

# Acid Sulfate Soil Management Plan

## *Keysbrook Mineral Sands Project*

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## 1.0 INTRODUCTION

This plan describes the Acid Sulfate Soil (ASS) management practices that will be implemented during operation of the open cut mineral sand mine and primary processing plant at Keysbrook by MZI Resources Ltd (MZI). The mining area of 1,366 hectares is located on privately owned land, actively used for grazing.

The following characteristics of the project are important in regard to the risk of generating Acid Sulfate Soils (ASS):

- The portion of the elevated dunes which are permanently above the winter water table are considered to be low ASS risk.
- The potential for higher risk ASS layers are predicted at depths greater than three metres below ground level. This profile consists of the clay layers of the Guildford Formation. This zone will not be impacted or disturbed by mining as the mineralised profile is confined to the Bassendean sands above this zone.
- Collection of water within the open pit occurs using drains and sumps. This will have minimal effect on dewatering the profile below the pit floor. All water is pumped to a lined dam for use in the process.

### 1.1 Purpose, Objectives and Targets

This plan has been prepared to comply with Condition 12 of Ministerial Statement 810. The purpose of this Acid Sulfate Soils Management Plan (ASSMP) is to outline the management strategies and procedures to assess and manage possible formation of acid sulfate soils associated with the operation. MZI will make the ASSMP and the results of the monitoring publicly available.

The plan has been developed in accordance with guidelines provided by the Department of Environment and Conservation (DER). The guiding principles are:

- Planning mining operations to minimise potential disturbance of ASS materials.
- Outline design and management strategies to avoid, minimise or mitigate the formation of ASS.
- Implementing appropriate monitoring programs to measure soil and water quality.
- Establish appropriate 'Action Criteria' to provide an early warning system for disturbance of ASS materials.
- Identify appropriate remediation strategies to minimise potential environmental impacts resulting from ASS disturbance.

The objective of this plan is to ensure that all mining activities with the potential to disturb ASS materials protect environmental values. The objectives and targets for ASS management are outlined in Table 1.

**Table 1: Keysbrook Mineral Sand Mine ASS Management Objectives and Targets**

Objective	Target
Avoid disturbance of PASS soils.	No inadvertent disturbance of PASS soils.
Prevent acid generation from disturbed soils.	Acidity and metal concentrations in surface and groundwater to be maintained at pre-mining levels.
All employees and contractors will be aware of ASS issues relating to the project and their responsibilities.	All employees and contractors instructed on content of the ASSMP in the induction process.

## 2.0 EXISTING ENVIRONMENT

### 2.1 Regional Setting

The project is situated along the eastern edge of the Swan Coastal Plain approximately 70 kilometres south of Perth, near the small townships of Keysbrook and North Dandalup (Figure 1). It is located two to seven kilometres west of the Darling Scarp and between 22 and 48 metres AHD. The topography of the mine area is flat to very gently undulating. A cross section of the open pit and its relationship to local topographic features and the annual water table fluctuation is shown in Figure 2.

The mining area of 1,366 hectares is located on privately owned rural zoned land. A large portion of the mine area has been cleared for grazing activities. Patches of remnant native vegetation also remain, ranging from stands of trees over pasture grasses with little to no understorey to areas of trees with a partially intact understorey.

### 2.2 Land Systems

The geomorphology of the Swan Coastal Plain comprises a series of accretionary marine deposits eroding a gently dipping Tertiary alluvial surface. The whole marine assemblage is overprinted by Quaternary fluvial and aeolian deposits. On the eastern side of the Swan Coastal Plain the marine deposits and dunes are interlayered with fluvial deposits producing a strongly variable sequence with depth, but broad areas of similar deposits in horizontal layers.

### 2.3 Soils

The heavy mineral resource is hosted within the dunes of the Bassendean Sand, which partly covers mottled clayey sand or a pisolitic ironstone-clay unit of the Guildford Formation, also referred to as the Pinjarra Plain.

#### 2.3.1 Bassendean Dunes

The dominant soil parent materials within the Bassendean system are highly leached quartzose sands. The dune sands contain potentially economic heavy mineral mineralisation. The more easterly dunes are higher, up to six metres above the plain level, and better defined. The Bassendean Dunes form a series of subdued low relief dunes, sandplains and intervening swamps adjacent to and partly overlying the finer textured soils of the Pinjarra Plain (Guildford Formation). Some inland movement by wind action has also occurred. The

majority of the soils are podzols. Soils in the eastern part of the unit are more severely leached than those to the west. The mine is within the eastern part of the unit.

### **2.3.2 Pinjarra Plain**

The soils of the Pinjarra Plain have largely formed from unconsolidated alluvial material of Tertiary and Quaternary Age. The depositional systems can be grouped into three main types based on soil parent material these are:

- The older alluvium occurring in extensive flat plains and forming imperfect to poorly drained soils - mottled yellow duplex soils and mottled yellow or greyish brown gradational earths.
- Fine textured alluvium of generally intermediate age, in areas of lowest relief and forming very poorly drained soils - uniform cracking black grey or yellow-grey clays.
- The youngest alluvium occurring along the major present river systems and forming well to moderately well-drained soils - red duplex or gradational soils and uniform reddish brown loams or earthy sands.

The Department of Agriculture and Food (DAFWA) published a series of land resource maps for the Swan Coastal Plain, which have now been reproduced and can be accessed electronically from NRM Info (DAFWA, 2008). Soil units are shown in Figure 3 and descriptions are presented in Table 2.

**Table 2: Description of Soil Types**

<b>Soil Units</b>	<b>Description</b>
<b>Bassendean Dune and Sandplains</b>	
B1	Extremely low to very low relief dunes, undulating sandplain and discrete sand rises with deep bleached grey sands sometimes with a pale yellow B horizon or a weak iron-organic hardpan at depths generally greater than two metre; Banksia dominant.
B1a	Extremely low to very low relief dunes, undulating sandplain and discrete sand rises with deep bleached grey sands with an intensely coloured yellow B horizon occurring within one metre of the surface; Marri and Jarrah dominant.
B2	Flat to very gently undulating sandplain with well to moderately well drained deep bleached grey sands with a pale yellow B horizon or a weak iron-organic hardpan one to two metres.
B4	Broad poorly drained sandplain with deep grey siliceous sands or bleached sands, underlain at depths generally greater than 1.5 metres by clay or less frequently a strong iron-organic hardpan.
B5	Shallowly incised stream channels of minor creeks and rivers with deep grey siliceous sands or bleached sands, underlain at depths generally greater than 1.5 metres by clay or less frequently a strong iron-organic hardpan.
B6	Sandplain similar to B4 with imperfectly drained deep or very deep grey siliceous sands.
<b>Pinjarra Plain</b>	
P1a	Flat to very gently undulating plain with deep acidic mottled yellow duplex (or 'effective duplex') soils. Shallow pale sand to sandy loam over clay; imperfect to poorly drained and generally not susceptible to salinity.
P1b	Flat to very gently undulating plain with deep acidic mottled yellow duplex (or 'effective duplex') soils. Moderately deep pale sand to loamy sand over clay; imperfectly drained and moderately susceptible to salinity in limited areas.
P1c	Flat to very gently undulating plain with deep acidic mottled yellow duplex (or 'effective duplex') soils. Deep pale brown to yellowish sand to sandy loam over clay; imperfectly drained and moderately susceptible to salinity in limited areas.
P2	Flat to very gently undulating plain with deep alkaline mottled yellow duplex soils which generally consist of shallow pale sand to sandy loam over clay.
P7	Seasonally inundated swamps and depressions with very poorly drained variable acidic mottled yellow and grey sandy duplex and effective duplex soils.
P8	Broad poorly drained flats and poorly defined stream channels with moderately deep to deep sands over mottled clays; acidic or less commonly alkaline grey and yellow duplex soils to uniform bleached or pale brown sands over clay.
P11	Shallow brown loamy soils or less commonly, very shallow sands over ironstone pavement which is a clear barrier to drainage.



## 2.4 Hydrogeology

The main aquifers in the project area are the Superficial Formation containing both the Bassendean Dunes and Guilford Formation, the underlying Leederville Formation and below that, the Yarragadee Formation (Allen, 1981). Information on the aquifers of the project area is presented in Table 3 and Table 4.

The upper four to eight metres of Bassendean Sand in the Superficial Formation is moderately permeable material. In the project area, depending on the season and the local aquifer geometry, there is zero to approximately two metres saturation above the base of the Bassendean Sand. This aquifer will be affected by the mining operations as it contains the mineral sand deposit.

**Table 3: Stratigraphical Sequence in the Serpentine Area**

Age	Strata	
Quaternary	Superficial Formation	Bassendean Sand Guildford Clay
-----Unconformity-----		
Cretaceous	Leederville Formation South Perth Shale Gage Formation	Wanneroo Member Mariginup Member
-----Unconformity-----		
Jurassic	Yarragadee Formation Cattamarra Coal Measures	

In relation to the ASSMP, dewatering of this aquifer during the winter period represents the impact most relevant to the possible generation of acidity. The open pit mining operation will have no direct effect on aquifers in the underlying Leederville and Yarragadee Formation. These aquifers will not be addressed further in the ASSMP.

Mining operations during winter will temporarily lower the groundwater level in and around the active mining cell to the base of the Bassendean Sand unit. The backfilling operation after mining re-saturates the mined profile.

**Table 4: Aquifers in the Serpentine Area**

<b>Aquifer</b>	<b>Geological Formation(s)</b>	<b>Maximum Thickness (m)</b>	<b>Aquifer Type</b>	<b>Thickness of Sand/Sandstone Beds (m)</b>	<b>Salinity (mg/L TDS)</b>
Superficial aquifer	Superficial Formation	15	Unconfined	up to 12	200 – 1,500
Leederville aquifer	Leederville Formation	130	Semi-confined	up to 30	500 – 3,000
Yarragadee aquifer	Gage Formation Yarragadee Formation Cattamarra Coal Measures	1,500	Confined, multi-layer	10 – 100	250 – 3,000

## 2.5 Ground Water

### 2.5.1 Superficial Aquifer

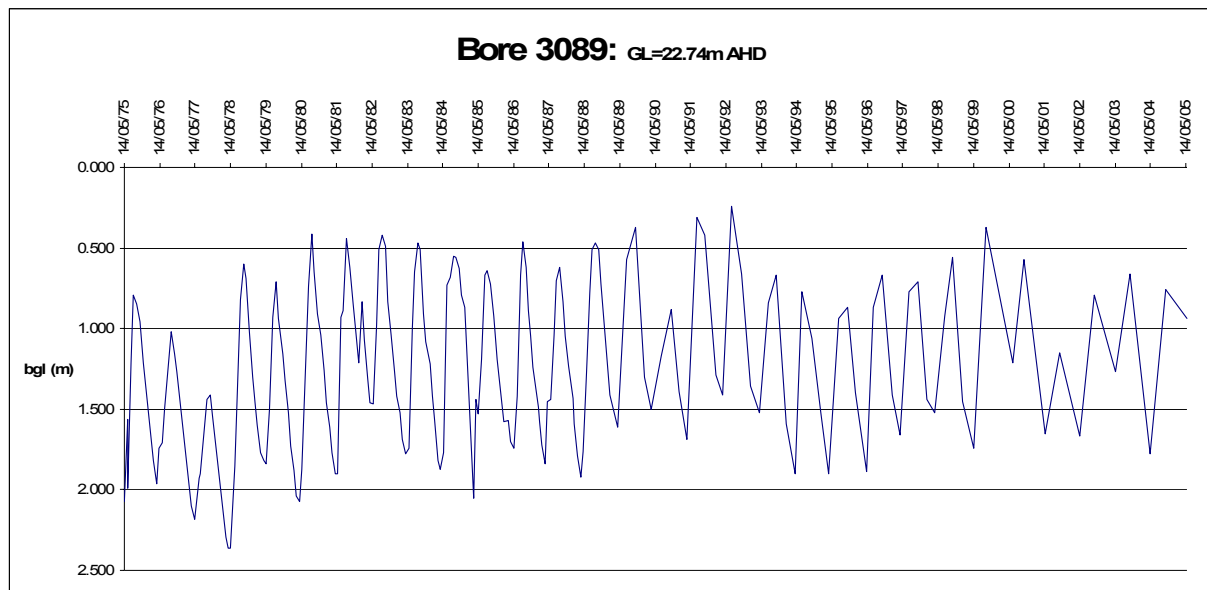
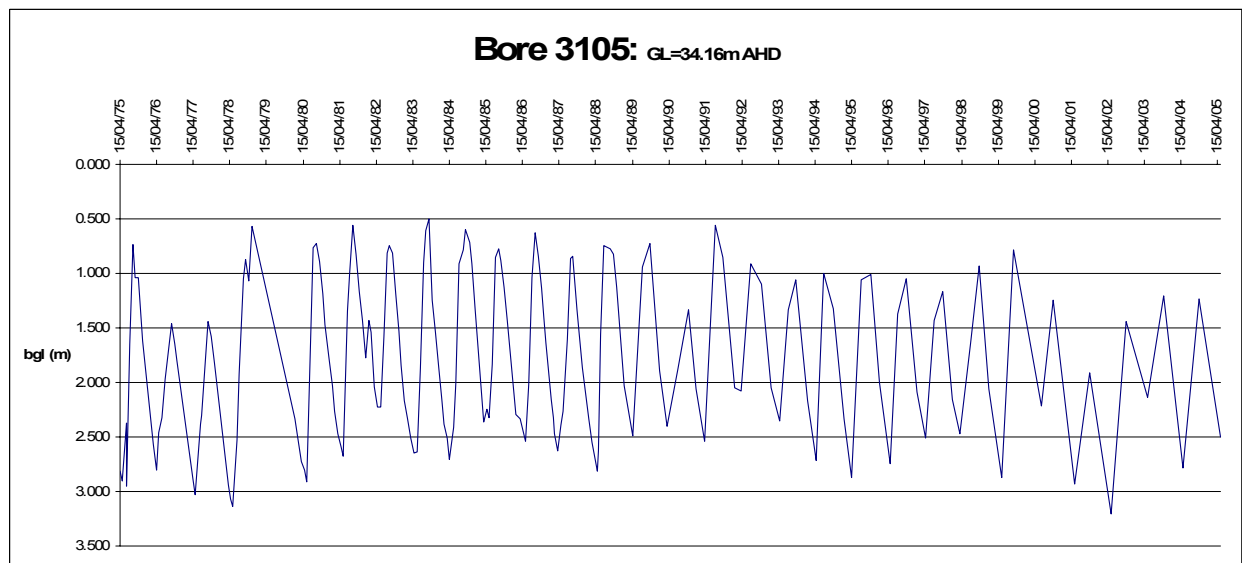
An unconfined aquifer averaging approximately 12 metres thick occurs beneath the Serpentine area within the Superficial Formation. The lithological log from a Department of Water (DoW) monitoring bore (WIN ID 3111) indicates that here the upper four metres of the Superficial Formation consists of Bassendean Sand; a fine to coarse-grained, poorly-sorted quartz sand, with common heavy minerals in the lower two metres.

Information on the four DoW monitoring bores, referred to as the Lake Thompson monitoring bores, located around the project site is presented in Table 5. They were constructed in 1975 and have recorded water levels since that time.

Data from two Lake Thompson Superficial Formation monitoring bores near the mine site indicating water levels ranging from 0.35 metre below ground level in winter to 3.2 metres below ground level in summer is shown in Chart 1 and Chart 2.

**Table 5: Lake Thompson Monitoring Bores**

<b>Name</b>	<b>WIN Site ID</b>	<b>Location</b>	<b>Drilled Depth (m)</b>
T610	3089	Hopelands Road (west side of project)	22
T670	3098	Readhead Road (south side of project)	15.5
T570	3105	Elliott Road (north side of project)	22
T620	3111	Westcott Road (east side of project)	24

**Chart 1: Lake Thompson Monitoring Bore 3089****Chart 2: Lake Thompson Monitoring Bore 3105**

## 2.6 Surface Hydrology

At a regional level, all of the surface drainage ultimately flows to the Peel-Harvey estuary. Streams from the Darling Scarp and foothills flow through the project area. All surface drainage through the project area is ephemeral. Creek lines and damp lands in the area dry out over the summer months.

The project area and surrounds are characterised by low relief topography that becomes flatter and increasingly poorly draining westward from the Scarp. In the pastured areas, most of the low-lying areas, creeks and wetlands have been cleared and drained.

### 3.0 ACID SULFATE SOILS

#### 3.1 Definitions

ASS is the common name given to naturally occurring soil and sediments containing iron sulfides. These naturally occurring sulphides are generally formed under anaerobic conditions such as swamps and estuarine sediments. Although benign in their natural state, when exposed to air they oxidise and produce sulphuric acid, iron precipitates, and concentrations of dissolved heavy metals such as aluminium, iron and arsenic (Planning Bulletin Western Australia Number 64, WA Planning Commission, November 2003). For a full list of impacts see the WA Planning Commission Bulletin Number 64 as well as other government publications covering ASS listed in Section 3.2.

ASS materials include both Actual Acid Sulfate Soils (AASS) and Potential Acid Sulfate Soils (PASS). AASS are Acid Sulfate Soil materials that have been previously oxidised. PASS are Acid Sulfate Soil materials that have not been oxidised, but have the potential to produce acid when oxidised.

Identification of AASS and PASS materials is based on results from two field tests:

- $pH_F$  is the field pH of the soil, measured on a 1:5 soil to water paste.
- $pH_{FOX}$  is the pH of the soil after oxidation with hydrogen peroxide solution.

AASS soils are characterised by  $pH_F$  values of  $<4$ .

PASS samples are typically neutral to alkaline, but react with peroxide to produce free sulphuric acid.  $pH_{FOX}$  values for PASS materials are usually  $<3$ .

It is important to note that whilst a useful exploratory tool, soil field  $pH_F$  and  $pH_{FOX}$  tests are indicative only and cannot be used as a substitute for laboratory analysis to determine the presence or absence of ASS. Recent review of field  $pH_F$  and  $pH_{FOX}$  tests in Western Australian soils indicates that these tests provide an accurate identification of ASS in only 60% to 80% of cases and are capable of providing both false positives and false negatives (i.e. may underestimate or overestimate acid-generating potential).

#### 3.2 Relevant Standards and Guidelines

The following documents were used in the preparation of this ASSMP.

- *Preparation of Acid Sulfate Soil Management Plan (ASSMP)*. DER Acid Sulfate Soils Guideline Series, April 2003.
- *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes*. DER Acid Sulfate Soils Guideline Series, May 2009.
- *General Guidance on Managing Acid Sulfate Soils*. DER Acid Sulfate Soils Guideline Series, August 2003.
- Western Australian Planning Commission (WAPC) *Planning Bulletin No. 64. Acid Sulfate Soils*. (November 2003).

#### 3.3 Desktop Study

The WAPC (2003) Bulletin 64 provides broad scale mapping of the ASS risk status of the Swan Coastal Plain. An extract from the Bulletin 64 maps which also shows the lot numbers of properties included in the project area is provided as Figure 4. The ASS map from

Planning Bulletin 64 shows the project area as low to moderate risk of acidity, with two small areas shown as high risk. A larger high risk site, partially located on Lot 63 is outside the project area and will not be disturbed. The high risk mapped areas correspond to B4 unit of Table 2.

Within the project area, the available information indicates there are three separate zones, each with different potential to generate ASS (Figure 5). These are described in Table 6.

**Table 6: Zones of ASS Generating Potential**

Zones	Risk Level	Description
Zone 1	Very low	The elevated Bassendean Dunes permanently above the highest water table level. Dry mining will always occur in this zone. Mining will occur in this zone.
Zone 2	Low to moderate	The profile between Zones 1 and 3. This zone represents the zone of annual water table fluctuation. This comprises the lower 1.5 to 2 metres of the Bassendean sand profile. The interface of the Bassendean Sand and Guildford Formation represents the floor level of the open pit and the general level of the summer water table. Dewatering of the mine pit will need to occur in this zone during winter.
Zone 3	High	The profile three metres or more below ground level in the flat part of the mine area. This zone is generally one metre below the pit floor and into the Guildford Formation, comprising sandy clay, gravels and iron stone (coffee rock). This zone will not be impacted by the operation as no mining will occur in this profile.

### 3.4 Site Specific ASS Surveys

Two site specific ASS surveys were undertaken as part of baseline environmental surveys for the Keysbrook project. These were discussed in Sections 5.4.1 and 9.4 of the PER and the initial 2005 survey included as Appendix 2.

A summary of the findings of both surveys are provided in the following subsections to provide context for the site risk of ASS.

#### 3.4.1 Initial 2005 Survey

An initial survey was undertaken in 2005 over a range of different soil types, focusing on the identified high risk sites as mapped in WAPC Bulletin 64 and on low-lying landforms that are the most likely sources of PASS. Results for laboratory analysis of the samples collected are presented in Appendix 1. The results indicated PASS occurrence across the general area is as described in the WAPC Bulletin 64 maps, of low to moderate risk, with most results less than half the Action Criteria (Table A1 in Appendix 1).

The assessment of the two high risk sites shown in the WAPC Bulletin 64 maps demonstrated that they were not high risk sites, with Titratable Peroxide Acidity (TPA) levels generally a quarter to a half of the action criteria. An additional sampling program was

undertaken to provide more detailed results on these two areas (Table A2 in Appendix 1). The results of the additional sampling program were consistent with the first assessment and confirmed the low to moderate risk status of these sites.

### 3.4.2 Follow Up 2007 Survey

Further field assessment sampling for ASS was undertaken in February 2007 at locations shown in Appendix 2. Eighteen holes were drilled to depths of up to 4.6 metres, using a Geoprobe Macro-core. The results of the sampling program are consistent with the previous assessments and confirm the general low to moderate risk status of the site.

Soil samples were tested in the field for field pH ( $pH_F$ ) and pH after oxidation ( $pH_{FOX}$ ). The complete results of both field testing and laboratory analysis of selected samples are presented in Appendix 2. Results indicated PASS occurrence is of low to moderate risk.

Sixteen samples were selected and submitted for laboratory analysis. This confirmed that three samples, in two separate holes, exceeded the target values for sand presented in Section 5. Comparison with the geological database confirmed the elevated result for Hole 10 at 1.9 metre depth is below the base of the pit floor at this location. The result for Hole 8 at 2.4 metres depth is within the mine profile, however the TPA value measured is only just above the Action Criteria.

## 4.0 POTENTIAL ENVIRONMENTAL IMPACTS

Mining within an area in which ASS materials exist can result in acidic drainage from either AASS materials or oxidation of PASS materials. Acidic drainage from soil can result in adverse effects on groundwater, surface water quality, mining infrastructure, environmental values and the success of post-mining rehabilitation.

Oxidation of ASS materials at Keysbrook can occur by either:

- Exposure of ASS materials in soil stockpiles to air.
- Lowering of the water table to allow exposure of ASS materials previously located in an anaerobic environment to air.

The potential environmental impacts associated with the proposal are:

- The effect dewatering the Bassendean Sand profile during the winter will have on activating potential acidity in the sand profile to be mined.
- The effect dewatering the Bassendean Sand profile has on activating potential acidity in the underlying Guildford Formation.
- The effect dewatering the Bassendean Sand profile within the open pit has on adjacent land.

## 5.0 TRIGGER SETTING (ACTION CRITERIA)

### 5.1 Soil

Although Western Australia was the first Australian state to recognise the impact of disturbance of ASS, most of the recent research into ASS has been conducted in Queensland and New South Wales. The Western Australian DER has adopted Action Criteria adopted by Queensland regulators based on the recommendations provided by Ahern *et al.* (1998).

These Action Criteria are based on the sum of existing plus potential acidity. Different values have been established for different soil types, depending on the texture or clay content of the soil.

Target Level:	Less than 18 moles $H^+$ /tonne (0.03%S).
Limit:	No sample shall exceed 25 moles $H^+$ /tonne (0.04%S).
Trigger Level:	<p>If any sample exceeds 18 mol <math>H^+</math>/tonne, then the average of any six consecutive samples (including the exceeding sample) shall have an average content not exceeding 18 moles <math>H^+</math>/tonne (0.03%S).</p> <p>If more than one sample in every six consecutive samples exceed 25 moles <math>H^+</math>/tonne, then the average of any six consecutive samples (including the exceedance sample) shall have an average content not exceeding 18 moles <math>H^+</math>/tonne (0.03%S).</p>

The Target, Limit and Trigger levels have been applied to a monitoring and response strategy which is detailed below.

### 5.2 Water

Interim trigger levels have been developed in consultation with DER for the project. These are:

- Total Titratable Acidity >60 milligrams per litre (as  $CaCO_3$ ).
- pH variance >10% acid trend (DERreasing pH values) of background levels.

The Environmental Officer is responsible for developing site specific water trigger levels when sufficient data becomes available to assign statistically valid values.

If results from either field testing or laboratory analysis exceed assigned trigger values, the Environmental Officer is responsible for ensuring that management responses provided in Section 7.2 are implemented.

## 6.0 MANAGEMENT AND MITIGATION MEASURES

The principal strategy to manage ASS and acid drainage issues at Keysbrook will be to:

- Identify ASS risk areas
- avoid disturbance of these soils where practicable, and
- where ASS material is excavated, treat risk areas to manage soil pH and buffer against acidification of soils.

Mitigation strategies will involve:

- Minimising exposure of AASS materials to the atmosphere by storage beneath the water table.
- Use of acid neutralising materials to prevent production of acid drainage.
- Use of acid neutralising materials to treat acidic waters.

These strategies are described in more detail in the following sub sections.

### **6.1 Visual Checks**

MZI shall complete regular (generally daily) checks within the mining area to identify pyrite and marcasite in ore by way of visual observance when panning. Should suspect material be identified, the Site Manager will commence a process to isolate the area from disturbance, undertake pH<sub>F</sub> and pH<sub>FOX</sub> field testing and determine whether the material shall be mined or avoided.

### **6.2 Soil Survey**

The Environmental Officer will ensure that monitoring of soil pH is regularly undertaken within the active mining area.

The Environmental Officer will communicate results of the soil survey to the Site Manager who shall then ensure the treatment of applicable production streams and excavations is undertaken.

### **6.3 Water Table Management**

The mineralised profile is confined to the Bassendean Sand. The underlying clay layers in the Guildford Formation will not be disturbed. In summer, the pit floor will be above the water table however collection of groundwater flowing into the mine pit will be required during winter.

Dewatering of the mine pit will be achieved via drains on the pit floor directing inflow water to collection sumps (i.e. passive means). This type of pit dewatering will have minimal effect on the profile below the pit floor. It is the profile one metre below the pit floor that is accepted as the most likely source of ASS. Oxidation of this material due to dewatering is unlikely as this material shall not be excavated and will likely remain saturated.

### **6.4 Lime Treatment**

Buffering of any acidity generated above the established trigger levels for either soil or groundwater will occur through;

- The addition of ground lime (CaCO<sub>3</sub>) into the process tails that returns with the mine void (washed quartz sand and clay fraction) as backfill.
- The application and incorporation of lime directly to disturbed areas.

The Environmental Officer is responsible for regularly reviewing monitoring data to determine if relevant soil or groundwater trigger criteria are being exceeded or not. The Environmental Officer is responsible for advising the Site Manager when lime treatment is required.

The Site Manager is responsible for ensuring that sufficient lime supplies are maintained on site to allow addition when monitoring results indicate it is required.



The Site Manager is responsible for ensuring lime is added in sufficient quantities to process water being used to return waste materials to the pit. The rate of lime addition will be calculated on the net acidity of the identified soil profile and include a safety factor of two. The quantity of lime added will be calculated to reduce the net acidity to levels below the trigger levels stated in Section 5.

## **6.5 Assay Review**

MZI will undertake regular assay of its HMC and Leucoxene products. MZI will monitor trends in reported Sulfur to reconcile against acid sulphate risk areas that have been identified. This information may then be used to assess lime application and improve rehabilitation.

## **6.6 Monitoring Programs**

Preliminary assessment of soil generally showed that the predominantly low/medium risk mapping of the Project Area was accurate on a broad scale. 2007 sampling showed that within the ore zone, a single sample exceeded the Target Level of 18 moles  $H^+$ /tonne (0.03%S), recording 19 moles  $H^+$ /tonne (0.03%S). Additional monitoring shall be undertaken during mining to ensure that ASS risk is identified and managed to avoid residual environmental impacts.

### **6.6.1 Soil Sampling**

During the mining process, regular soil sampling shall be undertaken to monitor ASS risk. As part of Operational activities, MZI will undertake soil sampling of Ore, Tails and Mine Pit Floor material and undertake field pH testing of this material.

The ore body is typically homogenous and characterised by yellow or grey sands. Sampling shall target the Low to Moderate Risk zone identified in Figure 5. Where multiple horizons are present within the Low to Moderate Risk zone, sampling shall be applied to each additional horizon.

#### **6.6.1.1 Ore Sampling**

A single soil sample per horizon shall be taken routinely each week to confirm the ASS risk of the ore body at the current mining location. It is in the seasonally saturated Low to Moderate Risk zone that sampling shall be targeted. Ore samples shall be field tested according to the Procedure below.

#### **6.6.1.2 Tails Sampling**

A soil sample shall be taken from the tails discharge stream each week. Assessment of the tails shall be undertaken to verify that the backfill material is suitably low risk material that will not acidify. Tails samples shall be field tested according to the Procedure below.

#### **6.6.1.3 Mine Void Floor Sampling**

A sample shall be taken from the mine pit floor each week to determine whether AASS material has been exposed. This sample shall be tested for AASS by completing a  $pH_F$  test. A  $pH_F$  result of less than or equal to 4.0 will verify the presence of AASS. In this situation the Site Manager shall;

- ensure that lime is applied to the exposed base of the mine void prior to backfilling. This will ensure the neutralisation of any acidification, and

- where practicable, manage dewatering activities in the void to maintain a saturated condition of the mine void basement.

#### **6.6.1.4 Field Test Procedures**

Soil samples taken from the ore body and the tails stream shall be field tested for  $\text{pH}_F$  and  $\text{pH}_{FOX}$ . The procedure for conducting field tests for  $\text{pH}_F$  and  $\text{pH}_{FOX}$  is described in Appendix 1 of the *Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes* Guidelines (DER 2009). Personnel involved in field testing must be made aware of the hazardous nature of the hydrogen peroxide reagent and wear appropriate personal protective equipment.

A brief description of each soil profile including soil texture, grain size, roundness, sorting, colour (using a Munsell colour chart), mottling, organic matter, moisture content, water table level and other diagnostic features (e.g. jarosite, shell fragments).

#### **6.6.1.5 Criteria for Selection of Samples Requiring Laboratory Analysis**

Ore and tails samples shall be subject of laboratory testing should field test results indicate AASS or PASS characteristics.

The Environmental Officer is responsible for ensuring that samples requiring laboratory analysis to verify the presence of AASS or PASS materials will be identified by:

- A  $\text{pH}_F$  value of less than 4.5 to verify suspected presence of AASS materials.
- A difference between  $\text{pH}_F$  and  $\text{pH}_{FOX}$  of greater than 3.0 verify suspected presence of PASS materials.

Samples requiring laboratory analysis are required to be placed in a plastic snap-lock bag with exclusion of air and then transferred to a field freezer or an esky with sufficient ice to keep the samples cool for at least 24 hours. The Environmental Officer is responsible for ensuring that samples requiring analysis are submitted to a NATA accredited laboratory within 24 hours. All samples submitted to the laboratory require testing by the  $S_{Cr}$  method.

The Environmental Officer is responsible for ensuring that all samples are carefully marked using a waterproof pen for easy identification and kept out of direct sunlight.

The Environmental Officer is responsible for ensuring that samples not submitted for laboratory testing are frozen and retained until the ASS assessment is complete.

### **6.6.2 Groundwater Monitoring Program**

The Environmental Officer is responsible for implementing the groundwater monitoring program to determine whether mining operations are having measurable effects on groundwater level and water quality.

#### **6.6.2.1 Monitoring Locations**

The groundwater monitoring program with respect to determining ASS impacts will include fortnightly assessment of field measurements from three key sampling locations defined below:

- Sampling Location 1 is groundwater inflow collected by the drainage system in the active mine pit(s), and represents existing groundwater quality (the 'before' state).

- Sampling Location 2 is process water recovered by the drainage system in the mine pit(s) as backfilling occurs and represents the water quality after it has been through the process (the 'after' state).
- Sampling Location 3 is from the Process Water Dam. This water includes water sourced from the Leederville bores and represents the 'average' water quality from all sources on site.

As the position of the active and backfilled pits will change during the course of the project, the actual location of Sampling Locations 1 and 2 will also change. The Environmental Officer will assign unique monitoring location names as the monitoring program is implemented.

#### **6.6.2.2 Groundwater Quality**

The groundwater monitoring program relating to ASS management is as follows:

- pH, EC and Total Titratable Acidity (TTA) will be monitored in the field fortnightly at the two sampling locations for each pit and the Process Water Dam as defined in Section 6.6.2.1.
- Groundwater samples will be collected quarterly from all monitoring bores. These will be submitted to a laboratory to be analysed for total acidity, total alkalinity, pH and EC, Fe, Mn, Cl, SO<sub>4</sub> and Al to assess potential impacts from ASS disturbance. Further details are provided in the Water Management Plan (MBS 2010).

#### **6.6.2.3 Groundwater Level**

The Environmental Officer is responsible for ensuring groundwater levels are monitored Monthly from all monitoring bores as described in the Water Management Plan.

### **6.7 Data Review and Reporting**

The Environmental Officer will be responsible for ensuring that all laboratory ASS soil assessment and water quality results are reviewed within one week of receipt. The review of groundwater quality results will allow determination of whether or not mining operations are responsible for long term changes in groundwater quality.

If review of groundwater monitoring results indicates acidification of groundwater or soil is occurring, they shall notify the Site Manager immediately.

The General Manager is responsible for ensuring OEPA is advised immediately in the event of any indication of acidification of soil, groundwater or surface water at Keysbrook.

## **7.0 MANAGEMENT RESPONSE**

### **7.1 Soil**

If unexpected soil materials are encountered in the mining operations or a need arises to stockpile suspected ASS materials, the Site Manager is responsible for ensuring the contingency plan outlined below is implemented.

- Where field testing of the mine void basement shows a pH<sub>F</sub> value of less than or equal to 4.0 the Site Manager shall ensure that lime is applied to the base of the mine void prior to backfilling.

- Where the trigger of 25 moles  $H^+$ /tonne (0.04%S) is reached, further soil testing shall be undertaken by sampling the ore zone in 6 locations immediately ahead of the Mining face. The soil samples shall be field tested and submitted to for further  $S_{Cr}$  testing if they report:
  - A  $pH_F$  value of less than 4.5, or
  - A difference between  $pH_F$  and  $pH_{FOX}$  of greater than 3.0.
- If the field testing results do not trigger the threshold for additional laboratory  $S_{Cr}$  testing Operations shall revert to routine monitoring and management.
- If additional testing is required, the results shall be assessed against the Trigger Criteria.
- If any sample exceeds 25 mol  $H^+$ /tonne and the average of the six samples (including the exceeding sample) has an average content exceeding 18 moles  $H^+$ /tonne (0.03%S), the Site Manager shall ensure that crushed lime is added to the tails stream and/or tail discharge in suitable quantities as to buffer the material against acid generation.
- Depending on the size, location and quantity of ore contained within the high risk area, the Site Manager will determine whether the site is to be avoided (and adjust the future mine plan accordingly) or to proceed with mining the area and provide sufficient lime treatment through the process plant to buffer any potential acidity from this material. The lime treatment process is detailed in Section 6.4.
- Upon identifying tailings indicating exceedance of 25 moles  $H^+$ /tonne (0.04%S), the Site Manager will ensure:
  - The monitoring results are reported to the OEPA within seven days.
  - Details of the management measures proposed to be implemented to address the exceedance are submitted to the Contaminated Sites Branch within seven days.
  - The management measures proposed to address the exceedance are implemented.
- If extended exposure to air cannot be avoided, samples suspected of containing PASS material from the results of the field test will be collected by the Environmental Officer and submitted to a NATA accredited laboratory for analysis by the  $S_{Cr}$  procedure. Criteria for selection of samples for laboratory testing are described in Section 6.6.1.5.
- The effectiveness of the remedial procedures will be assessed by the Site Manager and Environmental Officer through additional field testing. A second application of neutralising material may be required if the Action Criteria specified in Section 5 are exceeded.

The management flow process is shown in Figure 6,7and 8.

## 7.2 Groundwater

If results from fortnightly field tests or quarterly groundwater quality monitoring trigger any of the Action Criteria defined in Section 5.2, the Site Manager is responsible for ensuring the contingency plan outlined below is implemented.

- The Environmental Officer will advise MZI Management immediately of the issue.
- Additional water samples will be collected and analysed to confirm the original results and identify the source of contamination.
- The Site Manager will confirm that sufficient lime has been added to neutralise acidity and increase the dosage rate if required.

- The Site Manager will increase the groundwater level by pumping water from the Leederville aquifer production bores to ensure that all PASS material is below the water table where feasible.

## 8.0 RECORDS, REVIEW AND REPORTING

The Environmental Officer is responsible for ensuring that the ASSMP is reviewed annually and amended if necessary to ensure that it remains relevant, practical and effective.

The Environmental Officer is responsible for ensuring that all results for soil and groundwater monitoring undertaken in the year are included in MZI's Annual Environmental Report (AER) for DER. The AER will also present the findings from any ASS related investigations resulting from exceedence of relevant trigger levels. The report will propose any amendments to the ASSMP.

The Site Manager shall ensure all records are kept in accordance with the site document control procedure. Records relevant to this Management Plan that shall be maintained include the items listed in Table 7.

**Table 7: ASS Record to be Kept at Keysbrook**

Record	Responsibility
Results of water monitoring	Environmental Officer
Results of ASS sampling	Environmental Officer
Lime usage: <ul style="list-style-type: none"> <li>– Volume</li> <li>– Date</li> <li>– Location</li> </ul>	Site Manager
Locations of PASS ore & topsoil stockpiles	Site Manager
Non-compliance Reports	Site Manager

## 9.0 RESPONSIBILITIES

### 9.1 General Manager

The General Manager is responsible for the following:

- Ensuring the project has adequate resources to meet the requirements of this Management Plan.
- In consultation with the Site Manager, determining areas of PASS to be managed.

### 9.2 Site Manager

The Site Manager is responsible for the following:

- Recording topsoil removed and stockpiled in the Topsoil Stockpile Register.
- Ensuring earthworks operators are appropriately trained and competent to operate the machinery, and have been informed of the conditions of clearing and locations of any environmentally significant sites.

- Regularly inspect excavation activities..
- Ensuring PASS material is managed in accordance with this Management Plan.
- In conjunction with the Environmental Officer, assess the effectiveness of contingency actions.
- Ensuring that sufficient lime supplies are maintained on site to allow addition when monitoring results indicate it is required.
- Ensuring that lime is crushed or ground.
- Ensuring ground lime is added in sufficient quantities to process water being used to return waste materials to the pit. The rate of lime addition will be calculated on the net acidity of the identified soil profile and include a safety factor of two. The quantity of lime added will be calculated to reduce the net acidity to levels below the trigger levels.
- Providing relevant training and awareness to all site employees and contractors to ensure they comply with the requirements of this Management Plan.
- Reviewing and approving ASS management information presented in the AER.
- Ensuring investigations into non-compliance with this plan are conducted.
- Ensuring management actions are put in place if Action Criteria are exceeded.
- Ensuring non-compliance with this Management Plan are rectified and reported to the relevant authorities.

### 9.3 Environmental Officer

The Environmental Officer is responsible for:

- Ensuring the site induction contains information regarding ASS.
- Ensuring appropriate ASS surveys are undertaken.
- Ensuring regular monitoring is carried out according to the Management Plan.
- Ensuring that water levels in monitoring bores are monitored in accordance with procedures.
- Ensuring that standing water levels and water quality data is reviewed..
- Regularly reviewing monitoring data to determine if relevant soil or groundwater trigger criteria are being exceeded or not.
- Advising the Site Manager when lime treatment is required.
- Ensuring that the management responses are implemented.
- Developing site specific water trigger levels when sufficient data becomes available to assign statistically valid values.
- Ensuring that the ASSMP is reviewed annually and amended if necessary to ensure that it remains relevant, practical and effective.
- Ensuring that all results for soil and groundwater monitoring undertaken in the year are included in MZI's Annual Environmental Report (AER).

## 10.0 REFERENCES

Allen, A.D., 1981. *Groundwater Resources of the Swan Coastal Plain near Perth, Western Australia: in Proceedings of the Groundwater Resources of the Swan Coastal Plain (1981).*

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## 11.0 GLOSSARY OF TERMS

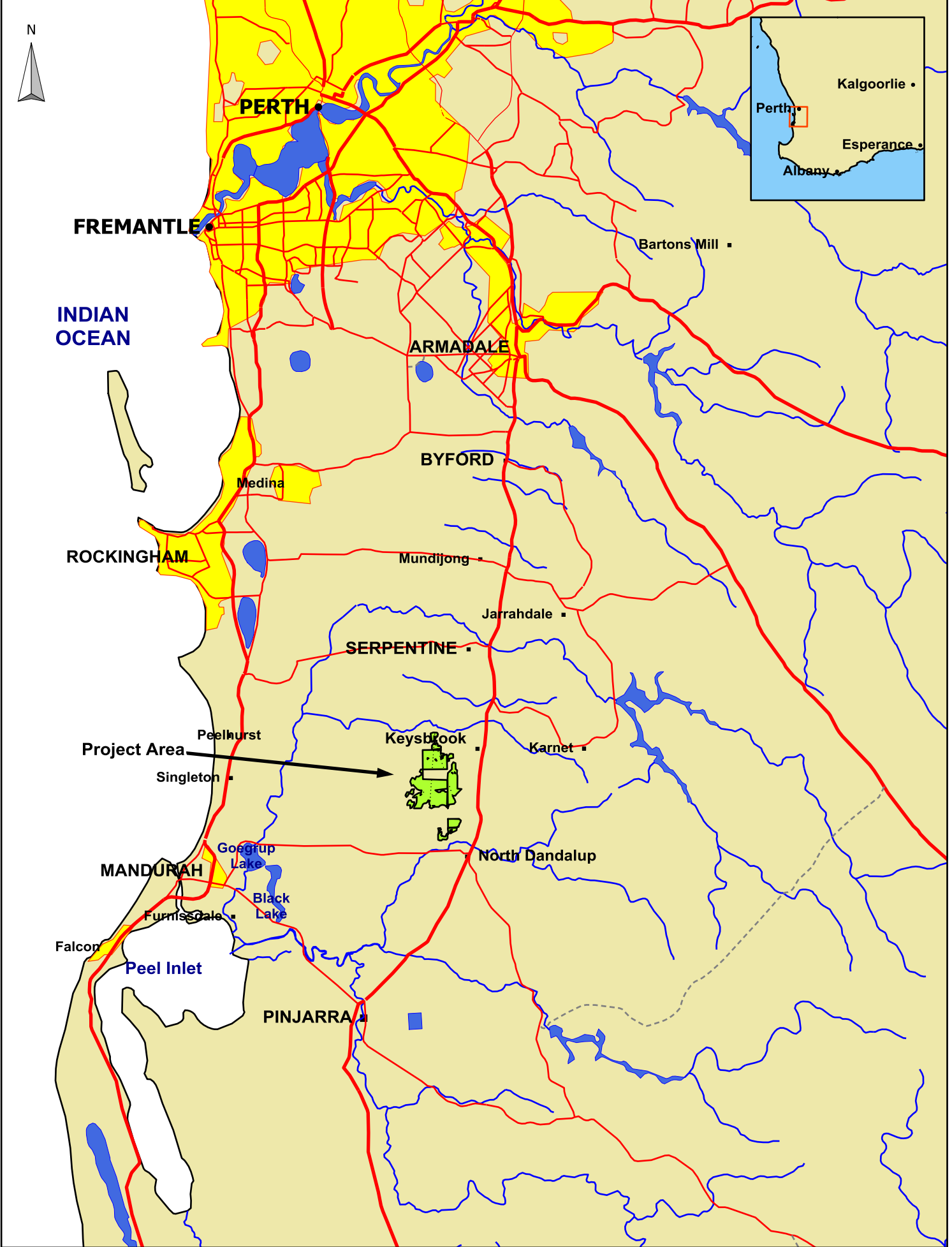
AASS	Actual Acid Sulfate Soils.
ANC	Acid Neutralising Capacity.
ASS	Acid Sulfate Soils.
NATA	National Association of Testing Authorities.
PASS	Potential Acid Sulfate Soils.
pH <sub>F</sub>	pH of a soil paste measured under field conditions.
pH <sub>FOX</sub>	pH of a soil paste measured in the field following reaction with hydrogen peroxide.
pH <sub>KCl</sub>	pH of a soil paste in 1 M KCl measured in the laboratory.
SPOCAS	Suspension Peroxide Oxidation Combined Acidity and Sulfate method.
S <sub>POS</sub>	Peroxide-oxidisable sulphur in soil samples.
TAA	Total Actual Acidity of soil samples.
TPA	Titratable Peroxide Acidity of soil samples.
TTA	Total Titratable Acidity of water samples.






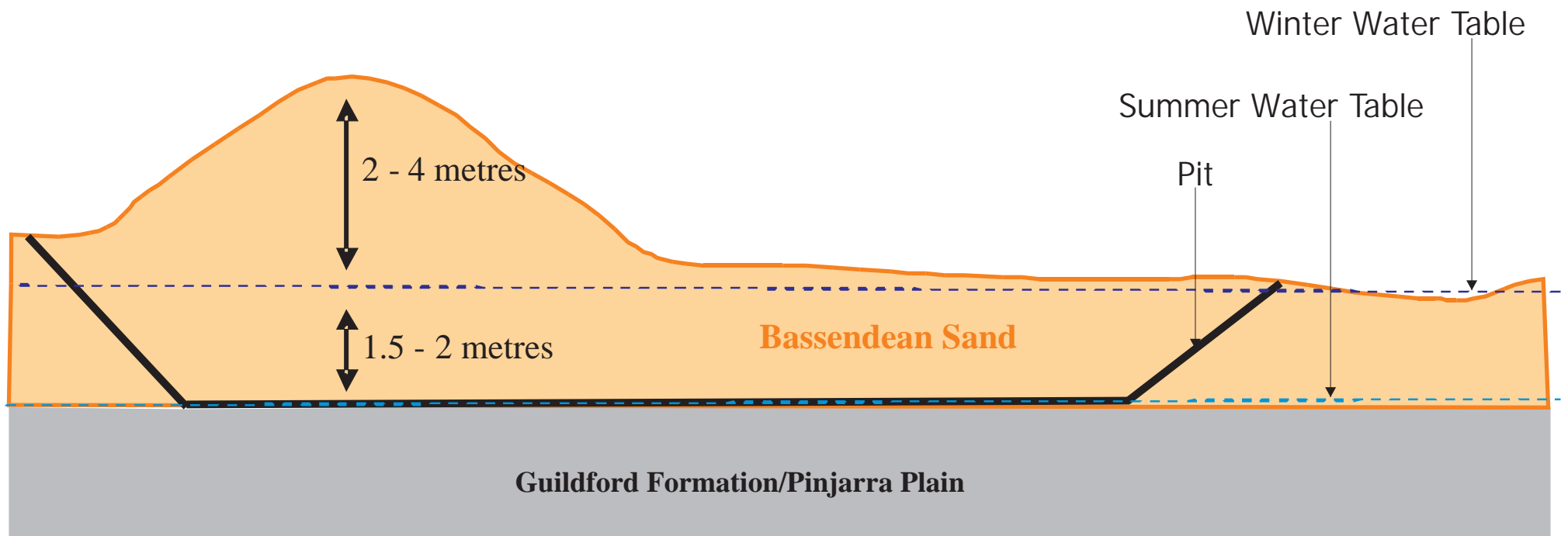
## Figures

**Figure 1: Location of Project**

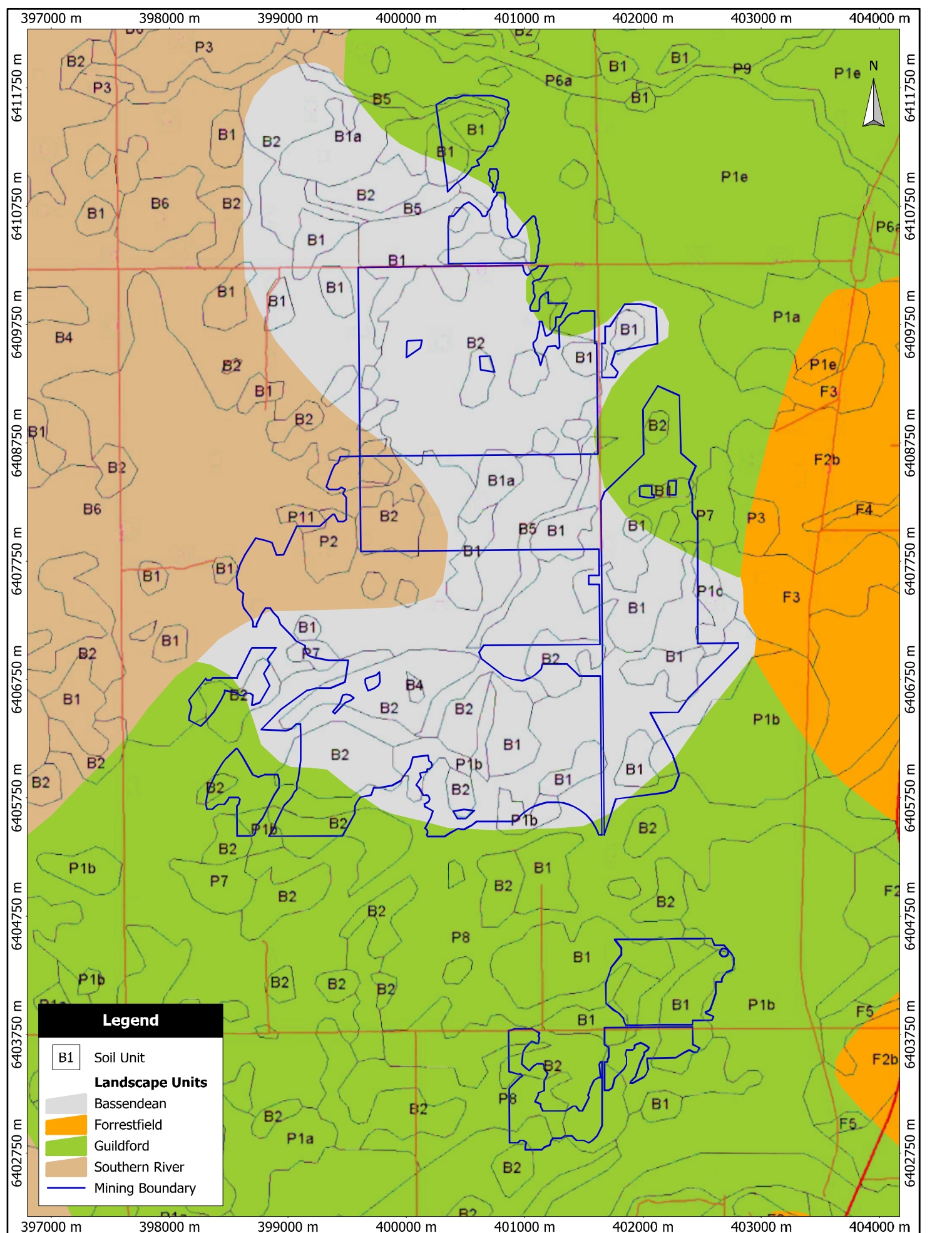


 <b>MBS</b> ENVIRONMENTAL	Environmental + Water Resource Consultants  4 Cook St West Perth WA 6005 Telephone: + 618 9226 3166 Facsimile: + 618 9226 3177 info@mbsenvironmental.com.au	Scale 1:400000 Original Size: A4  0 10 km	Matilda Zircon Limited Keysbrook Mineral Sands Project	Location Plan
				Figure 1

**Figure 2: Cross Section of Mine Pit**

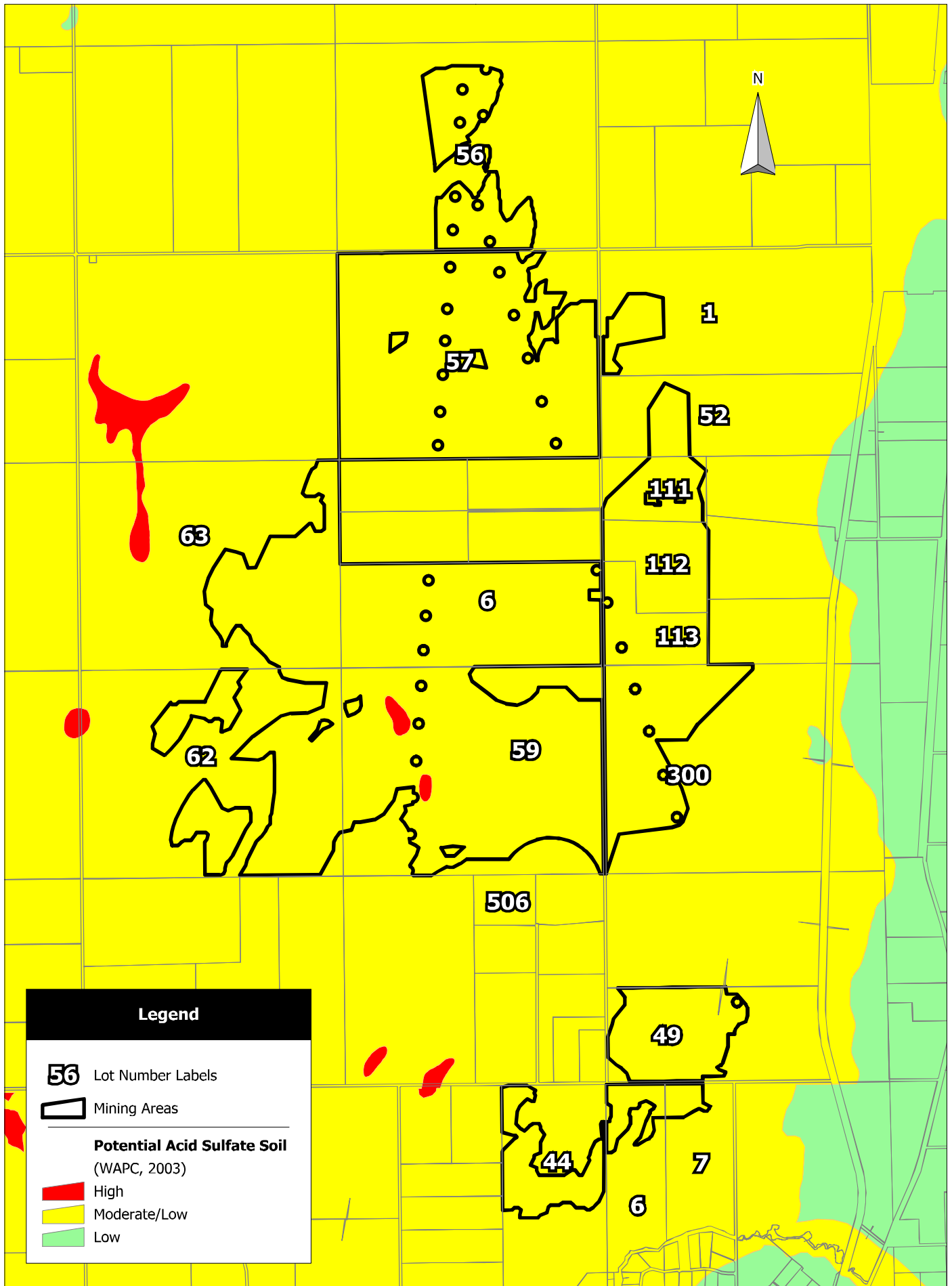


**Figure 3: Soil Units in the Project Area**



**Figure 4: WAPC Potential Acid Sulfate Soil Risk Areas Within Keysbrook Mineral Sands**





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info@mbsenvironmental.com.au

Scale: 1:40000  
Original Size: A4  
Grid: Australia MGA94 (50)

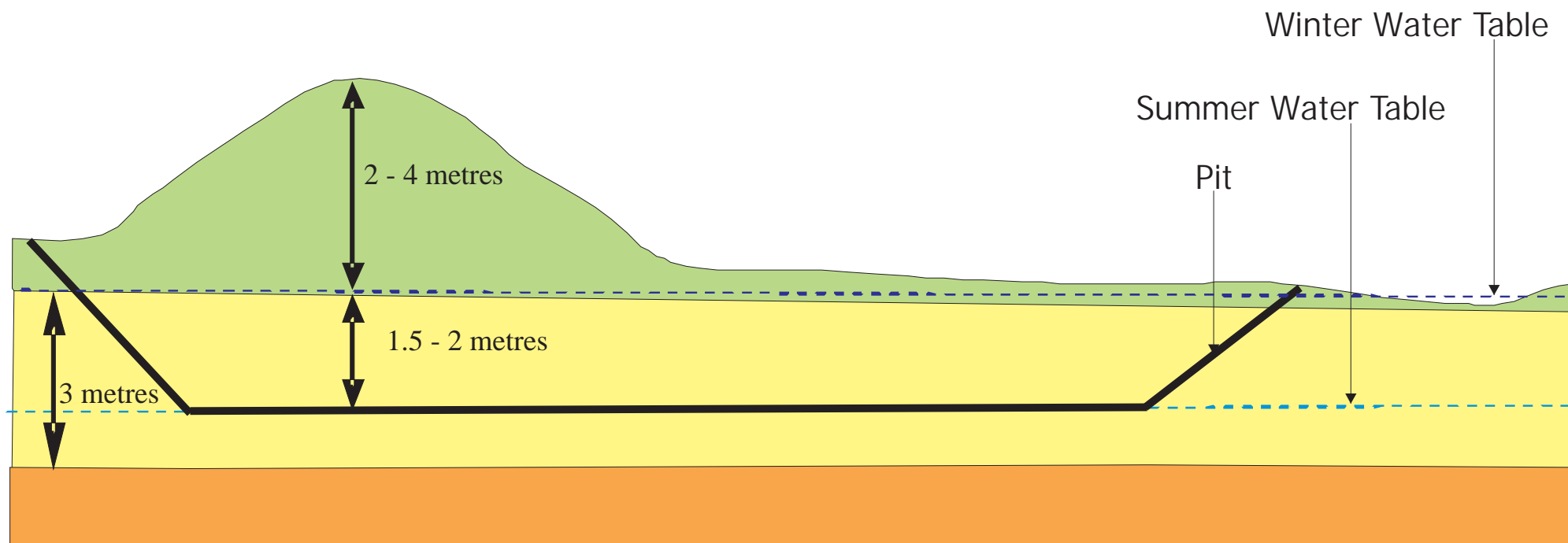
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Matilda Zircon Limited  
Keysbrook  
Mineral Sands Project

WAPC Potential Acid Sulfate  
Soil Risk Areas Within  
the Project Area

**Figure 4**

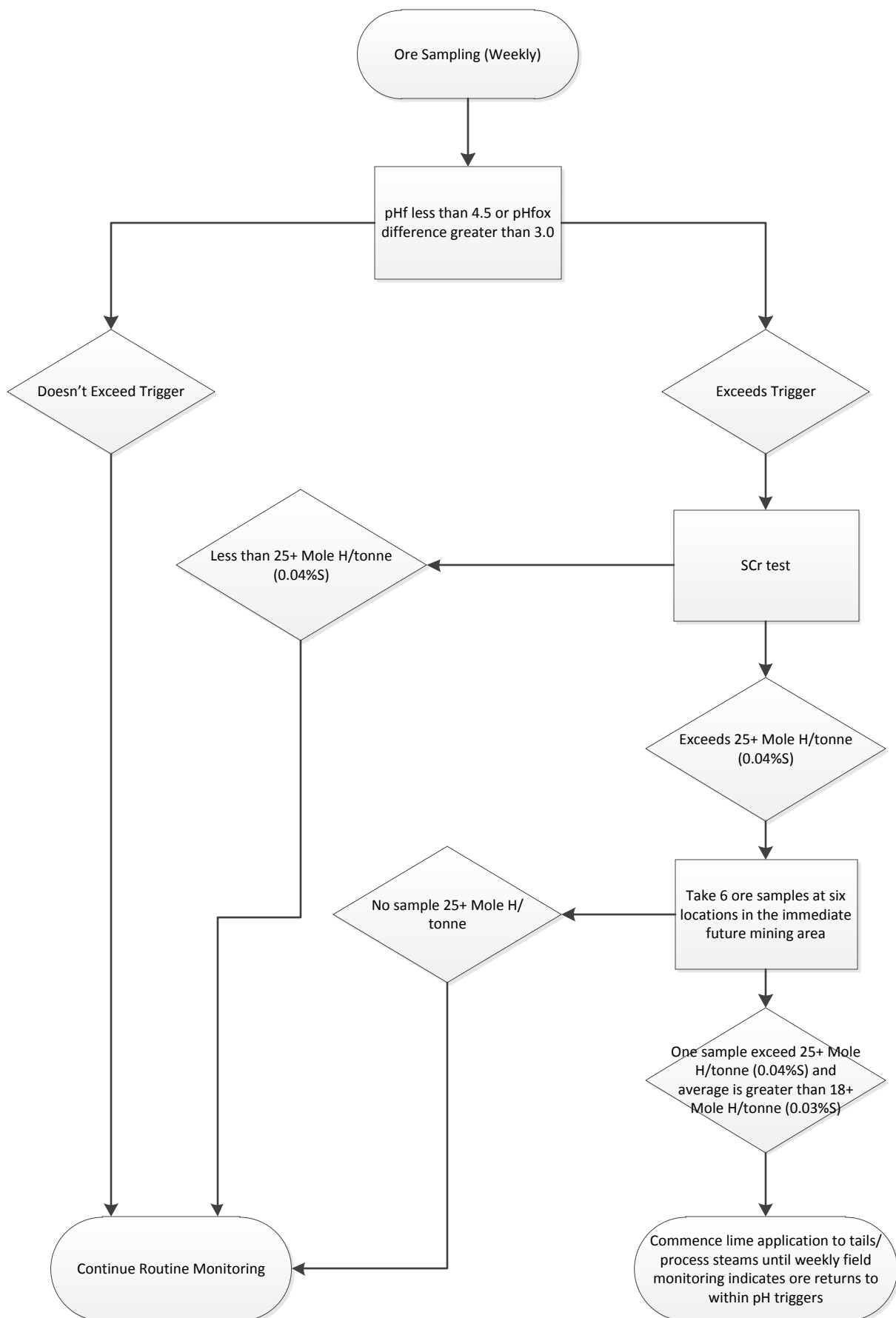
**Figure 5: PASS Zones Within the Mine Pit**



- Zone 1: Very Low Risk
- Zone 2: Low - Moderate Risk
- Zone 3: High Risk

not to scale

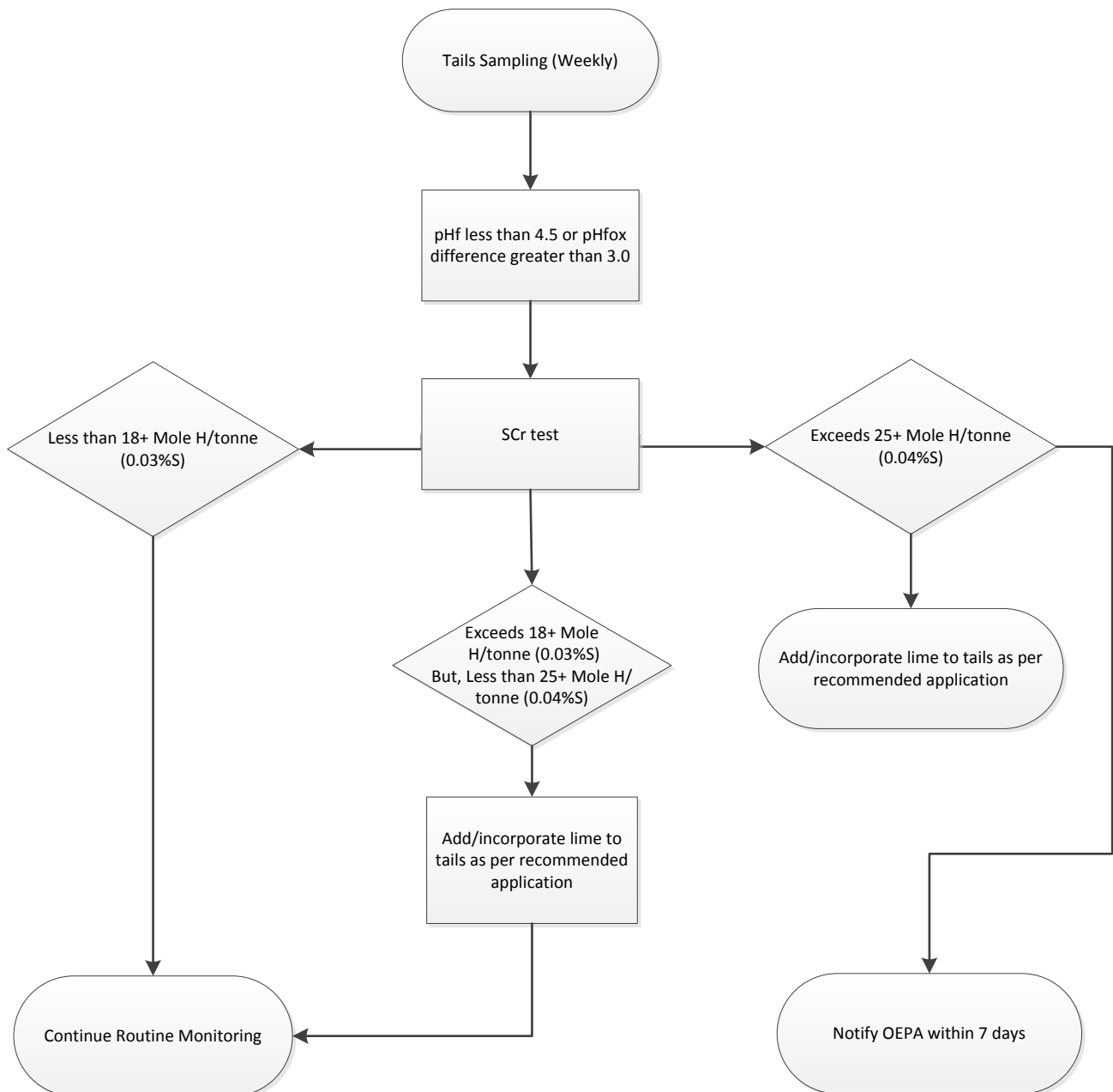
**Figure 6: Ore Sampling Management Process**



**Figure 7: Tails Sampling Management Process**

# TAILS SAMPLING

August 2014

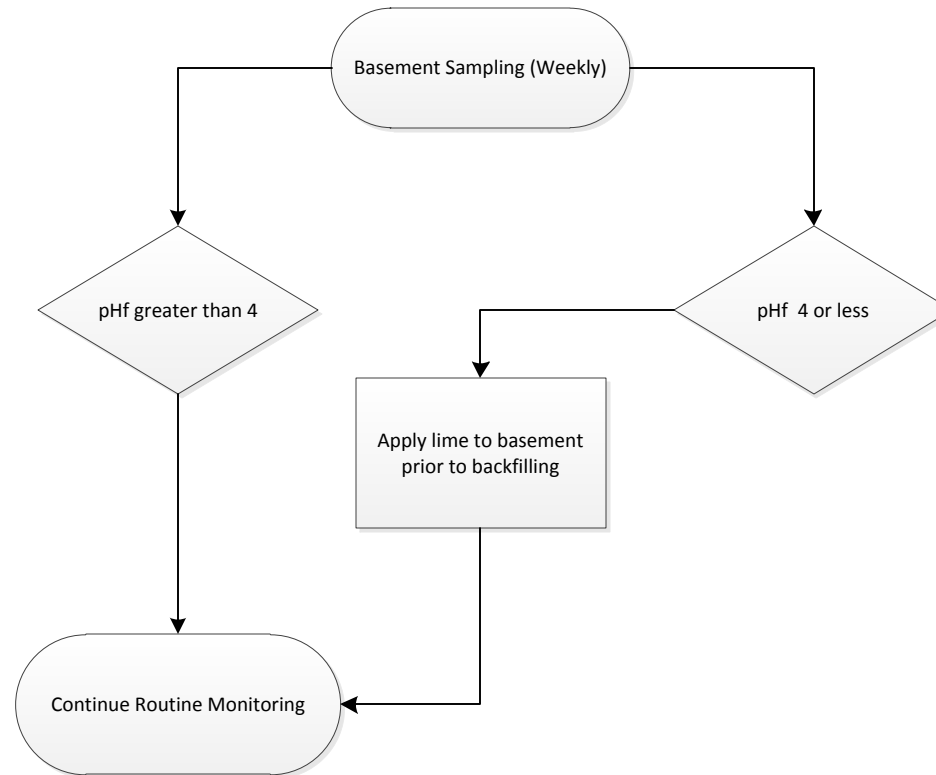


**Figure 8: Mine Void Basement Sampling Management Process**



# Basement Sampling

August 2014



## **APPENDICES**

**APPENDIX 1:**  
Acid Sulfate Soil Survey 2005

**Table A1: 2005 Survey Results, Initial Sampling**

Test Site	Depth	pH <sub>KCl</sub>	pH <sub>ox</sub>	S <sub>KCl</sub>	S <sub>p</sub>	S <sub>pos</sub>	ANC	TPA	TAA	TPA Action Criteria for Sand
				%	%	%	moles H <sup>+</sup> /tonne			
1:H2	0-0.5	5.3	4.7	<0.01	<0.01	<0.01		6	<2	18
	0.5-1	5.1	4.3	0.01	0.01	<0.01		15	4	18
	1-1.5	5.1	4.5	<0.01	0.01	0.01		15	5	18
	1.5-2	5.4	4.4	0.01	0.01	<0.01		12	5	18
	2-2.5	5.5	4.7	0.01	0.01	<0.01		8	3	18
	2.5-3	6.2	5.6	0.02	0.02	<0.01		<2	<2	18
2:H2	0-0.5	4.9	4.9	0.01	0.01	<0.01		3	6	18
	0.5-1	5.1	4.5	0.01	0.02	0.01		5	4	18
	1-1.5	4.9	4.4	0.02	0.03	0.01		13	8	18
	1.5-2	4.8	4.2	0.03	0.04	0.01		20	13	18
	2-2.5	4.8	4.3	0.02	0.03	0.01		19	12	18
	2.5-3	5.3	4.5	0.01	0.02	0.01		9	<2	18
3:H4	0-0.5	5	4.7	<0.01	0.01	0.01		6	4	18
	0.5-1	5.4	4.4	<0.01	0.01	0.01		4	5	18
	1-1.5	5.5	4.7	0.01	0.02	0.01		5	2	18
	1.5-2	5.7	5.5	0.03	0.03	<0.01		<2	<2	18
	2-2.5	5.6	4.8	0.02	0.02	<0.01		7	3	18
	2.5-3	5	5	0.01	0.01	<0.01		4	6	18
4:H4	0-0.5	5.5	5	<0.01	0.01	0.01		<2	3	18
	0.5-1	5.1	4.4	0.01	0.01	<0.01		8	4	18
	1-1.5	5	4.4	<0.01	0.01	0.01		6	8	18
	1.5-2	4.7	4.4	0.01	0.01	<0.01		8	5	18
	2-2.5	4.7	4.6	0.01	0.01	<0.01		5	9	18
	2.5-3	4.6	4.6	0.01	0.01	<0.01		8	6	18
5:H4	0-0.5	5.6	4.3	<0.01	<0.01	<0.01		5	<2	18
	0.5-1	5.5	4.5	<0.01	0.01	0.01		4	2	18
	1-1.5	5.9	4.5	<0.01	<0.01	<0.01		3	<2	18
	1.5-2	5.8	4.7	<0.01	0.01	0.01		3	<2	18
	2-2.5	5.5	4.5	0.01	0.01	<0.01		10	3	18
	2.5-3	5.4	5.4	0.01	0.01	<0.01		5	<2	18
6:H2	0-0.5	4.8	4.4	<0.01	<0.01	<0.01		15	6	18
	0.5-1	5.1	4.7	<0.01	<0.01	<0.01		4	3	18
	1-1.5	4.6	5.7	0.01	0.02	0.01		<2	8	18
	1.5-2	4.5	6.5	<0.01	0.03	0.03	12	<2	12	18
	2-2.5	4.5	6.5	0.01	0.02	0.01	9	<2	10	18
	2.5-3	4.7	6.5	<0.01	<0.01	<0.01	11	<2	9	18

**Table A2: 2005 Survey Results, Initial Sampling**

Client ID		pH <sub>KCl</sub>	pH <sub>ox</sub>	S <sub>p</sub>	S <sub>KCl</sub>	S <sub>pos</sub>	ANC	TPA	TAA
Site	Sample			%	%	%	Moles	H <sup>+</sup> /tonne	
Site 1	Hole 1(H1) 0.5	5.4	4.7	0.01	0.01	<0.01	<2	8	5
	Hole 1(H1) 1.0	5.0	4.6	0.03	0.03	<0.01	<2	17	7
	Hole 1(H1) 1.5	4.9	4.7	0.04	0.04	<0.01	<2	15	13
Site 1	Hole 3(H2) 0.5	5.7	6.0	<0.01	<0.01	<0.01	<2	<2	<2
	Hole 3(H2) 1.0	5.9	6.4	<0.01	<0.01	<0.01	<2	3	<2
	Hole 3(H2) 1.5	5.8	6.3	0.01	<0.01	0.01	<2	10	3
	Hole 3(H2) 2.0	5.9	6.5	0.01	<0.01	0.01	<2	2	<2
Site 2	Hole 2(H2) 0.5	6.0	5.7	<0.01	<0.01	<0.01	<2	2	<2
	Hole 2(H2) 1.0	5.6	5.8	0.01	0.01	<0.01	<2	10	5
	Hole 2(H2) 1.5	5.4	5.6	0.01	0.01	<0.01	<2	13	8
Site 2	Hole 4(H2) 0.5	6.0	6.1	<0.01	<0.01	<0.01	<2	<2	<2
	Hole 4(H2) 1.0	5.9	6.1	<0.01	<0.01	<0.01	<2	<2	<2
	Hole 4(H2) 1.5	5.5	5.7	0.01	0.01	<0.01	<2	<2	3
	Hole 4(H2) 2.0	5.7	6.0	0.01	0.01	<0.01	<2	<2	<2

**APPENDIX 2:**  
Acid Sulfate Soil Survey 2007

**Table A3: 2007 Survey Results, Field Tests**

Date	Hole Number	Sample Depth	Texture and colour	Field Results		
				pH <sub>F</sub>	Peroxide Reaction	pH <sub>FOX</sub>
27/02/2007	1	0.2	black sand and organics	5	X	3.7
27/02/2007	1	0.7	grey sand	5	X	4.1
27/02/2007	1	1.2	grey sand	5.2	X	5.2
27/02/2007	1	1.9	grey/yellow sand	5.8	X	5.2
27/02/2007	1	2.4	grey/black sand	5.9	X	4.5
27/02/2007	1	2.9	grey/black sand	6.1	X	3.3
27/02/2007	1	3.4	grey/black sand	6	X	5
27/02/2007	1	4	grey sand/clay	5.5	X	4.9
27/02/2007	1	4.6	grey sand/clay	4.9	X	4.4
27/02/2007	2	0.7	black sand and organics	6.2	X	5.3
27/02/2007	2	1.2	yellow sand	5.8	X	5.1
27/02/2007	2	1.9	yellow sand	6	X	5.2
27/02/2007	2	2.4	grey sand/clay	6.1	X	5.4
27/02/2007	2	2.9	yellow sand/clay	6.1	X	5.4
27/02/2007	2	3.4	grey sand/clay	5.7	X	5.1
27/02/2007	3	0	black sand and organics	5.2	X	4.3
27/02/2007	3	0.5	yellow sand	5.2	X	4.8
27/02/2007	3	1	yellow sand	4.6	X	4.8
27/02/2007	3	1.5	yellow sand	5.6	X	5
27/02/2007	3	1.9	red clay	5.9	X	5.1
27/02/2007	3	2.4	yellow clay/sand	6.2	X	5.5
27/02/2007	4	0.2	black sand with organic matter	4.9	X	3.5
27/02/2007	4	0.7	grey sand	4.7	X	4.5
27/02/2007	4	1.2	yellow sand	5.2	X	4.6
27/02/2007	4	1.9	yellow/white sand	5.2	X	4.3
27/02/2007	4	2.4	white clay	5.7	X	4.5
27/02/2007	4	2.9	white clay	5.3	X	4.2
27/02/2007	4	3.4	white clay/gravel	5.4	X	4.4
27/02/2007	5	0.2	black sand and organics	6	X	4.2
27/02/2007	5	0.7	yellow/black sand	6	X	4.8

Date	Hole Number	Sample Depth	Texture and colour	Field Results		
				pH <sub>F</sub>	Peroxide Reaction	pH <sub>FOX</sub>
27/02/2007	5	1.2	yellow sand	6.2	X	5.1
27/02/2007	5	1.9	yellow sand	5.6	X	4.5
27/02/2007	5	2.4	yellow sand	5.5	X	4.2
27/02/2007	5	2.9	grey/yellow sand/clay	5.4	X	4.3
27/02/2007	5	3.4	grey/yellow sand/clay	5.3	X	4.4
27/02/2007	6	0.2	black sand and organics	5.6	X	5.2
27/02/2007	6	0.7	yellow sand	5.6	X	5.2
27/02/2007	6	1.2	yellow sand	5.9	X	5.4
27/02/2007	6	1.9	yellow sand	6	X	5.3
27/02/2007	6	2.4	yellow sand	5.9	X	5.4
27/02/2007	6	2.9	yellow sand	6	X	5.4
27/02/2007	6	3.4	yellow/black sand	5.9	X	5.3
27/02/2007	6	4	grey clay/sand	6	X	5.3
27/02/2007	6	4.6	grey clay/sand	6.2	X	5.3
27/02/2007	7	0.2	black sand and organics	5.7	X	4
27/02/2007	7	0.7	grey/black sand	5.2	X	3.4
27/02/2007	7	1.2	grey/yellow sand	5	X	4
27/02/2007	7	1.9	white/yellow sand	4.9	X	4.6
27/02/2007	7	2.4	yellow sand	5.4	X	4.2
27/02/2007	7	2.9	yellow/black sand	6	X	4.9
27/02/2007	7	3.4	grey/black sand	5	X	3.1
27/02/2007	7	4	yellow sand/ coffee rock	5.7	X	4.7
27/02/2007	7	4.6	yellow/red clay	5.9	X	4.8
27/02/2007	8	0.2	yellow/grey sand	4.3	X	2.4
27/02/2007	8	0.7	grey sand	4.7	X	3.5
27/02/2007	8	1.2	black sand	4.9	X	3.5
27/02/2007	8	1.9	yellow sand	4.2	XX	3.1
27/02/2007	8	2.4	yellow sand	4	X	2.9
27/02/2007	8	2.9	yellow clay	4.7	XX	4.3
27/02/2007	8	3.4	yellow clay	5	XX	4.5
22/02/2007	9	0.2	black sand and organics	5.4	X	5.5
22/02/2007	9	0.7	yellow sand	4.9	X	4.6



Date	Hole Number	Sample Depth	Texture and colour	Field Results		
				pH <sub>F</sub>	Peroxide Reaction	pH <sub>FOX</sub>
22/02/2007	9	1.2	black/yellow sand	5.2	X	5.1
22/02/2007	9	1.9	yellow sand	6	X	5.3
22/02/2007	9	2.4	yellow/white sand	5.6	X	5.3
22/02/2007	9	2.9	grey sand/clay	5.4	X	4.8
22/02/2007	9	3.4	grey sand/clay	4.9	X	3.3
22/02/2007	9	4	grey sand/clay	5.5	X	3.3
22/02/2007	9	4.6	grey sand/clay	5.7	X	4
22/02/2007	10	0.2	black sand and organics	4.6	X	4.1
22/02/2007	10	0.7	grey sand	4.7	X	4.8
22/02/2007	10	1.2	yellow sand	5.6	X	5.4
22/02/2007	10	1.9	grey sand/clay	5.5	XXX	2.9
22/02/2007	10	2.4	grey sand/clay	5.6	XX	2.8
22/02/2007	10	2.9	grey sand/clay	5.7	XX	2.7
22/02/2007	10	3.4	grey sand/clay	5.2	XX	3.5
22/02/2007	11	0.2	black sand and organics	4.7	X	4.3
22/02/2007	11	0.7	white sand	4.6	X	4.7
22/02/2007	11	1.2	yellow sand	4.9	X	5
22/02/2007	11	1.9	yellow sand/clay	5.3	X	5
22/02/2007	11	2.4	yellow sand/clay	5	X	4.1
22/02/2007	11	2.9	yellow sand/clay	5.3	X	5
22/02/2007	11	3.4	orange gravel	5.6	X	5
22/02/2007	12	0.2	black sand and organics	5.3	X	4.8
22/02/2007	12	0.7	white sand/clay	4.9	X	4.5
22/02/2007	12	1.2	white sand/clay	5.8	X	5.1
22/02/2007	12	1.9	white sand/clay	5	X	4.1
22/02/2007	12	2.4	white sand/clay	5.4	X	4.5
22/02/2007	13	0.2	black sand and organics	5.1	X	4.5
22/02/2007	13	0.7	yellow sand/clay	4.8	X	4.5
22/02/2007	13	1.2	yellow sand/clay	5.3	X	4.9
22/02/2007	13	1.9	orange clay/gravel	5.1	X	4.7
22/02/2007	14	0.2	black sand and organics	5	X	4
22/02/2007	14	0.7	yellow sand	4.6	X	4.6

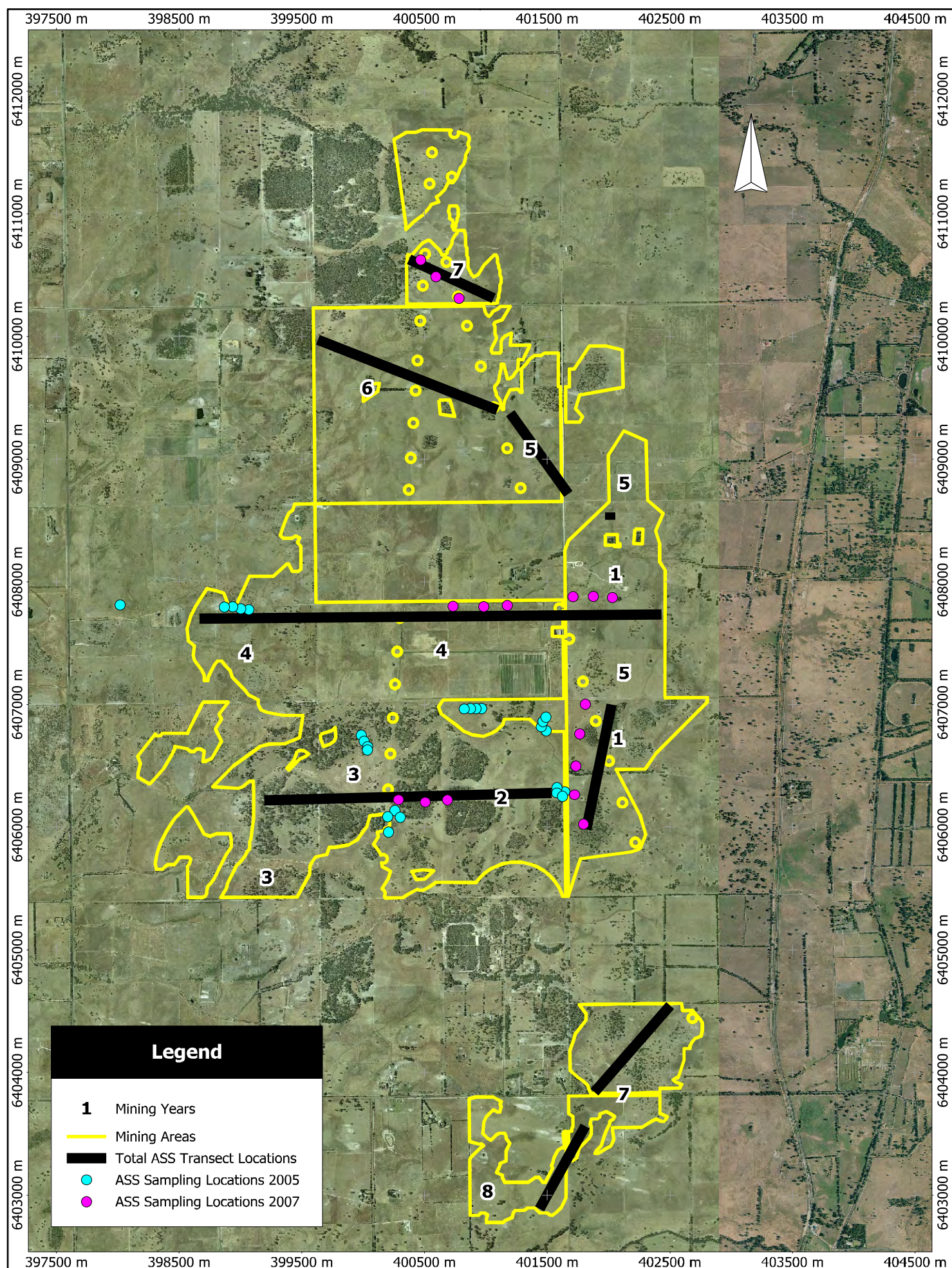
Date	Hole Number	Sample Depth	Texture and colour	Field Results		
				pH <sub>F</sub>	Peroxide Reaction	pH <sub>FOX</sub>
22/02/2007	14	1.2	yellow sand/clay	6.1	X	5.5
22/02/2007	14	1.9	yellow/brown clay	6.2	X	5.6
22/02/2007	14	2.4	yellow/brown clay	6.1	X	6
1/03/2007	15	0.2	black sand and organics	4.5	X	4.7
1/03/2007	15	0.7	white sand	4.6	X	5.2
1/03/2007	15	1.2	yellow sand/gravel	5.6	X	5.1
1/03/2007	15	1.9	yellow sand/gravel	6.1	X	5.3
1/03/2007	15	2.4	white sand/gravel	6.2	X	5.3
1/03/2007	16	0.2	black sand and organics	5.3	X	4.7
1/03/2007	16	0.7	yellow sand	4.5	X	5.1
1/03/2007	16	1.2	yellow sand	5.9	X	5.4
1/03/2007	16	1.9	red clay	6.2	X	5.1
1/03/2007	16	2.4	red clay	5.6	X	4.7
22/02/2007	17	0.2	black sand and organics	4.5	X	3.9
22/02/2007	17	0.7	grey sand	4.3	X	4.6
22/02/2007	17	1.2	white sand/clay	5.5	X	4.9
22/02/2007	17	1.9	white sand/clay	5.7	X	4.8
22/02/2007	17	2.4	gravel clay	5.6	X	4.8
22/02/2007	18	0.2	black sand and organics	5.5	X	5.2
22/02/2007	18	0.7	yellow sand	4.5	X	4.7
22/02/2007	18	1.2	yellow sand	4.2	X	3.9
22/02/2007	18	1.9	yellow sand	5.5	X	4.5
22/02/2007	18	2.4	grey sand/clay	5.6	X	5

**Table A4: 2007 Survey Results, Laboratory Analysis**

No	Sample ID	pH <sub>KCl</sub>	pH <sub>ox</sub>	S <sub>p</sub>	S <sub>KCl</sub>	S <sub>pos</sub>	S <sub>ras</sub>	ANC	TAA	TPA	TPA Action Criteria
				%	%	%	%	Moles H <sup>+</sup> /tonne			
1	Hole 1-3.1m	5.6	5.9	0.01	<0.01	0.01			<2	6	18
2	Hole 7-0.7m	9.3	5.2	<0.01	<0.01	<0.01			<2	<2	18
3	Hole 7-3.6m	6.0	6.4	<0.01	<0.01	<0.01			<2	3	18
4	Hole 8-0.7m	5.0	6.3	<0.01	<0.01	<0.01			5	<2	18
5	Hole 8-1.2m	5.0	4.8	0.01	0.01	<0.01			5	<2	18
6	Hole 8-1.9m	4.9	5.2	0.01	0.01	<0.01			8	6	18
7	<b>Hole 8-2.4m</b>	4.6	4.7	0.02	0.02	<0.01			15	<b>19</b>	18
8	<b>Hole 8-3.1m</b>	4.4	5.2	0.04	0.04	<0.01			30	<b>32</b>	18
9	Hole 8-3.6m	4.5	6.5	0.02	0.02	<0.01			21	16	18
10	Hole 9-3.6m	5.9	7.5	<0.01	<0.01	<0.01		<2	<2	<2	18
11	Hole 9-4.3m	5.6	6.6	<0.01	<0.01	<0.01		<2	<2	16	18
12	<b>Hole10-1.9m</b>	5.3	3.9	0.03	<0.01	0.03	<0.01		2	<b>40</b>	18
13	Hole 10-2.4m	5.2	4.9	0.02	<0.01	0.02			3	10	18
14	Hole 10-3.1m	5.3	6.3	0.01	<0.01	0.01			3	9	18
15	Hole 10-3.6m	4.7	5.8	0.01	0.01	<0.01			9	14	18
16	Hole 18-1.2m	4.7	5.2	0.01	0.01	<0.01			10	17	18

**Figure A1: 2007 ASS Sampling Locations**







**APPENDIX 3:**  
**SOIL SAMPLING FIELD RECORD FORM**

Field Observations					Field Test						
Sample ID			Soil Description	Depth to Water							
Location	Depth/mBGL				pH <sub>F</sub>	pH <sub>FOX</sub>	pH <sub>F</sub> - pH <sub>FOX</sub>	Reaction Rate	Temperature	Reference # of Photograph	Sample collected for Laboratory Analysis Y/N
	From	To		mBGL	pH units	pH units	pH units	LMHXV	°C		

Reaction Rate Descriptions:  
L = Low reaction  
M = Medium reaction  
H = High reaction  
X = Extreme reaction  
V = Volcanic reaction

Sampling Conducted by: \_\_\_\_\_  
Date Sampled: \_\_\_\_\_  
Date Entered into Database: \_\_\_\_\_  
Entered by: \_\_\_\_\_

Field Observations					Field Test						
Sample ID			Soil Description	Depth to Water	pH <sub>F</sub>	pH <sub>FOX</sub>	pH <sub>F</sub> - pH <sub>FOX</sub>	Reaction Rate	Temperature	Reference # of Photograph	Sample collected for Laboratory Analysis Y/N
Location	Depth/mBGL										
	From	To		mBGL	pH units	pH units	pH units	LMHXV	°C		
MZ01: 395565.32mE / 6390725.45mN											
MZ01	0.00	0.25	Silty sand. Grass root zone. Sand fraction mostly fine grained, well sorted, angular. Munsell colour 7.5YR 3/2 dark brown.		5.85	3.14	2.71	L	-		
MZ01	0.25	0.50	Peaty silty clay. Minor roots (fine fibrous). Munsell colour 7.5YR 2.5/1 black.	0.40	4.76	2.47	2.29	M	42		
MZ01	0.50	0.75	Clayey sand. Minor root material. Greyish brown sand to fine grained, angular, moderately sorted. Munsell colour 2.5Y 5/1 grey.		3.92	2.95	0.97	M	39		

Reaction Rate Descriptions:

L = Low reaction

M = Medium reaction

H = High reaction

X = Extreme reaction

V = Volcanic reaction

Sampling Conducted by: \_\_\_\_\_

Date Sampled: \_\_\_\_\_

Date Entered into Database: \_\_\_\_\_

Entered by: \_\_\_\_\_