it seeps into the backfill material. The layered option of the material will reduce the seepage or moisture migration as the material properties of the various layers differ.

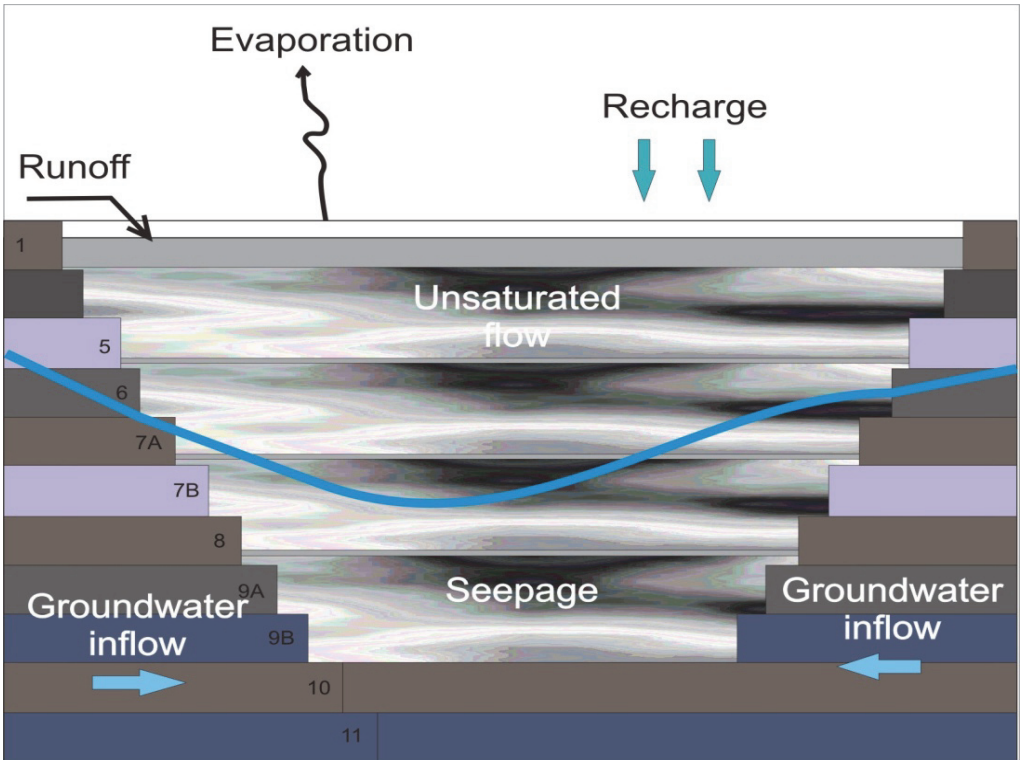

Figure 4-7: Schematic representation for the proposed water flow within the backfilled pit

Salts and metals are primarily sourced from soluble salt and metal contents associated with backfill materials. The materials used as backfill coal discard; interburden and ash all have a soluble salt fraction. This fraction will dissolve upon contact with water. The dissolved salts are

flushed from the material with the first introduction to water. The materials that contain sulphide minerals will undergo oxidation, and produce ARD. The oxidation products of ARD include salinity (SO_4, Cl^-, Ca, Mg, Na, and K) and acidity (proton and metal acidity). Trace elements form part of the flushed dissolved metals and can also have a toxic impact on the water quality. The impact of ARD on water systems is strongly influenced by the buffering minerals present in the water (either acid or alkaline). Mineral precipitation occurs after the dissolved components exceed the solubility of a stable mineral. The mineral will begin to precipitate to maintain equilibrium with the solution at the solubility limit.

The time for the backfill material to acidify for a layered backfill scenario will take the longest time. This point is reached when the available NP is consumed and results in an acidic leachate from the backfill. The blending with ash would reduce the risk of acidity as it adds additional NP to the system and due to the low hydraulic conductivity present in fly ash material the water retention in ash would be increased. Fly ash “clog/block” the system reducing the infiltration rate of waster to underlying material.

5 Conclusions

5.1 The following main conclusions were made:

1. Chemical and biological processes play an important role in the production, release, mobility, and attenuation of contaminants in ARD waters. The rate of oxidation can vary depending on the accessibility of air, moisture and microbes to the Pyrite surfaces. The type of mining and mineral processing plays a part in the initiation of the acid mine waters in the mining environment, and the methods that are employed have to be used in connection with the appropriate remediation and treatment to minimise the generation of ARD. Neglect to these factors can cause ARD problems that will be hard to control once it has begun.
2. The ABA results determined that the interburden and discards used as backfill material has a potential to generate acid. This includes the composite samples with various densities from the processing plant. While overburden material has a neutralising potential.
3. The ABA illustrated that the shale and mudstone samples have both acid and neutralising potentials and the majority of sandstone samples beneath 60 m have a distinct acid generating potential.
4. The amount of metal in solution increases as the pH drops. Majority of the samples that were analysed exhibit a similar trend where a decrease in pH causes an increase in the heavy metals. The Ca and Mg carbonate analysed have a natural buffer capacity that will increase the pH. Calcium and magnesium will increase until they are depleted from the calcite, dolomite and siderite minerals they are hosted within. Depending on the ratio of acidic to buffer material, an acidic system can be neutralised. Sulphate and iron has the highest concentration when compared to other analytes, which increases as the pH drops. The high concentration may be due to the presence of pyrite in the coal and interburden sandstone samples. Overburden samples have the lowest sulphate concentration which is ten times lower and more when compared to all areas of analysis as well as composite samples.
5. The pH directly affects the type of metals that are mobilised. In pH conditions around 2 there is a high leaching of heavy metals occurring. Various analytes are released at different pH values. Nickel and other constituents' increases in solution at lower pH environments.
6. The amounts of TDS from the full, partly weathered and Middle Ecca successions are directly related to the iron and sulphate values. The increase of these elements increases the amount of salts that are liberated from the samples. The Middle Ecca has a lower total salts that are liberated than the full and partly weathered successions.
7. The fly ash from Matimba Power Station has a high potential to reduce acidity. The fly-ash showed a limited alkalinity over time, in the event of an acidic condition persisting for long periods. The readily available soluble salts in ash will result in higher salt loads that will be mobilised into the pit water.
8. The composite material can be used as backfill material within the pit. It only becomes a risk upon exposure to oxygen and water. The Waterberg area has a relatively low annual rainfall, high evaporation and deep groundwater levels, thus the risk to produce acid from infiltrating water is limited. The risk of exposure to oxygen leads to the spontaneous combustion of discard material.

9. Based on the investigated scenarios for backfilling, the mixture and or layering of a combination of material are recommended. Either Option 1 or 2 can be implemented depending on the economic motivation or viability of each option.
10. The layered option proposed by Adamski (2003), which is the current means of backfilling at Grootegeluk Mine, has the lowest long-term environmental risk for water impact. It reduces ARD rates and leaches alkalinity into underlying acid generating discard material.
11. The process of mining and beneficiation, stockpiling of coal, coal products and waste is an important factor in management practice, as it makes the environment and water more vulnerable to degradation. More care should be taken in understanding and managing exposed rock or waste piles, which creates paths for pollution migration. It is also important to understand the physical characteristics of the mine waste/stockpiles such as permeability and weathering, which play a role in accelerating the process of ARD. Prints of mismanagement, neglect and a lack of knowledge have left areas with abandoned mines with ARD issues.

5.2 Recommendation for future work

1. Geochemical modelling to assess the various chemical changes for the different suggested scenarios.
2. The ideal is to set up a test pad in the field on the site and collect leachate. Analyze leachate and get the data of the analyses of the groundwater samples where available
3. A small scale field test should be done based on the best scenario and monitored to understand the full extent of the changes to the surrounding backfilled areas.
4. Studies on the mixing of overburden, interburden and composites, as well as ash to determine how long the system would buffer itself, as the laboratory trials during this study could not run long enough.

5.3 Guidance for implementation

Different composite samples were prepared at ACT (African Coal Technologies) by using discards separated during beneficiation processes. This separation process makes use of gravity to separate the samples into different fractions of RD 1.80 - 2.20, RD 1.90 – 2.20 and RD 2.10 – 2.20. The different fractions of the material are from the washing processes at the beneficiation plant. Double washed materials have lower densities and higher densities are present for single washed material.

The results from the various washing processes are populated for samples from the Middle Ecca and Upper Ecca in Table 5-A and Table 5-B. The peroxide step of the static ABA is used to calculate the percentage sulphur for the various zones. The relevance of the table is to relate the amount of sulphur in the material from the different zones found in the mined coal formations, to the various densities.

There is a clear distinction in the sulphur content for the discards form the Upper and Middle Ecca. The samples from the Middle Ecca indicated high sulphur content for all the density fractions, with the highest values for the RD 1.80-2.20 fraction. The Upper Ecca samples indicated that both RD1.9-2.20 and RD 2.1-2.20 fractions have high sulphur contents with the highest in the most dense fraction.

The high sulphur values are associated with the materials potential to produce acid. The samples with higher densities RD 2.10-S2.20 have lower final pH values. These values correlate with the ABA results for the composite samples.

Table 5-A: The percentage Sulphur in Upper Ecca composite samples

		%S		
Borehole sample	**Zones**	**RD 1.80-2.20**	**RD 1.9-2.20**	**RD 2.1-2.20**
MY	MY11		9.2	
	MY10			1.67
	MY8		1.96	
	MY6		1.2	
	MY5			0.74
	MY5		0.5	
CZONE	CZONE10A			4.46
	CZONE9A		0.91	
	CZONE9B			0.95
	CZONE8A		0.48	
	CZONE8B			0.79
	CZONE7A		0.59	
	CZONE7B			8.21
	CZONE6A		0.39	
	CZONE6B			0.34
	CZONE5A			1.15
	CZONE5AA		0.74	
PZONE	PZONE10A		1.25	
	PZ10A		5.16	
	PZ10B			7.34
	PZONE9A		1.7	
	PZONE9B			2.38
	PZ9A		0.43	
	PZ9B			5.25
	PZONE8A		0.55	
	PZONE8B			0.87
	PZ8A		0.32	
	PZ8B			0.75
	PZONE7A		0.32	
	PZONE7B			0.43
	PZ7A		1.44	
	PZ7B			0.86
	PZONE6A		0.26	
	PZONE6B			0.19
	PZ6A		1.54	
	PZ6B			0.96
	PZONE5A		0.79	

		%S		
Borehole sample	**Zones**	**RD 1.80-2.20**	**RD 1.9-2.20**	**RD 2.1-2.20**
	PZONE5B			0.78
	PZ5A		1.45	
	PZ5B			0.71
JYZONE	JYZ9A		2.44	
	JYZ9B			1.07
	JYZ8A		0.21	
	JYZ8B			0.93
	JYZ7A		1.53	
	JYZ7B			1.98
	JYZ6A		0.17	
	JYZ6B			0.72
	JYZ5A		0.23	
	JYZ5B			0.58
ZTZONE	ZTZONE10A		1.41	
	ZTZONE10B			1.14
	ZTZ10		1.42	
	ZT9		0.34	
	ZT9A			0.27
	ZTZ9		0.13	
	ZTZ8		0.13	
	ZTZ8B			0.08
	ZTZ7		2.63	
	ZTZ7			1.09
	ZTZONE7		0.41	
	ZTZ7		2.55	
	ZTZ7A			0.07
	ZTZ6A		0.09	
	ZTZ6B			0.17
	ZTZ6		1.32	
	ZTZ6			1.02
	ZTZ5B			0.51
	ZTZ5		1.48	
	ZTZ5A			1.54
SNZONE	SN10		1.09	
	SN9			1.84
	SN9		1.82	
	SN6		1.8	
	SN6(B)			1.7
	SN5		0.84	
	SN8			1.78
	SN7		0.42	

Table 5-B: the percentage Sulphur in Middle Ecca composite samples

		%S		
BOREHOLE SAMPLE	**ZONES**	**RD 1.80-2.20**	**RD 1.9-2.20**	**RD 2.1-2.20**
CZONE	CZONE4AA	3.06		
	CZONE3A	7.37		
	CZONE2A	7.97		
	CZONE1A			0.73
PZONE	PZONE4AA			1.14
	PZONE4A			8.02
	PZ4			12.55
	PZ4A			2.13
	PZ3	3.9		
	PZONE3A	2.51		
	PZONE2A	3.25		
	PZ2	7.3		
	PZONE1B	5.17		
	PZ1	3.32		
JYZONE	JYZ4B			0.91
	JYZ4AB			0.3
	JYZ2A	5.73		
	JYZ1A	1.07		
ZTZONE	ZTZONE4			5.44
	ZTZ4AA			0.05
	ZTZ3A	6.23		
	ZTZ2A	12.13		
	ZTZ2		6.22	
	ZTZ1A	13.94		
	ZTZONE1A	0.02		
	ZTZ1A		3.15	
	ZTZ1B		1.13	
	ZTZONE1B	2.11		
SNZONE	SN4A			5.2
	SN4			5.44
	SN3	5.98		
	SN2	5.81		
	SN1B	0.5		
	SN1B		0.48	
MYZONE	MY4			6.2
	MY4A			1.93
	MY1		11.8	
	MY1B	0.14		
	MY1B	1.03		

It is evident from Table 5-A and Table 5-B that higher precautions should be taken when handling the discards from the Middle Ecca Formation. The high sulphur content within the discard has the potential to generate acid leading to a potential threat to the surrounding environment. It is thus recommended that the Upper Ecca be placed above the Middle Ecca to limit the amount of oxygen and water ingress.

6 References

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7 Appendices

Table 7-A: Summary of the ABA results for the Sasol samples

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
W10A	8.32	8.38	43.64	14.47	Verify with other tests	interburden	mudstone
W10B	8.39	8.26	86.95	71.86	Probably Excess Neutralising Minerals	interburden	mudstone
W11A	8.41	8.38	30.22	-5.16	Verify with other tests	interburden	mudstone/coal
W11B	8.38	8.26	-13.64	-44.19	Potential Acid Generator	interburden	mudstone/coal
W12A	8.34	8.38	-0.88	-51.48	Potential Acid Generator	interburden	mudstone/coal
W12B	8.43	8.22	52.65	19.77	Verify with other tests	interburden	mudstone/coal
W13A	8.25	3.07	-9.58	-82.38	Potential Acid Generator	interburden	mudstone/coal
W13B	8.26	8.18	21.99	-20.34	Potential Acid Generator	interburden	mudstone/coal
W14A	8.46	6.8	20.61	-30.24	Potential Acid Generator	interburden	mudstone/coal
W14B	8.11	2.54	-42.7	-124.86	Potential Acid Generator	interburden	mudstone/coal
W15A	8.3	8.01	36.83	31.04	Probably Excess Neutralising Minerals	interburden	mudstone/coal
W15B	8.35	7.76	12.1	3.2	Verify with other tests	interburden	mudstone/coal
W16A	8.53	7.88	50.83	49.16	Probably Excess Neutralising Minerals	interburden	mudstone/coal
W16B	8.34	7.8	28.4	25.67	Probably Excess Neutralising Minerals	interburden	mudstone/coal
W17A	7.58	4.09	-3.04	-7.6	Verify with other tests	interburden	coal
W17B	8.01	3.45	-11.76	-20.32	Potential Acid Generator	interburden	mudstone/coal
W18A	8.47	7.21	30.35	29	Probably Excess Neutralising Minerals	interburden	mudstone/coal
W18B	8.3	8.3	68.19	65.93	Probably Excess Neutralising Minerals	interburden	mudstone/coal
W19A	8.06	4.98	-0.07	-37.64	Potential Acid Generator	interburden	mudstone/coal
W19B	7.92	7.93	34.59	25.86	Probably Excess Neutralising Minerals	interburden	mudstone/coal
W1A	8.53	5.91	-9.78	-18.76	Verify with other tests	interburden	mudstone
W1B	8.13	5.42	-2.12	-2.29	Verify with other tests	interburden	mudstone
W2A	8.23	6.01	-2.4	-2.42	Verify with other tests	interburden	mudstone
W2B	8.1	6.85	0.74	0.82	Verify with other tests	interburden	mudstone
W3A	7.26	6.91	2.07	2.07	Verify with other tests	interburden	mudstone
W3B	8.08	6.79	1.36	1.41	Verify with other tests	interburden	mudstone
W4A	7.68	7.22	0.82	0.77	Verify with other tests	interburden	mudstone
W4B	7.9	6.89	2.65	2.58	Verify with other tests	interburden	mudstone
W5B	7.99	6.06	-0.03	-0.11	Verify with other tests	interburden	mudstone
W6A	8.39	6.6	1.24	1.16	Verify with other tests	interburden	mudstone
W6B	8.03	7.29	-0.01	-0.07	Verify with other tests	interburden	mudstone
W7A	7.25	5.69	1.1	1.13	Verify with other tests	interburden	mudstone
W7B	8.36	5.78	0.43	0.35	Verify with other tests	interburden	mudstone
W8A	8.49	5.68	-0.03	-0.13	Verify with other tests	interburden	mudstone
W8B	8.59	5.65	0.08	0.1	Verify with other tests	interburden	mudstone
W9A	8.58	8.3	52.92	41.13	Probably Excess Neutralising Minerals	interburden	mudstone
W9B	7.85	5.94	0.96	0.89	Verify with other tests	interburden	mudstone
WGA1	7.48	1.55	1.66	-5.72	Verify with other tests	interburden	ss/coal
WGA10	6.61	1.29	-24.85	-43.35	Potential Acid Generator	interburden	mudstone/coal
WGA10 (F)	7.41	2.28	18.96	7.52	Verify with other tests	interburden	mudstone/coal
WGA11	6.13	2.35	-66.5	-137.24	Potential Acid Generator	interburden	mudstone

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
WGA11 (A)	6.9	1.4	-24.22	-45.57	Potential Acid Generator	interburden	mudstone
WGA2	6.85	1.29	-3.79	-19.66	Verify with other tests	interburden	coal/mudstone
WGA2 (A)	7.69	1.63	11.12	-14.82	Verify with other tests	interburden	ss/coal
WGA3	7.78	3.64	-3.61	-12.8	Verify with other tests	interburden	mudstone/coal
WGA3 (A)	7.95	7.58	114.5	107.8	Probably Excess Neutralising Minerals	interburden	ss/coal
WGA4	6.4	2.09	-82.38	-148.01	Potential Acid Generator	interburden	mudstone/coal
WGA5	7.96	4.43	39.52	30.97	Probably Excess Neutralising Minerals	interburden	mudstone/coal
WGA5 (A)	7.32	3.13	-3.17	-3.67	Verify with other tests	interburden	mudstone/coal
WGA6	6.61	2.07	-10.07	-15.14	Verify with other tests	interburden	mudstone/coal
WGA6 (A)	7.86	1.42	-19.41	-21.23	Potential Acid Generator	interburden	mudstone/coal
WGA6 (B)	7.63	1.88	-16.88	-17.47	Verify with other tests	interburden	mudstone/coal
WGA6 (C)	8.3	3.97	-49.67	-83.05	Potential Acid Generator	interburden	mudstone/coal
WGA7	7.18	3.46	3.15	-5.96	Verify with other tests	interburden	mudstone/coal
WGA7 (C)	7.5	4.03	-0.97	-1.1	Verify with other tests	interburden	mudstone/coal
WGA8	7.66	4.16	45.25	33.59	Probably Excess Neutralising Minerals	interburden	mudstone/coal
WGA8 (A)	7.25	1.53	-5.56	-10.07	Verify with other tests	interburden	mudstone/coal
WGA9	7.33	2.02	36.94	-13.01	Verify with other tests	interburden	mudstone/coal
WGA9 (A)	7.37	2.61	7.72	-7.77	Verify with other tests	interburden	mudstone/coal
WGB10 (A)	8.28	4.8	41.63	41.44	Probably Excess Neutralising Minerals	interburden	mud/ss/coal
WGB10 (B)	8.17	1.29	8.09	-52.26	Potential Acid Generator	interburden	mudstone/coal
WGB10 (C)	8.04	1.45	5.56	2.36	Verify with other tests	interburden	ss/mudstone
WGB10 (D)	8.11	2.05	-7.54	-15.93	Verify with other tests	interburden	ss/mud/coal
WGB10 (E)	8.1	1.24	-34.74	-51.33	Potential Acid Generator	interburden	ss/mudstone
WGB3	7.82	1.28	-69.75	-126.97	Potential Acid Generator	interburden	ss
WGB4 (A)	7.9	1.07	-372.45	-723.04	Potential Acid Generator	interburden	ss/coal/mudstone
WGB4 (B)	5.69	1.24	-71.52	-125.87	Potential Acid Generator	interburden	coal/ss
WGB4 (C)	8.41	3.06	-12.2	-18.36	Verify with other tests	interburden	ss
WGB4 (D)	8	2.86	-0.57	-22.63	Potential Acid Generator	interburden	ss
WGB5 (A)	7.45	1.5	-14.14	-14.67	Verify with other tests	interburden	mud/ss/coal
WGB5 (B)	8.28	2.86	-31.28	-40.58	Potential Acid Generator	interburden	ss/coal
WGB5 (C)	7.35	5.01	-24.92	-27.87	Potential Acid Generator	interburden	ss/coal
WGB5 (D)	8.29	2.48	-13.77	-23.96	Potential Acid Generator	interburden	ss/coal
WGB7 (A)	8.12	1.54	1.68	-11.69	Verify with other tests	interburden	ss/coal
WGB7 (B)	7.94	3.09	-66.4	-122.09	Potential Acid Generator	interburden	mudstone/ss/coal
WGB7 (C)	7.55	2.04	-23.37	-25.08	Potential Acid Generator	interburden	mudstone/coal
WGB7 (D)	7.8	2.06	-22.31	-29.42	Potential Acid Generator	interburden	mud/ss/coal
WGB8 (A)	8.18	1.71	-12.12	-14.11	Verify with other tests	interburden	mudstone/coal
WGB8 (B)	7.89	1.73	-50.02	-87.89	Potential Acid Generator	interburden	coal
WGB8 (C)	8.08	1.05	-24.01	-27.9	Potential Acid Generator	interburden	mudstone/coal
WGB8 (D)	7.85	1.06	-19.85	-20.48	Potential Acid Generator	interburden	ss
WGB8 (E)	8.13	4.44	29.58	15.43	Verify with other tests	interburden	mudstone
WGB9 (A)	8.36	1.72	-7.46	-10.9	Verify with other tests	interburden	mudstone/coal
WGB9 (B)	7.63	2.93	-11.36	-12.33	Verify with other tests	interburden	mud/ss/coal
WGC10 (A)	6.78	1.31	-59.11	-101.29	Potential Acid Generator	interburden	mudstone/coal
WGC10 (B)	7.53	4.41	32.31	22.24	Probably Excess Neutralising Minerals	interburden	mudstone/coal

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
WGC11 (A)	7.4	1.78	-10.44	-20.88	Potential Acid Generator	interburden	mudstone/coal
WGC11 (B)	7.53	1.53	9.41	-4.05	Verify with other tests	interburden	mudstone/coal
WGC4 (A)	6.49	1.44	-29.15	-50.81	Potential Acid Generator	interburden	mudstone/coal
WGC4 (B)	7.58	1.43	-13.37	-39.19	Potential Acid Generator	interburden	mudstone/coal
WGC5	7.11	4.06	13.38	8.48	Verify with other tests	interburden	mudstone/coal
WGC6 (A)	7.33	1.62	-20.66	-39.51	Potential Acid Generator	interburden	mudstone/coal
WGC6 (B)	7.78	3.93	11.71	8.88	Verify with other tests	interburden	mudstone/coal
WGC7	6.9	1.77	-5.82	-15.05	Verify with other tests	interburden	mudstone/coal
WGC7 (A)	7.31	1.54	-21.21	-41.93	Potential Acid Generator	interburden	mudstone/coal
WGC8	7.6	2.31	-29.07	-69.63	Potential Acid Generator	interburden	mudstone/coal
WGC8 (A)	7.39	2.5	7.84	6.24	Verify with other tests	interburden	mudstone/coal
WGC9 (A)	7.58	1.65	0.66	-13.04	Verify with other tests	interburden	mudstone/coal
WGC9 (B)	7.26	2.2	-0.69	-13.69	Verify with other tests	interburden	mudstone/coal
WGD1	7.84	2.19	4.24	-3.49	Verify with other tests	interburden	mudstone/coal
WGD1 (A)	8.15	7.28	48.28	41.35	Probably Excess Neutralising Minerals	interburden	mudstone/coal
WGD2 (A)	7.5	1.99	-89.71	-179.58	Potential Acid Generator	interburden	ss
WGD3	7.42	2.06	-103.797	-248.71	Potential Acid Generator	interburden	ss/coal
WGD4	6.68	1.94	-3.54	-2.6	Verify with other tests	interburden	mudstone/coal
WGD4 (D)	5.21	1.34	-11.33	-18.54	Verify with other tests	interburden	mudstone/coal
WGD5	7.86	1.94	-7.64	-11.26	Verify with other tests	interburden	mudstone/coal
WGD5 (A)	7.88	4.11	14.51	-1.85	Verify with other tests	interburden	mudstone/coal
WGD6 (A)	7.67	3.62	-2.66	-3.39	Verify with other tests	interburden	mudstone/coal
WGD6 (B)	7.87	5.27	41.18	40.28	Probably Excess Neutralising Minerals	interburden	mudstone/coal
WGD6 (C)	7.51	5.29	16.43	1.02	Verify with other tests	interburden	mudstone/coal
WGD7	7.98	2.04	-7.4	-9.45	Verify with other tests	interburden	mudstone/coal
WGD7 (A)	6.9	2	-6.06	-8.32	Verify with other tests	interburden	mudstone/coal
WGD7 (B)	7.45	3.24	11.47	-13.82	Verify with other tests	interburden	mudstone/coal
WGD8 (A)	6.73	1.49	-13.14	-23.54	Potential Acid Generator	interburden	mudstone/coal
WGD8 (B)	7.58	2.86	10.42	3.69	Verify with other tests	interburden	mudstone/coal
WGD8 (C)	6.84	2.83	-4.43	-5.63	Verify with other tests	interburden	mudstone/coal
WGD9	5.03	1.51	-19.35	-32.8	Potential Acid Generator	interburden	clay ground/mudstone
WGE2	7.61	1.77	-42.83	-67.12	Potential Acid Generator	interburden	
WGE4 (A)	8.09	4.12	-9.94	-10.94	Verify with other tests	interburden	
WGE4 (B)	8.28	2.88	-6.21	-11.55	Verify with other tests	interburden	
WGF10	8.1	4.82	26.63	17.39	Verify with other tests	interburden	mudstone/coal
WGF7	3.96	1.07	-19.26	-28.52	Potential Acid Generator	interburden	coal/mudstone
WGG1	7.42	1.78	-38.49	-97.83	Potential Acid Generator	interburden	ss
WGG2	7.52	3.99	-5.75	-15.66	Verify with other tests	interburden	ss/mud/coal
WGG2 (A)	7.7	1.61	22.06	13.37	Verify with other tests	interburden	coal/mudstone
WGG2 (C)	7.59	2.18	-64.64	-167.62	Potential Acid Generator	interburden	coal/ss
WGG3	7.31	2.8	-18.76	-47.12	Potential Acid Generator	interburden	coal/ss
WGG4	7.16	2.03	15.63	-5.27	Verify with other tests	interburden	mudstone/coal
WGG4 (A)	5.3	1.43	30.76	29.72	Probably Excess Neutralising Minerals	interburden	mudstone/coal
WGG4 (D)	8.01	4.43	-1.25	-2.97	Verify with other tests	interburden	mudstone/ss
WGG4 (E)	6.69	1.52	33.39	31.37	Probably Excess Neutralising Minerals	interburden	mudstone/ss

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
WGG4 (F)	7.99	6.13	-4.41	-6.8	Verify with other tests	interburden	mudstone
WGG5 (C)	7.31	3.34	2.7	2.62	Verify with other tests	interburden	coal/mudstone
WGG5 (E)	7.93	4.02	27.19	21.8	Probably Excess Neutralising Minerals	interburden	mudstone
WGG5 (F)	7.73	3.96	5.24	-38.78	Potential Acid Generator	interburden	mudstone/coal
WGG6	7.53	3.99	50.57	45.47	Probably Excess Neutralising Minerals	interburden	mudstone/coal
WGG6 (A)	8.08	7.23	23.12	18.6	Verify with other tests	interburden	mudstone
WGG6 (B)	7.53	2.73	2.74	-2.13	Verify with other tests	interburden	carbonaceous mudstone
WGH (160)	7	2.56	-8.72	-29.2	Potential Acid Generator	interburden	mudstone
WGH (161)	6.98	2.06	-1.06	-2.77	Verify with other tests	interburden	mudstone
WGH (162)	6.61	2.48	2.88	1.46	Verify with other tests	interburden	mudstone
WGH (163)	6.09	2.23	-37.06	-67.68	Potential Acid Generator	interburden	mudstone
WGH(164)	6.66	1.61	-17.43	-34.25	Potential Acid Generator	interburden	siltstone
WGH (165)	7.86	5.93	46.87	14.51	Verify with other tests	interburden	siltstone
WGH (166)	7.91	4.59	2.14	-13.4	Verify with other tests	interburden	ss
WGH (167)	6.9	1.71	-4.91	-5.78	Verify with other tests	interburden	ss
WGH (168)	7	2.31	10.18	8.61	Verify with other tests	interburden	ss
WGH (169)	7.2	1.91	-19.82	-40.72	Potential Acid Generator	interburden	ss
WGH (170)	6.77	1.76	-10.12	-21.12	Potential Acid Generator	interburden	ss
WGH (171)	5.78	1.72	-44.06	-86	Potential Acid Generator	interburden	mudstone
WGH (172)	6.8	3.1	-0.07	-1.26	Verify with other tests	interburden	mudstone
WGH (173)	6.71	2.69	-0.77	-2.65	Verify with other tests	interburden	ss
WGH (174)	5.61	1.72	-53.97	-106.95	Potential Acid Generator	interburden	ss
WGH (175)	6.9	1.69	-278.31	-552.57	Potential Acid Generator	interburden	mudstone
WGH (176)	7.43	6.1	64.59	64.1	Probably Excess Neutralising Minerals	interburden	mudstone
WGH (177)	7.35	3.27	6.17	5.64	Verify with other tests	interburden	mudstone
WGH (178)	7.02	3.99	-13.74	-14.35	Verify with other tests	interburden	mudstone
WGH (179)	6.79	2.92	1.14	0.42	Verify with other tests	interburden	mudstone
WGH (180)	7.46	2.27	1.8	1.24	Verify with other tests	interburden	mudstone
WGH (181)	6.8	3.84	4.73	2.64	Verify with other tests	interburden	mudstone
WGH (182)	6.39	2.97	-0.34	-1.16	Verify with other tests	interburden	mudstone
WGH (183)	6.8	2.58	-1.88	-2.72	Verify with other tests	interburden	ss
WGH (184)	7.65	1.76	-7.68	-24.44	Potential Acid Generator	interburden	ss
WGH (185)	6.89	3.35	49.86	48.58	Probably Excess Neutralising Minerals	interburden	ss
WGH (187)	6.54	2.98	-0.44	-0.85	Verify with other tests	interburden	ss
WGH (188)	6.61	1.67	0.24	0.11	Verify with other tests	interburden	ss
WGH (189)	6.8	2.46	-1.89	-2.33	Verify with other tests	interburden	ss
WGH (190)	6.62	2.4	-3.3	-6.86	Verify with other tests	interburden	shale/ss
WGH (191)	6.41	3.17	4.08	3.77	Verify with other tests	interburden	mud/silt
WGH (192)	7.11	2.43	-1.28	-21.74	Potential Acid Generator	interburden	siltstone
WGH (193)	8.08	5.57	128.31	125.13	Probably Excess Neutralising Minerals	interburden	siltstone
WGH (194)	5.02	2.09	-86.07	-170.19	Potential Acid Generator	interburden	siltstone
WGH (195)	7.22	2.62	-2.01	-3.68	Verify with other tests	interburden	ss
WGH (196)	7.46	2.3	-41.29	-81	Potential Acid Generator	interburden	ss

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
WGH (197)	7.57	2.96	25.44	25.5	Probably Excess Neutralising Minerals	interburden	coal
WGH (186)	6.56	2.53	-1.31	-1.41	Verify with other tests	interburden	ss
WRA2 (B)	2.76	1.76	-12.77	-20.13	Potential Acid Generator	interburden	coal
WRA3 (B)	7.11	1.4	-29.75	-75.71	Potential Acid Generator	interburden	coal/ss
WRA4 (A)	7.74	3.72	9.36	8	Verify with other tests	interburden	mudstone/coal
WRA4 (A)	6.99	2.72	-24.8	-74.12	Potential Acid Generator	interburden	ss/coal
WRA4 (D)	7.34	3.15	7.7	5.14	Verify with other tests	interburden	mud/coal/ss
WRA4 (G)	7.65	3.7	-33.21	-65.71	Potential Acid Generator	interburden	coal
WRA5 (B)	7.59	4.68	33.78	32.09	Probably Excess Neutralising Minerals	interburden	mudstone/coal
WRA5 (F)	7.52	1.63	-12.75	-33.58	Potential Acid Generator	interburden	coal/mudstone
WTA1	3.99	1.15	-69.65	-77.03	Potential Acid Generator	interburden	coal/ss
WTA2	4.13	1.05	-147.01	-280.27	Potential Acid Generator	interburden	coal
WTB1 (A)	5.28	1.2	-35.52	-49.35	Potential Acid Generator	interburden	coal/ss
WTB1 (B)	4.06	1.2	-59.92	-92.91	Potential Acid Generator	interburden	coal
WTB2	7.99	2.63	-15.51	-15.85	Verify with other tests	interburden	coal/siltstone
WTB3	3.62	1.02	-41.68	-56.05	Potential Acid Generator	interburden	ss/mud/coal
WTB4	7.48	1.52	-5.52	-113.65	Potential Acid Generator	interburden	coal/mudstone
WTC1	3.37	1.24	-50.04	-65.64	Potential Acid Generator	interburden	coal/ss
WTC2 (A)	6.15	1.5	-77.76	-120.69	Potential Acid Generator	interburden	coal/ss
WTC2 (B)	4.64	2.2	-7.08	-10.68	Verify with other tests	interburden	coal/ss
WTC3 (A)	6.2	1.63	-30.56	-68.7	Potential Acid Generator	interburden	ss/mudstone
WTC4 (A)	7.3	2	-6.54	-8.97	Verify with other tests	interburden	coal/mudstone
WTC4 (B)	6.72	2.06	-11.15	-17.93	Verify with other tests	interburden	coal/mudstone
WTC4 (C)	3.98	2.01	-8.55	-25.83	Potential Acid Generator	interburden	coal/mudstone
WTC4 (D)	7.57	4.21	-169.45	-313.85	Potential Acid Generator	interburden	mudstone
WTD2	7.68	0.83	-28.67	-50.46	Potential Acid Generator	interburden	coal/mudstone
WTD2 (A)	3.12	1.86	-124.23	-222.73	Potential Acid Generator	interburden	coal
WTD3 (A)	5.31	2.45	-54.03	-109.13	Potential Acid Generator	interburden	coal
WTD3 (B)	4.4	1.65	-196.62	-379.45	Potential Acid Generator	interburden	coal
WTD4 (A)	4.55	0.92	-27.55	-43.28	Potential Acid Generator	interburden	mudstone/coal
WTD4 (B)	4.03	1.45	-47.79	-48.48	Potential Acid Generator	interburden	coal
WTD4 (C)	7.05	1.94	-49.2	-98.12	Potential Acid Generator	interburden	coal
WVA1	4.16	1.17	-34.41	-61.27	Potential Acid Generator	interburden	coal
WVA2 (A)	3.53	1.17	-27.72	-56.06	Potential Acid Generator	interburden	coal
WVA3	4.84	1.82	-7.89	-16.21	Verify with other tests	interburden	coal/mudstone
WVA4	3.42	1.21	-41.03	-45.6	Potential Acid Generator	interburden	coal/mudstone
WVA4 (A)	7.25	2.94	-198.31	-484.27	Potential Acid Generator	interburden	coal/mudstone
WVA4 (C)	3.95	1.17	-32.75	-61.93	Potential Acid Generator	interburden	coal/mudstone
WVA4 (D)	6.64	1.66	-61.34	-126.95	Potential Acid Generator	interburden	coal
WVA5	5.52	1.47	-1.09	1.45	Verify with other tests	interburden	coal/mudstone
WVA5 (A)	5.59	1.05	-5.3	-6.98	Verify with other tests	interburden	coal/mudstone
WVB2)	3.8	2.13	-158.41	-301.56	Potential Acid Generator	interburden	
WVB3	3.5	1.23	-17.47	-26.91	Potential Acid Generator	interburden	
WVB4	6.11	0.77	-17.5	-28.85	Potential Acid Generator	interburden	
WVB4 (A)	3.95	1.3	-10.82	-20.25	Potential Acid Generator	interburden	

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
WVB4 (B)	4.1	1.32	-57.38	-99.09	Potential Acid Generator	interburden	
WVB4 (C)	3.43	1.29	-54.27	-98.34	Potential Acid Generator	interburden	
WVB4 (E)	7.38	2.06	-70.69	-183.92	Potential Acid Generator	interburden	
WVB4 (D)	5.82	1.82	-7.68	-12.82	Verify with other tests	interburden	
WVC1	3.58	1.34	-95.5	-170.51	Potential Acid Generator	interburden	coal/ss
WVC2	2.5	0.98	-19.64	-25.44	Potential Acid Generator	interburden	coal/clay
WVC3	2.62	1.15	-23.17	-31.9	Potential Acid Generator	interburden	coal/ss
WVC3 (A)	2.85	1	-18.72	-22.11	Potential Acid Generator	interburden	ss
WVC4 (A)	3.39	3.08	16.75	21.24	Probably Excess Neutralising Minerals	interburden	ss/mudstone
WVC4 (B)	5.5	2.34	-10.68	-12.27	Verify with other tests	interburden	coal/mudstone
WVC9	3	0.92	-24.45	-38.47	Potential Acid Generator	interburden	coal/mudstone
WVC9	3	0.92	-24.45	-38.47	Potential Acid Generator	interburden	coal/mudstone

Table 7-B: Interpretation of NP/AP rations for the Sasol samples.

Site Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
WGA2	0.001	Likely Acid Generator	Likely Acid Generator
WGA11	0.060	Likely Acid Generator	Likely Acid Generator
WGA10	0.001	Likely Acid Generator	Likely Acid Generator
WGA9	1.742	Acid under certain conditions	Likely Acid Generator
WGA3	0.608	Likely Acid Generator	Likely Acid Generator
WGA7	1.290	Acid under certain conditions	Likely Acid Generator
WGA4	0.000	Likely Acid Generator	Likely Acid Generator
WGA6	0.002	Likely Acid Generator	Likely Acid Generator
WGA8	4.856	No Acid Potential	Acid under certain conditions
WGA5	5.251	No Acid Potential	Acid under certain conditions
WGA6 (C)	0.000	Likely Acid Generator	Likely Acid Generator
WGA6 (A)	0.005	Likely Acid Generator	Likely Acid Generator
WGA6 (B)	0.017	Likely Acid Generator	Likely Acid Generator
WGA3(A)	1185.088	No Acid Potential	No Acid Potential
WGA5(A)	0.013	Likely Acid Generator	Likely Acid Generator
WGB9 (B)	0.003	Likely Acid Generator	Likely Acid Generator
WGB9 (A)	0.006	Likely Acid Generator	Likely Acid Generator
WGB5 (B)	0.002	Likely Acid Generator	Likely Acid Generator
WGB5 (A)	0.000	Likely Acid Generator	Likely Acid Generator
WGB5 (D)	0.003	Likely Acid Generator	Likely Acid Generator
WGB4 (A)	0.000	Likely Acid Generator	Likely Acid Generator
WGB10 (A)	1.488	Acid under certain conditions	Likely Acid Generator
WGB7 (A)	1.126	Acid under certain conditions	Likely Acid Generator
WGB3	0.000	Likely Acid Generator	Likely Acid Generator
WGB8 (E)	3.090	Acid under certain conditions	Acid under certain conditions
WGB4 (C)	0.002	Likely Acid Generator	Likely Acid Generator
WGB7 (B)	0.000	Likely Acid Generator	Likely Acid Generator
WGB8 (D)	0.016	Likely Acid Generator	Likely Acid Generator
WGB7 (D)	0.001	Likely Acid Generator	Likely Acid Generator
WGB8 (B)	0.000	Likely Acid Generator	Likely Acid Generator
WGB7 (C)	0.006	Likely Acid Generator	Likely Acid Generator
WGB8 (A)	0.005	Likely Acid Generator	Likely Acid Generator
WGB5 (C)	0.003	Likely Acid Generator	Likely Acid Generator
WGB10 (B)	1.134	Acid under certain conditions	Likely Acid Generator
WGB8 (C)	0.003	Likely Acid Generator	Likely Acid Generator
WGB10 (E)	0.001	Likely Acid Generator	Likely Acid Generator
WGB4 (B)	0.000	Likely Acid Generator	Likely Acid Generator
WGB10 (C)	2.734	Acid under certain conditions	Acid under certain conditions
WGB10 (D)	0.101	Likely Acid Generator	Likely Acid Generator
WGA2(A)	1.249	Acid under certain conditions	Likely Acid Generator

Site Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
WGA7(C)	0.075	Likely Acid Generator	Likely Acid Generator
WGA10(F)	2.561	Acid under certain conditions	Acid under certain conditions
WGC10 (A)	0.000	Likely Acid Generator	Likely Acid Generator
WGC9 (B)	0.966	Likely Acid Generator	Likely Acid Generator
WGC9 (A)	1.058	Acid under certain conditions	Likely Acid Generator
WGC4 (A)	0.000	Likely Acid Generator	Likely Acid Generator
WGC6 (A)	0.001	Likely Acid Generator	Likely Acid Generator
WGC8	0.287	Likely Acid Generator	Likely Acid Generator
WGC7	0.360	Likely Acid Generator	Likely Acid Generator
WGC6 (B)	5.984	No Acid Potential	Acid under certain conditions
WGC11 (B)	1.724	Acid under certain conditions	Likely Acid Generator
WGC5	3.843	Acid under certain conditions	Acid under certain conditions
WGC4 (B)	0.482	Likely Acid Generator	Likely Acid Generator
WGC11 (A)	0.001	Likely Acid Generator	Likely Acid Generator
WGC7 (A)	0.001	Likely Acid Generator	Likely Acid Generator
WGC10 (B)	5.075	No Acid Potential	Acid under certain conditions
WGC8(A)	6.114	No Acid Potential	Acid under certain conditions
WGD7	0.006	Likely Acid Generator	Likely Acid Generator
WGD4	0.002	Likely Acid Generator	Likely Acid Generator
WGD8(C)	0.009	Likely Acid Generator	Likely Acid Generator
WGD5	0.009	Likely Acid Generator	Likely Acid Generator
WGD1	1.567	Acid under certain conditions	Likely Acid Generator
WGD1(A)	8.568	No Acid Potential	No Acid Potential
WGD3	0.237	Likely Acid Generator	Likely Acid Generator
WGD5(A)	1.912	Acid under certain conditions	Likely Acid Generator
WGD6(A)	0.010	Likely Acid Generator	Likely Acid Generator
WGD6(B)	39.075	No Acid Potential	No Acid Potential
WGD7(B)	1.463	Acid under certain conditions	Likely Acid Generator
WGD7(A)	0.006	Likely Acid Generator	Likely Acid Generator
WGD8(A)	0.001	Likely Acid Generator	Likely Acid Generator
WGD2(A)	0.002	Likely Acid Generator	Likely Acid Generator
WGD4(D)	0.001	Likely Acid Generator	Likely Acid Generator
WGD6(C)	2.175	Acid under certain conditions	Acid under certain conditions
WGD8(B)	2.797	Acid under certain conditions	Acid under certain conditions
WGD9	0.001	Likely Acid Generator	Likely Acid Generator
WGE4 (A)	0.010	Likely Acid Generator	Likely Acid Generator
WGE2	0.000	Likely Acid Generator	Likely Acid Generator
WGE4 (B)	0.002	Likely Acid Generator	Likely Acid Generator
WGF10	3.883	Acid under certain conditions	Acid under certain conditions
WGF7	0.001	Likely Acid Generator	Likely Acid Generator
WVA5 (A)	0.005	Likely Acid Generator	Likely Acid Generator
WVA5	0.001	Likely Acid Generator	Likely Acid Generator
WVA3	0.052	Likely Acid Generator	Likely Acid Generator

Site Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
WVA4 (A)	0.310	Likely Acid Generator	Likely Acid Generator
WVA2(A)	0.021	Likely Acid Generator	Likely Acid Generator
WVA1	0.000	Likely Acid Generator	Likely Acid Generator
WVA4	0.002	Likely Acid Generator	Likely Acid Generator
WVA4(C)	0.000	Likely Acid Generator	Likely Acid Generator
WVA4(D)	0.065	Likely Acid Generator	Likely Acid Generator
WVB4 (A)	0.001	Likely Acid Generator	Likely Acid Generator
WVB3	0.001	Likely Acid Generator	Likely Acid Generator
WVB4	0.001	Likely Acid Generator	Likely Acid Generator
WVB4 (C)	0.000	Likely Acid Generator	Likely Acid Generator
WVB4 (B)	0.000	Likely Acid Generator	Likely Acid Generator
WVB2)	0.000	Likely Acid Generator	Likely Acid Generator
WVB4 (E)	0.376	Likely Acid Generator	Likely Acid Generator
WVB4(D)	0.002	Likely Acid Generator	Likely Acid Generator
WVC2	0.001	Likely Acid Generator	Likely Acid Generator
WVC3 (A)	0.003	Likely Acid Generator	Likely Acid Generator
WVC4 (B)	0.005	Likely Acid Generator	Likely Acid Generator
WVC9	0.001	Likely Acid Generator	Likely Acid Generator
WVC3	0.001	Likely Acid Generator	Likely Acid Generator
WVC4 (A)	0.003	Likely Acid Generator	Likely Acid Generator
WVC1	0.000	Likely Acid Generator	Likely Acid Generator
W1A	0.001	Likely Acid Generator	Likely Acid Generator
W1B	0.058	Likely Acid Generator	Likely Acid Generator
W2A	0.396	Likely Acid Generator	Likely Acid Generator
W3A	5090.404	No Acid Potential	No Acid Potential
W4A	16.700	No Acid Potential	No Acid Potential
W4B	35.714	No Acid Potential	No Acid Potential
W5B	0.702	Likely Acid Generator	Likely Acid Generator
W6A	16.851	No Acid Potential	No Acid Potential
W6B	0.894	Likely Acid Generator	Likely Acid Generator
W7B	6.235	No Acid Potential	Acid under certain conditions
W8A	0.645	Likely Acid Generator	Likely Acid Generator
W9A	5.490	No Acid Potential	Acid under certain conditions
W9B	16.208	No Acid Potential	No Acid Potential
W10A	2.496	Acid under certain conditions	Acid under certain conditions
W10B	6.764	No Acid Potential	Acid under certain conditions
W11A	1.854	Acid under certain conditions	Likely Acid Generator
W11B	0.554	Likely Acid Generator	Likely Acid Generator
W12A	0.983	Likely Acid Generator	Likely Acid Generator
W12B	2.601	Acid under certain conditions	Acid under certain conditions
W13A	0.868	Likely Acid Generator	Likely Acid Generator
W13B	1.520	Acid under certain conditions	Likely Acid Generator
W14A	1.405	Acid under certain conditions	Likely Acid Generator

Site Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
W14B	0.480	Likely Acid Generator	Likely Acid Generator
W15A	7.355	No Acid Potential	Acid under certain conditions
W15B	2.359	Acid under certain conditions	Acid under certain conditions
W16A	31.394	No Acid Potential	No Acid Potential
W16B	11.381	No Acid Potential	No Acid Potential
W17A	0.335	Likely Acid Generator	Likely Acid Generator
W17B	0.001	Likely Acid Generator	Likely Acid Generator
W18A	23.379	No Acid Potential	No Acid Potential
W18B	31.241	No Acid Potential	No Acid Potential
W19A	0.998	Likely Acid Generator	Likely Acid Generator
W19B	4.962	No Acid Potential	Acid under certain conditions
WGG2	9.935	No Acid Potential	No Acid Potential
WGG4 (A)	4.064	No Acid Potential	Acid under certain conditions
WGG6	18.857	No Acid Potential	No Acid Potential
WGG1	0.351	Likely Acid Generator	Likely Acid Generator
WGG4(B)	0.004	Likely Acid Generator	Likely Acid Generator
WGG2 (A)	1.065	Acid under certain conditions	Likely Acid Generator
WGG3	0.721	Likely Acid Generator	Likely Acid Generator
WGG2 (C))	0.761	Likely Acid Generator	Likely Acid Generator
WGG4 (D)	30.749	No Acid Potential	No Acid Potential
WGG4 (E)	0.277	Likely Acid Generator	Likely Acid Generator
WGG4 (F)	17.559	No Acid Potential	No Acid Potential
WGG5 (C)	36.162	No Acid Potential	No Acid Potential
WGG5 (E)	12.240	No Acid Potential	No Acid Potential
WGG5 (F)	2.255	Acid under certain conditions	Acid under certain conditions
WGG6 (A)	22.267	No Acid Potential	No Acid Potential
WGG6 (B)	3.186	Acid under certain conditions	Acid under certain conditions
WRA2 (B)	0.000	Likely Acid Generator	Likely Acid Generator
WRA3 (B)	0.744	Likely Acid Generator	Likely Acid Generator
WRA4 (A)	1.084	Acid under certain conditions	Likely Acid Generator
WRA4 (D)	4.010	No Acid Potential	Acid under certain conditions
WRA4 (G)	7.853	No Acid Potential	Acid under certain conditions
WRA4 (A)	3.755	Acid under certain conditions	Acid under certain conditions
WRA5 (B)	21.025	No Acid Potential	No Acid Potential
WRA5 (F)	0.796	Likely Acid Generator	Likely Acid Generator
WTA1	0.001	Likely Acid Generator	Likely Acid Generator
WTA2	0.000	Likely Acid Generator	Likely Acid Generator
WTB1 (A)	0.001	Likely Acid Generator	Likely Acid Generator
WTB2	0.030	Likely Acid Generator	Likely Acid Generator
WTB4	0.949	Likely Acid Generator	Likely Acid Generator
WTB1 (B)	0.000	Likely Acid Generator	Likely Acid Generator
WTB3	0.001	Likely Acid Generator	Likely Acid Generator
WTC4 (A)	0.001	Likely Acid Generator	Likely Acid Generator

Site Name	**Neutralising Potential Ratio(NP/AP) for Open System**	**Interpretation Open System**	**Interpretation Closed System**
WTC1	0.001	Likely Acid Generator	Likely Acid Generator
WTC4 (B)	0.505	Likely Acid Generator	Likely Acid Generator
WTC1	0.000	Likely Acid Generator	Likely Acid Generator
WTC2(A)	0.003	Likely Acid Generator	Likely Acid Generator
WTC2(B)	0.199	Likely Acid Generator	Likely Acid Generator
WTC3(A)	0.004	Likely Acid Generator	Likely Acid Generator
WTC4(C)	0.000	Likely Acid Generator	Likely Acid Generator
WTC4(D)	0.002	Likely Acid Generator	Likely Acid Generator
WTD4 (B)	0.014	Likely Acid Generator	Likely Acid Generator
WTD4 (A)	0.001	Likely Acid Generator	Likely Acid Generator
WTD2	0.000	Likely Acid Generator	Likely Acid Generator
WTD2(A)	0.000	Likely Acid Generator	Likely Acid Generator
WTD3(A)	0.019	Likely Acid Generator	Likely Acid Generator
WTD3(B)	0.000	Likely Acid Generator	Likely Acid Generator
WTD4(B)	0.000	Likely Acid Generator	Likely Acid Generator

Table 7-C: Summary of the ABA results for the Resgen samples.

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
RA1	7.02	3.61	-7.09	-7.19	Verify with other tests	Interburden	soil
RA10	8.06	7.43	11.20	11.23	Verify with other tests	Interburden	calcrete
RA11	7.82	5.73	-0.05	-0.11	Verify with other tests	Interburden	calcrete
RA12	6.5	2.8	####	-38.27	Potential Acid Generator	Interburden	calcrete
RA14	7.65	5.73	61.54	61.52	Probably Excess Neutralising Minerals	Interburden	calcrete
RA15	5.5	3.24	3.79	3.83	Verify with other tests	Interburden	shale
RA17	7.03	4.82	1.05	1.03	Verify with other tests	Interburden	shale
RA18	6.71	3.67	-0.35	-0.69	Verify with other tests	Interburden	mudstone
RA2	8.82	8.56	2.48	2.44	Verify with other tests	Interburden	calcrete
RA20	6.42	3.7	-2.55	-3.06	Verify with other tests	Interburden	mudstone
RA22	7.43	7.52	-1.94	-2.20	Verify with other tests	Interburden	mudstone
RA25	7.52	4.5	-1.86	-3.68	Verify with other tests	Interburden	shale/mudstone
RA25	6.28	3.15	####	-17.67	Verify with other tests	Interburden	shale/mudstone
RA26	7.74	7.31	1.61	0.21	Verify with other tests	Interburden	mudstone
RA26	4.96	3.67	-6.21	-8.63	Verify with other tests	Interburden	shale/mudstone
RA28	6.6	3.62	-3.85	-5.31	Verify with other tests	Interburden	mudstone
RA29	7.75	7.45	6.87	5.88	Verify with other tests	Interburden	mudstone
RA29	7.14	6.78	-4.56	-5.82	Verify with other tests	Interburden	mudstone/shale
RA3	6.43	4.59	1.72	1.83	Verify with other tests	Interburden	calcrete
RA30	5.74	3.22	-4.62	-5.65	Verify with other tests	Interburden	mudstone/shale
RA31	6.57	4.5	6.57	4.5	Potential Acid Generator	Interburden	mudstone/shale
RA32	7.27	4.38	-0.54	-0.56	Verify with other tests	Interburden	shale
RA34	8.59	8.05	14.91	14.82	Verify with other tests	Interburden	shale
RA34	7.22	4.8	-7.64	-9.15	Verify with other tests	Interburden	shale
RA35	7.01	3.15	-3.81	-4.63	Verify with other tests	Interburden	ss
RA35	7.17	6.28	-0.5	2.37	Verify with other tests	Interburden	ss
RA36	6.9	4.2	1.06	0.79	Verify with other tests	Interburden	shale/ss
RA38	6.8	4.42	####	-27.47	Potential Acid Generator	Interburden	mudstone
RA39	8.11	7.04	15.19	14.19	Verify with other tests	Interburden	shale
RA39	6.43	4.21	####	-22.71	Potential Acid Generator	Interburden	shale/mudstone
RA4	8.42	8.46	-0.33	-0.36	Verify with other tests	Interburden	calcrete
RA40	8.28	6.64	2.21	2.17	Verify with other tests	Interburden	shale/mudstone
RA41	8.35	7.88	-0.31	-0.34	Verify with other tests	Interburden	mudstone
RA44	6.9	3.39	-3.21	-5.28	Verify with other tests	Interburden	shale/mudstone
RA45	6.91	1.74	-2.70	-3.26	Verify with other tests	Interburden	shale/mudstone
RA46	6.95	6.07	-1.27	-1.73	Verify with other tests	Interburden	mudstone
RA48	7	4.85	-1.41	-1.67	Verify with other tests	Interburden	mudstone
RA51	6.61	5.23	-1.10	-1.08	Verify with other tests	Interburden	ss/mudstone
RA52	7.03	2.29	-3.31	-4.80	Verify with other tests	Interburden	shale
RA53	7.17	1.7	66.84	65.69	Probably Excess Neutralising Minerals	Interburden	shale
RA54	4.44	2.34	####	-77.69	Potential Acid Generator	Interburden	carbonaceous shale

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
RA58	8.06	7.9	####	-16.44	Verify with other tests	Interburden	ss
RA6	8.02	6.69	-0.10	-0.19	Verify with other tests	Interburden	calcrete
RA60	6.7	2.41	####	-42.64	Potential Acid Generator	Interburden	shale/ss
RA63	8.2	6.61	19.66	19.48	Verify with other tests	Interburden	ss
RA68	8.02	3.64	11.94	11.73	Verify with other tests	Interburden	ss
RA69	6.06	6.54	-0.60	-0.60	Verify with other tests	Interburden	shale/ss
RA7	8.32	7.54	8.59	8.60	Verify with other tests	Interburden	calcrete
RA77	3.75	1.32	-9.88	-18.65	Verify with other tests	Interburden	ss
RA78	7.46	2.66	####	-18.34	Verify with other tests	Interburden	ss
RA79	6.35	1.65	-3.50	-5.52	Verify with other tests	Interburden	shale/ss
RA8	8.09	7.1	0.39	0.32	Verify with other tests	Interburden	calcrete
RA82	6.41	3.55	27.87	25.52	Probably Excess Neutralising Minerals	Interburden	ss
RA84	7.43	3.7	####	-11.82	Verify with other tests	Interburden	ss
RA9	8.1	6.9	26.12	26.09	Probably Excess Neutralising Minerals	Interburden	calcrete
Rb1	6.93	2.72	1.80	1.74	Verify with other tests	interburden	soil
RB10	7.61	5.24	-0.44	-0.54	Verify with other tests	interburden	ss
RB11	7.37	4.26	-3.21	-3.44	Verify with other tests	interburden	ss
RB12	7.71	5.23	####	-16.53	Verify with other tests	interburden	ss
RB13	8.02	4.54	-6.24	-6.29	Verify with other tests	interburden	shale/ss
RB14	7.37	3.15	-3.25	-3.32	Verify with other tests	interburden	shale/mudstone
RB15	7.07	3.16	1.37	0.06	Verify with other tests	interburden	mudstone
RB16	6.96	4.38	-2.26	-2.72	Verify with other tests	interburden	ss/mudstone
RB17	7.69	5.81	20.50	19.67	Verify with other tests	interburden	ss/shale
RB18	8.07	3.62	-4.62	-4.70	Verify with other tests	interburden	shale
RB19	7.04	3.69	1.21	0.93	Verify with other tests	interburden	shale
Rb2	7.43	5.74	14.08	14.04	Verify with other tests	interburden	soil
RB20	7.27	3.94	-8.30	-8.64	Verify with other tests	interburden	shale/mudstone
RB21	7.04	3.18	13.60	13.28	Verify with other tests	interburden	mudstone
RB22	7.1	3.14	27.04	26.93	Probably Excess Neutralising Minerals	interburden	mudstone
RB23	7.08	3.04	-1.09	-10.74	Verify with other tests	interburden	shale
RB24	7.35	3.54	-3.25	-3.56	Verify with other tests	interburden	mudstone
RB25	7.25	3.53	7.71	7.46	Verify with other tests	interburden	mudstone
RB26	7.13	3.19	30.41	30.25	Probably Excess Neutralising Minerals	interburden	shale
RB27	7.4	5.16	4.04	3.59	Verify with other tests	interburden	shale
RB28	7.46	2.71	-4.07	-4.67	Verify with other tests	interburden	shale
RB29	7	5.95	5.78	5.26	Verify with other tests	interburden	ss
Rb3	9.01	8.45	####	-32.46	Potential Acid Generator	interburden	calcrete
RB30	8.01	5.57	10.79	10.29	Verify with other tests	interburden	ss/mudstone
RB31	8.23	2.58	-4.34	-4.61	Verify with other tests	interburden	mudstone
RB32	6.65	2.33	1.06	-0.28	Verify with other tests	interburden	mudstone
RB33	7.63	3.1	-2.70	-4.97	Verify with other tests	interburden	mudstone
RB34	7.74	6.53	51.11	46.36	Probably Excess Neutralising Minerals	interburden	shale
RB38	7.6	3.37	23.04	22.62	Probably Excess Neutralising Minerals	interburden	ss

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
RB39	7.16	3.04	-1.69	-2.03	Verify with other tests	interburden	ss
Rb4	9.03	8.56	24.62	24.48	Probably Excess Neutralising Minerals	interburden	calcrete
RB40	7.2	5.84	43.33	40.79	Probably Excess Neutralising Minerals	interburden	ss
Rb41	8.28	5.49	20.48	4.24	Verify with other tests	interburden	ss
Rb42	7.68	5.16	1.83	-2.58	Verify with other tests	interburden	ss
Rb43	8.57	5.42	9.42	8.92	Verify with other tests	interburden	shale
Rb44	7.72	2.92	-0.46	-3.11	Verify with other tests	interburden	shale
Rb45	7.33	2.33	6.25	3.99	Verify with other tests	interburden	shale
Rb46	8.19	2.83	20.00	17.74	Verify with other tests	interburden	shale
Rb47	8.24	1.94	####	-55.76	Potential Acid Generator	interburden	shale
Rb48	8.27	2.12	-7.36	-19.52	Verify with other tests	interburden	shale
Rb49	4.6	2.66	####	-20.21	Potential Acid Generator	interburden	shale
Rb5	8.6	5.86	26.87	26.87	Probably Excess Neutralising Minerals	interburden	calcrete
RB51	7.49	2.46	-8.51	-22.00	Potential Acid Generator	interburden	mudstone
RB52	7.33	2.45	24.38	23.78	Probably Excess Neutralising Minerals	interburden	mudstone/ss
RB53	8.5	4.37	1.23	0.80	Verify with other tests	interburden	ss/shale
RB54	7.09	2.28	-8.82	-17.04	Verify with other tests	interburden	shale
RB55	6.37	1.58	-6.81	-8.36	Verify with other tests	interburden	shale/ss
RB56	8.38	4.36	5.94	5.61	Verify with other tests	interburden	ss
RB57	7.31	3.12	-9.49	-10.10	Verify with other tests	interburden	ss
RB58	7.21	3.08	-5.23	-5.67	Verify with other tests	interburden	ss
RB59	6.78	2.71	-7.48	-7.93	Verify with other tests	interburden	ss/shale
Rb6	7.65	5.33	11.03	11.01	Verify with other tests	interburden	mudstone
RB60	7.82	2.47	-7.62	-8.32	Verify with other tests	interburden	shale
Rb61	7.41	3.99	####	-65.03	Potential Acid Generator	interburden	shale
Rb62	7.33	3.99	-1.52	-2.12	Verify with other tests	interburden	shale
Rb63	8.89	5.91	11.37	11.02	Verify with other tests	interburden	shale
Rb64	8.06	4.24	-1.64	-1.94	Verify with other tests	interburden	shale
Rb65	4.96	2.71	-2.77	-3.59	Verify with other tests	interburden	shale
Rb66	8.68	5.5	5.75	0.21	Verify with other tests	interburden	shale
Rb67	8.36	4.02	19.83	17.21	Verify with other tests	interburden	shale
Rb68	7.46	4.4	-4.83	-11.43	Verify with other tests	interburden	ss
Rb69	7.7	3.99	####	-51.69	Potential Acid Generator	interburden	ss
Rb7	7.72	5	0.09	0.06	Verify with other tests	interburden	mudstone
Rb70	8.39	5.93	-2.14	-5.11	Verify with other tests	interburden	ss
Rb71	8.49	5.62	-0.80	-1.73	Verify with other tests	interburden	ss
Rb72	8.42	7.53	13.72	13.39	Verify with other tests	interburden	ss
Rb8	7.76	4.97	16.85	16.81	Verify with other tests	interburden	sandstone
Rb9	7.58	4.95	-0.13	-0.18	Verify with other tests	interburden	shale
RC1	4.92	1.88	-4.41	-4.56	Verify with other tests	overburden	soil
RC10	5.55	2.20	-2.07	-3.30	Verify with other tests	interburden	ss
RC11	3.46	1.92	-1.53	-3.01	Verify with other tests	interburden	ss
RC12	3.35	1.86	-6.91	-7.34	Verify with other tests	interburden	ss
RC13	7.36	2.32	2.68	-1.33	Verify with other tests	interburden	ss
RC14	5.89	1.96	0.96	0.78	Verify with other tests	interburden	ss

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
RC15	5.61	2.04	-1.00	-1.28	Verify with other tests	interburden	ss
RC16	4.05	2.00	16.59	16.02	Verify with other tests	interburden	ss
RC17	6.38	2.32	1.18	0.74	Verify with other tests	interburden	ss
RC18	5.56	2.22	1.52	0.79	Verify with other tests	interburden	ss
RC19	6.93	2.44	1.49	1.17	Verify with other tests	interburden	ss
RC2	8.48	2.54	57.83	57.74	Probably Excess Neutralising Minerals	interburden	ss
RC20	6.21	2.02	1.74	1.49	Verify with other tests	interburden	ss
RC21	6.48	2.01	0.95	0.72	Verify with other tests	interburden	ss
RC22	7.34	2.06	9.18	8.97	Verify with other tests	interburden	ss
RC23	6.19	2.35	2.84	2.41	Verify with other tests	interburden	ss
RC24	7.47	2.15	-0.05	-0.11	Verify with other tests	interburden	ss
RC25	7.30	2.39	2.41	2.28	Verify with other tests	interburden	ss
RC3	6.08	2.26	1.65	1.62	Verify with other tests	interburden	ss
RC4	4.12	2.20	-2.91	-4.19	Verify with other tests	interburden	ss
RC5	6.78	2.23	7.99	7.88	Verify with other tests	interburden	ss
RC6	5.23	2.30	-4.37	-4.47	Verify with other tests	interburden	ss
RC7	3.32	2.09	-4.97	-5.98	Verify with other tests	interburden	ss
RC8	3.73	1.88	12.26	11.83	Verify with other tests	interburden	ss
RC9	3.50	2.45	-4.73	-5.93	Verify with other tests	interburden	ss

Table 7-D: Interpretation of the NP/AP ratios for the Resgen samples.

Site Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
S1	27.413	No Acid Potential	No Acid Potential
S2	338.974	No Acid Potential	No Acid Potential
S3	0.221	Likely Acid Generator	Likely Acid Generator
S4	168.359	No Acid Potential	No Acid Potential
S5	16622.729	No Acid Potential	No Acid Potential
S6	591.303	No Acid Potential	No Acid Potential
S7	4.099	No Acid Potential	Acid under certain conditions
S8	484.996	No Acid Potential	No Acid Potential
S9	0.221	Likely Acid Generator	Likely Acid Generator
S10	0.093	Likely Acid Generator	Likely Acid Generator
S41	2.261	Acid under certain conditions	Acid under certain conditions
S42	1.415	Acid under certain conditions	Likely Acid Generator
S43	19.517	No Acid Potential	No Acid Potential
S44	0.825	Likely Acid Generator	Likely Acid Generator
S45	3.763	Acid under certain conditions	Acid under certain conditions
S46	9.848	No Acid Potential	No Acid Potential
S47	0.185	Likely Acid Generator	Likely Acid Generator
S48	0.395	Likely Acid Generator	Likely Acid Generator
S49	0.001	Likely Acid Generator	Likely Acid Generator
S61	0.011	Likely Acid Generator	Likely Acid Generator
S62	0.017	Likely Acid Generator	Likely Acid Generator
S63	33.796	No Acid Potential	No Acid Potential
S64	0.034	Likely Acid Generator	Likely Acid Generator
S65	0.012	Likely Acid Generator	Likely Acid Generator
S66	2.038	Acid under certain conditions	Acid under certain conditions
S67	8.565	No Acid Potential	No Acid Potential
S68	0.268	Likely Acid Generator	Likely Acid Generator
S69	0.005	Likely Acid Generator	Likely Acid Generator
S70	0.281	Likely Acid Generator	Likely Acid Generator
S71	0.133	Likely Acid Generator	Likely Acid Generator
S72	41.722	No Acid Potential	No Acid Potential
RB12	0.495	Likely Acid Generator	Likely Acid Generator
RB13	0.055	Likely Acid Generator	Likely Acid Generator
RB51	0.135	Likely Acid Generator	Likely Acid Generator
RB52	16.107	No Acid Potential	No Acid Potential
RB53	1.297	Acid under certain conditions	Likely Acid Generator
RB54	0.000	Likely Acid Generator	Likely Acid Generator
RB55	0.006	Likely Acid Generator	Likely Acid Generator
RB56	19.092	No Acid Potential	No Acid Potential
RB57	0.016	Likely Acid Generator	Likely Acid Generator
RB58	0.009	Likely Acid Generator	Likely Acid Generator

Site Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
RB59	0.009	Likely Acid Generator	Likely Acid Generator
RB60	0.014	Likely Acid Generator	Likely Acid Generator
RB11	0.042	No Acid Potential	No Acid Potential
RB14	0.145	Likely Acid Generator	Likely Acid Generator
RB15	2.047	Acid under certain conditions	Acid under certain conditions
RB16	0.022	Likely Acid Generator	Likely Acid Generator
RB17	25.723	No Acid Potential	No Acid Potential
RB18	0.116	Likely Acid Generator	Likely Acid Generator
RB19	5.219	No Acid Potential	Acid under certain conditions
RB20	0.029	Likely Acid Generator	Likely Acid Generator
RB21	43.441	No Acid Potential	No Acid Potential
RB22	243.758	No Acid Potential	No Acid Potential
RB23	0.887	Likely Acid Generator	Likely Acid Generator
RB24	0.032	Likely Acid Generator	Likely Acid Generator
RB25	32.452	No Acid Potential	No Acid Potential
RB26	66.042	No Acid Potential	No Acid Potential
RB27	9.883	No Acid Potential	No Acid Potential
RB28	0.017	Likely Acid Generator	Likely Acid Generator
RB29	12.060	No Acid Potential	No Acid Potential
RB30	22.869	No Acid Potential	No Acid Potential
RB31	0.038	Likely Acid Generator	Likely Acid Generator
RB32	1.793	Acid under certain conditions	Likely Acid Generator
RB33	0.004	Likely Acid Generator	Likely Acid Generator
RB34	11.756	No Acid Potential	No Acid Potential
RB38	56.086	No Acid Potential	No Acid Potential
RB39	0.029	Likely Acid Generator	Likely Acid Generator
RB40	18.046	No Acid Potential	No Acid Potential
RC1	0.042	No Acid Potential	No Acid Potential
RC2	601.191	No Acid Potential	No Acid Potential
RC3	55.417	No Acid Potential	No Acid Potential
RC4	0.008	Likely Acid Generator	Likely Acid Generator
RC5	75.243	No Acid Potential	No Acid Potential
RC6	0.094	Likely Acid Generator	Likely Acid Generator
RC7	0.010	Likely Acid Generator	Likely Acid Generator
RC8	29.430	No Acid Potential	No Acid Potential
RC9	0.008	Likely Acid Generator	Likely Acid Generator
RC10	0.008	Likely Acid Generator	Likely Acid Generator
RC11	0.007	Likely Acid Generator	Likely Acid Generator
RC12	0.023	Likely Acid Generator	Likely Acid Generator
RC13	1.668	Acid under certain conditions	Acid under certain conditions
RC14	6.382	No Acid Potential	Acid under certain conditions
RC15	0.036	Likely Acid Generator	Likely Acid Generator
RC16	30.050	No Acid Potential	No Acid Potential
RC17	3.680	Acid under certain conditions	Acid under certain conditions
RC18	3.087	Acid under certain conditions	Acid under certain conditions

Site Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
RC19	5.747	No Acid Potential	Acid under certain conditions
RC20	8.149	No Acid Potential	No Acid Potential
RC21	5.212	No Acid Potential	Acid under certain conditions
RC22	44.992	No Acid Potential	No Acid Potential
RC23	7.608	No Acid Potential	Acid under certain conditions
RC24	0.190	Likely Acid Generator	Likely Acid Generator
RC25	18.782	No Acid Potential	No Acid Potential

Table 7-E: Summary of the ABA results for the Sekoko samples.

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
DP01 (10)	6.94	2.08	-4.18	-4.99	Verify with other tests	interburden	
DP01 (3)	6.42	3.49	-0.82	-1.05	Verify with other tests	interburden	
DP01 (4)	6.17	2.97	-1.6	-2.18	Verify with other tests	interburden	
DP01 (5)	5.88	3.48	-10.18	-17.81	Verify with other tests	interburden	
DP01 (6)	4.88	3.52	-2.68	-3.36	Verify with other tests	interburden	
DP2 (1)	6.81	5.3	-2.97	-3.09	Verify with other tests	interburden	
DP2 (5)	6.75	3.17	-3.72	-4.97	Verify with other tests	interburden	
DP2 (6)	6.11	2.28	-37.58	-68.48	Potential Acid Generator	interburden	
DP22 (1)	6.32	3.94	-16.94	-17.06	Verify with other tests	interburden	
DP3 (3)	6.82	2.95	-3.42	-3.47	Verify with other tests	interburden	
DP713 (3)	6.84	2.84	-2.78	-3	Verify with other tests	interburden	
PM18 (3)	5.78	2.24	16.09	14.9	Verify with other tests	interburden	siltstone/sandstone
PS94 (1)	7.31	2.39	-0.65	-1.32	Verify with other tests	interburden	carbonaceous mudstone
PS95 (1)	7.58	6.28	1.22	1.17	Verify with other tests	interburden	mudstone
PS95 (2)	6.95	6.54	39.29	18.29	Verify with other tests	interburden	mudstone
SV35 (1)	6.57	2.05	-96.35	-185	Potential Acid Generator	interburden	ss
SV35 (3)	7.79	2.76	-2.44	-3.57	Verify with other tests	interburden	ss
005 (1)	7.01	4.19	-3.25	-3.13	Verify with other tests	interburden	
5A (2)	7.27	4.33	15.49	15.02	Verify with other tests	interburden	
DP01 (1)	7.12	1.79	-7.06	-12.57	Verify with other tests	interburden	
DP01 (11)	6.64	4.75	-3.65	-4.09	Verify with other tests	interburden	
DP01 (2)	7.64	2.04	-13.29	-21.95	Potential Acid Generator	interburden	
DP01 (7)	6.68	1.81	-2.82	-4.87	Verify with other tests	interburden	
DP01 (8)	7.28	5.35	2.48	-0.8	Verify with other tests	interburden	
DP01 (9)	6.54	2.44	-2.85	-3.57	Verify with other tests	interburden	
DP2 (2)	6.83	5.71	-2.19	-2.29	Verify with other tests	interburden	
DP2 (3)	6.5	2.23	-8.79	-13.27	Verify with other tests	interburden	
DP2 (4)	6.59	4.09	-2.93	-3.01	Verify with other tests	interburden	
DP3 (1)	7.17	3.97	-6.6	-12.42	Verify with other tests	interburden	
DP3 (2)	6.45	4.3	-2.06	-2.17	Verify with other tests	interburden	
DP3 (5)	6.48	3.35	-20.8	-38.43	Potential Acid Generator	interburden	
DP3 (6)	7.18	4.07	3.37	3.16	Verify with other tests	interburden	
DP3(4)	6.67	2.93	-15.85	-16.69	Verify with other tests	interburden	
DP712 (1)	6.47	3.1	-3.45	-3.95	Verify with other tests	interburden	
DP713 (1)	6.74	4.07	-3.38	-3.41	Verify with other tests	interburden	
DP713 (2)	7.11	6.6	-2.24	-2.32	Verify with other tests	interburden	
PM18 (1)	6.92	3.92	-0.61	-0.7	Verify with other tests	interburden	ss
PM18 (2)	6.34	2.58	-2.62	-4.07	Verify with other tests	interburden	sideritic rock
PS93 (1)	7.56	4.83	0.81	0.78	Verify with other tests	interburden	mudstone
PS95 (3)	6.29	2.06	-101.96	-229.6	Potential Acid Generator	interburden	mudstone
S131 (1)	5.82	1.93	-6.59	-8.36	Verify with other tests	interburden	
SV35 (2)	6.95	2.94	-28.02	-58.1	Potential Acid Generator	interburden	ss

Table 7-F: Interpretation of the NP/AP ratios for the Sekoko samples.

Sample Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
DP3(4)	0.008	Likely Acid Generator	Likely Acid Generator
SV35 (3)	0.015	Likely Acid Generator	Likely Acid Generator
PS95 (2)	2.871	Acid under certain conditions	Acid under certain conditions
DP01 (3)	0.045	Likely Acid Generator	Likely Acid Generator
DP713 (1)	0.436	Likely Acid Generator	Likely Acid Generator
DP01 (2)	0.001	Likely Acid Generator	Likely Acid Generator
SV35 (1)	0.000	Likely Acid Generator	Likely Acid Generator
DP01 (10)	0.012	Likely Acid Generator	Likely Acid Generator
DP01 (7)	0.005	Likely Acid Generator	Likely Acid Generator
DP01 (6)	0.015	Likely Acid Generator	Likely Acid Generator
PM18 (3)	14.495	No Acid Potential	No Acid Potential
DP2 (2)	0.108	Likely Acid Generator	Likely Acid Generator
DP713 (3)	0.044	Likely Acid Generator	Likely Acid Generator
DP01 (8)	1.755	Acid under certain conditions	Likely Acid Generator
DP2 (6)	0.000	Likely Acid Generator	Likely Acid Generator
DP2 (5)	0.008	Likely Acid Generator	Likely Acid Generator
DP22 (1)	0.089	Likely Acid Generator	Likely Acid Generator
DP3 (3)	0.181	Likely Acid Generator	Likely Acid Generator
5A (2)	33.862	No Acid Potential	No Acid Potential
DP01 (1)	0.002	Likely Acid Generator	Likely Acid Generator
DP01 (9)	0.014	Likely Acid Generator	Likely Acid Generator
PS95 (3)	0.201	Likely Acid Generator	Likely Acid Generator
SV35 (2)	0.069	Likely Acid Generator	Likely Acid Generator
DP01 (11)	0.023	Likely Acid Generator	Likely Acid Generator
DP2 (3)	0.002	Likely Acid Generator	Likely Acid Generator
DP2 (4)	0.128	Likely Acid Generator	Likely Acid Generator
DP01 (4)	0.017	Likely Acid Generator	Likely Acid Generator
DP01 (5)	0.001	Likely Acid Generator	Likely Acid Generator
PM18 (1)	0.104	Likely Acid Generator	Likely Acid Generator
DP3 (5)	0.001	Likely Acid Generator	Likely Acid Generator
DP712 (1)	0.020	Likely Acid Generator	Likely Acid Generator
DP3 (2)	0.090	Likely Acid Generator	Likely Acid Generator
S131 (1)	0.006	Likely Acid Generator	Likely Acid Generator
DP3 (1)	0.002	Likely Acid Generator	Likely Acid Generator
PM18 (2)	0.007	Likely Acid Generator	Likely Acid Generator
DP3 (6)	17.610	No Acid Potential	No Acid Potential
DP713 (2)	0.129	Likely Acid Generator	Likely Acid Generator
005 (1)	0.022	Likely Acid Generator	Likely Acid Generator
DM19 (1)	0.005	Likely Acid Generator	Likely Acid Generator
DP2 (1)	0.083	Likely Acid Generator	Likely Acid Generator
PS93 (1)	27.181	No Acid Potential	No Acid Potential
PS94 (1)	0.044	Likely Acid Generator	Likely Acid Generator
PS95 (1)	28.952	No Acid Potential	No Acid Potential

Table 7-G: Summary of the ABA results for the Grootegeluk samples.

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
JB 21	7.56	5.53	-0.83	-0.92	Verify with other tests	ovb	clay
JB 22	8.15	4.78	32.93	32.87	Probably Excess Neutralising Minerals	ovb	clay
JB 23	7.25	4.68	-1.01	-1.08	Verify with other tests	ovb	clay
JB 24	7.76	4.83	-2.03	-2.11	Verify with other tests	ovb	clay
JB 25	7.2	4.68	-2.16	-2.25	Verify with other tests	ovb	clay
JB 26	7.89	4.82	-3.33	-3.42	Verify with other tests	ovb	clay
JB 27	7.1	4.73	-3.08	-3.17	Verify with other tests	ovb	clay
JB 28	7.83	4.74	-2.30	-2.34	Verify with other tests	ovb	shale
JB 29	7.5	4.73	-3.25	-3.32	Verify with other tests	ovb	shale
JB 30	7.79	4.66	7.81	7.74	Verify with other tests	ovb	shale
JB 31	7.43	4.63	-3.90	-3.99	Verify with other tests	ovb	shale
JB 32	7.48	4.57	-6.50	-6.53	Verify with other tests	ovb	shale
JB 33	7.36	4.07	-0.06	-0.51	Verify with other tests	ovb	shale
JB11	7.34	2.11	1.33	1.24	Verify with other tests	ovb	clay
JB12	7.36	2.14	-1.28	-1.27	Verify with other tests	ovb	clay
JB13	7.39	2.15	3.05	3.03	Verify with other tests	ovb	clay
JB15	7.38	2.13	2.51	2.52	Verify with other tests	ovb	clay
JB16	7.45	2.15	2.04	2.06	Verify with other tests	ovb	clay
JB17	7.42	5.07	-0.43	-0.35	Verify with other tests	ovb	clay
JB18	7.58	5.8	-1.26	-1.26	Verify with other tests	ovb	clay
MA10	7.89	6.82	-0.13	-0.14	Verify with other tests	ovb	soil
MA11	8.3	7.87	0.41	0.40	Verify with other tests	ovb	soil
MA12	8.04	5.34	0.30	0.27	Verify with other tests	ovb	soil
MA13	8.25	7.25	15.59	15.55	Verify with other tests	ovb	soil
MA14	8.12	7.35	4.90	4.29	Verify with other tests	ovb	shale
MA15	8.14	7.95	10.95	6.72	Verify with other tests	ovb	shale
MA16	7.91	7.64	17.15	-10.31	Verify with other tests	ovb	shale
MA18	8.11	7.29	18.41	3.59	Verify with other tests	ovb	shale
MA19	8.05	7.98	39.80	22.57	Probably Excess Neutralising Minerals	ovb	shale
MA2	7.6	6.19	0.61	0.56	Verify with other tests	ovb	soil
MA20	7.91	7.79	51.42	37.04	Probably Excess Neutralising Minerals	ovb	shale
MA21	7.91	7.64	61.44	45.91	Probably Excess Neutralising Minerals	ovb	shale
MA3	7.75	6.25	3.22	3.19	Verify with other tests	ovb	soil
MA4	7.87	5.89	-1.00	-1.01	Verify with other tests	ovb	soil
MA5	7.59	5.85	-0.17	-0.03	Verify with other tests	ovb	soil
MA6	7.75	5.57	0.40	0.44	Verify with other tests	ovb	soil
MA7	7.97	5.56	0.30	0.29	Verify with other tests	ovb	soil
MA8	7.68	5.97	1.30	1.39	Verify with other tests	ovb	soil
MA9	7.57	7.33	6.93	6.96	Verify with other tests	ovb	soil
MB1	7.8	7.37	181.38	#####	Probably Excess Neutralising Minerals	ovb	ss
MB10	8.7	5.88	1.54	1.50	Verify with other tests	ovb	shale
MB11	8.14	6.97	12.96	12.93	Verify with other tests	ovb	shale
MB12	8.36	5.39	20.88	20.84	Probably Excess Neutralising Minerals	ovb	shale
MB13	7.85	6.2	-0.33	-0.35	Verify with other tests	ovb	shale

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
MB14	8.17	4.78	2.74	2.69	Verify with other tests	ovb	shale
MB15	8	6.1	3.75	3.73	Verify with other tests	ovb	shale
MB16	8.04	5.93	2.13	2.13	Verify with other tests	ovb	shale
MB2	8.04	7.32	219.53	#####	Probably Excess Neutralising Minerals	ovb	shale
MB20	7.98	4.92	0.82	0.77	Verify with other tests	ovb	shale
MB22	8.09	6.92	33.14	32.87	Probably Excess Neutralising Minerals	ovb	shale
MB23	8.09	7.43	90.15	77.30	Probably Excess Neutralising Minerals	ovb	shale
MB24	7.85	6.78	3.35	-11.05	Verify with other tests	ovb	shale
MB25	8.07	7.52	-26.19	-51.02	Potential Acid Generator	ovb	shale
MB26	7.99	3.59	-4.24	-41.94	Potential Acid Generator	ovb	shale/coal
MB3	8.11	7.48	113.04	#####	Probably Excess Neutralising Minerals	ovb	shale
MB4	7.67	6.93	26.77	26.76	Probably Excess Neutralising Minerals	ovb	shale
MB5	8.04	7.37	72.05	72.04	Probably Excess Neutralising Minerals	ovb	shale
MB6	8.09	6.75	9.36	9.33	Verify with other tests	ovb	shale
MB7	7.76	6.57	2.09	2.11	Verify with other tests	ovb	shale
MB8	8.22	6.16	6.04	6.06	Verify with other tests	ovb	shale
MB9	7.95	5.45	-0.98	-1.00	Verify with other tests	ovb	shale
VA16	8.64	5.3	0.06	0.08	Verify with other tests	ovb	shale
VA17	8.18	6.83	19.11	19.08	Verify with other tests	ovb	shale
VA19	8.51	7.67	12.56	12.52	Verify with other tests	ovb	shale
VA21	8.01	7.63	6.60	6.57	Verify with other tests	ovb	shale
VA22	8.02	6.88	9.51	9.38	Verify with other tests	ovb	shale
VA23	8.16	7.62	19.48	19.41	Verify with other tests	ovb	shale
VA24	8.2	7.67	33.49	33.43	Probably Excess Neutralising Minerals	ovb	shale
VA25	7.85	7.79	38.55	38.48	Probably Excess Neutralising Minerals	ovb	shale
VA26	8.06	7.86	17.70	17.74	Verify with other tests	ovb	shale
VA27	7.59	7.59	30.90	30.83	Probably Excess Neutralising Minerals	ovb	shale
VA28	6.74	6.74	6.58	6.54	Verify with other tests	ovb	shale
VA29	6.84	6.84	25.30	25.41	Probably Excess Neutralising Minerals	ovb	shale
VA30	6.41	6.4	16.80	16.84	Verify with other tests	ovb	shale
VA31	5.91	5.91	3.99	3.99	Verify with other tests	ovb	shale
VA32	6.09	6.09	1.52	1.47	Verify with other tests	ovb	shale
VA33	5.79	5.79	1.91	1.83	Verify with other tests	ovb	shale
VA34	7.09	7.09	34.06	34.12	Probably Excess Neutralising Minerals	ovb	shale
VA35	6.61	6.61	32.71	32.75	Probably Excess Neutralising Minerals	ovb	shale
VA36	6.03	6.03	35.34	35.37	Probably Excess Neutralising Minerals	ovb	shale
VA38	7.12	7.12	-2.34	-2.29	Verify with other tests	ovb	shale
VA39	6.01	6.01	23.75	23.74	Probably Excess Neutralising Minerals	ovb	shale
VA40	8.25	6	31.87	31.88	Probably Excess Neutralising Minerals	ovb	shale
VA42	8.9	8.73	44.34	44.46	Probably Excess Neutralising Minerals	ovb	shale
VA43	8.8	8.04	60.22	58.45	Probably Excess Neutralising Minerals	ovb	shale
VA44	8.11	6.31	67.15	67.19	Probably Excess Neutralising Minerals	ovb	shale
VA45	8.76	7.43	11.90	8.14	Verify with other tests	ovb	shale
VA46	8.41	8.29	35.24	25.33	Probably Excess Neutralising Minerals	ovb	shale
VA47	8.32	8.27	77.45	73.69	Probably Excess Neutralising Minerals	ovb	shale

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
VA48	8.66	8.13	68.70	58.52	Probably Excess Neutralising Minerals	ovb	shale
VA49	8.62	8.21	60.49	46.93	Probably Excess Neutralising Minerals	ovb	shale
VA51	7.93	7.71	11.84	-35.54	Potential Acid Generator	ovb	shale
VA52	8.21	8.22	13.55	-21.87	Potential Acid Generator	ovb	shale
VA53	8.28	8.12	60.99	43.02	Probably Excess Neutralising Minerals	ovb	shale
VA54	7.72	7.71	52.75	33.73	Probably Excess Neutralising Minerals	ovb	shale
VA55	8.25	7.98	87.23	65.89	Probably Excess Neutralising Minerals	ovb	shale
VA56	8.28	7.1	38.40	10.11	Verify with other tests	ovb	shale
VA57	8.3	4.38	-11.10	-50.28	Potential Acid Generator	ovb	shale
VA58	7.44	7.46	19.67	-2.05	Verify with other tests	ovb	shale
VB1	7.29	4.05	-7.57	-7.64	Verify with other tests	ovb	calcrete
VB10	8.8	5.39	-1.19	-1.23	Verify with other tests	ovb	shale
VB11	8.93	5.68	1.78	1.74	Verify with other tests	ovb	shale
VB12	8.94	5.33	-0.42	-0.44	Verify with other tests	ovb	shale
VB13	8.55	5.54	1.76	1.86	Verify with other tests	ovb	shale
VB14	8.53	5.8	0.47	0.37	Verify with other tests	ovb	shale
VB15	8.54	5.21	1.85	1.81	Verify with other tests	ovb	shale
VB17	8.3	5.55	-2.38	-2.41	Verify with other tests	ovb	shale
VB18	8.31	5.34	-1.31	-1.42	Verify with other tests	ovb	shale
VB19	8.23	5.17	-1.29	-1.36	Verify with other tests	ovb	shale
VB20	8.12	5.69	-1.78	-1.90	Verify with other tests	ovb	shale
VB3	7.24	7.03	-0.03	0.10	Verify with other tests	ovb	shale
VB4	7.35	6.15	-1.15	-1.17	Verify with other tests	ovb	shale
VB5	7.33	5.82	3.38	3.32	Verify with other tests	ovb	shale
VB6	7.32	5.36	1.62	1.56	Verify with other tests	ovb	shale
VB7	7.49	5.68	3.59	3.48	Verify with other tests	ovb	shale
VB8	7.41	5.5	0.45	0.39	Verify with other tests	ovb	shale
VB9	7.42	5.32	-0.59	-0.62	Verify with other tests	ovb	shale
VC10	8.28	5.83	-3.61	-3.61	Verify with other tests	ovb	shale
VC17	7.74	5.86	-0.65	-0.63	Verify with other tests	ovb	shale
VC3	9.42	4.29	-1.01	-1.00	Verify with other tests	ovb	shale
VC4	8.11	4.69	-2.37	-2.37	Verify with other tests	ovb	shale
VC5	8.39	4.58	-13.52	-13.54	Verify with other tests	ovb	shale
JA1	7.05	3.29	-3.45	-3.43	Verify with other tests	ovb	ss
JA10	7.59	6	16.07	15.97	Verify with other tests	ovb	clay
JA11	7.46	4.98	-0.98	-1.03	Verify with other tests	ovb	clay
JA12	8.26	5.47	-1.23	-1.23	Verify with other tests	ovb	clay
JA13	7.34	6.22	10.06	10.04	Verify with other tests	ovb	clay
JA14	7.38	4.76	-3.98	-3.99	Verify with other tests	ovb	clay
JA15	6.51	4.94	-3.31	-3.32	Verify with other tests	ovb	clay
JA16	7.4	5.04	-1.63	-1.61	Verify with other tests	ovb	clay
JA17	7.14	5.01	-1.53	-1.57	Verify with other tests	ovb	clay
JA18	6.37	5.69	-2.38	-2.37	Verify with other tests	ovb	clay
JA19	7.23	5.81	-0.63	-0.57	Verify with other tests	ovb	clay
JA2	7.18	3.45	-4.24	-4.22	Verify with other tests	ovb	ss

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
JA20	6.48	6.18	0.86	0.95	Verify with other tests	ovb	clay
JA21	6.89	6.56	-0.08	-0.15	Verify with other tests	ovb	clay
JA22	6.8	6.3	42.82	42.73	Probably Excess Neutralising Minerals	ovb	clay
JA23	6.9	5.62	1.77	1.87	Verify with other tests	ovb	clay
JA24	6.95	6.76	-0.20	-0.21	Verify with other tests	ovb	calcrete
JA25	6.88	6.32	-0.42	-0.39	Verify with other tests	ovb	calcrete
JA26	6.89	5.05	-1.71	-1.78	Verify with other tests	ovb	clay
JA27	7.45	5.04	-3.04	-3.12	Verify with other tests	ovb	clay
JA28	7.11	5.53	-0.72	-0.68	Verify with other tests	ovb	clay
JA3	7.54	3.71	-4.19	-4.18	Verify with other tests	ovb	ss
JA30	7.14	5.64	0.93	0.96	Verify with other tests	ovb	clay
JA31	7.17	5.35	0.50	0.52	Verify with other tests	ovb	clay
JA32	7.27	4.98	-2.78	-2.76	Verify with other tests	ovb	clay
JA33	7.27	4.96	-1.49	-1.49	Verify with other tests	ovb	clay
JA34	6.96	5.01	1.40	1.42	Verify with other tests	ovb	clay
JA35	7.28	5.09	-0.72	-0.71	Verify with other tests	ovb	clay
JA36	6.58	5.44	-1.66	-1.77	Verify with other tests	ovb	clay
JA37	6.61	5.29	4.47	4.37	Verify with other tests	ovb	clay
JA38	6.75	4.78	-1.67	-1.87	Verify with other tests	ovb	clay
JA39	7.22	5.12	-2.27	-2.27	Verify with other tests	ovb	clay
JA4	7.12	3.81	-6.77	-6.75	Verify with other tests	ovb	ss
JA40	6.78	4.41	-7.71	-7.71	Verify with other tests	ovb	clay
JA41	6.58	4.55	0.14	-0.02	Verify with other tests	ovb	clay
JA43	6.54	5.11	-1.87	-1.67	Verify with other tests	ovb	clay
JA44	6.38	3.98	-2.10	-1.98	Verify with other tests	ovb	clay
JA45	6.51	4.12	-2.56	-2.72	Verify with other tests	ovb	clay
JA46	6.32	3.86	-1.12	-1.22	Verify with other tests	ovb	clay
JA5	7.71	4.82	-4.65	-4.62	Verify with other tests	ovb	ferrricreet
JA6	7.21	5.83	-3.06	-3.14	Verify with other tests	ovb	ss
JA7	7.42	6.26	1.08	1.06	Verify with other tests	ovb	ss
JA8	6.73	6.16	0.98	0.97	Verify with other tests	ovb	ss
JA9	7.45	5.84	-0.51	-0.57	Verify with other tests	ovb	clay
JB14	6.93	6.12	-0.10	-0.22	Verify with other tests	ovb	clay
JB19	6.86	5.89	-21.80	-42.88	Potential Acid Generator	ovb	clay
JB20	7.01	6.19	-52.63	#####	Potential Acid Generator	ovb	clay
JB32	7.48	4.57	-6.50	-6.53	Verify with other tests	ovb	shale
JB33	7.36	4.07	-0.06	-0.51	Verify with other tests	ovb	shale
JC10	7.77	4.790	0.36	0.52	Verify with other tests	ovb	shale
JC11	8.14	6.73	3.07	2.72	Verify with other tests	ovb	shale
JC12	8.06	6.86	1.20	0.88	Verify with other tests	ovb	shale
JC13	7.88	6.06	0.75	0.59	Verify with other tests	ovb	shale
JC14	7.47	6.52	7.47	7.49	Verify with other tests	ovb	shale
JC15	7.88	6.81	5.13	5.09	Verify with other tests	ovb	shale
JC16	7.21	5.93	-0.72	-0.84	Verify with other tests	ovb	shale
JC17	7.34	6.43	0.07	-0.01	Verify with other tests	ovb	shale

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
JC18	7.19	6.71	2.06	1.96	Verify with other tests	ovb	shale
JC19	7.22	6.55	0.63	0.35	Verify with other tests	ovb	shale
JC2	7.78	2.230	-5.17	-5.20	Verify with other tests	ovb	calcrete
JC20	7.38	6.73	0.26	0.13	Verify with other tests	ovb	shale
JC3	7.88	3.620	13.24	13.22	Verify with other tests	ovb	calcrete
JC31	7.40	5.530	-2.46	-2.53	Verify with other tests	ovb	shale
JC32	7.52	4.880	-8.59	-8.58	Verify with other tests	ovb	shale
JC33	7.70	4.620	-8.77	-8.78	Verify with other tests	ovb	shale
JC34	7.49	5.140	-11.43	-11.44	Verify with other tests	ovb	shale
JC35	7.71	5.600	-1.61	-1.60	Verify with other tests	ovb	shale
JC36	7.30	4.700	-4.03	-4.04	Verify with other tests	ovb	shale
JC37	7.57	4.790	-2.87	-2.87	Verify with other tests	ovb	shale
JC38	7.38	4.420	-3.95	-3.94	Verify with other tests	ovb	shale
JC39	7.39	4.740	-2.84	-2.83	Verify with other tests	ovb	shale
JC4	7.94	3.830	-3.46	-3.46	Verify with other tests	ovb	calcrete
JC40	7.42	4.800	-2.34	-2.34	Verify with other tests	ovb	shale
JC41	7.32	4.990	3.82	3.81	Verify with other tests	ovb	shale
JC42	7.37	4.800	-2.54	-2.52	Verify with other tests	ovb	shale
JC43	7.33	4.770	-4.16	-4.15	Verify with other tests	ovb	shale
JC44	7.27	4.290	-3.29	-3.28	Verify with other tests	ovb	shale
JC45	7.01	4.610	0.23	0.28	Verify with other tests	ovb	shale
JC5	8.13	4.080	-2.48	-2.44	Verify with other tests	ovb	shale
JC6	7.81	5.900	33.70	33.68	Probably Excess Neutralising Minerals	ovb	shale
JC7	8.11	5.950	3.99	3.93	Verify with other tests	ovb	shale
JC8	7.94	5.000	-11.68	-11.73	Verify with other tests	ovb	shale
JC9	8.18	4.120	-0.55	-0.62	Verify with other tests	ovb	shale
VA1	7.35	4.71	-0.09	-0.18	Verify with other tests	ovb	calcrete
VA10	8.02	7.5	7.81	7.72	Verify with other tests	ovb	shale
VA11	8.43	8.47	30.72	30.60	Probably Excess Neutralising Minerals	ovb	shale
VA13	8.28	7.88	8.97	8.83	Verify with other tests	ovb	shale
VA14	8.31	8.2	23.69	23.50	Probably Excess Neutralising Minerals	ovb	shale
VA15	8.26	7.9	3.64	3.48	Verify with other tests	ovb	shale
VA18	8.39	6.88	21.62	21.51	Probably Excess Neutralising Minerals	ovb	shale
VA2	8.62	8.6	310.95	#####	Probably Excess Neutralising Minerals	ovb	shale
VA20	7.9	6.67	2.61	2.45	Verify with other tests	ovb	shale
VA3	8.59	8.5	79.10	78.85	Probably Excess Neutralising Minerals	ovb	shale
VA4	8.72	8.38	70.94	70.89	Probably Excess Neutralising Minerals	ovb	shale
VA41	8.4	7.87	50.72	50.25	Probably Excess Neutralising Minerals	ovb	shale
VA5	8.93	8.66	89.17	89.06	Probably Excess Neutralising Minerals	ovb	shale
VA50	8.41	8.03	37.44	37.37	Probably Excess Neutralising Minerals	ovb	shale
VA6	8.59	8	38.92	38.71	Probably Excess Neutralising Minerals	ovb	shale
VA7	8.62	8.39	8.10	7.98	Verify with other tests	ovb	shale
VA8	8.43	8.23	5.28	5.06	Verify with other tests	ovb	shale
VA9	8.01	8.47	17.97	18.10	Verify with other tests	ovb	shale
VB2	6.28	3.06	-1.54	-1.54	Verify with other tests	ovb	shale

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
VB21	7.11	4.92	-4.12	-6.20	Verify with other tests	ovb	shale
VB22	6.94	5.29	-3.03	-3.24	Verify with other tests	ovb	shale
VB23	6.6	5	-3.30	-3.63	Verify with other tests	ovb	shale
VB24	6.8	5.09	-2.83	-2.99	Verify with other tests	ovb	shale
VB25	6.85	4.96	-3.81	-3.87	Verify with other tests	ovb	shale
VB26	6.89	5.05	-2.24	-2.29	Verify with other tests	ovb	shale
VB27	6.87	4.94	-2.99	-3.20	Verify with other tests	ovb	shale
VB28	7.01	4.63	-2.62	-2.97	Verify with other tests	ovb	shale
VB29	6.94	4.81	-9.03	-14.76	Verify with other tests	ovb	shale
VB30	6.86	4.51	-0.68	-0.54	Verify with other tests	ovb	shale
VB31	6.64	3.81	-1.03	-1.50	Verify with other tests	ovb	shale
VB32	6.54	3.09	-1.35	-1.76	Verify with other tests	ovb	shale
VB40	6.49	4.41	0.98	0.98	Verify with other tests	ovb	shale
VC11	6.5	4.57	-2.01	-2.07	Verify with other tests	ovb	shale
VC12	6.56	5.12	-0.69	-0.75	Verify with other tests	ovb	shale
VC13	6.47	5.34	0.07	0.03	Verify with other tests	ovb	shale
VC14	6.27	5.44	-0.85	-0.77	Verify with other tests	ovb	shale
VC15	6.61	6.28	1.55	1.52	Verify with other tests	ovb	shale
VC16	6.45	6.37	-0.93	-0.97	Verify with other tests	ovb	shale
VC18	6.53	5.05	0.02	-0.02	Verify with other tests	ovb	shale
VC19	6.64	4.97	-1.29	-1.33	Verify with other tests	ovb	shale
VC20	7.37	7.78	-2.09	-2.07	Verify with other tests	ovb	shale
VC21	7.26	7.03	-2.52	-2.54	Verify with other tests	ovb	shale
VC22	6.67	4.62	-1.82	-1.84	Verify with other tests	ovb	shale
VC23	7.33	7.06	-2.03	-2.04	Verify with other tests	ovb	shale
VC24	7.19	7	-1.60	-1.65	Verify with other tests	ovb	shale
VC25	7.23	6.72	5.48	5.47	Verify with other tests	ovb	shale
VC26	7.08	6.83	-6.11	-6.17	Verify with other tests	ovb	shale
VC27	6.88	6.67	1.32	1.32	Verify with other tests	ovb	shale
VC28	7.04	6.78	1.32	1.32	Verify with other tests	ovb	shale
VC29	6.6	4.04	8.78	8.80	Verify with other tests	ovb	shale
VC30	7.18	6.86	-3.02	-3.04	Verify with other tests	ovb	shale
VC31	7.01	7.04	-1.73	-1.71	Verify with other tests	ovb	shale
VC32	6.64	4.39	-2.37	-2.41	Verify with other tests	ovb	shale
VC33	6.82	6.41	6.85	6.86	Verify with other tests	ovb	shale
VC35	6.75	4.72	1.03	1.01	Verify with other tests	ovb	shale
VC36	6.42	4.43	-1.85	-1.86	Verify with other tests	ovb	shale
VC38	6.7	4.28	-2.06	-2.11	Verify with other tests	ovb	shale
VC39	7.20	4.21	-0.01	-0.01	Verify with other tests	ovb	shale
VC41	6.84	6.57	-10.45	-10.50	Verify with other tests	ovb	shale
VC42	6.57	4.25	-0.56	-0.60	Verify with other tests	ovb	shale
VC43	6.43	4.06	-1.73	-1.94	Verify with other tests	ovb	shale/coal
VC6	6.41	4.67	-1.50	-1.50	Verify with other tests	ovb	shale
VC8	7.85	4.72	-1.66	-1.57	Verify with other tests	ovb	shale
VD1	7.02	4.92	0.35	0.24	Verify with other tests	ovb	

sample	initial pH	final pH	NNP (open)	NNP (Closed)	interpretation	zone	lithology
VD10	5.85	4.32	-7.15	-7.29	Verify with other tests	ovb	
VD11	6.07	4.41	-1.49	-1.56	Verify with other tests	ovb	
VD12	5.8	4.2	-2.55	-2.64	Verify with other tests	ovb	
VD13	6.34	4.66	-9.21	-9.31	Verify with other tests	ovb	
VD14	5.48	3.67	-3.69	-3.76	Verify with other tests	ovb	
VD15	5.64	3.76	-3.52	-3.62	Verify with other tests	ovb	
VD16	5.63	3.57	-2.46	-2.53	Verify with other tests	ovb	
VD17	5.6	3.46	-4.00	-4.13	Verify with other tests	ovb	
VD18	5.28	2.18	-10.53	-11.01	Verify with other tests	ovb	
VD19	5.04	2.06	-11.69	-12.89	Verify with other tests	ovb	
VD2	7.95	7.53	4.14	4.11	Verify with other tests	ovb	
VD20	5.82	3.78	-7.85	-8.57	Verify with other tests	ovb	
VD21	5.71	3.09	-6.13	-6.46	Verify with other tests	ovb	
VD22	5.98	4.88	-6.18	-8.43	Verify with other tests	ovb	
VD23	4.69	1.79	-6.80	-8.73	Verify with other tests	ovb	
VD24	5.28	1.87	-7.20	-7.43	Verify with other tests	ovb	
VD3	8.1	5.51	1.87	1.84	Verify with other tests	ovb	
VD4	6.38	4.06	-1.19	-0.97	Verify with other tests	ovb	
VD5	6.66	4.49	-1.59	-1.64	Verify with other tests	ovb	
VD6	6.17	4.03	-2.86	-2.93	Verify with other tests	ovb	
VD7	6.08	4.21	-2.17	-2.25	Verify with other tests	ovb	
VD8	5.66	3.95	-2.73	-2.85	Verify with other tests	ovb	
VD9	6.05	4.43	-1.30	-1.43	Verify with other tests	ovb	

Table 7-H: Interpretation of the NP/AP ratios for the Grootegeluk samples.

Sample Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
JA 1		No Acid Potential	No Acid Potential
JA 2		No Acid Potential	No Acid Potential
JA 3		No Acid Potential	No Acid Potential
JA 4		No Acid Potential	No Acid Potential
JA 5		No Acid Potential	No Acid Potential
JA 6	0.1	Likely Acid Generator	Likely Acid Generator
JA 7	40.6	No Acid Potential	No Acid Potential
JA 8	97.5	No Acid Potential	No Acid Potential
JA 9	0.2	Likely Acid Generator	Likely Acid Generator
JA 10	164.2	No Acid Potential	No Acid Potential
JA 11	0.2	Likely Acid Generator	Likely Acid Generator
JA 12	14.6	No Acid Potential	No Acid Potential
JA 13	458.3	No Acid Potential	No Acid Potential
JA 14	0.6	Likely Acid Generator	Likely Acid Generator
JA 15	1.1	Acid under certain conditions	Likely Acid Generator
JA 16		No Acid Potential	No Acid Potential
JA 17	0.3	Likely Acid Generator	Likely Acid Generator
JA 18		No Acid Potential	No Acid Potential
JA 19		No Acid Potential	No Acid Potential
JA 20		No Acid Potential	No Acid Potential
JA 27	0.1	Likely Acid Generator	Likely Acid Generator
JB 21	0.1	Likely Acid Generator	Likely Acid Generator
JB 22	500.4	No Acid Potential	No Acid Potential
JB 23	0.1	Likely Acid Generator	Likely Acid Generator
JB 24	0.1	Likely Acid Generator	Likely Acid Generator
JB 25	0.1	Likely Acid Generator	Likely Acid Generator
JB 26	0.1	Likely Acid Generator	Likely Acid Generator
JB 27	0.1	Likely Acid Generator	Likely Acid Generator
JB 28	0.2	Likely Acid Generator	Likely Acid Generator
JB 29	0.1	Likely Acid Generator	Likely Acid Generator
JB 30	103.8	No Acid Potential	No Acid Potential
JB 31	0.1	Likely Acid Generator	Likely Acid Generator
JB 32	0.4	Likely Acid Generator	Likely Acid Generator
JB 33	0.9	Likely Acid Generator	Likely Acid Generator
JB32	0.4	Likely Acid Generator	Likely Acid Generator
JB33	0.9	Likely Acid Generator	Likely Acid Generator
JC2	0.3	Likely Acid Generator	Likely Acid Generator
JC3	629.7	No Acid Potential	No Acid Potential
JC4	1.4	Acid under certain conditions	Likely Acid Generator
JC5		No Acid Potential	No Acid Potential
JC6	1625.8	No Acid Potential	No Acid Potential
JC7	65.9	No Acid Potential	No Acid Potential
JC8	0.2	Likely Acid Generator	Likely Acid Generator

Sample Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
JC9	0.1	Likely Acid Generator	Likely Acid Generator
JC10		No Acid Potential	No Acid Potential
JC31	0.2	Likely Acid Generator	Likely Acid Generator
JC32		No Acid Potential	No Acid Potential
JC33	1.2	Acid under certain conditions	Likely Acid Generator
JC34	2.6	Acid under certain conditions	Acid under certain conditions
JC35		No Acid Potential	No Acid Potential
JC36	1.2	Acid under certain conditions	Likely Acid Generator
JC37		No Acid Potential	No Acid Potential
JC38		No Acid Potential	No Acid Potential
JC39		No Acid Potential	No Acid Potential
JC40	13.6	No Acid Potential	No Acid Potential
JC41	232.8	No Acid Potential	No Acid Potential
JC42		No Acid Potential	No Acid Potential
JC43		No Acid Potential	No Acid Potential
JC44		No Acid Potential	No Acid Potential
JC45		No Acid Potential	No Acid Potential
MA11	40.4	No Acid Potential	No Acid Potential
MA12	10.5	No Acid Potential	No Acid Potential
MA13	414.1	No Acid Potential	No Acid Potential
MA14	9.0	No Acid Potential	No Acid Potential
MA15	3.6	Acid under certain conditions	Acid under certain conditions
MA16	1.6	Acid under certain conditions	Likely Acid Generator
MA18	2.2	Acid under certain conditions	Acid under certain conditions
MA19	3.3	Acid under certain conditions	Acid under certain conditions
MA20	4.6	No Acid Potential	Acid under certain conditions
MA21	5.0	No Acid Potential	Acid under certain conditions
MB1	1506.6	No Acid Potential	No Acid Potential
MB2	5858.2	No Acid Potential	No Acid Potential
MB3		No Acid Potential	No Acid Potential
MB4	1666.7	No Acid Potential	No Acid Potential
MB5	7890.1	No Acid Potential	No Acid Potential
MB6	311.8	No Acid Potential	No Acid Potential
MB7		No Acid Potential	No Acid Potential
MB8		No Acid Potential	No Acid Potential
MB9	0.4	Likely Acid Generator	Likely Acid Generator
MB10	34.2	No Acid Potential	No Acid Potential
MB11	471.8	No Acid Potential	No Acid Potential
MB12	605.4	No Acid Potential	No Acid Potential
MB13	0.4	Likely Acid Generator	Likely Acid Generator
MB14	56.0	No Acid Potential	No Acid Potential
MB15	140.3	No Acid Potential	No Acid Potential
MB16	934.9	No Acid Potential	No Acid Potential
MB20	17.9	No Acid Potential	No Acid Potential
MB22	120.8	No Acid Potential	No Acid Potential

Sample Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
MB23	8.0	No Acid Potential	No Acid Potential
MB24	1.2	Acid under certain conditions	Likely Acid Generator
MB25	0.0	Likely Acid Generator	Likely Acid Generator
MB26	0.9	Likely Acid Generator	Likely Acid Generator
MA2	13.0	No Acid Potential	No Acid Potential
MA3	141.6	No Acid Potential	No Acid Potential
MA4	1.0	Likely Acid Generator	Likely Acid Generator
MA5		No Acid Potential	No Acid Potential
MA6		No Acid Potential	No Acid Potential
MA7	87.3	No Acid Potential	No Acid Potential
MA8		No Acid Potential	No Acid Potential
MA9		No Acid Potential	No Acid Potential
MA10	1.0	Acid under certain conditions	Likely Acid Generator
VA17	647.5	No Acid Potential	No Acid Potential
VA21	212.5	No Acid Potential	No Acid Potential
VA22	78.4	No Acid Potential	No Acid Potential
VA23	258.0	No Acid Potential	No Acid Potential
VA24	623.1	No Acid Potential	No Acid Potential
VA25	597.3	No Acid Potential	No Acid Potential
VA26		No Acid Potential	No Acid Potential
VA27	478.7	No Acid Potential	No Acid Potential
VA28	147.0	No Acid Potential	No Acid Potential
VA29		No Acid Potential	No Acid Potential
VA30		No Acid Potential	No Acid Potential
VA31	1674.5	No Acid Potential	No Acid Potential
VA32	36.2	No Acid Potential	No Acid Potential
VA33	26.9	No Acid Potential	No Acid Potential
VA34		No Acid Potential	No Acid Potential
VA35		No Acid Potential	No Acid Potential
VA36		No Acid Potential	No Acid Potential
VA38		No Acid Potential	No Acid Potential
VA39	2195.9	No Acid Potential	No Acid Potential
VA40		No Acid Potential	No Acid Potential
VA44		No Acid Potential	No Acid Potential
VA46	4.6	No Acid Potential	Acid under certain conditions
VA48	7.8	No Acid Potential	Acid under certain conditions
VA52	1.4	Acid under certain conditions	Likely Acid Generator
VA53	4.4	No Acid Potential	Acid under certain conditions
VA54	3.8	Acid under certain conditions	Acid under certain conditions
VA56	2.4	Acid under certain conditions	Acid under certain conditions
VA57	0.7	Likely Acid Generator	Likely Acid Generator
VC3		No Acid Potential	No Acid Potential
VC4	4.1	No Acid Potential	Acid under certain conditions
VC5	0.5	Likely Acid Generator	Likely Acid Generator
VC8		No Acid Potential	No Acid Potential

Sample Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
VC10	1.4	Acid under certain conditions	Likely Acid Generator
VC17		No Acid Potential	No Acid Potential
JA23		No Acid Potential	No Acid Potential
JA28		No Acid Potential	No Acid Potential
JA30		No Acid Potential	No Acid Potential
JA31		No Acid Potential	No Acid Potential
JA32		No Acid Potential	No Acid Potential
JA33		No Acid Potential	No Acid Potential
JA34		No Acid Potential	No Acid Potential
JA35		No Acid Potential	No Acid Potential
JA39		No Acid Potential	No Acid Potential
JA40		No Acid Potential	No Acid Potential
JB11	16.6	No Acid Potential	No Acid Potential
JB12		No Acid Potential	No Acid Potential
JB13	205.7	No Acid Potential	No Acid Potential
JB15		No Acid Potential	No Acid Potential
JB16		No Acid Potential	No Acid Potential
JB17		No Acid Potential	No Acid Potential
JB18	8.0	No Acid Potential	No Acid Potential
VA16		No Acid Potential	No Acid Potential
VA19	300.6	No Acid Potential	No Acid Potential
VA42		No Acid Potential	No Acid Potential
VA43	35.1	No Acid Potential	No Acid Potential
VA45	4.2	No Acid Potential	Acid under certain conditions
VA47	21.6	No Acid Potential	No Acid Potential
VA49	5.5	No Acid Potential	Acid under certain conditions
VA51	1.2	Acid under certain conditions	Likely Acid Generator
VA58	1.9	Acid under certain conditions	Likely Acid Generator
VB1	0.1	Likely Acid Generator	Likely Acid Generator
VB3		No Acid Potential	No Acid Potential
VB4	0.7	Likely Acid Generator	Likely Acid Generator
VB5	51.5	No Acid Potential	No Acid Potential
VB6	28.9	No Acid Potential	No Acid Potential
VB7	35.4	No Acid Potential	No Acid Potential
VB8	8.8	No Acid Potential	No Acid Potential
VB9	0.4	Likely Acid Generator	Likely Acid Generator
VB10	0.2	Likely Acid Generator	Likely Acid Generator
VB11	38.7	No Acid Potential	No Acid Potential
VB12	0.4	Likely Acid Generator	Likely Acid Generator
VB13		No Acid Potential	No Acid Potential
VB14	5.7	No Acid Potential	Acid under certain conditions
VB15	47.8	No Acid Potential	No Acid Potential
VB17	0.3	Likely Acid Generator	Likely Acid Generator
VB18	0.1	Likely Acid Generator	Likely Acid Generator
VB19	0.2	Likely Acid Generator	Likely Acid Generator

Sample Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
VB20	0.1	Likely Acid Generator	Likely Acid Generator
VA1	0.1	Likely Acid Generator	Likely Acid Generator
VA2	2587.0	No Acid Potential	No Acid Potential
VA3	320.2	No Acid Potential	No Acid Potential
VA9		No Acid Potential	No Acid Potential
VA10	93.3	No Acid Potential	No Acid Potential
VA11	259.3	No Acid Potential	No Acid Potential
VA13	62.1	No Acid Potential	No Acid Potential
VA14	125.1	No Acid Potential	No Acid Potential
VA15	23.1	No Acid Potential	No Acid Potential
VA18	208.2	No Acid Potential	No Acid Potential
VA20	17.9	No Acid Potential	No Acid Potential
VA41	110.7	No Acid Potential	No Acid Potential
VA50	581.4	No Acid Potential	No Acid Potential
JA17	0.0	Likely Acid Generator	Likely Acid Generator
JA21	0.1	Likely Acid Generator	Likely Acid Generator
JA22	515.6	No Acid Potential	No Acid Potential
JA24	0.7	Likely Acid Generator	Likely Acid Generator
JA25		No Acid Potential	No Acid Potential
JA26	0.2	Likely Acid Generator	Likely Acid Generator
JA36	0.1	Likely Acid Generator	Likely Acid Generator
JA37	48.3	No Acid Potential	No Acid Potential
JA38	0.0	Likely Acid Generator	Likely Acid Generator
JA41	1.9	Acid under certain conditions	Likely Acid Generator
JA43		No Acid Potential	No Acid Potential
JA44		No Acid Potential	No Acid Potential
JA45	0.1	Likely Acid Generator	Likely Acid Generator
JA46	0.1	Likely Acid Generator	Likely Acid Generator
JC11	9.8	No Acid Potential	No Acid Potential
JC12	4.7	No Acid Potential	Acid under certain conditions
JC13	5.9	No Acid Potential	Acid under certain conditions
JC14		No Acid Potential	No Acid Potential
JC15	152.2	No Acid Potential	No Acid Potential
JC16	0.1	Likely Acid Generator	Likely Acid Generator
JC17	1.9	Acid under certain conditions	Likely Acid Generator
JC18	21.7	No Acid Potential	No Acid Potential
JC19	3.3	Acid under certain conditions	Acid under certain conditions
JC20	3.0	Acid under certain conditions	Acid under certain conditions
JB14	0.2	Likely Acid Generator	Likely Acid Generator
JB19	0.0	Likely Acid Generator	Likely Acid Generator
JB20	0.0	Likely Acid Generator	Likely Acid Generator
VF7	0.1	Likely Acid Generator	Likely Acid Generator
VE37	0.1	Likely Acid Generator	Likely Acid Generator
MC1	0.2	Likely Acid Generator	Likely Acid Generator
VC29		No Acid Potential	No Acid Potential

Sample Name	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
VD1	4.3	No Acid Potential	Acid under certain conditions
VD2	148.2	No Acid Potential	No Acid Potential
VD3	78.4	No Acid Potential	No Acid Potential
VD4		No Acid Potential	No Acid Potential
VD5	0.2	Likely Acid Generator	Likely Acid Generator
VD6	0.1	Likely Acid Generator	Likely Acid Generator
VD7	0.1	Likely Acid Generator	Likely Acid Generator
VD8	0.1	Likely Acid Generator	Likely Acid Generator
VD9	0.1	Likely Acid Generator	Likely Acid Generator
VD10	0.1	Likely Acid Generator	Likely Acid Generator
VD11	0.1	Likely Acid Generator	Likely Acid Generator
VD12	0.1	Likely Acid Generator	Likely Acid Generator
VD13	0.1	Likely Acid Generator	Likely Acid Generator
VD14	0.2	Likely Acid Generator	Likely Acid Generator
VD15	0.1	Likely Acid Generator	Likely Acid Generator
VD16	0.2	Likely Acid Generator	Likely Acid Generator
VD17	0.1	Likely Acid Generator	Likely Acid Generator
VD18	0.0	Likely Acid Generator	Likely Acid Generator
VD19	0.0	Likely Acid Generator	Likely Acid Generator
VD20	0.0	Likely Acid Generator	Likely Acid Generator
VD21	0.0	Likely Acid Generator	Likely Acid Generator
VD23	0.0	Likely Acid Generator	Likely Acid Generator
VD24	0.0	Likely Acid Generator	Likely Acid Generator
VC6	70.4	No Acid Potential	No Acid Potential
VC11	0.2	Likely Acid Generator	Likely Acid Generator
VC12	0.2	Likely Acid Generator	Likely Acid Generator
VC13	2.6	Acid under certain conditions	Acid under certain conditions
VC14		No Acid Potential	No Acid Potential
VC15	42.7	No Acid Potential	No Acid Potential
VC16	0.3	Likely Acid Generator	Likely Acid Generator
VC18	1.5	Acid under certain conditions	Likely Acid Generator
VC19	0.3	Likely Acid Generator	Likely Acid Generator
VC22	0.2	Likely Acid Generator	Likely Acid Generator
VC32	0.3	Likely Acid Generator	Likely Acid Generator
VC35	51.0	No Acid Potential	No Acid Potential
VC36	0.6	Likely Acid Generator	Likely Acid Generator
VC38	0.2	Likely Acid Generator	Likely Acid Generator
VC42	0.2	Likely Acid Generator	Likely Acid Generator
VC43	0.0	Likely Acid Generator	Likely Acid Generator
VB2	1.5	Acid under certain conditions	Likely Acid Generator
VB31	0.0	Likely Acid Generator	Likely Acid Generator
VB32	0.0	Likely Acid Generator	Likely Acid Generator
VB40	141.9	No Acid Potential	No Acid Potential
VC39	1.8	Acid under certain conditions	Likely Acid Generator

Table 7-I: Summary of the ABA results for the Composite samples.

sample	initial pH	final pH	NNP (Open)	NNP (Closed)	Interpretation	Density	Zone
CZONE1A	5.19	1.57	-438.20	-687.32	Potential Acid Generator	**D1.80 S2,20**	**1**
CZONE2A	6.54	1.88	-273.68	-495.27	Potential Acid Generator	**D1.80 S2.20**	**2**
CZONE3A	4.71	2.09	-158.77	-250.36	Potential Acid Generator	**D1.80 S2.20**	**3**
CZONE4AA	7.06	3.48	-18.70	-41.81	Potential Acid Generator	**D2.10 S2.20**	**4**
CZONE5A	6.83	2.48	-36.09	-72.06	Potential Acid Generator	**D2.10 S2.20**	**5**
CZONE6A	6.79	2.3	-13.81	-25.48	Potential Acid Generator	**D1.90 -S2.20**	**6**
CZONE6B	6.54	2.12	-11.76	-21.86	Potential Acid Generator	**D2.10 S2.20**	**6**
CZONE7A	6.7	3.26	-16.40	-34.32	Potential Acid Generator	**D1.90 S2.20**	**7**
CZONE7B	5.86	1.64	-476.81	-725.58	Potential Acid Generator	**D2.10 S2.20**	**7**
CZONE9A	6.33	2.52	-31.47	-59.66	Potential Acid Generator	**D1.90 S2.20**	**9**
CZONE9B	6.12	2.32	-33.54	-62.91	Potential Acid Generator	**D2.10 S2.20**	**9**
CZONE10A	6.91	2.04	-148.74	-286.30	Potential Acid Generator	**D2.10 S2.20**	**10**
PZONE2A	6.96	3.02	-146.32	-244.74	Potential Acid Generator	**D1.80 S2.20**	**2**
PZONE3A	3.37	1.85	-125.22	-195.16	Potential Acid Generator	**D1.80 S2.20**	**3**
PZONE4AA	4.05	1.88	-46.82	-77.41	Potential Acid Generator	**D2.10 S2.20**	**3**
PZONE6A	6.48	2.02	-12.02	-19.81	Verify with other tests	**D1.90 S2.20**	**4**
PZONE6B	6.65	2.12	-8.25	-13.76	Verify with other tests	**D2.10 S2.20**	**6**
PZONE8A	6.29	2.78	-20.17	-36.60	Potential Acid Generator	**D1.90 S2.20**	**6**
PZONE9A	4.69	2.13	-120.83	-172.63	Potential Acid Generator	**D1.90 S2.20**	**8**
PZONE9B	6.05	2.04	-100.33	-172.42	Potential Acid Generator	**D2.10 S2.20**	**9**
PZONE10A	6.68	2.36	-37.89	-75.76	Potential Acid Generator	**D1.90 S2.20**	**10**
CZONE5AA	6.8	2.4	-27.63	-50.81	Potential Acid Generator	**D1.90 S2.20**	**5**
CZONE8A	6.86	2.63	-16.47	-30.27	Potential Acid Generator	**D1.90 S2.20**	**8**
CZONE8B	6.17	2.35	-34.16	-58.13	Potential Acid Generator	**D2.10 S2.20**	**8**
CZONE10B	6.83	2.06	-14.67	-14.67	Verify with other tests	**D1.90 S2.20**	**10**
PZONE1B	4.68	2.17	-344.24	-505.89	Potential Acid Generator	**D1.80 S2.20**	**1**
PZONE4A	6.69	1.97	-332.08	-574.07	Potential Acid Generator	**D2.10 S2.20**	**4**
PZONE5A	7.18	3.12	-35.85	-59.53	Potential Acid Generator	**D1.90 S2.20**	**5**
PZONE5B	7.13	2.95	-16.19	-39.34	Potential Acid Generator	**D2.10 S2.20**	**5**
PZONE7A	7	3.61	-15.16	-24.63	Potential Acid Generator	**D1.90 S2.20**	**7**
PZONE7B	7.17	3.56	-16.30	-29.23	Potential Acid Generator	**D2.10 S2.20**	**7**
PZONE8B	6.17	2.55	-42.40	-68.90	Potential Acid Generator	**D2.10 S2.20**	**8**
PZONE10B	6.91	2.52	-56.39	-109.16	Potential Acid Generator	**D2.10 S2.20**	**10**
Z9ZONE1B	7.13	5.46	6.44	5.73	Verify with other tests	**D1.80 S2.20**	**1**
ZTZONE1B	7.07	2.45	-64.83	-130.71	Potential Acid Generator	**D1.80 S2.20**	**1**
ZTZONE4	7.07	2.2	-237.31	-402.58	Potential Acid Generator	**D2.10 S2.20**	**4**
ZTZONE7BA	7.13	3.93	-0.74	-13.70	Verify with other tests	**D1.80 S2.20**	**7**
ZTZONE10A	6.81	2.38	-58.85	-102.00	Potential Acid Generator	**D1.90 S2.20**	**10**
ZTZONE10B	7.01	2.44	-40.78	-75.41	Potential Acid Generator	**D2.10 S2.20**	**10**
JYZ1A	5.4	2.28	-65.35	-97.40	Potential Acid Generator	**1.50 32,20**	**1**
JYZ2A	6.53	2.05	-231.78	-412.91	Potential Acid Generator	**D1.80 S2.20**	**2**
JYZ4B	7.37	3.14	-21.18	-50.34	Potential Acid Generator	**D2.10 S2.20**	**4**
JYZ4AB	7.46	6.8	37.61	28.20	Probably Excess Neutralising Minerals	**D2.10 32.20**	**4**

sample	initial pH	final pH	NNP (Open)	NNP (Closed)	Interpretation	Density	Zone
JYZ5A	6.12	1.93	-13.09	-20.30	Potential Acid Generator	**D1.90 -S2.20**	**5**
JYZ5B	7.03	2.76	-16.50	-35.02	Potential Acid Generator	**D2.10 32.20**	**5**
JYZ6A	5.43	1.89	-13.33	-18.86	Verify with other tests	**D1.90 -S2.20**	**6**
JYZ6B	6.72	2.68	-28.67	-51.72	Potential Acid Generator	**D2.10 32.20**	**6**
JYZ7A	6.65	2.39	-50.62	-99.23	Potential Acid Generator	**D1.90 S2.20**	**7**
JYZ7B	6.79	2.36	-73.30	-136.16	Potential Acid Generator	**D2.10 S2.20**	**7**
JYZ8A	4.9	1.59	-14.92	-21.73	Potential Acid Generator	**D1.90 S2.20**	**8**
JYZ8B	5.94	2.11	-44.48	-74.23	Potential Acid Generator	**D2.10 S2.20**	
JYZ9A	6.79	2.83	-64.59	-138.60	Potential Acid Generator	**D1.90 S2.20**	**8**
JYZ9B	6.72	6.83	-7.86	-39.99	Potential Acid Generator	**D2.10 S2.20**	**9**
PZ1	3.04	1.94	-121.78	-215.90	Potential Acid Generator	**D1.80 S2.20**	**9**
PZ2	6.04	2.07	-262.95	-479.22	Potential Acid Generator	**D1.80 S2.20**	**1**
PZ3	6.34	2.32	-123.93	-237.82	Potential Acid Generator	**D1.80 S2.20**	**2**
PZ4	5.16	2.83	-443.86	-822.58	Potential Acid Generator	**D2.10 S2.20**	**4**
PZ4A	7	2.18	-59.87	-126.11	Potential Acid Generator	**D2.10 S2.20**	**4**
PZ5A	6.84	3.11	-20.97	-65.73	Potential Acid Generator	**D1.90 S2.20**	**5**
PZ5B	7.11	2.2	-18.15	-40.11	Potential Acid Generator	**D2.10 S2.20**	**5**
PZ6A	6.46	2.29	-52.23	-100.35	Potential Acid Generator	**D1.90 S2.20**	**6**
PZ6B	6.96	2.66	-28.23	-57.88	Potential Acid Generator	**D2.10 S2.20**	**6**
PZ7A	7.12	3.84	-43.90	-87.80	Potential Acid Generator	**D1.90 S2.20**	**7**
PZ7B	7.22	3.48	-18.66	-44.73	Potential Acid Generator	**D2.10 S2.20**	**7**
PZ8A	5.39	2.99	-16.60	-26.60	Potential Acid Generator	**D1.90 S2.20**	**8**
PZ8B	6.75	2.8	-18.39	-41.55	Potential Acid Generator	**D2.10 S2.20**	**8**
PZ9A	5.29	2.33	-20.74	-34.13	Potential Acid Generator	**D1.90 S2.20**	**9**
PZ9B	5.81	1.96	-187.35	-354.34	Potential Acid Generator	**D2.10 S2.20**	**9**
PZ10A	6.6	2.09	-148.99	-309.65	Potential Acid Generator	**D1.90 S2.20**	**10**
PZ10B	5.6	1.88	-272.20	-498.77	Potential Acid Generator	**D2.10 S2.20**	**10**
ZT9	6.84	2.51	-11.56	-22.19	Potential Acid Generator	**D1.90 S2.20**	**9**
ZT9A	6.86	1.89	-6.26	-14.66	Verify with other tests	**D2.10 S2.20**	**9**
ZTZ1A	4.22	1.44	-607.65	-1034.28	Potential Acid Generator	**D1.80 S2.20**	**1**
ZTZ2A	4.18	1.63	-464.25	-819.69	Potential Acid Generator	**D1.80 S2.20**	**2**
ZTZ3A	4.35	1.84	-291.27	-472.54	Potential Acid Generator	**D1.80 S2.20**	**3**
ZTZ4AA	7.38	4.55	-14.19	-15.78	Verify with other tests	**D2.10 S2.20**	**4**
ZTZ5B	6.6	2.18	-32.14	-47.94	Potential Acid Generator	**D2.10 S2.20**	**5**
ZTZ6A	5.81	1.97	-11.14	-14.04	Verify with other tests	**D1.90 S2.20**	**6**
ZTZ6B	5.01	1.81	-21.98	-27.29	Potential Acid Generator	**D2.10 S2.20**	**6**
ZTZ7	7.26	2.31	-71.16	-150.78	Potential Acid Generator	**D1.90 S2.20**	**7**
ZTZ7A	4.48	2.21	-12.67	-14.96	Verify with other tests	**D2.10 S2.20**	**7**
ZTZ8	4.52	1.58	-9.24	-13.47	Verify with other tests	**D1.90 S2.20**	**8**
ZTZ8B	4.62	2.06	-12.76	-15.37	Verify with other tests	**D2.10 S2.20**	**8**
ZTZ9	7.22	4.44	0.64	-3.30	Verify with other tests	**D1.90 S2.20**	**9**
W1	6.57	2.76	-37.00	-77.77	Potential Acid Generator	**D1.90-S2.20**	
W2	6.56	2.75	-36.99	-83.88	Potential Acid Generator	**D1.90-S2.20**	
W3	6.82	2.49	-40.80	-89.52	Potential Acid Generator	**D2.10 S2.20**	
W4	5.6	2.69	-49.82	-94.96	Potential Acid Generator	**D1.90-S2.20**	

sample	initial pH	final pH	NNP (Open)	NNP (Closed)	Interpretation	Density	Zone
W5	5.84	2.15	-203.03	-395.46	Potential Acid Generator	**D1.90-S2.20**	
W6	5.8	1.92	-331.68	-598.89	Potential Acid Generator	**D1.90-S2.20**	
W7	6.85	1.55	-19.33	-33.39	Potential Acid Generator	**D1.90-S2.20**	
W8	6.81	2.76	-54.22	-111.05	Potential Acid Generator	**D1.90-S2.20**	
W9	5.78	2.49	-64.10	-121.87	Potential Acid Generator	**D2.10 S2.20**	
W10	6.34	2.41	-63.00	-119.34	Potential Acid Generator	**D2.10 S2.20**	
W11	6.52	2.21	-102.16	-200.22	Potential Acid Generator	**D1.90-S220**	
W12	6.43	2.41	-65.02	-124.81	Potential Acid Generator	**D190-S2.20**	
W13	6.43	2.19	-202.62	-369.97	Potential Acid Generator	**D2.10-S2.20**	
W14	6.68	2.56	-58.47	-109.44	Potential Acid Generator	**D2.10-S2.20**	
W15	6.7	2.85	-24.81	-47.97	Potential Acid Generator	**D2.10-S2.20**	
W16	3.87	1.92	-253.83	-427.81	Potential Acid Generator	**D1.80-S2.20**	
W17	6.73	2.34	-55.58	-109.48	Potential Acid Generator	**D2.10-S2.20**	
W18	7.02	1.81	-23.87	-50.12	Potential Acid Generator	**D1.90-S2.20**	
W19	6.95	1.72	-26.14	-62.27	Potential Acid Generator	**D1.90-S2.20**	
W20	4.88	2.27	-39.65	-74.11	Potential Acid Generator	**D1.90-S2.20**	
W21	6.29	2.6	-39.48	-76.04	Potential Acid Generator	**D1.90-S2.20**	
W22	5.19	1.86	-293.43	-646.86	Potential Acid Generator	**D1.90-S2.20**	
W23	6.15	1.97	-186.71	-375.26	Potential Acid Generator	**D2.10-S2.20**	
W24	6.6	1.51	-11.46	-27.44	Potential Acid Generator	**D1.80-S2.20**	
W25	6.87	1.94	-196.42	-358.96	Potential Acid Generator	**D2.10-S2.20**	
W26	7.1	2.92	-8.44	-12.92	Verify with other tests	**D1.80-S2.20**	
W27	5.38	2.22	-71.75	-130.71	Potential Acid Generator	**D2.10-S2.20**	
W28	7.17	1.76	-24.64	-57.23	Potential Acid Generator	**D1.80-S2.20**	
W29	6.83	1.83	-15.47	-30.91	Potential Acid Generator	**D1.90-S2.20**	
W30	6.52	1.8	-18.68	-31.84	Potential Acid Generator	**D1.90-S2.20**	
W31	6.72	2.22	-83.43	-165.80	Potential Acid Generator	**D1.90-S2.20**	
W32	6.09	2.38	-60.12	-117.06	Potential Acid Generator	**D1.90-S2.20**	
W33	6.68	2.09	-216.77	-397.33	Potential Acid Generator	**D1.80-S2.20**	
W34	6.73	2.17	-36.79	-70.49	Potential Acid Generator	**D2.10-S2.20**	
W35	6.64	2.76	-33.25	-65.04	Potential Acid Generator	**D2.10-S2.20**	

Table 7-J: Interpretation of the NP/AP ratios for the Composite samples.

sample	density	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
CZONE1A	D1.80 S2,20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE2A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE3A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE4AA	D2.10 S2.20	0.2	Likely Acid Generator	Likely Acid Generator
CZONE5A	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE6A	D1.90 -S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE6B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE7A	D1.90 S2.20	0.1	Likely Acid Generator	Likely Acid Generator
CZONE7B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE9A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE9B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE10A	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE2A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE3A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE4AA	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE6A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE6B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE8A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE9A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE9B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE10A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE5AA	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE8A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE8B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
CZONE10B	D1.90 S2.20		No Acid Potential	No Acid Potential
PZONE1B	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE4A	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE5A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE5B	D2.10 S2.20	0.3	Likely Acid Generator	Likely Acid Generator
PZONE7A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE7B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE8B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZONE10B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
Z9ZONE1B	D1.80 S2.20	10.1	No Acid Potential	No Acid Potential
ZTZONE1B	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZONE4	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZONE7BA	D1.80 S2.20	0.9	Likely Acid Generator	Likely Acid Generator
ZTZONE10A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZONE10B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ1A	1.50 32,20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ2A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ4B	D2.10 S2.20	0.3	Likely Acid Generator	Likely Acid Generator
JYZ4AB	D2.10 32.20	5.0	No Acid Potential	Acid under certain conditions
JYZ5A	D1.90 -S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ5B	D2.10 32.20	0.1	Likely Acid Generator	Likely Acid Generator
JYZ6A	D1.90 -S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ6B	D2.10 32.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ7A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ7B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ8A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ8B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
JYZ9A	D1.90 S2.20	0.1	Likely Acid Generator	Likely Acid Generator
JYZ9B	D2.10 S2.20	0.8	Likely Acid Generator	Likely Acid Generator
PZ1	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ2	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ3	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator

sample	density	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
PZ4	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ4A	D2.10 S2.20	0.1	Likely Acid Generator	Likely Acid Generator
PZ5A	D1.90 S2.20	0.5	Likely Acid Generator	Likely Acid Generator
PZ5B	D2.10 S2.20	0.2	Likely Acid Generator	Likely Acid Generator
PZ6A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ6B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ7A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ7B	D2.10 S2.20	0.3	Likely Acid Generator	Likely Acid Generator
PZ8A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ8B	D2.10 S2.20	0.2	Likely Acid Generator	Likely Acid Generator
PZ9A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ9B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
PZ10A	D1.90 S2.20	0.1	Likely Acid Generator	Likely Acid Generator
PZ10B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZT9	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZT9A	D2.10 S2.20	0.3	Likely Acid Generator	Likely Acid Generator
ZTZ1A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ2A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ3A	D1.80 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ4AA	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ5B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ6A	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ6B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ7	D1.90 S2.20	0.1	Likely Acid Generator	Likely Acid Generator
ZTZ7A	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ8	D1.90 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ8B	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
ZTZ9	D1.90 S2.20	1.2	Acid under certain conditions	Likely Acid Generator
W1	D1.90-S2.20	0.1	Likely Acid Generator	Likely Acid Generator
W2	D1.90-S2.20	0.2	Likely Acid Generator	Likely Acid Generator
W3	D2.10 S2.20	0.2	Likely Acid Generator	Likely Acid Generator
W4	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W5	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W6	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W7	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W8	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W9	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W10	D2.10 S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W11	D1.90-S220	0.0	Likely Acid Generator	Likely Acid Generator
W12	D190-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W13	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W14	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W15	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W16	D1.80-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W17	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W18	D1.90-S2.20	0.1	Likely Acid Generator	Likely Acid Generator
W19	D1.90-S2.20	0.3	Likely Acid Generator	Likely Acid Generator
W20	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W21	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W22	D1.90-S2.20	0.2	Likely Acid Generator	Likely Acid Generator
W23	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W24	D1.80-S2.20	0.3	Likely Acid Generator	Likely Acid Generator
W25	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W26	D1.80-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W27	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W28	D1.80-S2.20	0.2	Likely Acid Generator	Likely Acid Generator
W29	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W30	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W31	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator

sample	density	Neutralising Potential Ratio(NP/AP) for Open System	Interpretation Open System	Interpretation Closed System
W32	D1.90-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W33	D1.80-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W34	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator
W35	D2.10-S2.20	0.0	Likely Acid Generator	Likely Acid Generator

Table 7-K: List of samples that were subjected to XRF analysis for major elements.

	SiO2	Al2O3	Fe2O3	CaO	MgO	MnO	K2O	P2O5	TiO2	Total
WGH160	56.834	37.871	0.627	0.166	0.667	0.056	0.742	0.244	1.845	99.052
WGH165	81.414	9.663	1.634	3.01	1.229	0.174	0.003	0.176	2.192	99.495
WGH169	94.923	1.255	0.936	0.094	0.153	0.063	0	0.183	1.779	99.386
WGH170	76.536	20.098	0.901	0.042	0.014	0.056	0.152	0.12	1.541	99.46
WGH171	63.196	28.316	2.976	0.253	0.338	0.053	0.669	0.816	2.559	99.176
WGH172	61.22	34.889	0.718	0.083	0	0.055	0.41	0.127	1.779	99.281
WGH181	51.446	33.363	11.752	0.195	0.114	0.192	0.182	0.122	2.028	99.394
WGH182	60.079	34.799	1.151	0.092	0.941	0.064	0.261	0.156	2.291	99.834
WGH192	70.408	22.258	4.143	0.28	1.129	0.076	0.245	0.052	1.339	99.93
WGH193	70.478	22.111	4.183	0.279	0.666	0.077	0.242	0.05	1.345	99.431
WGH195	67.972	28.319	0.518	0.061	0.581	0.056	0.241	0.06	1.827	99.635
WGB9A	65.384	18.358	10.978	1.274	0.837	0.254	1.555	0.076	0.757	99.473
WGB4A	57.297	36.082	2.005	0.45	0.438	0.062	0.868	0.205	2.05	99.457
WGB8E	49.801	16.325	24.486	6.099	1.863	0.534	0.808	0.08	0.614	100.61
WGB9A	65.779	18.405	10.976	1.262	0.848	0.256	1.571	0.073	0.763	99.933
WGC9A	70.561	22.679	1.603	0.14	0.579	0.057	2.142	0.047	1	98.808
W1B	79.407	11.564	1.378	0.254	0.588	0.069	0.552	0.097	0.844	94.753
W10B	67.382	15.676	7.118	5.081	2.195	0.086	0.848	0.041	0.692	99.119
W13A	67.273	15.87	9.29	2.999	1.617	0.103	0.986	0.051	0.717	98.906
W15A	71.337	17.405	6.13	2.161	2.8	0.071	1.215	0.051	0.76	101.93
W16A	67.613	17.489	7.651	2.488	2.838	0.074	1.254	0.065	0.794	100.266
W19A	71.628	17.99	4.397	2.626	0.88	0.063	0.897	0.047	0.772	99.3
S4	56.235	37.607	1.487	0.723	0.449	0.055	0.548	0.113	1.69	98.907
S5	77.331	14.034	3.496	1.279	1.295	0.094	0.476	0.062	0.689	98.756
S8	72.052	23.543	1.051	0.172	0.948	0.057	0.349	0.075	1.242	99.489
S9	72.158	22.867	1.274	0.529	0.596	0.061	0.378	0.07	1.199	99.132
S47	57.302	37.278	1.599	0.713	0.203	0.056	0.589	0.11	1.714	99.564
S49	58.42	35.708	2.934	0.305	0.009	0.056	0.579	0.134	1.478	99.623
S61	91.739	5.292	0.8	0.028	0.169	0.058	0.279	0.029	0.281	98.675
S69	66.7	18.377	10.888	0.222	0.39	0.164	1.544	0.079	1.056	99.42
S71	90.914	5.647	0.745	0.104	0.647	0.058	0.738	0.032	0.275	99.16
WGC10B	68.12	20.94	5.40	1.43	1.12	0.07	1.69	0.06	0.85	99.68
WGC8	44.15	14.69	28.94	8.17	1.47	0.59	0.80	0.09	0.63	99.54
WGC9A	70.45	23.51	1.62	0.13	0.64	0.06	2.24	0.05	1.03	99.73
WRA2B	63.62	31.75	1.62	0.13	0.54	0.06	0.27	0.08	1.60	99.66
WTB1A	64.44	30.67	1.43	0.19	0.08	0.06	0.41	0.31	2.36	99.94
WTB2	78.94	16.71	0.71	0.20	0.13	0.07	1.71	0.07	1.28	99.83
WTB4	28.65	17.24	39.81	10.63	1.74	0.22	0.06	0.30	0.84	99.48
WTC4A	65.02	30.49	1.00	0.16	0.37	0.06	0.83	0.14	1.75	99.83
WVB4E	66.97	28.59	1.99	0.13	0.06	0.06	0.38	0.08	1.43	99.69
WVC3	68.75	26.32	2.10	0.21	0.36	0.06	0.29	0.08	1.64	99.80
WVC4A	58.02	33.31	0.48	2.37	1.10	0.06	0.28	2.38	1.63	99.63
RB11	71.018	24.567	2.315	0.109	-0.008	0.151	0.101	0.102	1.28	99.635
RB18	65.501	30.927	0.999	0.102	0.065	0.056	0.459	0.08	1.321	99.51
RB19	67.971	24.909	4.944	0.141	0.065	0.125	0.332	0.12	1.061	99.668
RB24	63.779	33.143	0.719	0.082	0.003	0.056	0.235	0.115	1.452	99.584
RB29	77.945	18.918	1.014	0.462	0.152	0.062	0.153	0.114	0.915	99.735
RB38	66.748	29.084	0.963	0.107	0.007	0.058	0.383	0.102	1.565	99.017
RB51	56.33	20.5	17.916	1.864	1.408	0.192	0.385	0.095	0.904	99.594
RC10	79.769	15.646	0.708	0.186	0.037	0.07	1.602	0.067	1.234	99.319
RC2	83.659	7.752	2.082	4.423	0.141	0.132	0.622	0.042	0.62	99.473
RC56	83.76	12.032	1.31	0.267	0.076	0.069	0.62	0.097	0.881	99.112

Table 7-L: List of samples that were subjected to XRF analysis for trace elements.

Sample	Sc	V	Cr	Co	Ni	Cu	Zn	Br	Rb	Sr	Y	Zr	Nb	Ag	Cd	Ba	Tl	Pb
WVC4(A)	21	76	80	7	26	113	26	2	20	1383	95	383	18	9	4	1628	8	42
WVC3	10	33	55	11	50	36	8	3	22	13	27	130	7	9	0	44	6	13
WVB4E	11	34	62	10	24	21	29	3	31	17	42	132	8	8	0	61	7	14
WTC4(A)	18	78	84	5	18	10	21	2	59	64	41	245	20	5	2	215	6	34
WTB4	17	63	73	11	50	243	41	3	19	139	26	100	4	16	7	413	8	18
WTB1(A)	9	57	111	18	78	60	15	4	23	109	20	156	9	7	3	201	6	22
WTA2	5	23	26	16	39	29	3	5	11	466	18	50	-1	5	2	529	7	6
WRA2(B)	10	92	144	11	49	73	3	4	21	24	26	145	5	5	1	29	7	14
RB38	10	73	78	12	39	15	58	1	39	69	30	956	17	10	4	268	8	25
RB29	13	70	97	6	35	120	18	2	33	57	22	294	11	9	1	538	7	22
RB24	18	118	164	6	49	76	49	1	41	57	33	377	21	8	-1	398	7	37
RB19	20	114	172	13	56	38	83	2	42	63	35	244	12	10	7	461	7	26
RB18	18	100	148	12	55	124	36	1	51	33	37	281	15	8	2	288	6	32
RB11	17	121	151	11	40	119	43	2	29	90	24	336	17	8	3	893	6	24
S5	16	93	164	11	48	46	28	2	44	40	28	206	8	9	7	747	7	19
S4	12	63	103	12	42	25	19	2	37	44	20	199	4	10	3	1557	7	12
RC10	9	84	130	13	29	17	41	2	56	109	17	706	10	14	3	474	5	22
RC2	12	44	95	13	31	101	28	2	39	64	13	324	4	8	6	897	4	11
RB56	7	52	88	9	33	65	51	3	30	136	13	393	6	10	2	482	6	14
RB51	12	73	90	26	49	52	79	3	29	63	26	152	7	11	7	205	9	14
S69	13	119	163	23	86	132	82	2	55	73	21	315	10	5	1	407	6	19
S61	4	26	42	9	18	33	16	2	25	34	9	131	2	12	2	93	5	8
S49	22	176	261	16	80	129	120	2	42	92	23	238	10	11	-1	274	6	28
S47	21	114	150	11	44	123	18	3	39	58	30	163	11	8	5	172	6	28
S9	18	73	154	7	37	16	23	5	48	32	33	254	18	12	4	393	6	31
S8	16	90	159	7	38	78	26	3	37	43	31	233	11	15	0	685	7	23
W13A	13	111	49	8	16	99	48	1	78	107	24	186	11	13	4	251	5	20
W10B	12	48	30	10	20	46	57	0	65	94	32	178	11	14	4	202	7	18
WGC10B	7	32	19	6	7	89	19	3	48	55	20	95	4	7	1	114	6	10
WGC9A	9	66	51	6	10	83	40	2	118	51	27	200	16	9	1	363	7	27
WGH171	31	338	401	13	62	145	172	2	49	476	47	414	19	9	2	1335	7	56
WGH170	6	66	94	8	33	68	37	2	29	45	29	743	14	9	2	337	8	29
WGH160	9	53	25	5	7	-6	14	1	15	86	45	455	16	13	0	595	6	13
WGH165	7	54	45	6	14	41	25	2	19	63	70	1148	11	11	9	610	9	26
WGC8	8	34	18	10	13	51	16	3	28	143	18	61	3	9	1	119	7	12
WGB9(A)	5	30	18	9	9	11	25	3	52	57	18	76	4	8	4	172	5	10
WGB8(C)	9	37	19	9	11	8	15	2	39	74	18	79	5	12	2	169	5	9
WGB4(A)	16	60	69	7	31	66	5	2	44	73	79	203	14	8	-1	247	8	40
W1B	15	67	47	7	29	54	40	2	105	40	37	204	11	12	7	273	7	19
S71	4	24	40	6	14	12	14	2	36	40	7	167	1	10	1	214	6	10
W16A	11	66	44	10	14	150	44	2	87	138	35	199	13	9	5	177	6	15
W15A	11	64	41	11	16	133	33	2	80	92	30	195	12	10	3	164	7	22
WGH160	14	95	89	6	33	92	37	2	52	128	30	207	21	8	3	398	6	46
W19A	13	69	44	12	13	90	260	1	74	81	27	211	13	11	2	142	9	24
WGH195	5	40	106	8	28	69	87	2	28	28	10	576	20	9	4	145	6	14
WGH193	8	8	13	5	15	-10	6	1	16	93	6	74	0	10	2	242	7	8
WGH192	9	59	123	21	50	38	53	1	29	35	7	233	13	13	1	229	7	25
WGH182	12	136	134	40	50	52	82	1	34	112	24	591	35	9	2	248	6	44
WGH181	15	168	125	73	91	83	84	1	29	79	19	405	30	15	3	192	6	40

Table 7-M: XRD results for the samples that are more likely to become acidic (dominant XXX, major XX, minor X, accessory xx, and rare x)

Sample	Quartz	Kaolinite	Siderite	Calcite	Ankerite/Dolomite	Muscovite/Illite	Rutile/Anatase	Pyrite	Ilmenite	Hematite	Marcasite	Apatite	Pyrrhotite	Feldspar
WGH160	X	XXX				xx	x							
WGH165	XXX	X		x	x		x	x						
WGH169	XXX	xx					x			x				
WGH170	XX	XX				x	x							
WGH171	XX	XXX				xx	xx	xx						
WGH172	XX	XXX				xx	x							
WGH181	X	XXX	X			x	x							
WGH182	XX	XXX	xx			x	x							
WGH192	XXX	XX	xx		x	x	x	x						
WGH193	XXX	XX		x	x	x	x	xx						
WGH195	XX	XXX				xx	x							
WGB4A	X	XXX		x	x	xx	x							
WGB8E	X	XX	XX	X	xx	xx	x							
WGB9A	XX	XX	X	x	x	X	x	x						
W1B	XXX	XX				xx	x							
W10B	XX	XX	xx	xx	xx	xx	x	x						
W13A	XX	XX	xx	x	xx	xx	x				x			
W15A	XX	XX	xx	xx	xx	X	x							
W16A	XX	XX	xx	xx	xx	X	x							
W19A	XX	XX	xx	xx	x	xx	x	x						
S4	XXX	XX		xx		xx	x		x					
S5	XXX	XX		xx		xx	x		xx					
S8	XXX	XX				x	x		x					
S9	XXX	XX				xx	x							
S47	X	XXX		x		xx	x							
S49	X	XXX				xx	x	x	x					
S61	XXX	X				x								
S69	XX	X	X			xx	x							X
S71	XXX	xx			x	x								xx
WGC10B	XXX	XX		x	x	X	x	x						
WGC8	XX	X	XX	X	xx	xx		xx						
WGC9A	XXX	XX				XX	x							
WRA2B	XXX	XX				xx	x	x						
WTB1A	XXX	XX				X	xx	x						
WTB2	X	XXX	XX				x	xx						
WTB4	X	XX		XX	xx			XX						
WTC4A	XXX	XX				xx	x	x						
WVB4E	XXX	XX					x			x				
WVC3	XX	XX					x			x				
WVC4A	XX	XX					x					xx	x	
RB11	XXX	XX				x	x	xx						x
RB18	XX	XX				xx	x	x						x

Sample	Quartz	Kaolinite	Siderite	Calcite	Ankerite/Dolomite	Muscovite/Illite	Rutile/Anatase	Pyrite	Ilmenite	Hematite	Marcasite	Apatite	Pyrrhotite	Feldspar
RB19	XXX	XX	xx			xx	x							
RB24	XX	XXX				x	x							x
RB29	XXX	XX	x	x	x	x	x							
RB38	XX	XXX	x			xx	x							
RB51	XX	XX	X	xx	x	xx	x	X						
RC10	XXX	X			x	xx	x							X
RC2	XXX	X	x	xx		x	x	x						xx
RC56	XXX	X	x	x	x	xx	x							x

Table 7-N: The samples and combination of samples selected for kinetic testing.

sample	Kinetic name	initial pH	final pH	NNP (open)	NNP (Closed)	Succession	lithology
WGC6 (B)	S7	7.78	3.93	11.71	8.88	Full succession	mudstone/coal
WGH (165)	S8	7.86	5.93	46.87	14.51	Full succession	siltstone
WGB10 (E)	S9	8.1	1.24	-34.74	-51.33	Full succession	ss/mudstone
WGB10 (D)	S10	8.11	2.05	-7.54	-15.93	Full succession	ss/mud/coal
WGG2 (C)	S11	7.59	2.18	-64.64	-167.62	Full succession	coal/ss
WGG4 (D)	S12	8.01	4.43	-1.25	-2.97	Full succession	mudstone/ss
WGA1	S13	7.48	1.55	1.66	-5.72	Full succession	ss/coal
WGH (192)	S14	7.11	2.43	-1.28	-21.74	Full succession	siltstone
WGH (170)	S15	6.77	1.76	-10.12	-21.12	Full succession	ss
WGH (172)	S16	6.8	3.1	-0.07	-1.26	Full succession	mudstone
WGA4	S17	6.4	2.09	-82.38	-148.01	Full succession	mudstone/coal
WGC11 (B)	S18	7.53	1.53	9.41	-4.05	Full succession	mudstone/coal
WVC1	S19	3.58	1.34	-95.5	-170.51	Full succession	coal/ss
WRA4 (A)	S20	6.99	2.72	-24.8	-74.12	Full succession	ss/coal
WTC2 (B)	S21	4.64	2.2	-7.08	-10.68	Full succession	coal/ss
WGG4 (F)	S22	7.99	6.13	-4.41	-6.8	Full succession	mudstone
WGG6 (A)	S23	8.08	7.23	23.12	18.6	Full succession	mudstone
WGD2 (A)	S24	7.5	1.99	-89.71	-179.58	Full succession	ss
WRA5 (B)	S25	7.59	4.68	33.78	32.09	Full succession	mudstone/coal
WVB4 (C)	S26	3.43	1.29	-54.27	-98.34	Full succession	
WTD4 (C)	S27	7.05	1.94	-49.2	-98.12	Full succession	coal
WVC4 (B)	S28	5.5	2.34	-10.68	-12.27	Full succession	coal/mudstone
WGA3 (A)	S29	7.95	7.58	114.5	107.8	Full succession	ss/coal
WGD9	S30	5.03	1.51	-19.35	-32.8	Full succession	clay ground/mudstone
WGH (195)	S31	7.22	2.62	-2.01	-3.68	Full succession	ss
WGB4 (B)	S32	5.69	1.24	-71.52	-125.87	Full succession	coal/ss
WGB10 (C)	S33	8.04	1.45	5.56	2.36	Full succession	ss/mudstone
WGH (181)	S34	6.8	3.84	4.73	2.64	Full succession	mudstone
W1B	S35	8.13	5.42	-2.12	-2.29	Full succession	mudstone
W16B	S36	8.34	7.8	28.4	25.67	Full succession	mudstone/coal
W1A	S37	8.53	5.91	-9.78	-18.76	Full succession	mudstone
W16A	S38	8.53	7.88	50.83	49.16	Full succession	mudstone/coal
DP01 (10)	SEK 1	6.94	2.08	-4.18	-4.99	Middle Ecca	
DP3 (6)	SEK 2	7.18	4.07	3.37	3.16	Middle Ecca	
DP01 (4)	SEK 3	6.17	2.97	-1.6	-2.18	Middle Ecca	
PS95 (2)	SEK 4	6.95	6.54	39.29	18.29	Partly weathered	mudstone
PS93 (1)	SEK 5	7.56	4.83	0.81	0.78	Partly weathered	mudstone
PM18 (3)	SEK 6	5.78	2.24	16.09	14.9	Partly weathered	siltstone/sandstone
VB4	G1	7.35	6.15	-1.15	-1.17	Partly weathered	shale
VA33	G2	5.79	5.79	1.91	1.83	Partly weathered	shale
JB15	G3	7.38	2.13	2.51	2.52	Partly weathered	clay
MB24	G4	7.85	6.78	3.35	-11.05	Partly weathered	shale

sample	Kinetic name	initial pH	final pH	NNP (open)	NNP (Closed)	Succession	lithology
VD4	G5	6.38	4.06	-1.19	-0.97	Partly weathered	
VB15	G6	8.54	5.21	1.85	1.81	Partly weathered	shale
VC15	G7	6.61	6.28	1.55	1.52	Partly weathered	shale
MA5	G8	7.59	5.85	-0.17	-0.03	Partly weathered	soil
VA15	G9	8.26	7.9	3.64	3.48	Partly weathered	shale
JC11	G10	8.14	6.73	3.07	2.72	Partly weathered	shale
JA36	G11	6.58	5.44	-1.66	-1.77	Partly weathered	clay
VA2	G12	8.62	8.6	310.95	310.8	Partly weathered	shale
JA18	G13	6.37	5.69	-2.38	-2.37	Partly weathered	clay
VC32	G14	6.64	4.39	-2.37	-2.41	Partly weathered	shale
JA28	G15	7.11	5.53	-0.72	-0.68	Partly weathered	clay
MB10	G16	8.7	5.88	1.54	1.5	Partly weathered	shale
JC31	G17	7.4	5.53	-2.46	-2.53	Partly weathered	shale
JA5	G18	7.71	4.82	-4.65	-4.62	Partly weathered	ferricreet
VC3	G19	9.42	4.29	-1.01	-1	Partly weathered	shale
JB27+VA3	Gm1	8.52	8.4	64.79	64.75	Partly weathered	
MB3+CZONE9B	Gm2	7.73	7.6	17.51	1.76	Partly weathered	
MB1+CZONE1A	Gm3	6.08	2.04	-122.90	-353.41	Partly weathered	
MB3+CZONE6B	Gm4	7.82	6.93	33.03	29.19	Partly weathered	
MB2+CZONE2A	Gm5	7.13	2.49	64.11	-36.91	Partly weathered	
VA47+PZONE10A	Gm6	7.47	3.07	-29.31	-114.04	Partly weathered	
VA43+PZONE6B	Gm7	7.78	7.31	11.02	-5.79	Partly weathered	
WGA3 (A)+WGA4	Sm1	7.4	4.57	26.96	-8.70	Full succession	
WGG2+WGG4(D)+WGG4(F)+WGG 6(A)	Sm2	7.65	4.76	23.67	2.18	Full succession	
WRA4(A)+WRA5(B)	Sm3	7.3	4.44	-5.56	-36.67	Full succession	
WGA3(A)+WGB10	Sm4	8.03	6.9	100.83	87.67	Full succession	

Table 7-O: Composite samples with acid potential values after complete oxidation.

Density	Sample name	Zones	Acid potential
D1.80 S2,20	CZONE1A	1	267.8
D1.80 S2.20	PZONE1B	1	166.6
D1.80 S2.20	ZTZONE1A	1	0.7
D1.80 S2.20	ZTZONE1B	1	64.5
D1.80 S2,20	JYZ1A	1	33.5
D1.80 S2.20	PZ1	1	103.9
D1.80 S2.20	ZTZ1A	1	435.5
D1.90-S220	ZTZ1A	1	98.3
D1.90-S2.20	ZTZ1B	1	35.2
D1.90-S2.20	MY1	1	368.8
D1.80-S2.20	MY1B	1	4.5
D1.80-S2.20	SN1B	1	15.7
D1.80-S2.20	MY1B	1	32.1
D1.90-S2.20	SN1B	1	14.9
D1.80 S2.20	CZONE2A	2	230.4
D1.80 S2.20	PZONE2A	2	101.4
D1.80 S2.20	JYZ2A	2	179.0
D1.80 S2.20	PZ2	2	228.2
D1.80 S2.20	ZTZ2A	2	379.2
D1.90-S2.20	ZTZ2	2	194.2
D1.80-S2.20	SN2	2	181.7
D1.80 S2.20	PZ3	3	122.0
D1.80 S2.20	PZONE3A	3	78.4
D1.80 S2.20	CZONE3A	3	95.6
D1.80 S2.20	ZTZ3A	3	194.7
D1.80-S2.20	SN3	3	186.9
D2.10 S2.20	PZ4	4	392.3
D2.10 S2.20	PZ4A	4	66.6
D2.10 S2.20	PZONE4AA	4	35.5
D2.10 S2.20	CZONE4AA	4	22.8
D2.10 S2.20	ZTZONE4	4	170.0
D2.10 S2.20	JYZ4B	4	28.5
D2.10 S2.20	JYZ4AB	4	9.4
D2.10 S2.20	PZONE4A	4	250.7
D2.10 S2.20	ZTZ4AA	4	1.6
D2.10-S2.20	MY4	4	193.8
D2.10-S2.20	NS4A	4	162.4
D2.10-S2.20	MY4A	4	60.3
D2.10-S2.20	SN4	4	170.1
D1.90 S2.20	PZONE5A	5	24.6
D2.10 S2.20	PZONE5B	5	24.4
D2.10 S2.20	CZONE5A	5	35.8
D1.90 S2.20	CZONE5AA	5	23.2

Density	Sample name	Zones	Acid potential
D1.90 -S2.20	JYZ5A	5	7.1
D2.10 32.20	JYZ5B	5	18.2
D1.90 S2.20	PZ5A	5	45.3
D2.10 S2.20	PZ5B	5	22.3
D2.10 S2.20	ZTZ5B	5	15.9
D1.90-S2.20	ZTZ5	5	46.2
D2.10 S2.20	ZTZ5A	5	48.1
D2.10-S2.20	MY5	5	23.2
D1.90-S2.20	SN5	5	26.3
D1.90-S2.20	MY5	5	15.6
D1.90 -S2.20	CZONE6A	6	12.1
D2.10 S2.20	CZONE6B	6	10.6
D1.90 S2.20	PZONE6A	6	8.2
D2.10 S2.20	PZONE6B	6	5.9
D1.90 -S2.20	JYZ6A	6	5.3
D2.10 32.20	JYZ6B	6	22.6
D1.90 S2.20	PZ6A	6	48.2
D2.10 S2.20	PZ6B	6	30.1
D1.90 S2.20	ZTZ6A	6	2.8
D2.10 S2.20	ZTZ6B	6	5.2
D1.90-S2.20	SN6	6	56.2
D1.90-S2.20	ZTZ6	6	41.3
D1.90-S2.20	MY6	6	37.6
D2.10-S2.20	SN6(B)	6	53.2
D2.10-S2.20	ZTZ6	6	31.9
D1.90-S2.20	SN7	7	13.3
D1.90-S2.20	ZTZ7	7	82.2
D2.10-S2.20	ZTZ7	7	34.1
D1.90 S2.20	CZONE7A	7	18.4
D2.10 S2.20	CZONE7B	7	256.7
D1.90 S2.20	PZONE7A	7	9.9
D2.10 S2.20	PZONE7B	7	13.5
D1.80 S2.20	ZTZONE7BA	7	12.7
D1.90 S2.20	JYZ7A	7	47.7
D2.10 S2.20	JYZ7B	7	61.7
D1.90 S2.20	PZ7A	7	45.1
D2.10 S2.20	PZ7B	7	26.8
D1.90 S2.20	ZTZ7	7	79.8
D2.10 S2.20	ZTZ7A	7	2.2
D1.90 S2.20	PZONE8A	8	17.1
D1.90 S2.20	CZONE8A	8	15.0
D2.10 S2.20	CZONE8B	8	24.6
D2.10 S2.20	PZONE8B	8	27.2
D1.90 S2.20	JYZ8A	8	6.7
D2.10 S2.20	JYZ8B	8	29.1

Density	Sample name	Zones	Acid potential
D1.90 S2.20	PZ8A	8	9.9
D2.10 S2.20	PZ8B	8	23.5
D1.90 S2.20	ZTZ8	8	4.1
D2.10 S2.20	ZTZ8B	8	2.5
D2.10 S2.20	SN8	8	55.6
D190-S2.20	MY8	8	61.2
D1.90 S2.20	CZONE9A	9	28.6
D2.10 S2.20	CZONE9B	9	29.7
D1.90 S2.20	PZONE9A	9	53.0
D2.10 S2.20	PZONE9B	9	74.5
D1.90 S2.20	JYZ9A	9	76.2
D2.10 S2.20	JYZ9B	9	33.5
D1.90 S2.20	PZ9A	9	13.3
D2.10 S2.20	PZ9B	9	164.2
D1.90 S2.20	ZT9	9	10.8
D2.10 S2.20	ZT9A	9	8.3
D1.90 S2.20	ZTZ9	9	4.1
D2.10 S2.20	SN9	9	57.4
D1.90-S2.20	SN9	9	56.8
D2.10 S2.20	PZONE10B	10	54.3
D1.90 S2.20	ZTZONE10A	10	44.0
D2.10 S2.20	ZTZONE10B	10	35.6
D2.10 S2.20	CZONE10A	10	139.3
D1.90 S2.20	PZONE10A	10	39.1
D1.90 S2.20	PZ10A	10	161.1
D2.10 S2.20	PZ10B	10	229.2
D1.90-S2.20	ZTZ10	10	44.4
D2.10-S2.20	MY10	10	52.3
D1.90-S2.20	SN10	10	34.2
D1.90-S2.20	MY11	11	287.4