University of Southern Queensland

Faculty of Engineering and Surveying

The Use of Industry By-Products in the Treatment of Acid Sulfate Soils

A dissertation submitted by

Timothy Fraser

in fulfilment of the requirements of

Courses ENG4111 and 4112 Research Project

towards the degree of

Bachelor of Engineering (Civil)

Submitted: October, 2004

Abstract

This research project investigated the use of a range of industry by-products as neutralising agents for treating acid sulfate soils in an effort to locate a cost effective alternative to commercial liming agents. To achieve this, relevant legislation was researched to determine performance criteria to be met by neutralising agents in treating acid sulfate soils. Three trial products were selected; two recycled concrete products and one concrete washout material. A leaching column experiment was carried out to test the effectiveness of these products as neutralising agents in treating an acid sulfate soil sample. A site specific cost analysis was conducted to determine the relative costs of using these products compared to using a commercial liming agent. The results showed that one recycled concrete product and the concrete washout material were effective as neutralising agents. However only the concrete washout material was comparable cost-wise with a commercial liming agent in treating onsite acid sulfate soils.

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111 & ENG4112 *Research Project*

Limitations of Use

Prof G Baker
Dean
Faculty of Engineering and Surveying

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Tim Fraser

Student Number: Q11200280

Signature

18 OCTOBER 2004.

Date

Acknowledgments

I wish to thank the following people and businesses for their assistance during this research project:

Australian Laboratory Services;

Boral Concrete;

Dr Richard Merifield;

QASSIT and the Department of Natural Resources, Mines and Energy especially Angus McElnea, Kristie Watling and Col Ahern;

Queensland Recycling Pty Ltd especially Bernard Murphy;

Queensland Weighing Machines;

Rosenlund Contractors Pty Ltd;

Ruth and Ben.

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Project Background

Acid sulfate soils are an environmental hazard prevalent along the coastal areas, and some inland areas, of Queensland and Australia. Developments in these coastal regions often have to address how these potentially harmful soils will be controlled.

In Queensland, accepted management techniques for the handling of these soils have been documented in legislation. One of these accepted management techniques involves the mixing of acid sulfate soils with a neutralising agent, which buffers the acidic effects of the soil. This neutralising is commonly performed using commercial lime such as Aglime. This can be a very costly exercise, especially if large volumes of soil need to be treated.

Rosenlund Constructions Pty Ltd, a Brisbane based demolition and earthworks contractor, is wishing to develop a block of land located at Armada Place, Banyo, on the north side of Brisbane, where some cut and fill earthworks will be required. The site has been identified as being in a possible acid sulfate soil area, and will therefore require a thorough site investigation to determine if any acid sulfate soils are present. If the site is found to contain acid sulfate soils, a management plan may need to be formulated as to how these soils will be managed during development. If the soils are found to be acid sulfate soils, they will not be allowed to be excavated and used as onsite fill without first being neutralised. As mentioned previously, this would usually involve the mixing lime with the soils which may prove quite costly. Other accepted management techniques would generally require the removal of the acid sulfate soils from site for treatment and disposal, which would then mean Rosenlund would need to pay for the export and treatment of these soils, and then pay to bring in material for filling.

Crushed Concrete Products, a company affiliated with Rosenlund Constructions, operates a concrete recycling yard, crushing demolished concrete from Rosenlund's demolition activities, producing a range of products. The crushing operations are performed at a site on the north side of Brisbane, a 15 minute drive from Armada Place.

Rosenlund wanted to investigate the possibility of using one of the crushed concrete products as an ameliorant for neutralising acid sulfate soils at their Armada Place site. As an extension to this, this project will also look at the possibility of using other industry by-products in treating the soils, with the view of finding a cheaper alternative to commercial liming products for the neutralising of acid sulfate soils.

1.2 Aims and Objectives

The aim of this research project is to investigate the feasibility of treating acid sulfate soils with various industry by-products, compared with treating them with commercial lime.

To fulfil this aim, several objectives will need to be met. The specific objectives of this research project are as follows:

- Gain an understanding of current treatment practices involved with the management of acid sulfate soils.
- Gain an understanding of governing standards and specifications associated with the treatment of acid sulfate soils.
- Identify various industry by-products that may be used in the treatment of acid sulfate soils.

- Test the effectiveness of the identified by-products to meet the required specifications and standards.
- Perform a cost analysis on the effective by-products, and determine if an economical product can be found.

These aims and objectives are outlined in the Project Specification, which can be viewed in Appendix A.

1.3 Project Benefits

This project has the opportunity to be beneficial in several respects, both economically and environmentally.

Economically, for Rosenlund Constructions and other developers the results from this research project could potentially lead to a less costly form of managing acid sulfate soils that may be found on projects, reducing development costs and increasing the potential for profit.

Environmentally, by finding an alternative use for an industry by-product or waste product, this can encourage reuse of materials that may otherwise become waste. Companies that normally have to deal with the disposal of these products may now have a marketable product, and more opportunities to recycle.

Chapter 2

Background

2.1 Acid Sulfate Soils

2.1.1 Definition of Acid Sulfate Soils

Acid sulfate soil (ASS) is the name given to naturally occurring wetland soils and unconsolidated sediment containing significant quantities of iron sulfides. Of these iron sulfides, the most common form is pyrite (FeS_2).

In Australia, the majority of these acid sulfate soils were formed within the last 10,000 years, after the last major sea rise (Sammut 2000). During this period, iron rich sediment (usually containing iron oxides) was laid down. Sulfide-forming, anaerobic bacteria contained within these waterlogged sediments converted sulfate from tidal waters, and iron from the sediments, to iron pyrite.

Whilst remaining in anaerobic reducing conditions under permanent groundwater, ASS are not problematic, with the soil pH somewhere between weakly acidic and weakly alkaline. These soils are known as Potential Acid Sulfate Soils (PASS), due to their capacity to form sulfuric acid if exposed to air.

Once PASS are disturbed and exposed to the air, however, the iron sulfides in the soils react with atmospheric oxygen and water to produce a range of iron compounds and, most notably, sulfuric acid. These oxidised, acid producing soils are known as Actual Acid Sulfate Soils (AASS). Exposure to the air can be caused through the excavation of the material during earthworks, or by removing covering waters such as the lowering of the water table by drainage.

This sulfuric acid has the potential to be flushed from the soils, leading to extremely acidic waters entering the surrounding environment. These acidic waters can be as low as about pH 2, and often around pH 4. If the pH level falls sufficiently, the generated

acid also attacks the fine clay particles in the surrounding soils, stripping it of aluminium and iron, which are then mobilised and released into surrounding waters. In very acidic cases, other heavy metals such as manganese and cadmium can also be dissolved.

2.1.2 Distribution of Acid Sulfate Soils

Due to the iron sulphide layers being formed under tidal conditions, acid sulfate soils are predominantly found in low lying coastal areas, usually below 5 metres Australian Height Datum (AHD). These soils can be found either close to natural ground level or at depth within the soil profile.

In Australia, there are estimated to be more than 40,000km^2 acid sulfate soils, containing in excess of one billion tonnes of pyrite (Davidson 2001 p.31), which can be found along the coastlines of the Northern Territory, Queensland and New South Wales as well as regions of Western Australia, South Australia and Tasmania.

In Queensland alone, there is estimated to be 2.3 million hectares, stretching over 6,500km of the Queensland coastline. Figure 2.1 shows a map indicating the distribution of acid sulfate soils in Queensland.

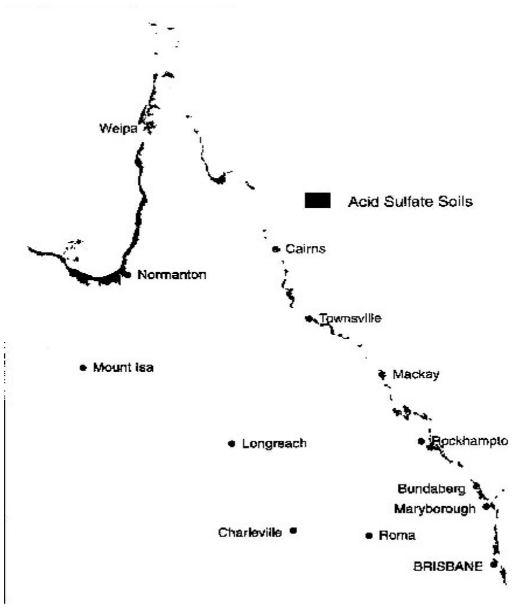


Fig 2.1: Map showing distribution of ASS in Queensland

2.1.3 Basic Acidification Process

As mentioned above, acid sulfate soils produce acid through the oxidation of iron sulfides. Initially a chemical reaction, the process is accelerated many-fold by bacteria such as *Thiobacillus ferrooxidans*. When performing calculations in regards to acid production and neutralising, the chemical equation that is used to describe the complete oxidation of pyrite is as follows:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

This shows that two moles of Sulfur (in pyrite) produces four moles of H^+ ions after oxidation (or one mole of S produces two of H^+).

Various other reactions and products, such as jarosite ($KFe_3(SO_4)_2(OH)_6$), may also be produced.

In regards to the extent of mobilisation of soluble aluminium through the attack of clay particles by sulfuric acid, aluminium chemistry is complex because species and solubilities are pH dependant with Aluminium species most toxic to fish occurring at pH 5.0 to 5.5 (Sammut *et a*l. 1996). Therefore, as extremely acid water is diluted or mixed with seawater and the pH increases to around 5.2, Aluminium toxicity becomes a serious consideration. Thus the pH of waters contaminated by Aluminium needs to be raised above 6.5 to remove toxic Al species from solution (Ahern *et a*l. 1998).

2.1.4 Environmental and Economic Impacts

The disturbance of ASS and the subsequent release of acids and metals can have far reaching environmental and economic impacts.

Environmental Impacts

Oxidation of ASS and associated acidification can have impacts on the environment in several ways. This can include:

- Fish and marine organism death. Acidic runoff is washed into local waterways, where the rapid changes in pH, low levels of dissolved oxygen, and mobilised metal contaminants can cause fish kills and other marine deaths.

- Fish disease. Exposure to acidified water damages fish skin and gills, impairing the general health of fish stocks and increasing the susceptibility of fish to 'red-spot' disease, an ulcerative skin disease of fish characterised by red lesions that leave fish unsaleable and may cause fish deaths. Outbreaks of this disease can affect up to 80 per cent of the fish catch in acidified waters. Other marine organisms such as oysters can also suffer damage due to acid waters, and the associated high aluminium and iron levels.

- Habitat degradation. Metal precipitates and acidic waters can destroy food resources, and change the chemical and physical properties of the water. Dissolved iron in the acidic water can precipitate out smothering plants and the streambed. These precipitates can move downstream to smother areas where there is no acid water. Acid tolerant species of plant can dominate affected waterways, and prevent the re-establishment of other species even when the pH returns to normal. High aluminium levels in acid water can cause overly clear water, which leads to excess light penetration. Other heavy metals such as cadmium which can be dissolved by sulfuric acid and washed into waterways, can also be absorbed by fish and other aquatic life.

- Human and animal health. Aluminium-rich waters may have significant impacts on human and animal health which could include stunted growth, poor health and mental impairment (White cited in Powell et. al. 1999). Higher iron levels (possibly an ASS source) in Deception Bay, QLD have been linked with toxic blue-green algae (Abal 1998 cited in Powell et. al. 1999). Inhalation of ASS dust could also lead to respiratory difficulties, and industrial dermatitis has been reportedly been caused by the handling or skin contact with acid soil materials. Absorption of heavy metals through the skin is also a possibility.

From the above, it can be seen that the environmental impacts of acid sulfate soil can be quite significant, and effect areas at a distance from the source.

Economic Impacts

ASS underlies significant areas of coastal Australia, where the majority of Australians reside. Substantial developments, including urbanisation, industrialisation, infrastructure and utility supply, agriculture, aquaculture, sand and gravel extraction as well as dredging, in these areas have disturbed ASS.

Unmanaged acid sulfate soils have the potential for high economic costs, due to reduced productivities, infrastructure degradation, and relocation costs to non-ASS areas or increased developmental costs.

The oxidation of iron sulfides can impact greatly on farm productivity. As sulfuric acid is produced, and strips iron, aluminium and other heavy metals from the soil, soil water can become to toxic and acidic for most plants to survive in. If enough acid is being produced, nothing will grow, leaving bare scalded ground which can be susceptible to erosion. In addition, lowered pH can make various nutrients less available to plants.

Animal productivity can also be affected, as acid conditions can discourage good quality pasture. Grazing animals may ingest high levels of aluminium and iron by feeding on acid-tolerant plant species and drinking acid water.

Acid sulfate soils are also generally very susceptible to subsidence, due to their waterlogged gel-like structure. This makes them very poor as foundation materials, as they will tend to settle slowly and unevenly under load, with a low bearing capacity. Surface structures built on these materials would require extensive piles or load spreading membranes. In addition, if these soils are drained, they can shrink and subside, which can make farmland more prone to flooding and waterlogging.

Acidic waters also corrode iron, steel, concrete and some aluminium alloys, leading to the premature replacement or costly repairs to infrastructure.

Another engineering consequence of ASS can be the blocking or impairment of drain systems, due to the precipitation of red ochre, iron hydroxide and oxide flocs when fresh or neutral pH water meets with acidic iron-rich waters (White *et a*l. 1995). There is the possibility that groundwater pumping from coastal aquifers may lower water tables, leading to the potential oxidation of buried ASS layers and acidification of the aquifer.

Where significant pyritic oxidation has occurred, groundwater pumping may allow movement in acidic drain water and the landward incursion of seawater into the aquifer (White *et al*. 1995). When the well-buffered seawater encounters acidic iron-rich waters it is possible that precipitation of ferric hydroxide/oxides can occur in the aquifer. If this takes place, seawater intrusions may be ‘frozen’ in place with little likelihood of being displaced seaward. As well as aquifer clogging, iron-rich waters can cause blocking or clogging of water wells, drains and pumps when exposed to air, due to iron hydroxide/oxide floc precipitation or due to the trapping of long strands of bacterial mats and filamentous bacteria.

2.1.5 Summary

From this information, we can see that acid sulfate soils can lead to large environmental and economic costs. Therefore, the appropriate management of these soils is vital to ensure that impacts are minimised in areas where development is to occur, so that acidity and metallic release is kept within acceptable levels.

Queensland legislation has been developed so as to ensure that developments occurring in ASS regions are appropriately managed, and impacts are minimised. This legislation will be discussed in the following chapter.

2.2 Armada Place development

The origin of this research project lies with Rosenlund Constructions Pty Ltd wanting to test the ability of a crushed concrete product, and locate other by-products that may be used to treat acid sulfate soils at their Armada Place development site. Therefore, some background information of this site would be beneficial, as it is influential in the selecting which by-products may be more suitable than others.

The Armada Place site is located at 6 Armada Place, on the corner of Nudgee Rd and Armada Place, Banyo, a suburb on the northern side of Brisbane situated near the Gateway Motorway. The area is zoned industrial, with a total area of 4,506m^2. The location of the site within Brisbane is shown on a map in Appendix B.

Figures 2.2, 2,3 and 2.4 contain photographs showing the current state of the site. It is currently being used as a storage yard for Rosenlund Constructions Pty Ltd.

Figure 2.2: Photograph of the Armada Place development site from Nudgee Rd (Western side)

Figure 2.3: Photograph of the Armada Place development site from Armada Place (Southern Side)

Figure 2.4: Photograph of the Armada Place development site from Armada Place (South Eastern Side)

The main distinguishing feature of this site is a large open concrete channel that effectively divides the site into two. This channel is connected to an extensive underground pipe system which flows into the channel, conveying stormwater east, discharging into the Kedron Brook Floodway. Figure 2.5 and Figure 2.6 contain photographs showing this stormwater culvert.

Figure 2.5: View of open stormwater culvert running through the Armada Place site (from South Western corner)

Figure 2.6: Further view of open stormwater culvert at the Armada Place development site (from Southern side)

Rosenlund Constructions Pty Ltd has proposed to construct a new warehouse with office on the site, and associated car parking and hardstand. This new building will span the stormwater channel, with some widening of the channel required in order to allow flood waters to pass under the building unobstructed.

The site altitude varies between approximately Australian Height Datum (AHD) 3.5 and AHD 4. Due to the fact that it lies below AHD 5, the State Planning Policy 2/02: Planning and Managing Development Involving Acid Sulfate Soils requires an investigation into the possibility of onsite acid sulfate soils that may be disturbed during the development, prior to development approval.

As of the date of writing, the development approval is still being negotiated, and the acid sulfate soil investigation has not been carried out. Therefore, the extent of any onsite acid sulfate soils, or their composition, is not yet known. There is the possibility that no onsite acid sulfate soil will be found, or at least will not be disturbed by the development, in which case no treatment will be required. However, Rosenlund Constructions would still like to investigate the possibility of utilising their crushed concrete product in the event that acid sulfate soils do need to be treated.

Chapter 3

Legislation

3.1 Relevant Acid Sulfate Soil Legislation

As this research project is focused on treating acid sulfate soils within Brisbane, I have focused on Queensland legislation. As mentioned in the preceding chapter, the objectives of this legislation are to ensure that the impacts of acid sulfate soils are eliminated or minimised.

As the issue of acid sulfate soils has only become more prevalent relatively recently, the documentation regarding the management of these soils is still fairly dynamic, with amendments and updates being produced fairly frequently by organisations such as QASSIT.

The most important document regarding Acid Sulfate Soils in Queensland is the State Planning Policy 2/02: Planning and Managing Development Involving Acid Sulfate Soils (SPP 2/02) and associated State Planning Policy 2/02 Guideline: Planning and Managing Development involving Acid Sulfate Soils (SPP 2/02 Guideline). Effective as of the 18 November 2002, this State Policy is effective under the *Integrated Planning Act 1997*.

The *Integrated Planning Act 1997* (IPA) essentially forms the foundation of Queensland's planning and development legislation. It is "An Act for a framework to integrate planning and development assessment so that development and its effects are managed in a way that is ecologically sustainable, and for related purposes" (Integrated Planning Act 1997, p.25).

Under the IPA, all developments are assessed under the Integrated Development Assessment System (IDAS), which establishes a common statutory system for making, assessing and deciding development applications in Queensland.
Under the *Statutory Instruments Act 1992*, State Planning Policies are legally binding documents, and therefore the SPP 2/02 must be complied with when assessing development applications under IDAS when an IPA planning scheme is in force. Under the *Statutory Instruments Act 1992* the SPP 2/02 Guideline is classified as "extrinsic material", and hence has legal status in interpreting SPP 2/02.

The purpose of these documents is to outline the necessary steps that need to be taken to ensure that acid sulfate soils are correctly managed on sites being developed. SPP 2/02 outlines two main Outcomes expected from developments assessed under the State Planning Policy, and how the Outcomes are to be obtained. The two Outcomes are as follows:

Outcome 1: When undertaking development to which this SPP applies, the release of acid and associated metal contaminants into the environment is avoided by:

- not disturbing acid sulfate soils when excavating or otherwise removing soil or sediment, extracting groundwater or filling land; or
- treating and, if required, undertaking ongoing management of any disturbed acid sulfate soils and drainage waters.

Outcome 2: For each local government identified in Annex 1, the planning scheme:

- identifies areas with a high probability of containing acid sulfate soils;
- contains planning strategies that, as far as practicable, give preference to land uses that will avoid or minimise the disturbance of acid sulfate soils;
- contains detailed measures, that;
    a) included a code(s) designed to achieve development outcomes that are consistent with Section 5; and
    b) ensure that development to which this SPP applies is assessable against that planning scheme code(s).

The planning scheme or planning scheme policy(s) specifies the information expected to be submitted with development applications subject to the code(s).

SPP 2/02 and Guidelines detail the following:

- Which developments need to be assessed for acid sulfate soils
- For sites that are located in potentially acid sulfate soil areas, the degree and type of testing that needs to be carried to ascertain the level of acid sulfate soils on site, and potential acid producing capability of these soils.
- The level of treatment and monitoring required for a given development based on various "Action Criteria".
- An indication of various approved treatment methods to be used in managing onsite acid sulfate soils.

SPP 2/02 and SPP 2/02 also refer to several other documents including the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*, and the *Queensland Acid Sulfate Soil Technical Manual.* As the SPP 2/02 is a fairly brief document, it refers to these other documents to provide further detail about best practice.

The *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998* provides in-depth detail as to sampling intensities, sampling equipment, soil sample care and preparation, and various laboratory testing methods to be employed when undertaking an onsite assessment.

In regards to the accepted laboratory testing methods, a recent document has been released titled *The Acid Sulfate Soils Laboratory Methods Guidelines (June 2004).* This document sets out the standard methods for routine laboratory analysis of existing acidity (ie. actual and retained acidity) and of the potential acid production from oxidation of iron sulfides in estuarine and coastal sediments that should be used to provide information for the assessment and management of acid sulfate soil (ASS).

The *Queensland Acid Sulfate Soil Technical Manual* is still in the process of being compiled. One of the completed chapters is the *Soil Management Guidelines Ver 3.8 (2002)*. These guidelines are in place to provide technical and procedural advice to avoid environmental harm and to assist in achieving "best practice environmental management" (Dear et al. 2002). The *Soil Management Guidelines (2002)* outline eight management principals regarding developments where ASS may be located. These management principals are shown below:

Management Principles

1. The disturbance of ASS should be avoided wherever possible.

2. Where disturbances of ASS is unavoidable, preferred management strategies are:
   - minimisation of disturbance;
   - neutralisation;
   - hydraulic separation of sulfides either on its own or in conjunction with dredging; and
   - strategic reburial (reinterment).

Other management measures may be considered but must not pose unacceptably high risks.

3. Works should be performed in accordance with ***best practice environmental management*** when it has been demonstrated that the potential impacts of works involving ASS are manageable to ensure that the potential short and long term environmental impacts are minimised.

4. The material being disturbed (including the *in situ* ASS) and any potentially contaminated waters associated with ASS disturbance, must be considered in developing a management plan for ASS and/or in complying with the ***general environmental duty.***

5. Receiving marine, estuarine, brackish or fresh waters are not to be used as a primary means of diluting and/or neutralising ASS or associated contaminated waters.

6. Management of disturbed ASS is to occur if the ASS ***action criteria*** listed in Table 1 of these guidelines is reached or exceeded.

7. Stockpiling of untreated ASS above the permanent groundwater table with (or without) containment is not an acceptable long-term management strategy. For example, soils that are to be stockpiled, disposed of, used as fill, placed as temporary or permanent cover on land or in waterways, sold or exported off the treatment site or used in earth bunds, that exceed the ASS ***action criteria*** listed in Table 1 should be treated/managed.

8. The following issues should be considered when formulating ASS environmental management strategies:
   - the sensitivity and environmental values of the receiving environment. This includes the conservation, protected or other relevant status of the receiving environment (eg. Fish Habitat Area, Marine Park, Coastal Management District and protected wildlife);
   - whether groundwaters and/or surface waters are likely to be directly or indirectly affected;
   - the heterogeneity, geochemical and textural properties of soils on-site; and
   - the management and planning strategies of Local Government and/or State Government, including Regional or Catchment Management Plans/Strategies and State and Regional Coastal Management Plans.

Figure 3.1: The eight Management Principles for ASS management

Principal Two briefly mentions the preferred management strategies for treating ASS soils on developments sites where disturbance is unavoidable. Section 3.2 of the dissertation describes these management principles.
As the aim of the neutralising agents is to eliminate harmful discharge from the acid sulfate soils, some output parameters for any discharge will need to be met. The *Soil Management Guidelines* and *Laboratory Methods Guidelines* does provide broad performance criteria for neutralising agents. However, local government guidelines will need to be met in regards to discharges into stormwater, as would be the case on a site such as Armada Place, where water runoff will enter the stormwater system.

The applicable document in regards to discharges into Brisbane waterways is the *Guidelines on Identifying and Applying Water Quality Objectives in Brisbane City, BCC 2000*. This document can be used to identify specific Water Quality Objectives (WQO's) for discharges from a site located within the Brisbane district. It also outlines criteria to be met if a site contains acid sulfate soils. These guidelines are also consistent with the national guidelines, such as the *Australian Water Quality Guidelines for Fresh and Marine Waters (ANZECC, 1992)* and the *Environmental Protection (Water) Policy* 1997. The ANZECC guidelines are referred to by the *Soil Management Guidelines* as an indicator of discharge quality, so by meeting the requirements of the BCC Guidelines, these guidelines will also be fulfilled.

3.2 Management strategies for the treatment of ASS

The *Soil Management Guidelines* details the various Management Strategies that may be adopted for developments with identified acid sulfate soils. It covers both the preferred management strategies, higher risk management strategies, and generally unacceptable management strategies.

Which management strategy is to be employed can only be assessed on a site by site basis. It will depend upon the environmental sensitivity of the site, the ASS extent and location as well as many other site characteristics. Each development is assessed on its own merits, and a site specific Management Plan will detail the treatment proposals based on site assessments required as per the State Planning Policy 2/02 and documents such as *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*.

For each Management Strategy, the associated environmental risks, performance criteria and verification testing, and management considerations are outlined.

The preferred management strategy for dealing with acid sulfate soils is avoidance of the soils altogether. This can involve giving preference to land not within zones of high acid sulfate soil probability, or preference to developments not involving excavation in these areas. Fill can also be placed over in situ potential acid sulfate soils, as long as this does not cause PASS to become exposed to the atmosphere, or groundwater conditions are not changed dramatically.

If the soils are unavoidable, the minimisation of any disturbance is the next most favoured strategy. This may involve a redesign of the earthworks layout, undertaking only shallow disturbances in ASS areas, and minimising groundwater fluctuations.

If the above two strategies cannot be reasonably undertaken, there are a range of treatment methods suitable for the management of acid sulfate soils. The first is the neutralisation of acid sulfate soils, which is the treatment method referred to in my project specification. This involves physically incorporating alkaline materials such as lime into the soil

A second treatment method involves hydraulic separation, where the differential settling is utilised to separate Sulfidic materials from the soil. Two examples of this method are hydro-sluicing, where Sulfidic fines are separated from sands by utilizing an artificial channel , and hydro-cycloning, where centrifugal classifiers separate particles based on their size and density.

The third “preferred” management strategy is strategic reburial. This method requires that any exposed *potential* acid sulfate soils are placed in anoxic, anaerobic conditions before oxidation can occur. This usually means reburying any excavated PASS in a void below the groundwater table, ensuring the PASS are kept underwater so as oxidation cannot occur. This underwater PASS can be capped with a compacted fill. Figure 3.2 shows a diagram of this strategic reburial.

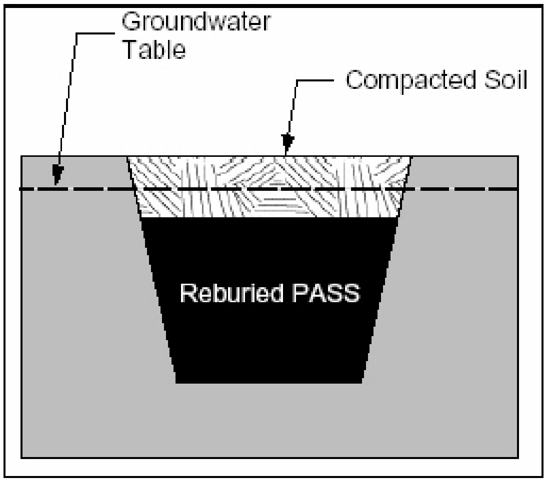


Figure 3.2: Schematic diagram of strategic reburial below groundwater and compacted soil (Ahern *et al* 2002)

Other than these preferred management strategies, there are also various high risk strategies. Even though these strategies are not completely ruled out for all situations, an extensive risk assessment would need to be carried out prior to a strategy being adopted. These high risk strategies include:

- stockpiling of acid sulfate soils;
- strategic reburial of actual acid sulfate soils;
- large-scale dewatering or drainage; and
- vertical mixing.

In addition, there are several management strategies that have been deemed as unacceptable, as the environmental risk is too great in any situation. These are:

- above ground capping, where untreated ASS are placed above ground and covered with a capping material;
- hastened oxidation, where ASS is allowed to oxidise using accelerating techniques;
- sea water neutralisation; and

- offshore disposal of ASS.

Of all the above mentioned management strategies, it is the neutralisation of acid sulfate soils that is the focus of this research project.

3.3 Legislative requirements pertaining to neutralisation

Now that the relevant legislation has been recognised, it is necessary to identify any performance requirements of neutralising agents used to treat acid sulfate soils, as this will indicate which by-products are effective and which are not.

The most useful resource is the *Soil Management Guidelines* from the *Queensland Acid Sulfate Soil Technical Manual.* Its chapter on the Neutralisation of Acid Sulfate Soils, contains recommendations as to the characteristics of potential neutralising agents, liming requirements, carrying out neutralisation, and performance criteria that must be attained for soil that has been treated using neutralisation.

3.3.1 Neutralising Agents

The *Soil Management Guidelines* identify the following factors to consider when choosing a neutralising agent:

- Solubility;
- pH;
- neutralising value;
- fineness / coarseness of the product;
- Ca:Mg balance of the soil;
- spreading and transport costs;
- chemical composition;
- purity of the agent.

It recommends that neutralising agents should be slightly alkaline, with a low solubility, and a pH ranging from seven to . This recommendation is made as such products will not flush out with the first heavy rain, and have minimal potential to contaminate surrounding waterways and groundwater.

No specific criteria are dictated as to the solubility levels, Ca:Mg balance of the soil, or chemical composition of the soil. These are expected to be assessed in regards to site specific characteristics.

The neutralising value, fineness / coarseness of the product, chemical composition and purity of the agent are all related to the neutralising quantities required for treating the acid sulfate soils. This is discussed in a later section.

The spreading and transport costs are all related to the overall cost effectiveness of the product.

3.3.2 Performance Criteria

Section 8.2 of the *Soil Management Guidelines* nominates the following performance criteria that must be attained for soil that has been treated using neutralisation:

1. The neutralising capacity of the treated soil must exceed the existing plus potential acidity of the soil;
2. Post-neutralising, the soil pH is to be greater than 5.5; and
3. Excess neutralising agent should remain within the soil until all acid generation reactions are complete and the soil has no further capacity to generate acidity.

Further to Criteria 2 above, Section 8.3.2 of the *Guidelines* recommends that the soil pH should not be raised above 8.5, unless the soils natural pH level is above this value.

As previously discussed, lowered pH levels lead to the mobilisation of metals within the soil, most notably aluminium and iron. Section 8.3.2 of the *Soil Management*

Guidelines, citing McElnea and Ahern (2000), recommends soil pH be raised above 5.5 to control the leaching of iron and aluminium. The *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998* also recommends that the pH of leachate (water passing through acid sulfate soils) should also be raised above 5.5, and ideally be in the range of 6.5 – 8.5 to remove toxic forms of aluminium and other heavy metals (Ahern et al 1998, p.16). These documents do not, however, indicate acceptable metallic levels. The *State Planning Policy 2/02 Guideline: Planning and Managing Development involving Acid Sulfate Soils* references the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (*ANZECC and ARMCANZ 2000a) and the *Australian guidelines for water quality monitoring and reporting* (ANZECC and ARMCANZ 2000b) in assessing water quality criteria, including metallic components.

3.3.3 Water Quality Objectives

As any water leaving the site will be flowing into the Brisbane City Council stormwater system, it is important to ensure that this discharge conforms to any water quality criteria for the region. As mentioned above, SPP 2/02 references ANZECC and ARMCANZ in regards to determining water quality criteria. For the Brisbane region, the *Guideline on Identifying and Applying Water Quality Objectives in Brisbane City* is used to satisfy this requirement. This document was developed to apply the principals of ANZECC and ARMCANZ to identify Water Quality Objectives (WQO) for an activity that is likely to adversely affect water quality in receiving waters in the Brisbane district. These WQO's are measurable 'criteria' or 'standards' that describe the quality of water that is needed in a receiving water such as a creek or river.

The *Guideline on Identifying and Applying Water Quality Objectives in Brisbane City* determines a set of steps to identify the WQO's for a specific site.
These steps are as follows:

- Identify the Nature of Affected Receiving Waters;
- Identify the Affected Creek Catchment and Planning Unit;
- Check Schedule 1 of the Water *Environmental Protection (Water) Policy 1997;*

- Check for (or Initiate) Site-specific Studies;
- Identify Where WQOs will apply;
- Determine the Waterway Type, Category and Set of Environmental Values;
- Match the Waterway Type and WQOs;
- Match the Type of Activity with the WQOs;
- Understanding the WQO's Once They Have Been Identified;
- Adopt the Relevant WQOs

Included in the document are various Appendices which are used to perform each step, including Maps of Creek Catchments in Brisbane with Planning Units, and descriptions of each major waterway in Brisbane. Working through these, the WQOs for the Armada Place site can be determined. A Stormwater Management Plan Report for Armada Place has been prepared by Storm Water Consulting, in which this process was followed, and the WQOs established.

The Stormwater Management Plan Report identifies the following key information about the Armada Place development:

- Water from the site flows east and discharges into the Kedron Brook Floodway;
- the site is located in Waterway Planning Unit K/010, BCC (2000b);
- Schedule I of the Environmental Protection (Water) Policy 1997 was checked and no WQOs or Environmental Values (EVs) are scheduled for the affected receiving waters;
- no site specific studies have been undertaken to set alternative Environmental Values or WQOs to those generated by Brisbane City Council for the City.

This information is then applied to the *Guideline on Identifying and Applying Water Quality Objectives in Brisbane City* to establish the relevant WQOs for the Armada Place site. The adopted WQOs are shown in Appendix C of this dissertation, and have been extracted from Appendix 5 of the *Guideline on Identifying and Applying Water Quality Objectives in Brisbane City*. The Stormwater Management Plan then further identifies the Kedron Brook Floodway as Tidal, which leads to Set "A" and Set "B" EV's being adopted.

These WQOs again enforce a discharge pH between pH 6.5 and pH 8.5. Various metallic limits are also set, though no criteria for Total Aluminium or Total Iron is recommended.

Appendix 6 of the *Guideline on Identifying and Applying Water Quality Objectives in Brisbane City* also describes the Best Practice Discharge Guidelines in which discharge guidelines for “Acid sulfate soil-related activities” are described. The only guideline specified is that pH must fall between 6.5 and 8.5 in order to control acid and metal pollutants, as also recommended by the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*.

Chapter 4

Selection of Neutralising Products to be Trialled

The aim of this research project was to test various industry by-products in the hope of locating a less costly, yet just as effective alternative to commercial agricultural lime, or other commercial limes traditionally used as neutralising agents.

Section 3.3.1 describes the recommendations made by the *Soil Management Guidelines* in regards to what needs to be considered when choosing a neutralising agent.

The solubility of a neutralising agent mainly implies the effectiveness of the material at neutralising any acidic waters that may be present. Insoluble substances are not going to effectively neutralise ponded waters etc. However, they can still be effective at neutralising acid soils, and less soluble substances are generally preferred as they are less likely to be dissolved and flushed from the soils after heavy rains. They will remain in the soil and continue to neutralise acidic pollutants.

The Ca:Mg balance of the soil is referred to as a consideration, as some neutralising agents usually contain active ingredients based on these elements. For soils containing less Calcium, and high Magnesium levels, a neutralising agent with a higher calcium content, and lesser magnesium content such as Aglime, should be considered, whereas a product such as Burnt Magnesia may be more suitable if the reverse were the case.

4.1 Selection Criteria

In order to locate potential neutralising by-products, we need to look at the objectives that must be fulfilled by the products. The two primary criteria that will need to be addressed are the effectiveness of the product at neutralising the soils, and the cost of the product.

4.1.1 Performance

In order for a product to be considered as a neutralising agent, it needs to be shown that it can meet the performance criteria required by legislation. This can only be discovered through testing potential products, and comparing their neutralising ability with an accepted neutralising agent such as lime, and assessing their ability to meet any criteria. These performance criteria are described in Section 3.3 of this dissertation, and relate to the pH of soil and leachate of neutralised acid sulfate soils, and the control of metallic pollutants such as iron and aluminium.

In summary, the key performance criteria are:

1. Soil pH should be between pH 5.5 and pH 8.5 after neutralisation;
2. Excess neutralising agent should remain within the soil until all acid generation reactions are complete and the soil has no further capacity to generate acidity;
3. Leachate pH should be between pH 6.5 and pH 8.5 after neutralisation;

4.1.2 Cost

To find a product that is more cost effective than lime, the overall cost of each product needs to be compared. The overall cost of a neutralising agent is related to several different factors. These include the purchase cost of the product, the amount of product needed to neutralise a given quantity of acid sulfate soil, the transport cost to get the product to site, processing costs that may be required to get a useable product, and the onsite mixing costs.

From this, we can see that the cost of using a particular product will depend on both product and site specific characteristics. For example, transport costs will depend on the storage location of the neutralising agent in relation to the site, which will change for every site. The cheapest transport costs will come from products closest to the site requiring neutralising.

Purchase or production cost (if making it yourself) is an important, but not conclusive factor in deciding the overall cost effectiveness of a product. The cheapest product to obtain may not be the cheapest overall, as transport and handling costs may be much higher than for a slightly more expensive, yet physically closer product.

The quantity of product needed to neutralise a given quantity of acid sulfate soil is important, as it will affect transport costs, and purchase costs. A product that requires a third the quantity by volume as another product to neutralise the same amount of acid sulfate soil is going to require less material to be brought to site, and thus will probably cost less in transport. This factor is directly related to the effective neutralising value of the product, which is dependant upon the composition of the neutralising agent, and its purity and its fineness. These cannot be established without testing of the product to be assessed, and is not as obvious as the other factors.

Mixing costs are going to be affected by factors such as the density of the material, as onsite handling costs are usually a rate per volume cost. Of course, the more material that needs to be mixed per quantity of soil, the higher these onsite handling costs are going to be. This is again related to the Effective Neutralising Value of the product.

The bulk density of a material is also going to affect the overall cost of the neutralising agent. As the liming rates are dependant upon weight, the denser products are going to have a smaller volume for the same weight. This will mean that transport costs, and onsite storage and handling costs, will be less, as less volume needs to be handled.

The most cost effective product is going to be that with the lowest combination cost of the above factors. So, in summary, the key criteria that should be assessed in order to find a low cost product are:

1. Close to site requiring treatment;
2. Low purchase / production cost;
3. Good effective neutralising value;
4. To a lesser extent, higher bulk density.

4.1.3 Effective neutralising value

It is important to look at the effective neutralising capacity of the products, as this selection criteria is used to give us an understanding of potentially good products. The effective neutralising value (ENV) of a product is a measure of the neutralising ability of a product, expressed as a percentage of pure lime. So an ENV of 100% means that it has the same neutralising capacity as pure lime ($CaCO_3$). For example, Aglime has a neutralising value of about 94-97%, whereas other neutralising agents can have a neutralising value of over 150%. The calculation of the ENV is described in detail in the next chapter, but briefly, it is dependant upon the amount of active neutralising agent in the product, and the fineness / coarseness of the product, and also the moisture content. A product that has a greater proportion of neutralising agent in its composition will have a greater ENV than one with less, and a finer material will have a greater ENV than a coarser one.

Therefore, for a product with a good effective neutralising value, we should look for one with:

1. Good proportion of neutralising agent in its composition;
2. Relatively fine grading.

4.2 Current Neutralising Agents and Industry By-products

There are many possible neutralising agents that can be used to treat acid sulfate soils. Potentially, any alkaline material can be used to treat these soils. However, each one has inherent characteristics, risks and management issues, meaning that not all will be suitable for all sites.

4.2.1 Commercial products

Of the neutralising agents used to treat acid sulfate soils, the most common are the commercially available limes. Of these Aglime is the recommended agent in treating most acid sulfate soils. This is due to its only slightly alkaline state, and low solubility, meaning it is unlikely to be washed from the soil with heavy rains. It has a chemical composition of mostly $CaCO_3$.

Other limes include Quick Lime (CaO), and Hydrated Lime ($Ca(OH)_2$). Both of these are much more alkaline (pH 12.5-13.5) and are carefully used due to the possibility of overshooting the desired pH and producing overly alkaline water.

Other commercial agents that have been utilised in the past include Burnt Magnesia (MgO), Burnt Dolomite (CaO MgO), Dolomite ($CaCO_3/MgCO_3$) and Magnesite ($MgCO_3$). Of these, Burnt Magnesia and Burnt Dolomite tend to be fairly risky due to their very alkaline nature. Magnesite and Dolomite, however, can be safely used.

Various sodium products have been used in the treatment of acidic waters. These include Soda Ash (Na_2CO_3), Sodium Bicarbonate ($NaHCO_3$), and Washing Soda ($Na_2CO_3.10H_2O$). However, these aren’t considered appropriate in neutralising acid soils, as the sodium ions create a dispersive effect on the soils.

4.2.2 Industry By-Products

Several industry by-products have been utilised in treating acid sulfate soils. I hope to identify and assess the possibility of using others in doing the same.

Cement Kiln Dust Lime (CKD) is a by-product of the cement manufacturing process. Its active neutralising ingredient is $CaCO_3$, but it contains many other compounds. It has a neutralising value of about 73%, and is quite fine. It has quite a high pH of about 12.6, meaning that again care should be taken that excess agent is not added, creating overly alkaline conditions. Thiess Environmental Services at Swanbank utilise CKD in treating acid sulfate soils, and research performed by QASSIT indicate that it is as effective, and in some cases more appropriate, than Aglime.

Another by-product is "red mud", a by-product of the alumina refining process, has also been utilised extensively in treating acid sulfate soils. This material is highly alkaline

and is can come in various modified forms. It is available commercially as Bauxsol, which is seawater neutralised red mud. Research by Ward, Sullivan et al (2002) has shown that seawater-neutralised bauxite refinery residue (from the Bayer Process in alumina production) can be as effective as lime in treating acid sulfate soils.

Other waste products such as SWAN-gypsum and sewerage sludge have also been utilised to treat ASS and other pyritic materials (Loomis and Hood 1984; Offiah and Fanning 1994).

4.3 Selection of By-Products

After considering the costs that would be involved in the testing and trialling of potential products, it was decided that three products would be the limit.

Concrete products have the potential to be good neutralising agents. Portland cement, a primary constituent of concrete, is composed mostly of lime (CaO), an active neutralising agent. Some concrete mixes also consist of a portion of fly-ash, another recognized neutralising agent.

Rosenlund Constructions had already suggested the use of their crushed concrete material.

Investigations into the use of the crushed concrete products seemed to indicate that little or no research had been done into using these as neutralising agents. However, personnel communications with Mr Phil Mulvey of Environmental and Earth Sciences in Sydney on 28 May 2004 identified that research had been done into using crushed concrete as lining of drains for acidic waters. This research indicated that this product could be utilised effectively as a neutralising agent in treating acid sulfate soils.

Rosenlund produce a range of crushed concrete products at their Fitzgibbon site, only 15 minutes drive from the Armada Place (refer to Appendix B for map showing relative locations) meaning transport costs would be fairly low.

It was decided that from these products, the finest material would be tested, as even though it may be marginally more expensive to produce, a greater Effective Neutralising Value would be obtained.

Queensland Recycling, which operates a concrete recycling plant only five minutes drive from Armada place, also produced various crushed concrete products. I decided to investigate if they might have any products that may be superior to the Rosenlund product as a neutralising agent. Queensland Recycling produced a crusher dust material that was less coarse than the Rosenlund material. Visually, it also appeared to be more purely concrete than the Rosenlund material, which contained some non-concrete product due to the less rigorous initial screening process. Therefore, it was decided that this product would be worth investigating as a neutralising agent.

Whilst investigating other concrete waste products, I discovered on the Envirotest website that waste concrete washout, unused premixed concrete washed from concrete trucks after the completion of a job, had been successfully used to neutralise acidic mine waters. Therefore, I decided to investigate the possibility of using this material as a neutralising agent for treating acid sulfate soils.

After extensive enquiry, and various site visits, I decided upon trialling the concrete washout material at Boral Concrete’s Geebung plant. Even though most premixed concrete batching plants have a concrete washout “bin”, the Geebung plant is the closest concrete plant to the Armada Place site. Discussions with Boral also indicated that if transport was provided, they would supply as much material as available at no cost. In addition, they indicated that some testing had been done on the materials, as they had investigated using the material as a neutralising agent at their quarry sites. These factors indicated that the material would probably be fairly low cost, had definite potential as a neutralising agent, and some information was available, hopefully reducing my research costs.

These three products, the Rosenlund “sand”, Queensland Recycling’s “crusher dust”, and the Boral “premixed concrete washout” material were decided upon as the three materials to be trialled as neutralising agents in treating acid sulfate soils.

4.3.1 Preliminary Testing

After the products to be trialled were selected, preliminary tests were carried out on the products. The tests chosen included obtaining information on the product’s pH, neutralising value, and grading of material. The pH would give a good indicator of the alkalinity of the product, and how effectively it will buffer the acidic conditions of the acid soils. The neutralising value and gradings were obtained as they would be necessary to calculate the Effective Neutralising Value, and hence the mixing quantities required for neutralising any acid sulfate soils.

The information in the following Section provides further information of the selected products, and results from these preliminary tests.

4.4 Selected Neutralising Products

The following section provides detailed information about the products selected to be trialled as neutralising agents in treating acid sulfate soils.

4.4.1 Rosenlund “sand”

The Rosenlund “sand” is a crushed concrete product produced by Crushed Concrete Products, a company affiliated with the Rosenlund Group of Companies. Crushed Concrete Products crushes waste concrete that comes from Rosenlund Contractor’s Pty

Ltd demolition sites. The material is recycled at a yard located approximately 20 minutes drive from Armada Place.

The waste concrete and other crushable material such as brick is usually roughly separated onsite from other demolition waste by excavators, and to a lesser extent by hand, loaded onto excavators and transported to the crushing site. Once onsite, it is loaded by excavator into the primary crusher. The primary crusher used is an Extec Megabite jaw crusher. A labourer working on the primary crusher further removes non-concrete materials to increase the purity of the material. A magnet in the crusher also removes metallic debris, such as reinforcing steel.

The crushed product from the primary crusher is passed through an Extec screening arrangement. Various products are produced in this process, including a 75mm rundown product, a 35 - 45mm product, and 25 – 30mm products, as well as the sand. The sand produced is more accurately described as a 5mm rundown product, meaning that it contains material up to approximately 5mm in size and below. This gives a product that has relatively large particles interspersed amongst fines. It has a density of approximately 1.4t/m^3 loose.

As other waste material such as brick can be passed through the crusher, the product is not comprised entirely of concrete. Some organic matter, even though very little, is present, as well as the occasional bits of plastic and other debris. These impurities are not prevalent however, and the majority of the product is crushed concrete.

Figure 4.1: Stockpile of Rosenlund crushed concrete product

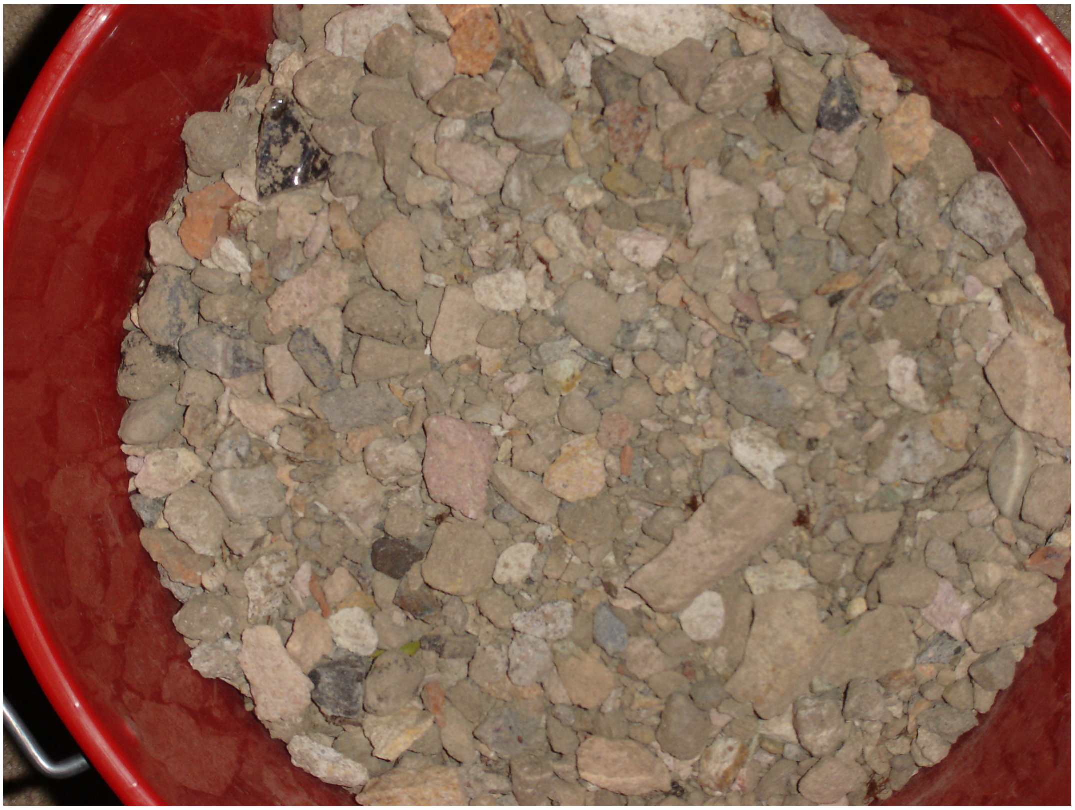


Figure 4.2: Overview of Rosenlund crushed concrete product

Figure 4.3: Close-up of Rosenlund crushed concrete product using pen as scale.

Australian Laboratory Services were enlisted to provide pH and neutralising value of the product. A grading of the material was obtained through Bowler Geotechnical. The results of these tests are given in Appendix D.

A pH of 11.5 shows the material to be quite alkaline. This is somewhat higher than the recommended pH of seven to nine in the *Soil Management Guidelines*. However, other effective neutralising agents such as CKD have similarly high pHs, so this does not automatically exclude the material as a neutralising agent. Care may need to be taken so that excess material is not used, as this may even create overly alkaline conditions in the soil.

The neutralising value is expressed as the Calcium Carbonate ($CaCO_3$) equivalent of the material, its neutralising ability compared with pure lime. This was tested and found to be 21.2%, or roughly one fifth the neutralising ability of pure lime. This value is quite low. However, due to the low cost to obtain the product, it is still worth investigating its potential, as the overall cost may still be less expensive than more expensive commercial neutralising agents.

The grading of the product shows it as quite coarse, as expected, especially compared with a commercial liming agent such as Aglime, where most of the material is smaller than 250 microns. We would expect this to impact fairly significantly on the effective neutralising value of this material. These neutralising value calculations, and a summary of the gradings are given in Section 5.5.2.

Even though solubility was not specifically tested for any of the materials, due to their relative coarseness and composition, we would expect the crushed concrete products to have quite a low solubility. This would suggest that these materials will tend to remain in the soil, and not be prone to being washed out.

The definite advantage this product will have over commercial products is its cheap cost to obtain. However, its low purity and coarseness seems to indicate a quite low neutralising value compared with Aglime, with a neutralising value of about 94%.

4.4.2 Queensland Recycling Crusher Dust

The Queensland Recycling product is produced in a similar way to the Rosenlund product, utilising a Cedar Rapids 5230 jaw crusher and Cedar Rapids screening plant. However, before screening, the crushed material is passed through a Cedar Rapids MVP380 gyro-cone secondary crusher. The Queensland Recycling product is also more rigorously screened for foreign materials before crushing, leading to a material that contains fewer impurities than the Rosenlund product. As finer materials lead to a greater effective neutralising value, I looked for the finest material produced by Queensland Recycling, which was their “crusher dust” product. This material contains smaller particles than the Rosenlund product. The grading for this material, and other information pertaining to this product can be seen in Appendix D. I had hoped that this finer grading, combined with the increased purity of the product, would lead to a material with a greater Effective Neutralising Value, and hence greater neutralising ability than the Rosenlund product.

Figure 4.4: Queensland Recycling Screening Plant overview

Figure 4.5: Queensland Recycling Crusher Dust stockpile

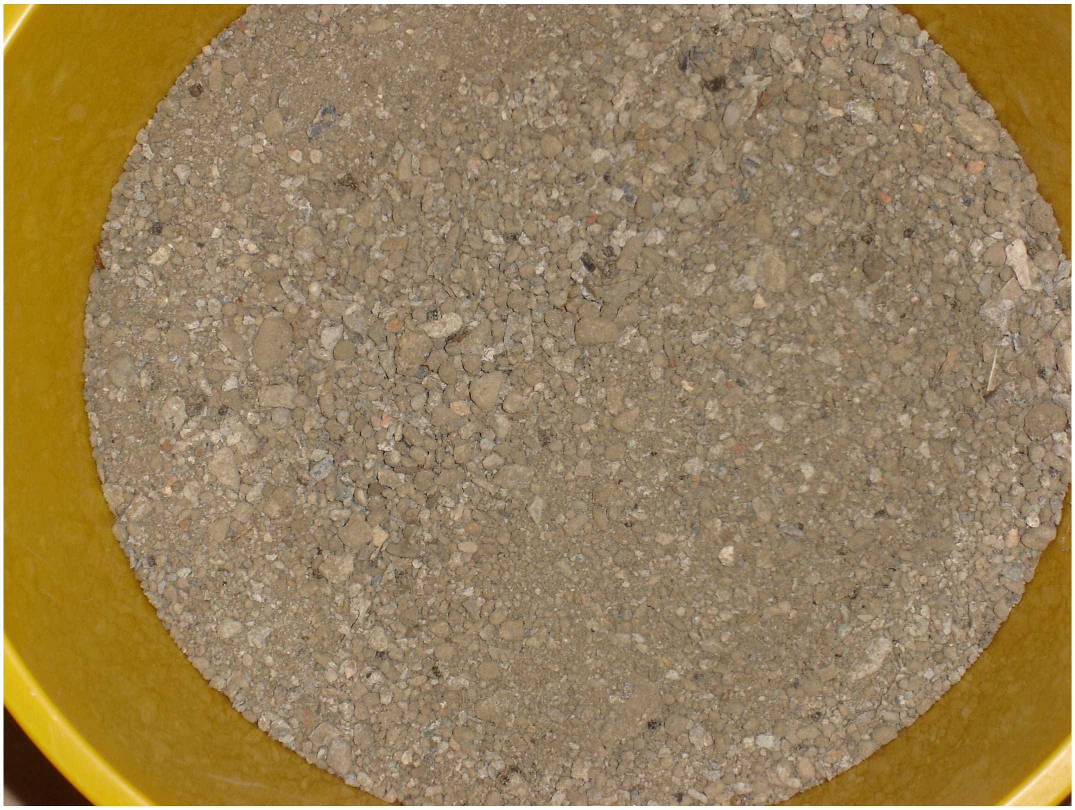


Figure 4.6: Queensland Recycling Crusher Dust overview

Figure 4.7: Queensland Recycling Crusher Dust close-up using pen as scale

Once tested, however, the results not only showed the Queensland Recycling product to be slightly less alkaline than the Rosenlund sand, but also with a slightly lower neutralising value (pH 10.8 and neutralising value of 18.2% $CaCO_3$).

Queensland Recycling reports a density of 1.5t/m^3 loose for this product.

As with the Rosenlund product, this product's greatest advantage is its cheap purchase cost. Its neutralising value, however, is again very low compared with commercial liming agents. Its grading is finer than Rosenlund material, but is still substantially coarser than Aglime.

4.4.3 Boral concrete washout

The concrete washout material is a waste product from the premixed concrete industry. Premixed concrete batching plants, such as the Boral plant at Geebung, generally have a concrete washout bin area. After completion of a job, concrete trucks will return to the plant, and any excess material left in the bowl is washed out into these bins. The Boral plant can batch several different types of concrete per day, as they often batch according to a particular job specifications, whether it be structural, block filling etc. As all these different concrete mixes then come back to the plant, the composition of the concrete washout can be quite variable. Mostly, though, the residue left is the relatively fine cement, as the larger aggregates tend to be removed onsite.

Figure 4.8: Concrete washout bins at Boral Geebung Premixed Concrete Plant

Figure 4.9: Boral Concrete Washout overview

Figure 4.10: Boral Concrete Washout closeup using pen as scale

After deciding upon using the Boral premixed concrete washout material, I spoke with Boral about my research project. It was indicated to me that similar previous research had been carried out by Boral, and some test results, including gradings, neutralising value and pH would be available for the product.

After initial conversations and emails, I was able to obtain some information regarding the neutralising value of the material. The information obtained revealed that one tonne of *screened* concrete washout has a neutralising capacity of 132kg of pure $CaCO_3$, which is the equivalent of a neutralising value of 13.2%. However, as no gradings were available to indicate what size particles this screened product consisted of, assumptions needed to be made. The washout material trialled as a neutralising agent in the leaching column experiment was passed through a hand-held sieve, with an aperture of approximately 0.75mm, producing a much finer product than both the Rosenlund and Queensland Recycling materials.

Due to a lack of funds and time, it was decided that some assumptions would be made and I would utilise this material with the information available, with the possibility of obtaining a grading later, and comparing this with the assumptions. A grading was eventually obtained for this material, from a sample taken straight from the Boral washout bins. However, these gradings are not able to be used to calculate the effective neutralising value of the trialled product, as the screened material used will have a different grading to an unscreened sample taken directly from the washout bins.

A Material Safety Data Sheet (MSDS) from Pioneer on their Premixed Concrete Washout Waste (shown in Appendix E) indicated that this material has a pH of between 12 and 13, which is very alkaline. This indicates again that over application may be harmful due to pH overshooting.

Even if found to be an effective neutralising agent, the usage of this product does have some extra factors that need to be considered. One of the main difficulties that may be encountered in using this product as a neutralising is its varying composition, and hence varying neutralising capability. As the type of material washed from the trucks will vary depending upon the types of jobs undertaken over any period of time, the actual make-up of the material in the bins would be expected to change over time. Even though the proportion of jobs undertaken using common mixes would be roughly similar, and the neutralising value of a sample would be considered to be roughly about the same, it will still vary. Therefore, before a sample is to be used as a neutralising agent, it would need to be tested prior to usage, as the actual amount of washout material needed to be used to treat a given soil sample could vary with each batch.

Another difficulty that may be encountered with this product lies with the supply quantities. The amount of neutralising agent that can be obtained at any one time will depend upon how much material is currently being stored in the Boral plant bins. At present, the bins only hold up to $80m^3$ of material. Very roughly, this quantity could possibly treat about $250\text{-}300m^3$ of soil. If more than this quantity was needed, one would need to wait until the stockpile was built up again, or product would need to be sourced from elsewhere. If a similar material was sourced from another premixed concrete plant, the cost effectiveness is also likely to change.

4.5 Testing of Neutralising Products

After the selection of the products to be tested, a suitable experiment was needed to be chosen to analyse the performance of each product.

The experiment chosen would mainly need to test that water running through neutralised soil, and the neutralised soil itself, would meet specified guidelines regarding pH and other indicators.

A leaching column experiment was decided upon as suitable. This experiment involves mixing the acid sulfate soils with the neutralising agents to be trialled, which are then placed in "leaching columns". These are then submitted to wetting and drying regimes. The wetting regime involves water being added to the top of the column, which then leaches through the column, discharging being at the base. After each wetting cycle, a water sample (leachate) is collected from the base of the column for analysis. The soil samples are also able to be tested as necessary.

4.5.1 The acid sulfate soils

It was envisaged that this experiment utilise a sample of acid sulfate soil extracted from the Armada Place site. This would then indicate how each of the products would perform on the actual soils needing to be neutralised. This would have been appropriate, as the performance and suitability of a product will depend on the soil type to be neutralised.

Unfortunately, the Armanda Place Development Approval is still under negotiation, and a site Acid Sulfate Soil Investigation has not yet been performed. Even though this is predicted to happen later this year, the research project needed to be conducted without these soils (if any are actually present) available. Therefore, another acid sulfate soil sample was required to conduct the project.

As the scientific testing required to determine the extent of acid sulfate soil acidity and other indicators can be quite expensive, I needed to locate a soil that already had the appropriate testing carried out. After some enquiry and investigation with various geotechnical organisations, the Queensland Acid Sulfate Soil Investigation Team at Indooroopilly generously supplied an acid sulfate soil sample obtained in their research some years ago. This sample was used in conducting the leaching column experiment. Section 5.4 of the dissertation provides further information regarding this acid sulfate soil sample.

Even though the soil is not the same as that which may be encountered at Armada Place, an indication of the performance of the various products will still be able to be tested. By also using Aglime as a neutralising agent on the soil, we can see how each product performs in comparison with an accepted neutralising agent.

4.5.2 Experimental Challenges

The primary concern with this experimentation is the timeframe over which it is to be run. One of the main aspects with a neutralising agent is that it needs to be able to continue neutralising until all acidity production within the soil is completed. This can take a long period of time, and similar leaching column experiments have been run over periods longer than one year. Acid sulfate soils can continue producing acids for many, many years. This research project was coordinated so as to maximise the amount of time that the experiment was run over, but this still only allowed just over 2 months of incubation.

The soils obtained from QASSIT are a sandy, fine soil. This would mean that they will tend to oxidise quite rapidly. By utilising these soils, I hope that the majority of oxidation will occur within this two month period.

From the above, we can see that this experiment, even though very useful in evaluating these products, is still only going to be an indicator as to their field performance. Therefore, the results obtained can only be applied to the soils on which the tests were applied, and may not indicate how well they will perform at the Armada Place site.

4.5.3 Safety

As this experiment would entail the handling of some potentially quite acidic and alkaline substances, various safety precautions needed to be taken. In addition, the collection of samples required entering operational batching plants and recycling facilities.

When entering sites, all appropriate Workplace Health and Safety requirements needed to be adhered with. This usually required the wearing of appropriate Personal Protective Equipment such as steel capped boots, high visibility clothing and a hard-hat.

There are several hazards that needed to be considered in regards to the handling of the acid sulfate soils themselves. Oxidised acid sulfate soils produce sulfuric acid, leading to low pHs of the soil, and leachate. These acidic conditions are quite corrosive, and can cause permanent damage to exposed skin and eyes, so care needed to be taken when handling these materials. Gloves, a P2 respiratory mask and gloves were worn when handling the soils during mixing, and placing the soils in the columns. Safety glasses were worn when adding water to the columns, to avoid splash-back into eyes.

Oxidising soils also produce hydrogen sulfide gas, which can overcome if encountered in confined areas. Therefore the soils were kept outside, so as to ensure adequate ventilation. A plastic cover was erected over the samples, so as to protect the columns from the elements, but this still allowed plenty of ventilation around the columns.

Lastly, the neutralising products themselves pose some safety considerations. As a fine powdered product, Aglime has the potential to cause respiratory problems if inhaled, and can cause irritation if it comes in contact with the eyes. A Material Safety Data Sheet (MSDS) for agricultural lime produced by DML Lime is given in Appendix E, which presents most information in regards to the safe handling of these materials. During mixing using this product, a P2 respiratory mask, safety goggles and gloves were worn.

The crushed concrete products, being fairly coarse, posed few safety hazards. PPE was worn only during mixing, due to the acid sulfate soil.

The MSDS for premixed concrete washout product prepared by Pioneer was referred to when handling the concrete washout product. Once again, mask, gloves and eyewear was worn during mixing to minimise any risk.

Chapter 5

Experimentation

5.1 Aims and scope of experimentation

The aim of this experiment was to measure the effectiveness of each of the products compared to agricultural lime as an ameliorant for an Acid Sulfate Soil.

The experimental method chosen to measure the effectiveness of each of the potential neutralising agents was a leaching column experiment.

The leaching column experiment involved mixing an acid sulfate soil sample of known acidity with each of the neutralising agents to be tested. Each mix is then contained in leaching columns, and subjected to wetting and drying. After each wetting, leachate was collected from each column, and the sample's pH level tested.

Two leaching columns for each by-product were set up, one containing 50% of the calculated theoretical mixing rate and the other containing 150% of the mixing rate. A leaching column was also set up containing the ASS mixed with lime in accordance with best practice. A control leaching column containing un-ameliorated ASS was prepared, indicating how the untreated soil would react.

5.1.1 Reasons for leaching column mixes

Each by-product was mixed at 150% of the theoretically required mixing rate and 50% of this rate. The 150% mixing rate was chosen so as to satisfy the minimum 1.5 safety factor as described in Section 8.3.5 of the *Soil Management Guidelines* in the *Queensland Acid Sulfate Soil Technical Manual*. The 50% mixing rate was chosen so as to test how the products would perform if the mixing rate was less than the theoretically required rate. The calculations for these mixing rates are described in Section 5.4 of this dissertation.

The leaching column containing the agricultural lime (Aglime) was set up so as to provide a performance comparison for the other ameliorants compared with an accepted neutralising agent.

The leaching column containing only acid sulfate soils was established so as to provide a control column, indicated how the leachate and soil would be affected by uncontrolled oxidation of the soil.

5.2 Apparatus

The apparatus used to conduct this experiment are as follows:

- 8 leaching columns
- Measuring cylinder (700mL).
- Electronic scales (accurate to 1 gram).
- Distilled water.
- Approx 34 litres of de-ionised water.
- 7 plastic garbage bags.
- 48 film canisters with sealable lids and labels
- TPS MC-80 handheld pH-mV-Temperature meter.

The following diagram and photographs describe the construction of each of the columns:

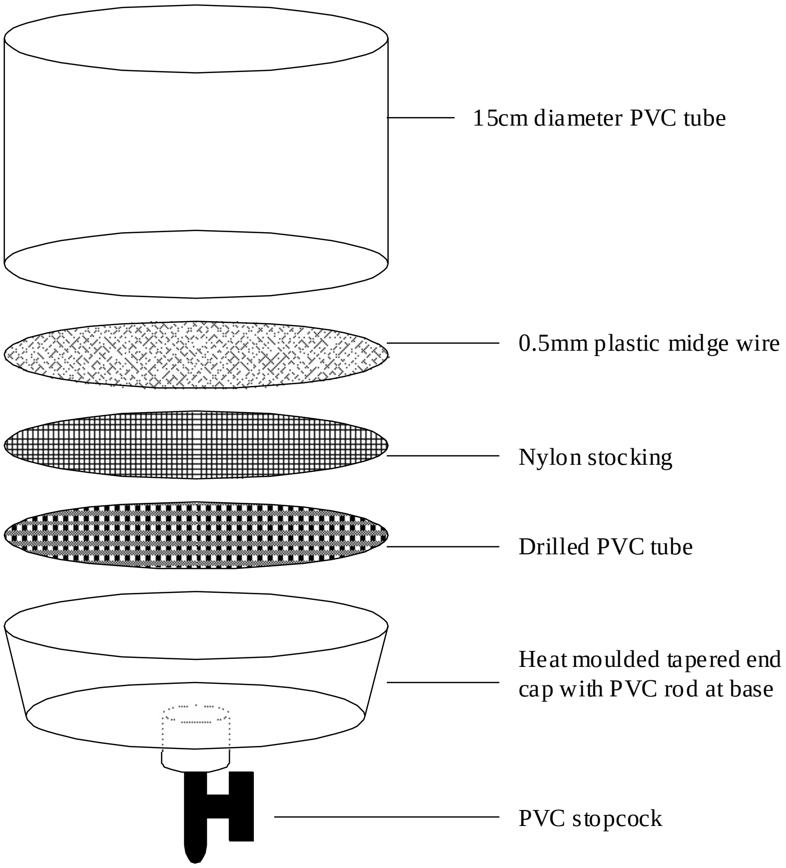


Figure 5.1: Leaching column construction

Figure 5.2: Photograph of typical leaching column

Figure 5.3: Photograph of leaching columns in holding rack

These columns, aside from the midge wire and nylon stocking filters, were borrowed from the QLD Department of Natural Resources, Mines and Energy, QASSIT.

Each leaching column was labelled from one to eight inclusive.

5.3 Method

1. 1.5kg of ASS weighed out with electronic scales and placed in leaching column one.
2. 1.5kg of ASS weighed with electronic scales and placed in plastic garbage bag.
3. 66g of agricultural lime (refer to Section 5.4 for liming calculations) weighed out and placed in plastic garbage bag.

4. Garbage bag containing ASS and agricultural lime shaken until thorough mixing has occurred.
5. ASS and lime mix poured from garbage bag into leaching column two, ensuring all material has been depositing in column.
6. 1.5kg of ASS and 339g of Rosenlund's crushed concrete weighed out, mixed in garbage bag and placed in leaching column three.
7. 1.5kg of ASS and 1.016kg of Rosenlund's crushed concrete weighed out, mixed in garbage bag and placed in leaching column four.
8. 1.5kg of ASS and 247g of Queensland Recycling's crushed concrete weighed out, mixed in garbage bag and placed in leaching column five.
9. 1.5kg of ASS and 740g of Queensland Recycling's crushed concrete weighed out, mixed in garbage bag and placed in leaching column six.
10. 1.5kg of ASS and 207g of Boral cement washout weighed out, mixed in garbage bag and placed in leaching column seven.
11. 1.5kg of ASS and 622g of Boral cement washout weighed out, mixed in garbage bag and placed in leaching column eight.
12. When wetting the columns, the stopcocks were closed on each leaching column and 700mL of de-ionised water added to each column.
13. The column was then allowed to sit for several hours, after which time the stopcock was opened, and the water allowed to drain out. A sample of leachate from each column was collected in a labelled film canister. The canisters for column 1 were labelled 1.1, 1.2, 1.3 etc, column 2 were 2.1, 2.2, 2.3 etc.
14. After the leachate was collected, the handheld pH meter was used to determine the pH of the leachate and the results recorded. Each sample was then dried out for two weeks, after which time the cycle was repeated.
15. After the sixth cycle was completed (after 11 weeks), the pH of the soils for the Untreated Acid Sulfate Soil, Aglime, Rosenlund 150%, Boral 150% and Queensland Recycling 150% treated soils was found, and the Aluminium and Iron content of the leachate for these same samples was also found.

Figure 5.4 shows the layout of each of the leaching columns and contents.

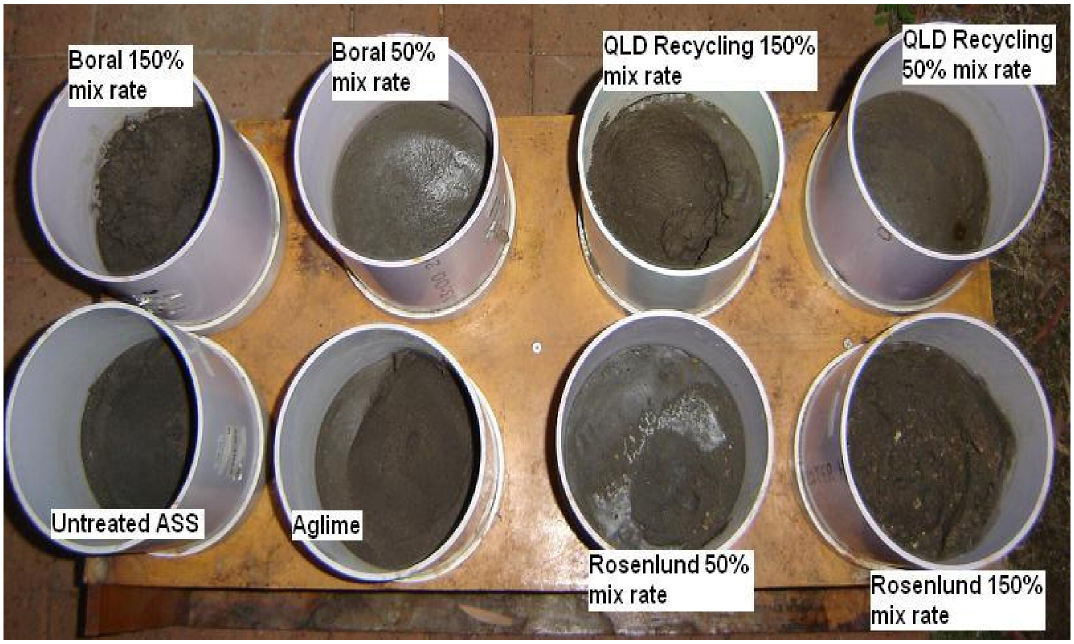


Figure 5.4: Leaching column layout, including content descriptions

5.4 The Acid Sulfate Soil Sample

The acid sulfate soil used in this leaching column experiment was donated by QASSIT.

It was originally collected from the Oyster Cove canal development site, next to Saltwater Creek (off the Coomera River), near Hope Island, inland from the Gold Coast in south-east Queensland. After collection, the soil samples were dried at 85^{o}C in a fan-forced oven, ground to pass through a 1mm sieve and thoroughly mixed. Figure 5.5 shows a photo of the ground soil as used in the experiment, and Figure 5.6 shows the storage container used to hold the soils prior to mixing.

Figure 5.5: Acid Sulfate Soil sample used in the leaching column experiment

Figure 5.6: Acid Sulfate Soil sample container

In order to calculate the liming rates for the soil, the Net Acidity of the soil needed to be calculated, as per the Acid Sulfate Soil Laboratory Method Guidelines.

As the soil was originally collected in 1998, QASSIT performed new tests on the soils to determine its current Net Acidity.

5.4.1 Calculating Net Acidity for Acid Sulfate Soil sample

Under the Acid Sulfate Soil Laboratory Method Guidelines (ASSLMG), "calculations for quantity of neutralising materials will need to be based on the net acidity from acid base accounting".

Net Acidity = Potential Sulfidic Acidity + Actual Acidity + Retained Acidity

Potential Sulfidic Acidity was calculated from the Chromium Reducible Sulfur method (S_{cr}) as described in the ASSLMG (Method Code 22B). The S_{cr} value was 0.558 %S.

Actual Acidity was taken as the Titratable Actual Acidity (TAA), as described in the ASSLMG (Method Code 23F). TAA was found to be 66mol H^+/t, which is equivalent to 0.106 %S (refer to Section 5.4.2 for an explanation of %S, and how this conversion can be made).

Retained Acidity was taken as s-SNAS x 0.75, where s-SNAS = S_{HCl} - S_{KCl}. S_{HCl} is the 4 M HCl Extractable Sulfur (ASSLMG - Method Code 20B) and S_{KCl} is the Sulfur 1 M KCl Extraction (ASSLMG - Method Code 23C). S_{HCl} was found to be 0.491 %S and S_{KCl} was found to be 0.134 %S.

s-SNAS = 0.75 x (S_{HCl} – S_{KCl}) = 0.75 x (0.491 – 0.196) = 0.221 %S

Therefore:

Net Acidity = Potential Sulfidic Acidity + Actual Acidity + Retained Acidity
Net Acidity = 0.558 %S + 0.106 %S + 0.221 %S

Net Acidity = 0.885 %S.

This Net Acidity value can now be used in the calculations for the liming rates of the various neutralising agents.

5.4.2 Explanation of %S value

The %S value describes the percentage of Sulfur present in a sample of ASS as pyrite (FeS_2) by weight, the main source of acidity in acid sulfate soils. This value can be used to calculate the maximum amount of acid that can be generated as a result of the complete oxidation of sulfides.

The equation produced by Dent (1986) that describes the complete oxidation of pyrite is as follows:

$$FeS_2 + 15/4\ O_2 + 7/2\ H_2O \rightarrow Fe(OH)_3 + 2SO_4^{2-} + 4H^+$$

This shows that two moles of Sulfur (in pyrite) produces four moles of H^+ ions after oxidation (or one mole of S produces two of H^+).

As an example, the ASS sample has a TAA of 66mol H^+/t. This will translate to 33mol of Sulfur present per tonne of soil. one mole of Sulfur weighs approximately 32 grams, so this translates to 1,056 grams of S per one tonne of soil, or 1,056 / 1,000,000, or approx 0.106% S by mass.

5.5 Calculation of Liming Rates

5.5.1 Stoichiometric calculations for $CaCO_3$ requirements

As previously discussed, when ASS oxidises, it produces H^+ ions through the oxidation of pyrite and jarosite and various other mechanisms.

As the potential neutralising agents are all lime based, the major neutralising constituent in them is lime, $CaCO_3$.

Ahern and McElnea (1999) and others describe the chemical reaction that occurs during neutralisation as per the following equation:

$$CaCO_3 + 2H^+ + SO_4^{2-} + H_2O \rightarrow CaSO_4.2H_2O + CO_2 \uparrow$$

This shows that one mole of $CaCO_3$ is able to neutralise two moles of H^+. Now Section 5.4.2 described that two moles of S produces four moles of H^+. Therefore, for every mole of S in the soil, one mole of $CaCO_3$ will be needed to neutralise the acid produced.

Now Section 5.4.1 gave us a net acidity for this sample of soil as approx. 0.885%S. Therefore, for one kilogram of soil:

1 x 1,000g x 0.885/100 = 8.85 grams of S are present.

Now, one mole of Sulfur weighs 32.07 grams (taken from the Periodic Table of Elements). Therefore, 8.8525g = 8.85/32.07 = 0.276 moles of Sulfur.

One mole of Sulfur requires one mole of $CaCO_3$, so 0.276 mole of Sulfur requires 0.276 moles of $CaCO_3$.

Now, one mole of $CaCO_3$ weighs 100.087 grams, so for one kilogram of soil:

$0.276 \times 100.087 \approx 27.63$ grams of $CaCO_3$.

Therefore, to neutralise the acid produced by one kilogram of this acid sulfate soil, 27.63 grams of pure $CaCO_3$ would need to be mixed with it.

5.5.2 Calculating the Effective Neutralising Value of By-products

As the by-products to be used as neutralising agents are not pure $CaCO_3$, Section 8.3.4 of *Soil Management Guidelines* from the *Queensland Acid Sulfate Soil Technical Manual* describes that a neutralising value for each of the products needs to be found so that a correction factor can be applied to compensate for this lack of purity. The neutralising value is usually described as its $CaCO_3$ equivalent, where 100% describes a material that has the same neutralising capability of pure $CaCO_3$.

In addition to this, a correction factor needs to be calculated to compensate for the coarseness of the material. The Effective Neutralising Value (ENV) takes into account the neutralising value of a material, the grading of the material and moisture content, and should be used to describe the actual neutralising capacity of the ameliorant when performing liming calculations. The ENV is effectively a measure of the lime's reactivity in soil and is an index of quality and fineness. The calculation of the ENV for each ameliorant is performed later in this section.

The neutralising value of each material can be found by finding the $CaCO_3$ equivalent for each product. For the Rosenlund and Queensland Recycling materials, this was calculated by Australian Laboratory Services, the results of which can be viewed in Appendix D. The neutralising value for the Boral Premixed Concrete Washout was obtained directly from Boral Environmental Services. The neutralising capacity of the agricultural lime was obtained from the packaging information. A summary of these neutralising values is shown in Table 5.1.

Table 5.1: Neutralising Values for ameliorants

Material description	Aglime	Rosenlund 5mm Sand	QLD Recycling Crusher Dust	Boral Premixed Concrete Washout
Neutralising Value ($CaCO_3$ equivalency)	94%	21.2%	18.2%	13.2%

Section 8.3.5 of the *Soil Management Guidelines* refers to the *Information Sheets on Neutralising Agents* in regards to procedures accounting for impurity and coarseness. The *Information Sheet* on *Neutralising Agents: Neutralising Considerations* outlines the procedure to calculate the ENV given a grading of a material. This Information Sheet is specifically referring to fine Aglime; however, I have chosen to employ the same technique in calculating an ENV for the products in this experiment, as no better method is suggested.

This Information Sheet explains that the ENV is the sum of the following:

- Neutralising Value (NV) % multiplied by the percentage of material of particle size less than 300 micron (< 0.3mm)
- 0.6 times NV% multiplied by the percentage of material greater than or equal to 300 micron but les than 850 micron (0.3mm - 0.85mm)
- 0.1 times NV% multiplied by the percentage of material greater than 850 micron (> 0.85mm)

The information sheets also describe how a further adjustment can be made for the moisture content of the product. This is done by multiplying the resultant of the above ENV value by one minus the moisture content percentage. As the product samples were all dried by sun previous to mixing, this value was assumed to be negligible for all products, and no adjustment was made. For future calculations, such as for field application, the moisture sample should be found for the product being taken to site, and the compensation applied. This compensation is also not referenced in calculating liming rates as per the *Soil Management Guidelines*, but is a further precaution. In addition, no moisture content for the Boral or Aglime product was available, so it was decided to test them as is.

The grading chart for each of the ameliorants is given in Appendix D of this dissertation. From these charts, we can calculate the percentage of material for each product that falls within the above sizes. Table 5.2 summarises these figures.

Table 5.2: Grading of ameliorants for ENV calculations

	Proportion %		
Size fractions	**< 0.300mm**	**0.3mm – 0.85mm**	**> 0.85mm**
Aglime	100	0	0
Rosenlund 5mm sand	16	9	75
QLD Recycling Crusher Dust	30	18.4	51.6
Boral Concrete Washout	Unknown	Unknown	Unknown

Unfortunately, no grading was available to be obtained for the Boral Concrete Washout material within the project timeframes, so an estimation of the ENV was made. This figure is given below.

Enough information is now available to calculate the ENV for the other ameliorants.

ENV Calculation for Aglime product

ENV = 94 x 100/100 + 94 x 0.6 x 0/100 + 94 x 0.1 x 0/100
ENV = 94%

ENV Calculation for Rosenlund 5mm sand product

ENV = 21.2 x 16/100 + 21.2 x 0.6 x 9/100 + 21.2 x 0.1 x 75/100
ENV = 6.12%

ENV Calculation for QLD Recycling Crusher Dust product

ENV = 18.2 x 30/100 + 18.2 x 0.6 x 18.4/100 + 18.2 x 0.1 x 51.6/100
ENV = 8.4%

ENV for Boral Concrete Washout product

As gradings were not available for the Boral Concrete Washout product, an estimate was made as to its ENV, given its Neutralising Value. As described in Section 4.4.3 the Boral product was screened using a sieve of approximately 0.75mm aperture. This lead to a product much finer that the crushed concrete products. Therefore, its Neutralising Capacity of 13.2% $CaCO_3$ equivalence was reduced to an ENV of only 10%, which is a smaller reduction in neutralising capacity compared with the other by-products.

5.5.3 Liming rate calculations for ameliorants

The liming rate for each ameliorant can now be calculated. This liming rate will be calculated as the pure $CaCO_3$ requirement, multiplied by the correction factor for the products ENV, multiplied by a safety factor. This safety factor is described in Section 8.3.5 of the *Soil Management Guidelines*, and ranges from 1.5 to 2, 1.5 being the minimum value. As described in the *Guidelines*, this safety factor is used to compensate for incomplete mixing of the neutralising agent with the soil, and coatings that form on the grains of the neutralising agent, reducing its neutralising efficiency.

For the products being tested, I have chosen a safety factor of 1.5 and 0.5 (150% and 50% of theoretical requirements). The reason for choosing the minimum 1.5 safety factor so was that the other allowances made in the ENV calculations were already fairly conservative, so by adding a further safety factor, the minimum only need be applied. If the products were to fail in neutralising the acid sulfate soil, this safety factor would need to be reconsidered, depending on the extent of the failure. The 0.5 safety factor was also applied to see how the by-products would perform if less than the calculated liming rate was applied.

The correction factor for the ENV will be the ENV divided by 100%. So, for a product with an ENV of 50%, the correction factor will be 100/50 = 2.

As 1.5kg of ASS per leaching column has been chosen, the per kilogram liming rate needs to be multiplied by 1.5 to get the correct rate for the column.

Liming rate calculation for Aglime

For 1.5 Safety Factor

Liming rate per 1.5 kg of ASS (g) = ($CaCO_3$/kg x 1.5) x 100/ENV x Safety factor

= (27.63 x 1.5) x 100/94 x 1.5

≈ 66g of Aglime / 1.5kg of ASS

Liming rate calculation for Rosenlund 5mm Sand

For 1.5 Safety Factor

Liming rate per 1.5kg of ASS (g) = ($CaCO_3$/kg x 1.5) x 100/ENV x (Safety factor)

= (27.63 x 1.5) x 100/6.12 x 1.5

≈ 1,016g / 1.5kg of ASS

For 0.5 Safety Factor

Liming rate per 1.5kg of ASS (g) = (27.63 x 1.5) x 100/6.12 x 0.5

≈ 339g / 1.5kg of ASS

Liming rate calculation for QLD Recycling Crusher Dust

For 1.5 Safety Factor

Liming rate per 1.5kg of ASS (g) = (27.63 x 1.5) x 100/8.4 x 1.5

≈ 740g / 1.5kg of ASS

For 0.5 Safety Factor

Liming rate per 1.5kg of ASS (g) = (27.63 x 1.5) x 100/8.4 x 0.5

≈ 247g / 1.5kg of ASS

Liming rate calculation for Boral Concrete Washout

For 1.5 Safety Factor

Liming rate per 1.5kg of ASS (g) = (27.63 x 1.5) x 100/10 x 1.5

≈ 622g / 1.5kg of ASS

For 0.5 Safety Factor

Liming rate per 1.5kg of ASS (g) = (27.63 x 1.5) x 100/10 x 0.5

≈ 207g / 1.5kg of ASS

These liming rates are the amount of each material added in the leaching column experiment.

5.6 Analysis of samples

As mentioned in the methodology in this Chapter, the leachate from the columns was collected at two weekly intervals, with the first sample collected one week after initial testing, over a total period of 11 weeks. This gave a total of six leachate samples for each column.

The results that I wanted to obtain were the pH of the leachate samples, pH of the soil, and metallic content of the leachate. From these results, we can evaluate the ability of the trial neutralising agents to raise the leachate and soil pHs to the levels specified in the performance criteria, and keep them at acceptable levels for the experimentation period.

The metallic component, even though related to pH levels, would also give a good indication of the ability of the products to control the export of dissolved metals, a major problem associated with acid sulfate soil oxidation. It was realised quite early that to test for all heavy metals would be very expensive, so therefore it was decided that testing of only dissolved aluminium and iron levels would be required, as these metals are generally the most readily mobilised in the acidic conditions, and the control of these would indicate the control of the heavy metals that require more acidic conditions.

The critical factor in deciding the extent of analysis that could be undertaken in this project was cost. When costing the tests required for this research project, the enquiries I made indicated that each leachate pH test would cost around $6 per sample, a soil pH test would cost around $6 per sample, and dissolved aluminium and iron would cost around $35 per metal per sample. For a total of 48 samples (six samples for each of the eight columns) this would cost around $4,000, which was quite out of my budget. After enquiries with USQ, I was able to obtain a handheld pH monitor for testing leachate pH. However, they were unable to test for aluminium or iron content.

It testing regime decided upon was that the leachate pH would be tested over the 11 week period, but the soil pH, aluminium and iron levels would only be tested on the final sample for the products containing the 150% mixing rates, Aglime and the control column. The leachate pH would give a good indicator of the performance of the agents during the eleven weeks. The soil pH, aluminium and iron levels at the end of this period, even though not showing peaks or troughs during the whole incubation period, would still be able to show if the agents were able to bring these indicators within acceptable levels. As the 150% mixing rate represented the actual in-field mixing rate, these were the critical samples to be tested, and the 50% mixing rates were demonstrative only, the results of which weren't critical.

The results from these analyses are discussed in the next chapter.

Chapter 6

Results of Leaching Column Experiment

The results from the leaching column experiment are as follows:

6.1 Leachate pH

The following table summarises the results from the leachate pH readings taken over the 77 day period. A line graph representing these values is given in Appendix F.

Table 6.1: Leachate pH for Leaching Column Experiment

	Number of Days Elapsed					
	7	**21**	**35**	**49**	**63**	**77**
Un-neutralised Acid Sulfate Soil	1.86	2.33	2.57	2.47	2.27	2.22
Aglime	6.55	5.92	6.74	6.9	6.84	6.87
Rosenlund Sand (50%)	2.94	3.76	3.9	3.5	3.3	3.04
Rosenlund Sand (150%)	3.51	5.54	7.07	6.5	6.2	6.26
QLD Recycling Crusher Dust (50%)	6.7	5.88	7.28	7.13	6.94	6.84
QLD Recycling Crusher Dust (150%)	6.4	6.2	6.75	7.41	7.34	7.23
Boral Concrete Washout (50%)	4.04	5.01	4.06	3.88	3.57	3.35
Boral Concrete Washout (150%)	6.52	5.78	7.25	6.7	7.2	7.24

It was established that the performance criteria for leachate pH was that it should fall between pH 6.5 – 8.5 (refer to Section 3.3.2). From these pH tests, we can see that both the Queensland Recycling Crusher Dust and the Boral Concrete Washout performed satisfactorily. The Queensland Recycling Crusher Dust took almost a month, however, until the leachate was within acceptable levels, whereas the Boral Concrete Washout raised the leachate pH within seven days. After raising the pH to the required level, we can see that both these products kept the pH at sufficient levels for the duration of the incubation period, and performed just as well as the Aglime in neutralising acidic leachate.

The Rosenlund material, however, was not as successful as the other products. It was slower to raise the pH of the leachate, and then only held the pH at an acceptable level for about two weeks, where it fell away. This may have occurred due to insufficient neutralising agent being used, meaning that the neutralising agent of the material was used up in the neutralisation of the sulfuric acid before the soil had completed the production of acids. This is a failure of the third performance criteria, that requires excess neutralising agent to remain in the soil until all acid production has ceased. Larger grained neutralising products can also be prone to build ups of coatings of gypsum, iron and aluminium compounds, leading to a decrease in their neutralising efficiency, which may have also been the case.

By using a higher safety factor, say two or three as opposed to 1.5, it is quite possible that this product would perform satisfactorily. However, this would then greatly reduce the cost effectiveness of the product, as larger quantities of the material would need to be used to neutralise the soils.

6.2 Soil pH and metallic pollutants

After 77 days of incubation, at the conclusion of the leaching column experiment, a leachate sample and soil sample was taken from the leaching columns. The soil sample was tested for pH, and the leachate tested for soluble aluminium and iron.

The soil pH test will test the ability of the products being trialled to meet the *Soil Management Guideline*'s performance criteria of being able to raise the soil pH to between pH 5.5 and pH 8.5. It would have been preferable to monitor the soil pH during the incubation period, as with the leachate pH, but the portable pH monitoring equipment is only suited to liquid. The cost of having each column tested was too inhibitive to warrant constant testing, and hence it was decided that only a final reading would be obtained. This will at least serve as an indicator as to the product's performance, but does not show how rapidly the soil pH was altered, or any fluctuations that may have occurred over the period.

As previously discussed, in acidic conditions caused by ASS oxidation, metal pollutants, and most notably aluminium and iron, are mobilised and leached from the soil. Therefore, it is important that these metallic substances are controlled, and not contributed to, by the neutralising agents.

Due to the costs associated with testing of soil pH and metallic contents, it was decided that the three under-neutralised columns would not be tested. We would expect that the lower pH columns would have higher levels of aluminium and iron in the leachate, as it is dissolved from the soil.

The *Soil Management Guidelines* list the ability of the neutralising agent to lift the soil pH above 5.5 as a performance criterion. It also recommends a maximum pH of 8.5. The following table summarises the soil pH as reported by ALS. The ALS reporting sheets can be found in Appendix D.

Table 6.2: Soil pH after 77 days incubation

Untreated Acid Sulfate Soil	**Aglime treated ASS**	**Rosenlund product (150%) treated ASS**	**QLD Recycling Product (150%) treated ASS**	**Boral concrete washout (150%) treated ASS**
3.6	7.2	7.7	8.5	8.1

This shows that all the neutralising agents were able to substantially raise the soil pH from the pH 3.6 of the untreated soil. However, we can see that both the QLD Recycling material and the concrete washout have caused the soil to reach the upper limits of the acceptable range. The Aglime was able to place the soil at a quite neutral pH 7.2, which is more suitable.

The following table summarises the soluble aluminium and iron levels in the leachate after 77 days of incubation:

Table 6.3: Leachate Aluminium and Iron Levels after 77 days incubation

	Untreated ASS	**Aglime Treated ASS**	**Rosenlund sand treated ASS**	**QLD Recycling treated ASS**	**Concrete washout treated ASS**
Aluminium (mg/L)	**42.2**	**< 0.1**	**< 0.1**	**< 0.1**	**< 0.1**
Iron (mg/L)	**228**	**0.04**	**.20**	**0.04**	**0.02**

These results show that all materials were effective in drastically reducing the export of aluminium and iron from the soil. However, we can see that the iron levels in the leachate from the Rosenlund material column was five times greater than that of the Aglime treated ASS and the QLD Recycling material, and ten times greater than the best performer, the Boral concrete washout material. As the pH of the leachate for this material was substantially less than the other products at this stage, it is understandable that a greater amount of metallic materials will be leached out of the soil in the more acidic environment.

6.3 Summary

From these results, we can see that of the trialled neutralising agents, the Boral Concrete Washout product, and the Queensland Recycling Products appeared to perform as well as Aglime in neutralising the acid sulfate soil. Both these products were able to raise the leachate and soil pH levels to within the required parameters, and keep them at these levels for the duration of the experiment. The Boral concrete washout did appear to perform slightly better, able to raise the leachate pH to an acceptable level quite quickly (even more rapidly than Aglime).

The Rosenlund sand material, at the mixing rates used, was able to raise the soil pH sufficiently. However, the leachate pH, even though reaching the required level of 6.5, was only maintained for two weeks when the pH level dropped to below 6.5. It should be said that the pH level was not far below the required level, and appeared to have stabilised at this level. However, due to the completion of the experimental period, it was unable to be seen if the pH would rise again, though this is highly unlikely. As mentioned previously, it would appear that this would mean that the products neutralising efficiency has been reduced so far as to not be able to neutralise the acids being produced by the soil.

All products were able to significantly reduce the aluminium and iron levels in the leachate by the end of the experiment. Once again, however, the Rosenlund product allowed far more aluminium and iron to be dissolved than the other products. The Water Quality Objectives for the Armada Place site do not set limits for dissolved iron and aluminium levels, but by comparing the results with those of the commercial Aglime product, we can see that the Boral concrete washout and the Queensland Recycling product were able to perform as well as the commercial product.

One important point that can be made from these results is the importance of incorporating sufficient neutralising product into the soil. Table 6.1 shows that for the Rosenlund and Boral products where only 50% the theoretical mixing rate was used, the leachate pH was only raised slightly above that for the un-neutralised soil, and was substantially lower than the required pH 6.5. However, even at 50% the theoretical mixing rate, the QLD Recycling product was able to raise the pH to within the required range. It is unknown as to why this might have occurred. Even though this lower mixing rate was able to perform satisfactorily over the period of this experiment, I would imagine that their would be insufficient neutralising capacity in this quantity of material to continue neutralising effectively for a sustained period of time.

Therefore, as far as their ability to effectively neutralise acid sulfate soils, both the Boral concrete washout product, and the Queensland Recycling crusher dust were effective neutralising agents during this experiment. However, as mentioned previously, due to the relatively short timeframe over which this experiment was conducted, it is unknown as to whether these products would perform over the long-term. Even though the

Queensland Recycling Product was able to perform effectively within the 11 week, we can see that the last six weeks showed a gradual decline in the leachate pH, whereas the Boral product and the Aglime product maintained a fairly stable leachate pH. This could indicate that the Queensland Recycling Product, like the Rosenlund product, will not sustain its neutralising capabilities for extended period of time. However, again, this experiment cannot effectively conclude this either way.

6.3.1 Usage difficulties

Even though these products may be effective as neutralising agents, it is envisaged that there would be difficulties associated with applying these products in the field.

One of the main problems I can see in using these products is the bulking of the soil. When using 66 grams of Aglime per 1.5 kilograms of soil, this has little to no effect of the volume of the soil. However, when using the crushed concrete products at an application rate of one kilogram or seven hundred grams per 1.5 kilograms of soil, especially with the coarse grain sizes, this can bulk the material out to an extra 50% or more of its original volume. In the field, 250m^3 of ASS may become 350m^3 of neutralised soil. If, as at the Armada Place site, the excavated ASS is to be reused as fill, this could lead to excess material that requires disposal, which adds to the cost of using these products.

As mentioned in the introduction to the Boral concrete washout product in Section 4.4.3, the supply of this material may pose some problems, as a limited supply of varying composition would be available. Therefore, even though the sample trialled was satisfactory, this does not mean that all product taken from that plant will prove as effective. If testing of other samples from the plant show a lower neutralising value, this will adversely affect the cost effective of this product. If insufficient material is available when needed, then another product may need to be sourced. It is these sorts of issues that make commercial products so useable, as they are available on demand, and of an assured quality.

Chapter 7

Cost Analysis

The final stage of this research project is to compare the cost effectiveness of the various trial products in treating on site acid sulfate soils, as compared to a commercial liming agent. By doing so, it may be possible that a more cost effective alternative to these commercial products may be found.

As discussed in Section 4.1.2, the total cost of a neutralising agent is dependant upon a number of different factors. These factors are the purchase cost of the product, transport cost, and onsite mixing costs. Any single one of these factors cannot determine the cheapest product, but they must be looked at collectively.

To reiterate, the purpose of this cost analysis is to determine the cost of using each product at the Armada Place development site, on Brisbane’s north side, and the chosen trial products were partly selected due to their proximity to the site, in order to decrease transport costs. A map of the area is shown in Appendix B, showing the location of each of the sites in relation to Armada Place.

After enquiries to several lime product suppliers, it was found that fine Aglime could be supplied to Armada Place at a cost of $55 per tonne delivered. This was quite a lot cheaper than originally anticipated. This cost was taken as the representative cost to supply a commercial liming agent to the Armada Place site, and the cost which the trial products would need to better if they are to be considered as more cost effective than commercial products.

7.1 Supply cost calculations

7.1.1 Rosenlund "sand"

The Rosenlund sand is able to be produced at a cost of $10 per tonne. The price was supplied by Rosenlund Constructions Pty Ltd, and includes all processing, and crushing costs. However, it does not include any transport costs. Transport costs were calculated on using semi-tippers of 20m^3 capacity to cart the material from the Crushed Concrete Products Pty Ltd. Using a rate of $85 per hour for a semi-tipper, and a 45 minute turnaround from the Crushed Concrete yard to Armada Place, including time to dump at Armada Place, the leads to a rate of $63.75 per 20m^3 load, or $3.20 per loose cubic metre of material. Using a density of 1.4 tonne / m^3 loose for the Rosenlund product, this gives a rate of $2.30 per tonne.

Therefore, to supply the Rosenlund sand to the Armada Place site, the total cost will be production cost plus transport cost, which comes to $12.30 per tonne. We can see this is substantially lower than the $55/t for the Aglime product.

7.1.2 Queensland Recycling Crusher Dust

Similar calculations can be made for the Queensland Recycling product. Queensland Recycling can supply the product at a cost of $11.60 per tonne. Based on a 30 minute turnaround time with semi-tippers, this gives a transport cost of $2.15/m^3. Using the given density of 1.5 tonne per loose cubic metre, this gives a transport rate of $1.45 per tonne. Therefore, the total supply cost to Armada Place will be $13.05 per tonne.

7.1.3 Boral concrete washout

The cost to supply the Boral concrete washout product needs to be calculated slightly differently. Even though the material is available from Boral at no cost, this unprocessed material is likely to have a very low neutralising value due to the large inert stone present. It was therefore priced to cart the material from the Boral yard to the Crushed Concrete recycling site, pass the material through the screening plant, and then transport back to Armada Place. It is hoped that the screening process could produce a material similar to the screened product used in the leaching column trial. The turnaround time to the Crushed Concrete recycling yard from the Boral plant is approximately 30 minutes (refer to Figure B1 in Appendix B), giving a transport cost of \$2.15/m^3. Even though the official density was not available, some basic measures of weight and volume gave the concrete washout material a density of approximately 1.5t/m^3 loose. Information supplied by Crushed Concrete Product Pty Ltd indicated that the cost to process material through the screening plant is \$3.50/m^3. This allows for the cost of loading with an excavator and the cost of the screening plant. Therefore to transport the material to the recycling yard and screen would be in the range of \$5.65 / m^3, which translates to \$3.80 per tonne.

It is possible to transport the screening plant to Armada Place, and if significant quantities were required, this could possibly work out a cheaper rate. However, the cost of transporting plant and equipment from the recycling site to Armada Place would be quite substantial, and it would very much depend on the quantity of material required to offset the \$2.15 transport from the Boral site to the Crushed Concrete recycling yard. An establishment cost of \$500 to move the screening plant and machinery would require at least 230m^3 of material to be screened to make it cost effective, for example. However, as this option would mean taking the screening plant away from the recycling yard, it was decided that this would not be an acceptable option for Crushed Concrete Products.

At a transport cost of \$3.20 per metre from the recycling yard to Armada Place (\$2.15 per tonne at 1.5t/m^3), this gives a total supply cost for the screened Boral concrete washout material of \$5.95 per tonne.

7.1.4 Supply cost summary

To summarise, the supply costs for each of the materials is as follows:

Fine Aglime:	\$55.00/t
Rosenlund sand:	\$12.30/t

Queensland Recycling crusher dust:	$13.05/t
Boral concrete washout:	$5.95/t

This shows that the trial products are substantially cheaper than the lime to supply to site. However, this is not a true comparison of the total cost for using these products. It is necessary to adjust these figures to represent the differences in the mixing quantities needed to neutralise a given quantity of acid sulfate soils.

7.2 Usage cost calculations

Using the calculated effective neutralising values, it is possible to calculate the amount of each product that will be required to neutralise a given quantity of soil, and this can be utilised to give a true cost comparison between the products.

If we look at the quantity of soil that can be neutralised by one tonne of Aglime, we can use the effective neutralising values to calculate the quantity of each product that will be required to neutralise the same amount of soil. This is done by dividing the effective neutralising value of Aglime by the effective neutralising value of each trial product. This is calculated thus:

Aglime:	94 / 94	=	1.00
Rosenlund sand:	94 / 6.12	=	15.36
Queensland Recycling crusher dust:	94 / 8.2	=	11.46
Boral concrete washout:	94 / 10	=	9.40

This shows that to neutralise the same of soil that can be neutralised by one tonne of Aglime, 15.36 tonnes of Rosenlund sand needs to be used, 11.46 tonnes of Queensland Recycling crusher dust, and 9.4 tonnes of Boral concrete washout would be required. The cost to supply these quantities of material can easily be calculated by multiplying the tonnages required by the supply costs calculated previously shown in Section 7.1.4.

The total costs are as follows:

Aglime:	$55
Rosenlund sand:	$189
Queensland Recycling crusher dust:	$150
Boral concrete washout:	$56

Even though the actual quantities of acid sulfate soil, or the soil's acidity, at Armada Place is not known, this gives an effective cost comparison between the varying products.

7.3 Summary

From these figures, we can see that even though the crushed concrete products are far less expensive to supply per tonne to the site, the total cost of supplying these materials compared with how much it would cost to supply Aglime is very great. Neither of the crushed concrete products would be considered cost effective when compared with using Aglime. However, the Boral concrete product, using the mixing rates used in this leaching column experiment, is still a viable option, only costing one dollar more to supply for every tonne of Aglime that would need to be used.

As a quick comparison, if the soil were similar to the test acid sulfate soil, and 66 grams of Aglime were needed for every 1.5 kilograms of ASS, then one tonne of Aglime would treat approximately 22.7 tonnes of soil. At a density of approximately 1.5 tonnes per cubic metre of soil, this equates to approximately 15.2 cubic metres of soil. Even if only 100m^3 of soil were needed to be treated, using Aglime would save around $625 compared with using the cheapest crushed concrete product. However, using the Boral washout product would only be about $15 more expensive. So we can see that the Boral product is certainly a viable alternative.

However, as these products are untrialled, the fact that commercial Aglime is still cheaper to obtain would probably mean that this proven product would still be the more attractive option for neutralising onsite acid sulfate soils.

Chapter 8

Conclusion

8.1 Conclusions on Effectiveness of Trial Products

After performing the leaching column experiment to determine the effectiveness of the trial products as neutralising agents, and a cost analysis to determine their cost effectiveness compared with a commercial liming product, we can make an overall analysis of these products.

Of the three trialled neutralising agents, Rosenlund sand, Queensland Recycling crusher dust, and the Boral concrete washout, there was only one product that was able to perform as effectively as a commercial liming agent, and remain competitive in respect to cost. This product was the Boral concrete washout.

The Boral concrete washout product met all the performance criteria established during the course of the experimental period, as did the Queensland Recycling crusher dust, proving them to be effective neutralising agents in treating acid sulfate soils. However, only the Boral concrete washout product was close to the commercial Aglime in the cost to supply the product to the Armada Place development site.

However, even though a product was found that may be an effective alternative in treating acid sulfate soils, it still can’t be said that this product is a more cost effective alternative to Aglime. Though the prices are very similar, Aglime still is slightly cheaper, and due to its availability and assured quality compared to concrete washout, is still the most economical and effective method of neutralising onsite acid sulfate soils at Armada Place out of the trialled products tested.

8.2 Achievement of Objectives

In undertaking this research project, I believe that I have been able to fulfil the objectives outlined in the Introduction to this dissertation.

As discussed in Chapter 2, I was able to describe and show an understanding of acid sulfate soils, the environmental and economic effects associated with them, and the various management and treatment options available for dealing with acid sulfate soils.

Chapter 3 outlined the relevant legislation regarding acid sulfate soils, from which I was able to establish a range of performance criteria to be met by neutralising agents for treating acid sulfate soils at the Armada Place development.

Chapter 4 discussed the requirements of neutralising agents, various industry by-products currently in use, and the selection of three trial products to be tested as neutralising agents in the treatment of acid sulfate soils.

A leaching column experiment was undertaken to test the effectiveness of the trial products in treating acid sulfate soils in comparison with a commercial liming agent. The experimental method was outlined in Chapter 5, and the results of this experiment discussed and analysed in Chapter 6.

Finally, a cost analysis was undertaken, comparing the real cost of using each of the three trial products in treating onsite acid sulfate soils at Armada Place compared to using Aglime.

From these results, I was able to choose which of the trial products was most effective, and if any of the products was a more cost effective alternative to Aglime, a traditional commercial liming agent. The results showed that the Boral concrete washout material was the most cost effective of the trial products, and was a viable alternative to using Aglime at the Armada Place development site.

8.3 Further Work

As discussed in Section 4.4.2, the primary difficulty with the leaching column experiment is the timeframe over which it was carried out. To get a more accurate picture of the effectiveness of these products, it would be necessary to conduct the leaching experiment over an extended period of time, preferably a year or more. This would then give a better indication as to whether these products will continue neutralising until all acid production in the soil has completed. The leaching column experiment conducted in this research project indicated that the untreated soil was still very acidic at the completion of the experimental period, and hence possibly had much more acid generating capacity left.

Another research addition would be to trial these neutralising agents on various other acid sulfate soil samples. Often in these experiments, a neutralising agent is trialled on various soils, of differing acidity, texture and composition to analyse their behaviour with varying soil types. A neutralising agent can sometimes perform better in one soil type, such as a sandy soil, than in another type, like a clay. This leads in to the possibility of trialling these products on acid sulfate soils that may be located at the Armada Place development site. By testing the products on the actual soils to be treated, one would then get an accurate indicator as to their performance in a site specific situation.

I believe it would also be beneficial to investigate the neutralising effectiveness of a range of concrete washout materials. By testing a range of concrete washout materials, or by testing one stockpile over a period of time, an indication of variations in composition and neutralising values could be obtained to get a better picture of the consistency of this material. In the same manner, more crushed concrete materials could be sourced and investigated, possibly revealing a more suitable product than those tested.

Eventually, testing these materials on site on in situ acid sulfate soils would also need to be carried out. Experimentation such as leaching column experiments can give a strong indication as to the effectiveness of a product, but only using a product in field will conclusively show if these materials will perform suitably.

List of References

Acid Sulphate Soil / Acid Mine Drainage [Online], 1998, Available: http://www.envirotest.com.au/cstudies/cs_ass.html [Accessed 10 March 2004]

Ahern CR, Hey KM, Watling KM and Eldershaw VJ (eds) 2000, *Acid Sulfate Soils: Environmental Issues, Assessment and Management, Technical Papers,* Brisbane, 20-22 June, 2000. Department of Natural Resources, Indooroopilly, Queensland, Australia.

Ahern, CR, Ahern MR and Powell B 1998, *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998.* QASSIT, Department of Natural Resources, Resource Sciences Centre, Indooroopilly.

ANZECC, 1992. *Australian Water Quality Guidelines for Fresh and Marine Waters.* Australian and New Zealand Environment and Conservation Council, Australia

Bennett, B 1999, 'Laid Waste', *Ecos*, Oct-Dec 1999, Issue 101, p.11

Brisbane City Council, Urban Management Division 2000, *Guideline on Identifying and Applying Water Quality Objectives in Brisbane City Ver. 1*., Brisbane

Colmer, TD et.al. 1999, 'Beneficial Use of Fly Ash in Amendment of Sandy Soils for Agriculture and Horticulture', *Into the New Millenium: Waste and Recycle Convention*, Burswood International Resort Casino and Convention Centre.

Cook, FJ, Gardner, EA, Rassam DW 2002, ‘Field and Laboratory Studies of Acid Sulfate Soils’, *Journal of Irrigation and Drainage Engineering*, Mar-Apr 2002, Vol 128 Issue 2, p100-107

Creagh, C 1993, ‘Working together with Acid Sulfate Soils’, *Ecos*, Spring 1993 Issue 77 pp 25 - 29

Davidson, S, Pyper, W 2001, ‘Bubble bubble’, *Ecos,* Jan/March 2001, Issue 106 pp 28 – 31

Dear SE, Moore NG, Dobos SK, Watling KM and Ahern CR 2002, Q*ueensland Acid Sulfate Soil Technical Manual Ver 3.8,.* Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

Department of Local Government, Planning, Sport and Recreation 2001, *IDAS Overview.*

Department of Natural Resources and Mines 2002, *State Planning Policy 2/02 Guidelines: Planning and Managing Development Involving Acid Sulfate Soils*

Department of Natural Resources and Mines 2002, *State Planning Policy 2/02: Planning and Managing Development Involving Acid Sulfate Soils*.

Evans G (n.d.) *Acid Soils in Australia: A Summary of the Issues for Government*. Bureau of Rural Resources, Victoria.

Fitzpatrick, R, Merry, R, Williams, J, White, I, Bowman, G, Taylor, G 1998, *Acid Sulfate Soil Assessment: Coastal, Inland and Minesite Conditions*, from the National Land and Water Resources Audit Australia. Available: ftp://ftp.nlwra.gov.au/pub/public_v2/30_projects/50_scoping_projects/04_methods_papers/fitzpatrick_acid.pdf.

Hey KM, Ahern CR et. al (eds) (1999). *Acid Sulfate Soils and their Management in Coastal Queensland: Forum and Technical Papers*, Brisbane, 21-23 April, 1999. Department of Natural Resources, Indooroopilly, Queensland, Australia.

Instructions for the Treatment and Management of Acid Sulfate Soils, 2001. Queensland Environmental Protection Agency.

McConchie, D, Clark, MW 1996, An Innovative Neutralising Treatment for Acid Sulfate Soils. IN: RJ Smith and HJ Smith (eds) *Proceedings of the 2nd National Conference on Acid Sulfate Soils*, Coffs Harbour, September 1996, RJ Smith and Associates and ASSMAC Pub., 227-229

National Working Party on Acid Sulfate Soils 1999, *National Strategy for the Management of Coastal Acid Sulfate Soils*.

Powell B and Ahern CR (1999). *QASSMAC Acid Sulfate Soils Management Strategy for Queensland*. QASSMAC and Queensland Department of Natural Resources, Indooroopilly, Queensland.

Recycled Concrete [Online], 2003, Available: http://www.csiro.au/promos/ozadvances/Series8ConcreteL.html, [Accessed 5 May 2004].

Sammut, J 2000, *An Introduction to Acid Sulfate Soils* , 2nd edn, National Heritage Trust Australia.

The Calcium Connection [Online], 2001, Available: http://www.limeindustries.com.au/the.htm, [Accessed 5 May 2004].

Wang, HL, Hedley, MJ, Bolan, NS, Horne, DJ 1999 'The influence of surface incorporated lime and gypsiferous by-products on surface and subsurface soil acidity', *Australian Journal of Soil Research*, vol. 37, number 1, pp.165-80

Ward, NJ, Sullivan, LA, Bush, RT (2002). *Sulfide oxidation and acidification of acid sulfate soil materials treated with* $CaCO_3$ *and seawater-neutralised bauxite refinery residue*. Centre for Acid Sulfate Soil Research, Southern Cross University, Lismore.

Weber, EL 2003. *The Use of Modified Alumina Refinery Residues (Bauxsol*^{TM}*) for Acid Sulfate Soil Remediation.* Science Teachers Association of NSW.

Appendix A

Project Specification

UNIVERSITY OF SOUTHERN QUEENSLAND
FACULTY OF ENGINEERING AND SURVEYING

ENG 4111/4112 RESEARCH PROJECT
PROJECT SPECIFICATION

FOR: Timothy Fraser

TOPIC: Use of Industry By-Products in the treatment of Acid Sulphate Soils

SUPERVISOR: Dr Richard Merifield

ENROLMENT: ENG 4111 – S1, X, 2004
ENG 4112 – S2, X, 2004-02-24

PROJECT AIM: The aim of this project is to investigate the possibility of finding a more economical method of treating acid sulphate soils through the use of industry by-products.

SPONSORSHIP: University of Southern Queensland

PROGRAMME: **Issue A, 25 February 2004**

1. Research current treatment practices involved with the management of acid sulphate soils.
2. Research governing standards applicable to the treatment of acid sulphate soils.
3. Investigate possible industry by-products that could be used in the treatment of acid sulphate soils.
4. Develop a simple test to determine the effectiveness of various by-product materials in the treatment of acid sulphate soils.
5. Perform a cost analysis on the various by-products to determine the most economical material in the treatment of acid-sulphate soils.

AGREED: ____________ (Student) ____________ (Supervisor)

Dated 10 / 3 / 04

Appendix B

Map of Site Locations

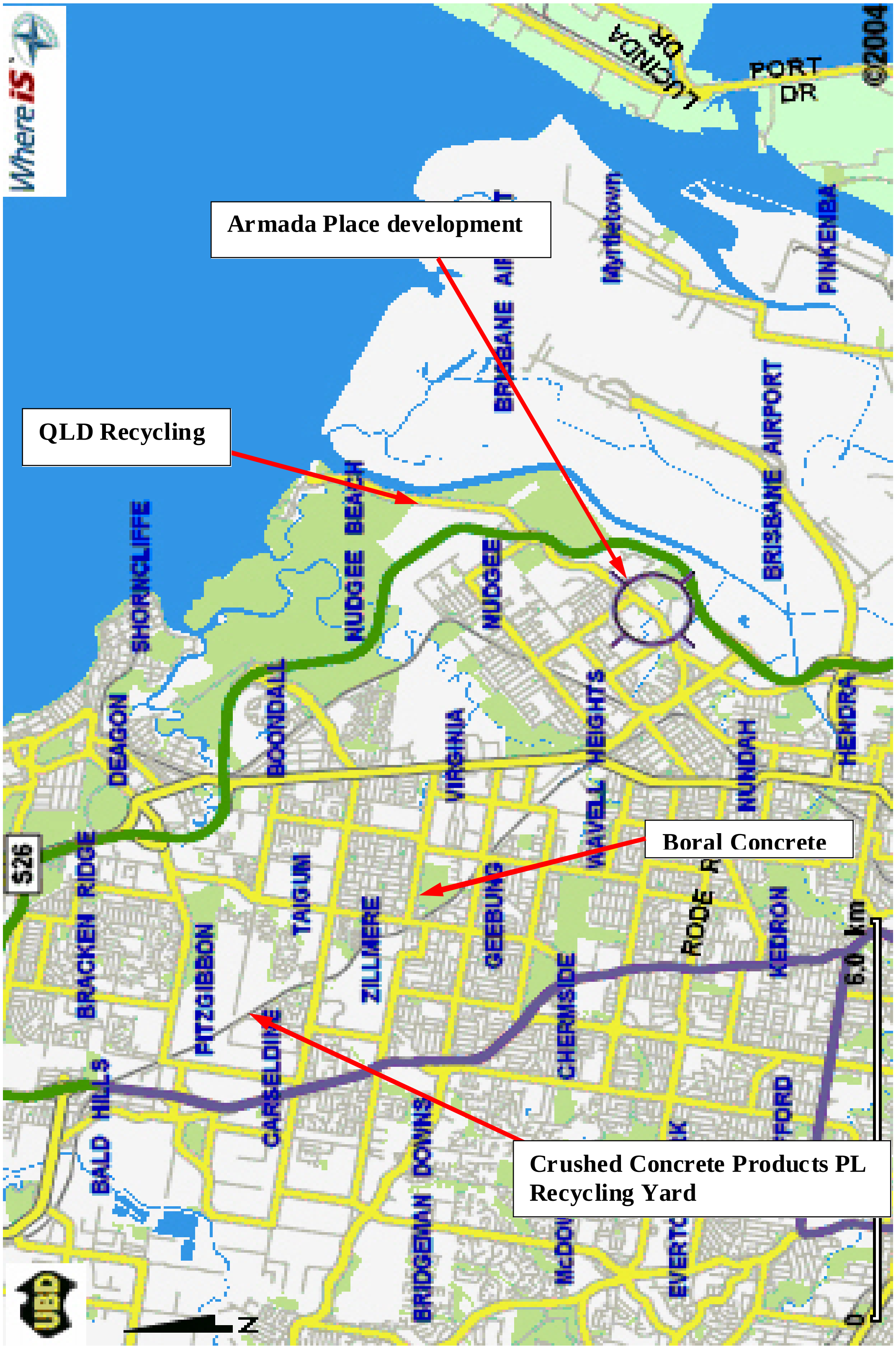
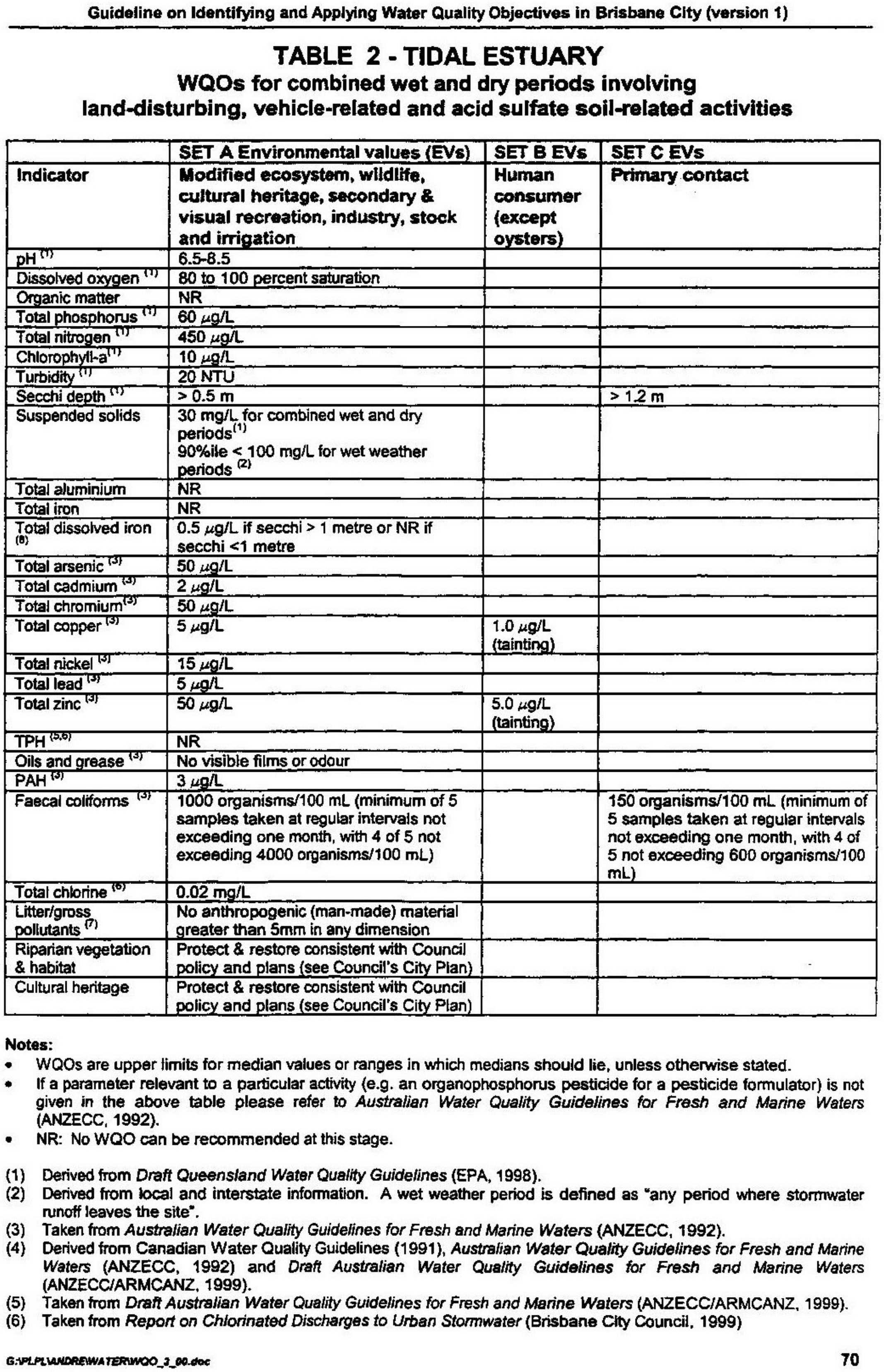


Figure B1: Map of Brisbane's north side showing the location of the Armada Place development, Queensland Recycling, Boral Concrete Geebung, and the Crushed Concrete Products recycling yard.

Appendix C

Armada Place Development Water Quality Objectives



Guideline on Identifying and Applying Water Quality Objectives in Brisbane City (version 1)

TABLE 2 - TIDAL ESTUARY

WQOs for combined wet and dry periods involving land-disturbing, vehicle-related and acid sulfate soil-related activities

	SET A Environmental values (EVs)	SET B EVs	SET C EVs
Indicator	**Modified ecosystem, wildlife, cultural heritage, secondary & visual recreation, industry, stock and irrigation**	**Human consumer (except oysters)**	**Primary contact**
pH (1)	6.5-8.5		
Dissolved oxygen (1)	80 to 100 percent saturation		
Organic matter	NR		
Total phosphorus (1)	60 µg/L		
Total nitrogen (1)	450 µg/L		
Chlorophyll-a(1)	10 µg/L		
Turbidity (1)	20 NTU		
Secchi depth (1)	> 0.5 m		> 1.2 m
Suspended solids	30 mg/L for combined wet and dry periods(1) 90%ile < 100 mg/L for wet weather periods (2)		
Total aluminium	NR		
Total iron	NR		
Total dissolved iron (8)	0.5 µg/L if secchi > 1 metre or NR if secchi <1 metre		
Total arsenic (3)	50 µg/L		
Total cadmium (3)	2 µg/L		
Total chromium(3)	50 µg/L		
Total copper (3)	5 µg/L	1.0 µg/L (tainting)	
Total nickel (3)	15 µg/L		
Total lead (3)	5 µg/L		
Total zinc (3)	50 µg/L	5.0 µg/L (tainting)	
TPH (5,6)	NR		
Oils and grease (3)	No visible films or odour		
PAH (3)	3 µg/L		
Faecal coliforms (3)	1000 organisms/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month, with 4 of 5 not exceeding 4000 organisms/100 mL)		150 organisms/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month, with 4 of 5 not exceeding 600 organisms/100 mL)
Total chlorine (6)	0.02 mg/L		
Litter/gross pollutants (7)	No anthropogenic (man-made) material greater than 5mm in any dimension		
Riparian vegetation & habitat	Protect & restore consistent with Council policy and plans (see Council's City Plan)		
Cultural heritage	Protect & restore consistent with Council policy and plans (see Council's City Plan)		

Notes:

- WQOs are upper limits for median values or ranges in which medians should lie, unless otherwise stated.
- If a parameter relevant to a particular activity (e.g. an organophosphorus pesticide for a pesticide formulator) is not given in the above table please refer to *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 1992).
- NR: No WQO can be recommended at this stage.

(1) Derived from *Draft Queensland Water Quality Guidelines* (EPA, 1998).

(2) Derived from local and interstate information. A wet weather period is defined as "any period where stormwater runoff leaves the site".

(3) Taken from *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 1992).

(4) Derived from Canadian Water Quality Guidelines (1991), *Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC, 1992) and *Draft Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC/ARMCANZ, 1999).

(5) Taken from *Draft Australian Water Quality Guidelines for Fresh and Marine Waters* (ANZECC/ARMCANZ, 1999).

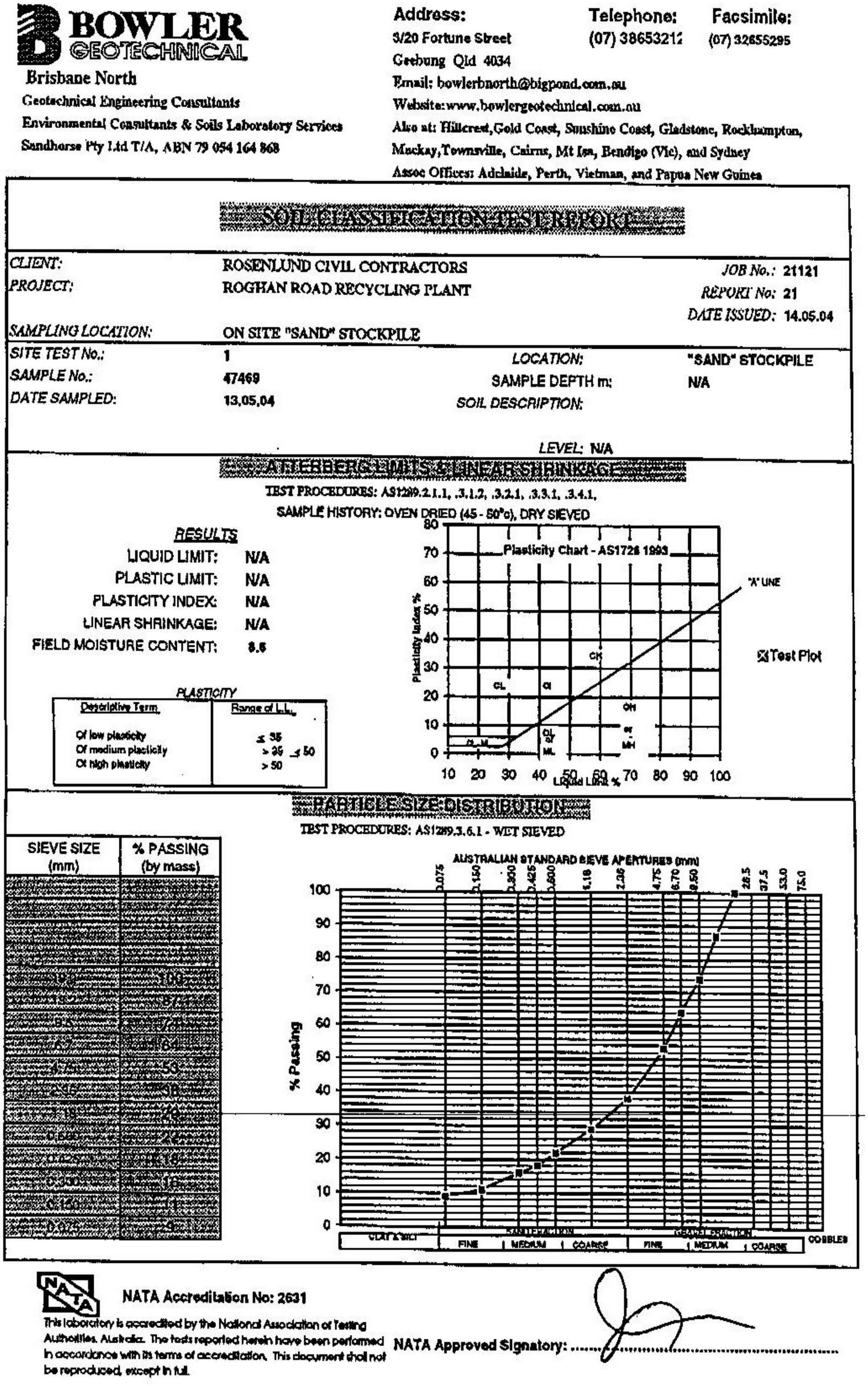
(6) Taken from *Report on Chlorinated Discharges to Urban Stormwater* (Brisbane City Council, 1999)

G:\PLPLAN\DREWATER\WQO_3_00.doc 70

Figure C1: Water Quality Objectives for Armada Place development extracted from Appendix 5 of the *Guideline on Identifying and Applying Water Quality Objectives in Brisbane City Version 1 – March 2000*

Appendix D

Laboratory Analysis



BOWLER GEOTECHNICAL
Brisbane North
Geotechnical Engineering Consultants
Environmental Consultants & Soils Laboratory Services
Sandhorse Pty Ltd T/A, ABN 79 054 164 868

Address: 3/20 Fortune Street
Geebung Qld 4034
Telephone: (07) 3865321?
Facsimile: (07) 32655295
Email: bowlerbnorth@bigpond.com.au
Website: www.bowlergeotechnical.com.au
Also at: Hillcrest, Gold Coast, Sunshine Coast, Gladstone, Rockhampton, Mackay, Townsville, Cairns, Mt Isa, Bendigo (Vic), and Sydney
Assoc Offices: Adelaide, Perth, Vietnam, and Papua New Guinea

SOIL CLASSIFICATION TEST REPORT

CLIENT:	ROSENLUND CIVIL CONTRACTORS	*JOB No.:*	21121
PROJECT:	ROGHAN ROAD RECYCLING PLANT	*REPORT No:*	21
		DATE ISSUED:	14.05.04
SAMPLING LOCATION:	ON SITE "SAND" STOCKPILE		
SITE TEST No.:	1	*LOCATION:*	"SAND" STOCKPILE
SAMPLE No.:	47469	SAMPLE DEPTH m:	N/A
DATE SAMPLED:	13.05.04	*SOIL DESCRIPTION:*	
		LEVEL:	N/A

ATTERBERG LIMITS & LINEAR SHRINKAGE

TEST PROCEDURES: AS1289.2.1.1, .3.1.2, .3.2.1, .3.3.1, .3.4.1,
SAMPLE HISTORY: OVEN DRIED (45 - 50°c), DRY SIEVED

RESULTS

LIQUID LIMIT:	N/A
PLASTIC LIMIT:	N/A
PLASTICITY INDEX:	N/A
LINEAR SHRINKAGE:	N/A
FIELD MOISTURE CONTENT:	8.6

PLASTICITY

Descriptive Term	Range of L.L.
Of low plasticity	≤ 35
Of medium plasticity	> 35 ≤ 50
Of high plasticity	> 50

PARTICLE SIZE DISTRIBUTION

TEST PROCEDURES: AS1289.3.6.1 - WET SIEVED

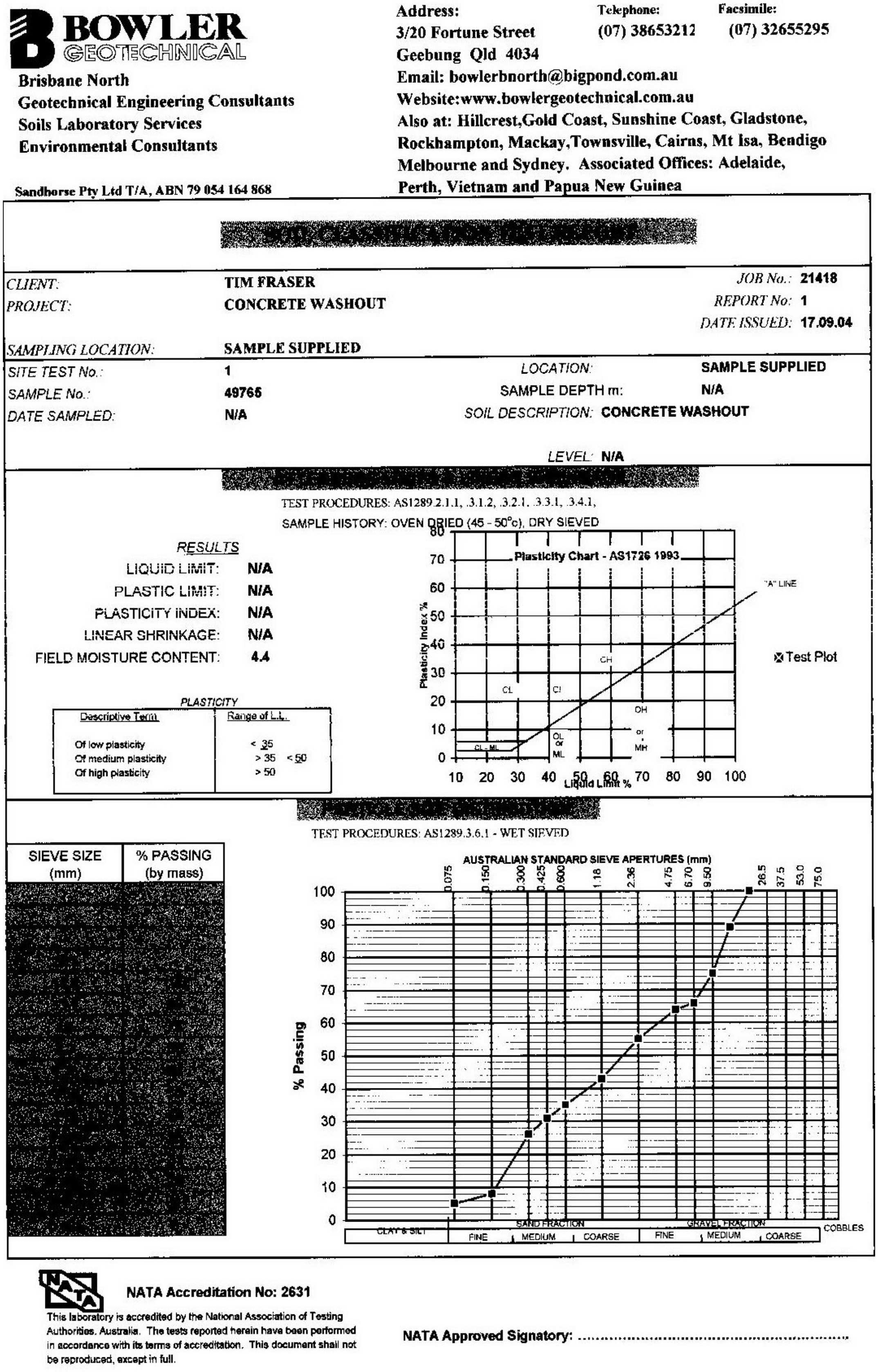
SIEVE SIZE (mm)	% PASSING (by mass)
19	100
13.2	87
9.5	74
6.7	64
4.75	53
2.36	38
1.18	29
0.600	22
0.425	18
0.300	16
0.150	11
0.075	9

NATA Accreditation No: 2631

This laboratory is accredited by the National Association of Testing Authorities, Australia. The tests reported herein have been performed in accordance with its terms of accreditation. This document shall not be reproduced, except in full.

NATA Approved Signatory: ....

Figure D1: Grading chart for the Rosenlund 5mm rundown "sand".



BOWLER
GEOTECHNICAL
Brisbane North
Geotechnical Engineering Consultants
Soils Laboratory Services
Environmental Consultants

Sandhorse Pty Ltd T/A, ABN 79 054 164 868

Address:
3/20 Fortune Street
Geebung Qld 4034
Email: bowlerbnorth@bigpond.com.au
Website:www.bowlergeotechnical.com.au
Also at: Hillcrest,Gold Coast, Sunshine Coast, Gladstone, Rockhampton, Mackay,Townsville, Cairns, Mt Isa, Bendigo Melbourne and Sydney. Associated Offices: Adelaide, Perth, Vietnam and Papua New Guinea

Telephone: **(07) 38653212**
Facsimile: **(07) 32655295**

[redacted]

CLIENT:	**TIM FRASER**	*JOB No.:*	**21418**
PROJECT:	**CONCRETE WASHOUT**	*REPORT No:*	**1**
		DATE ISSUED:	**17.09.04**
SAMPLING LOCATION:	**SAMPLE SUPPLIED**		
SITE TEST No.:	**1**	*LOCATION:*	**SAMPLE SUPPLIED**
SAMPLE No.:	**49765**	SAMPLE DEPTH m:	**N/A**
DATE SAMPLED:	**N/A**	*SOIL DESCRIPTION:*	**CONCRETE WASHOUT**
		LEVEL:	**N/A**

[redacted]

TEST PROCEDURES: AS1289.2.1.1, .3.1.2, .3.2.1, .3.3.1, .3.4.1,
SAMPLE HISTORY: OVEN DRIED (45 - 50°c), DRY SIEVED

RESULTS

LIQUID LIMIT:	**N/A**
PLASTIC LIMIT:	**N/A**
PLASTICITY INDEX:	**N/A**
LINEAR SHRINKAGE:	**N/A**
FIELD MOISTURE CONTENT:	**4.4**

PLASTICITY

Descriptive Term	Range of L.L.
Of low plasticity	< 35
Of medium plasticity	> 35 < 50
Of high plasticity	> 50

[redacted]

TEST PROCEDURES: AS1289.3.6.1 - WET SIEVED

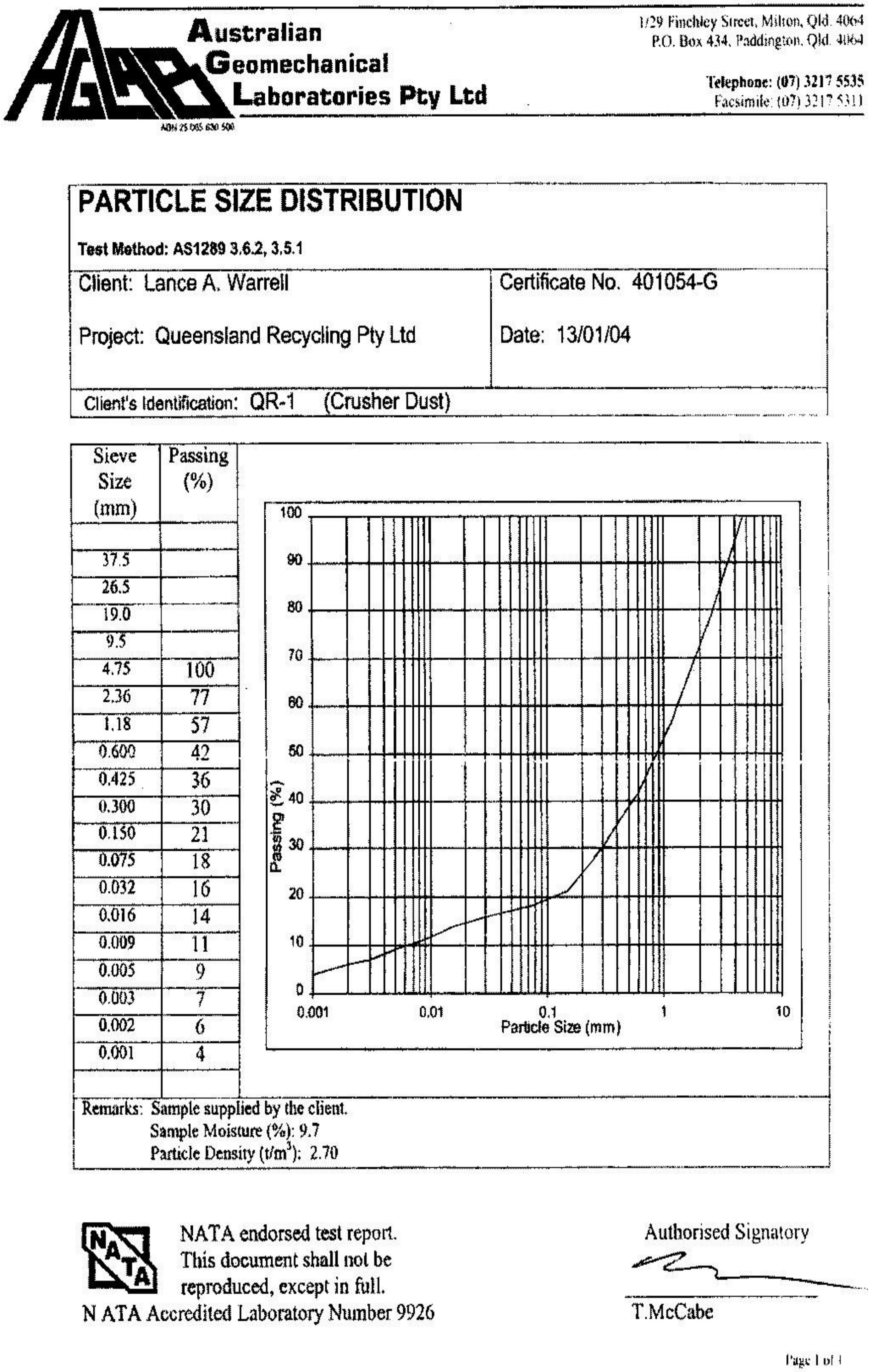
SIEVE SIZE (mm)	% PASSING (by mass)
[redacted]	[redacted]

NATA Accreditation No: 2631

This laboratory is accredited by the National Association of Testing Authorities, Australia. The tests reported herein have been performed in accordance with its terms of accreditation. This document shall not be reproduced, except in full.

NATA Approved Signatory: ....

Figure D2: Grading chart for the Boral Premixed Concrete Washout product



Australian Geomechanical Laboratories Pty Ltd

ABN 25 065 630 500

1/29 Finchley Street, Milton, Qld. 4064
P.O. Box 434, Paddington, Qld. 4064

Telephone: (07) 3217 5535
Facsimile: (07) 3217 5311

PARTICLE SIZE DISTRIBUTION

Test Method: AS1289 3.6.2, 3.5.1

Client: Lance A. Warrell

Project: Queensland Recycling Pty Ltd

Certificate No. 401054-G

Date: 13/01/04

Client's Identification: QR-1 (Crusher Dust)

Sieve Size (mm)	Passing (%)
37.5	
26.5	
19.0	
9.5	
4.75	100
2.36	77
1.18	57
0.600	42
0.425	36
0.300	30
0.150	21
0.075	18
0.032	16
0.016	14
0.009	11
0.005	9
0.003	7
0.002	6
0.001	4

Remarks: Sample supplied by the client.
Sample Moisture (%): 9.7
Particle Density (t/m^3): 2.70

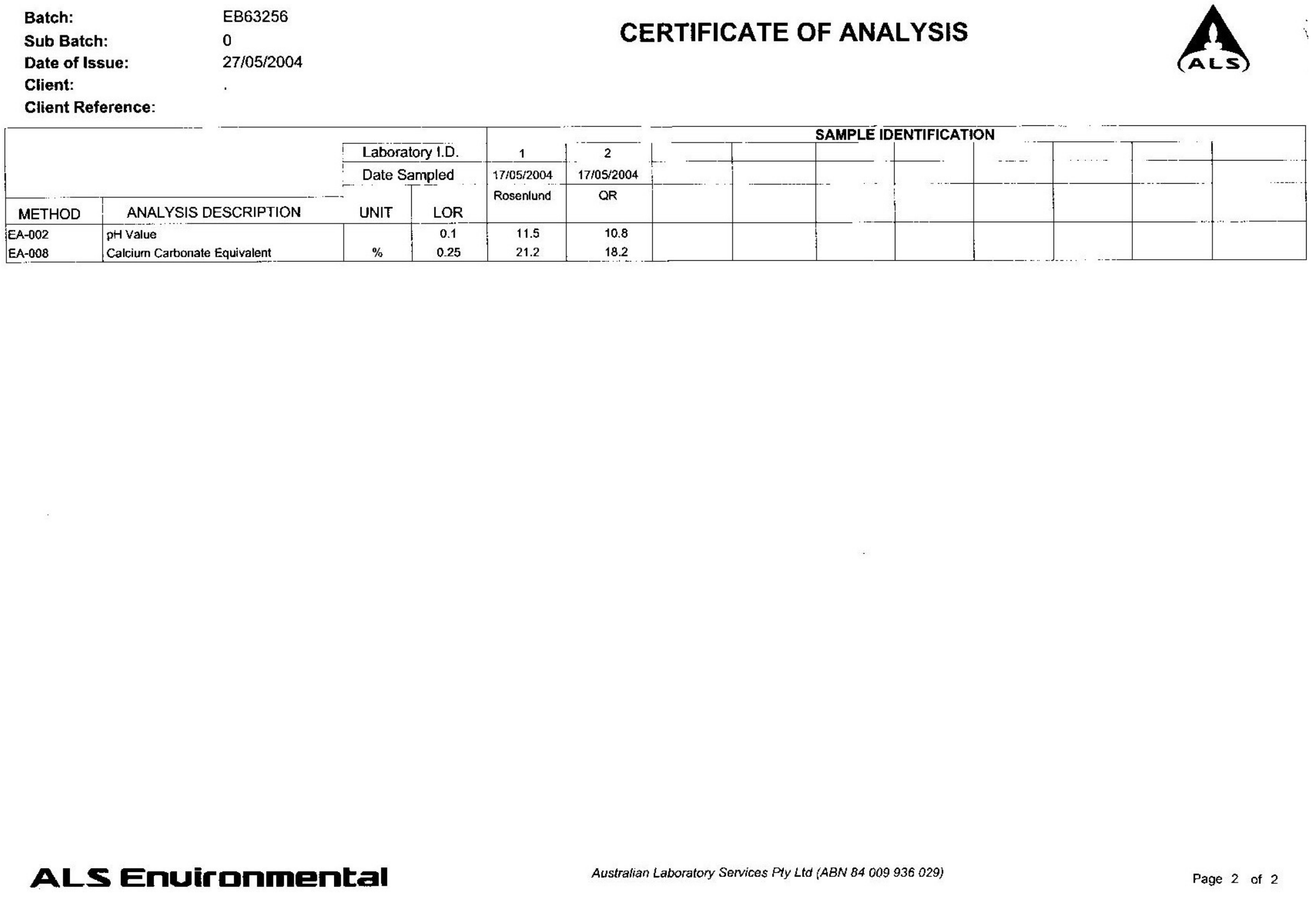
NATA endorsed test report.
This document shall not be
reproduced, except in full.
N ATA Accredited Laboratory Number 9926

Authorised Signatory

T.McCabe

Page 1 of 1

Figure D3: Grading chart for Queensland Recycling crusher dust product



Batch: EB63256
Sub Batch: 0
Date of Issue: 27/05/2004
Client: .
Client Reference:

CERTIFICATE OF ANALYSIS

				SAMPLE IDENTIFICATION									
		Laboratory I.D.		1	2								
		Date Sampled		17/05/2004	17/05/2004								
METHOD	ANALYSIS DESCRIPTION	UNIT	LOR	Rosenlund	QR								
EA-002	pH Value		0.1	11.5	10.8								
EA-008	Calcium Carbonate Equivalent	%	0.25	21.2	18.2								

ALS Environmental

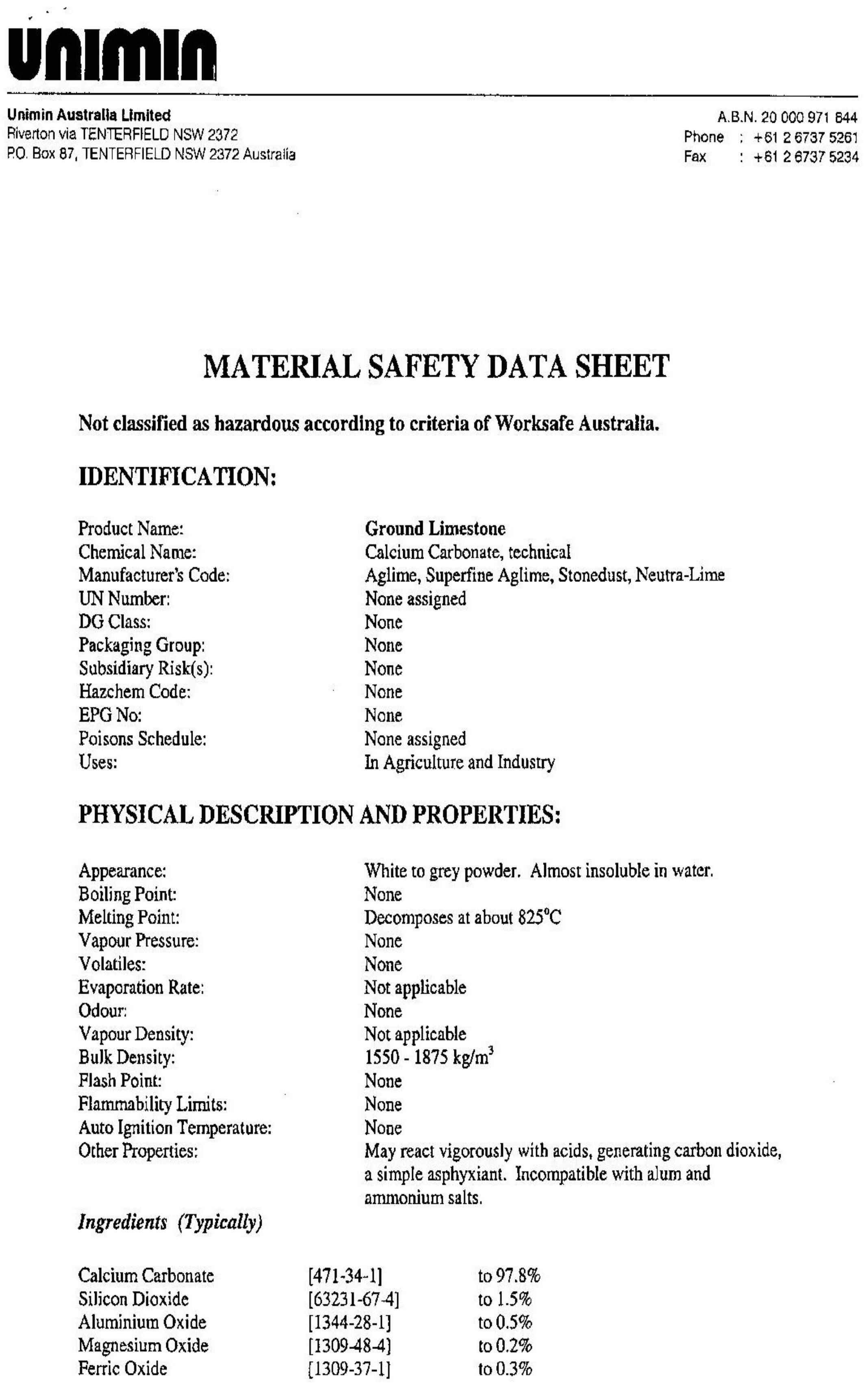
Australian Laboratory Services Pty Ltd (ABN 84 009 936 029)

Page 2 of 2

Figure D4: Certificate of Analysis for pH and Calcium Carbonate Equivalent (Neutralising Values) for the Rosenlund "sand" and the Queensland Recycling crusher dust.

Appendix E

Material Safety Data Sheets



Unimin Australia Limited
Riverton via TENTERFIELD NSW 2372
P.O. Box 87, TENTERFIELD NSW 2372 Australia

A.B.N. 20 000 971 644
Phone : +61 2 6737 5261
Fax : +61 2 6737 5234

MATERIAL SAFETY DATA SHEET

Not classified as hazardous according to criteria of Worksafe Australia.

IDENTIFICATION:

Product Name:	**Ground Limestone**
Chemical Name:	Calcium Carbonate, technical
Manufacturer's Code:	Aglime, Superfine Aglime, Stonedust, Neutra-Lime
UN Number:	None assigned
DG Class:	None
Packaging Group:	None
Subsidiary Risk(s):	None
Hazchem Code:	None
EPG No:	None
Poisons Schedule:	None assigned
Uses:	In Agriculture and Industry

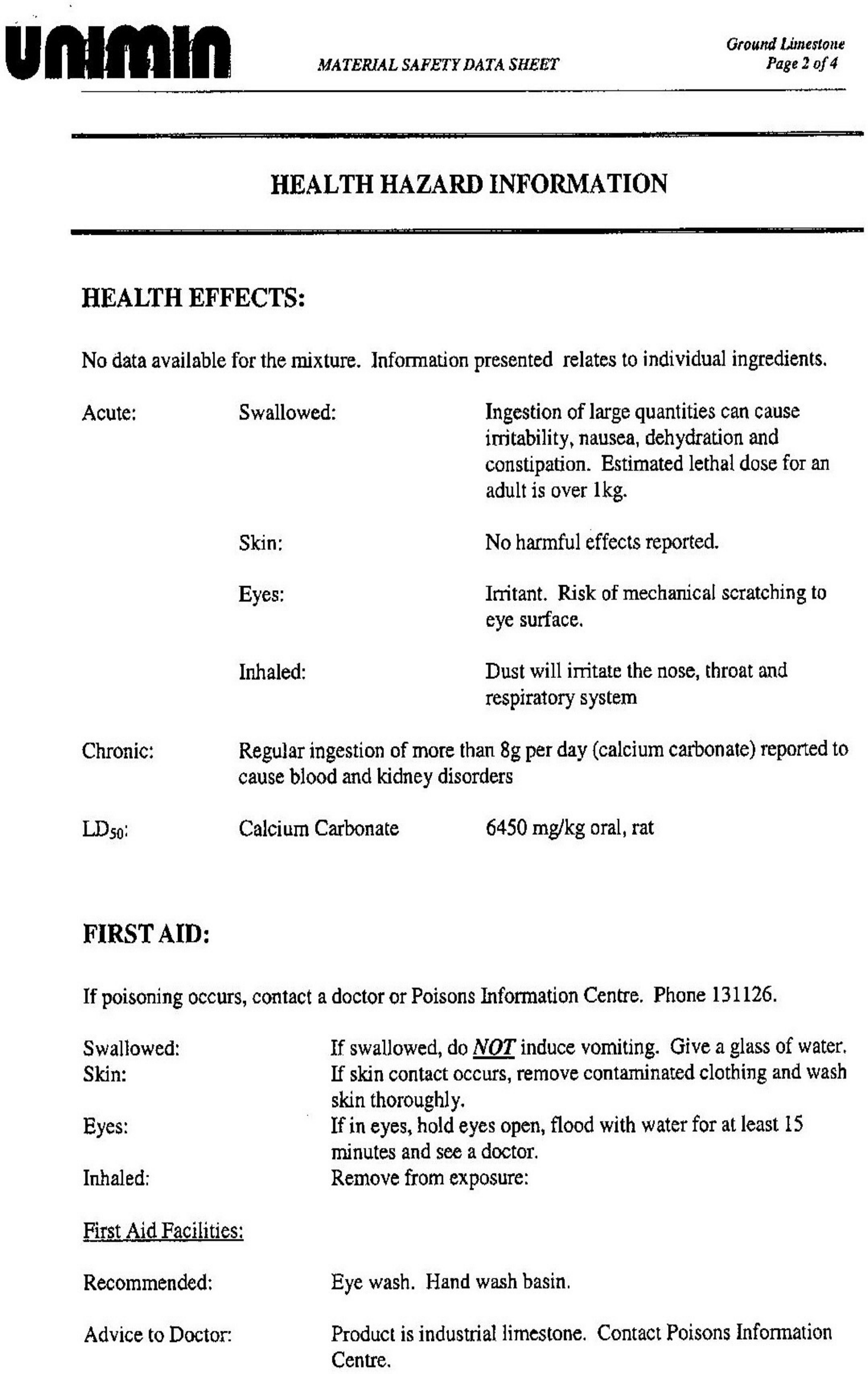
PHYSICAL DESCRIPTION AND PROPERTIES:

Appearance:	White to grey powder. Almost insoluble in water.
Boiling Point:	None
Melting Point:	Decomposes at about 825°C
Vapour Pressure:	None
Volatiles:	None
Evaporation Rate:	Not applicable
Odour:	None
Vapour Density:	Not applicable
Bulk Density:	1550 - 1875 kg/m^3
Flash Point:	None
Flammability Limits:	None
Auto Ignition Temperature:	None
Other Properties:	May react vigorously with acids, generating carbon dioxide, a simple asphyxiant. Incompatible with alum and ammonium salts.

Ingredients (Typically)

Calcium Carbonate	[471-34-1]	to 97.8%
Silicon Dioxide	[63231-67-4]	to 1.5%
Aluminium Oxide	[1344-28-1]	to 0.5%
Magnesium Oxide	[1309-48-4]	to 0.2%
Ferric Oxide	[1309-37-1]	to 0.3%

Figure E1: Aglime Material Safety Data Sheets



UNIMIN MATERIAL SAFETY DATA SHEET

Ground Limestone
Page 2 of 4

HEALTH HAZARD INFORMATION

HEALTH EFFECTS:

No data available for the mixture. Information presented relates to individual ingredients.

Acute:	Swallowed:	Ingestion of large quantities can cause irritability, nausea, dehydration and constipation. Estimated lethal dose for an adult is over 1kg.
	Skin:	No harmful effects reported.
	Eyes:	Irritant. Risk of mechanical scratching to eye surface.
	Inhaled:	Dust will irritate the nose, throat and respiratory system
Chronic:	Regular ingestion of more than 8g per day (calcium carbonate) reported to cause blood and kidney disorders	
LD_{50}:	Calcium Carbonate	6450 mg/kg oral, rat

FIRST AID:

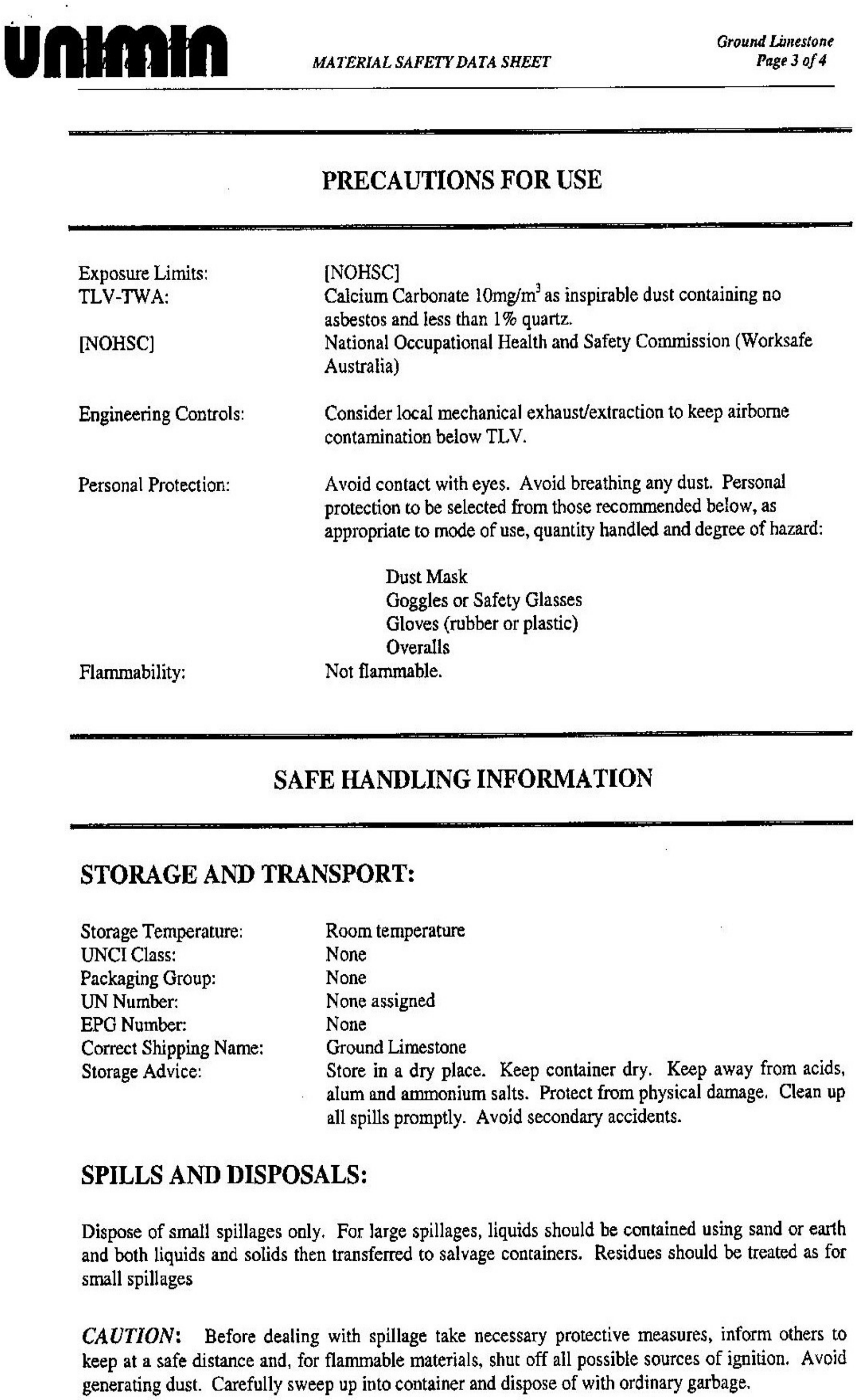
If poisoning occurs, contact a doctor or Poisons Information Centre. Phone 131126.

Swallowed:	If swallowed, do ***NOT*** induce vomiting. Give a glass of water.
Skin:	If skin contact occurs, remove contaminated clothing and wash skin thoroughly.
Eyes:	If in eyes, hold eyes open, flood with water for at least 15 minutes and see a doctor.
Inhaled:	Remove from exposure:

First Aid Facilities:

Recommended:	Eye wash. Hand wash basin.
Advice to Doctor:	Product is industrial limestone. Contact Poisons Information Centre.

Figure E1 continued



PRECAUTIONS FOR USE

Exposure Limits: TLV-TWA:	[NOHSC] Calcium Carbonate 10mg/m^3 as inspirable dust containing no asbestos and less than 1% quartz.
[NOHSC]	National Occupational Health and Safety Commission (Worksafe Australia)
Engineering Controls:	Consider local mechanical exhaust/extraction to keep airborne contamination below TLV.
Personal Protection:	Avoid contact with eyes. Avoid breathing any dust. Personal protection to be selected from those recommended below, as appropriate to mode of use, quantity handled and degree of hazard: Dust Mask Goggles or Safety Glasses Gloves (rubber or plastic) Overalls
Flammability:	Not flammable.

SAFE HANDLING INFORMATION

STORAGE AND TRANSPORT:

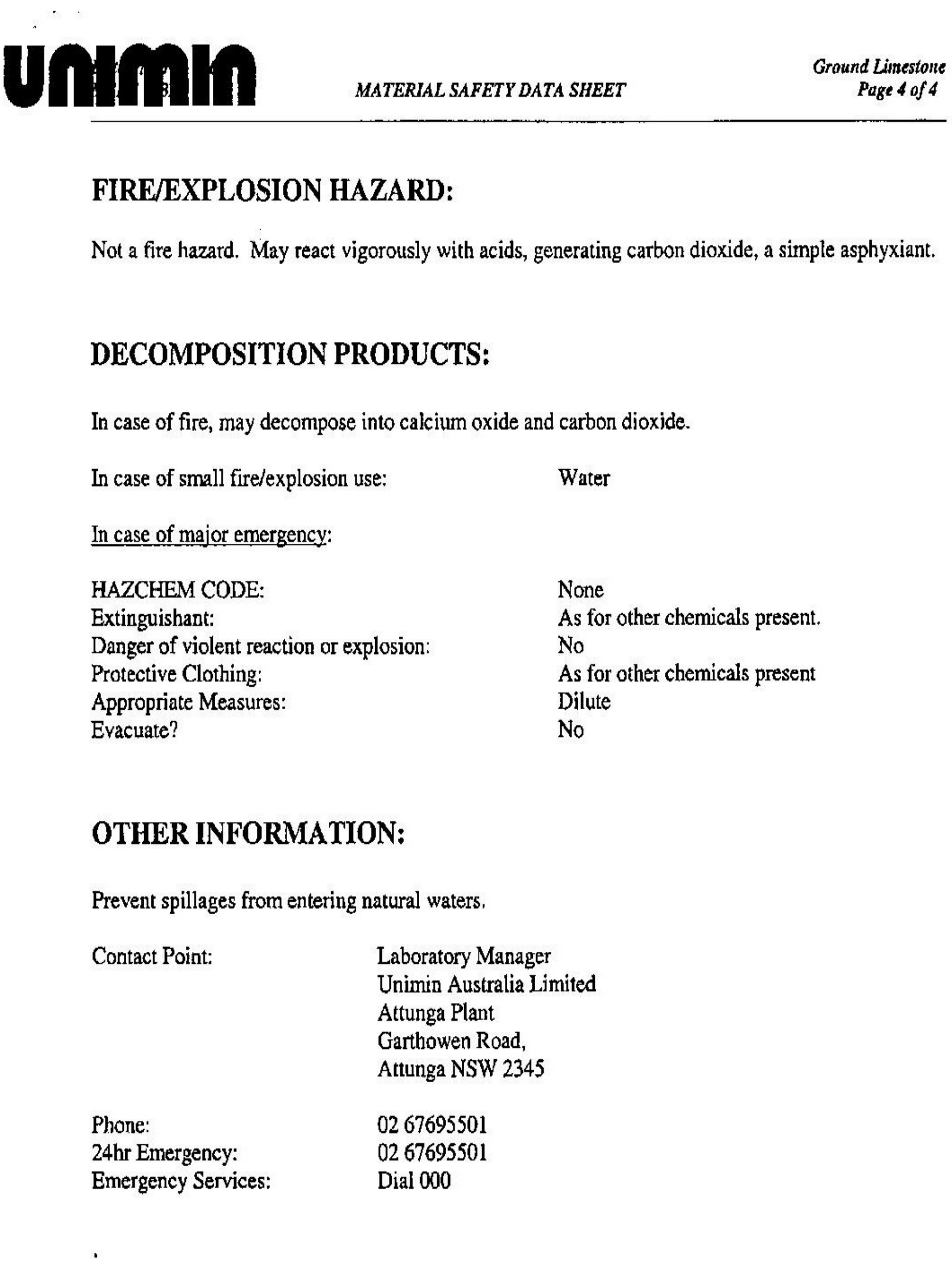
Storage Temperature:	Room temperature
UNCI Class:	None
Packaging Group:	None
UN Number:	None assigned
EPG Number:	None
Correct Shipping Name:	Ground Limestone
Storage Advice:	Store in a dry place. Keep container dry. Keep away from acids, alum and ammonium salts. Protect from physical damage. Clean up all spills promptly. Avoid secondary accidents.

SPILLS AND DISPOSALS:

Dispose of small spillages only. For large spillages, liquids should be contained using sand or earth and both liquids and solids then transferred to salvage containers. Residues should be treated as for small spillages

***CAUTION*:** Before dealing with spillage take necessary protective measures, inform others to keep at a safe distance and, for flammable materials, shut off all possible sources of ignition. Avoid generating dust. Carefully sweep up into container and dispose of with ordinary garbage.

Figure E1 continued



FIRE/EXPLOSION HAZARD:

Not a fire hazard. May react vigorously with acids, generating carbon dioxide, a simple asphyxiant.

DECOMPOSITION PRODUCTS:

In case of fire, may decompose into calcium oxide and carbon dioxide.

In case of small fire/explosion use:	Water

In case of major emergency:

HAZCHEM CODE:	None
Extinguishant:	As for other chemicals present.
Danger of violent reaction or explosion:	No
Protective Clothing:	As for other chemicals present
Appropriate Measures:	Dilute
Evacuate?	No

OTHER INFORMATION:

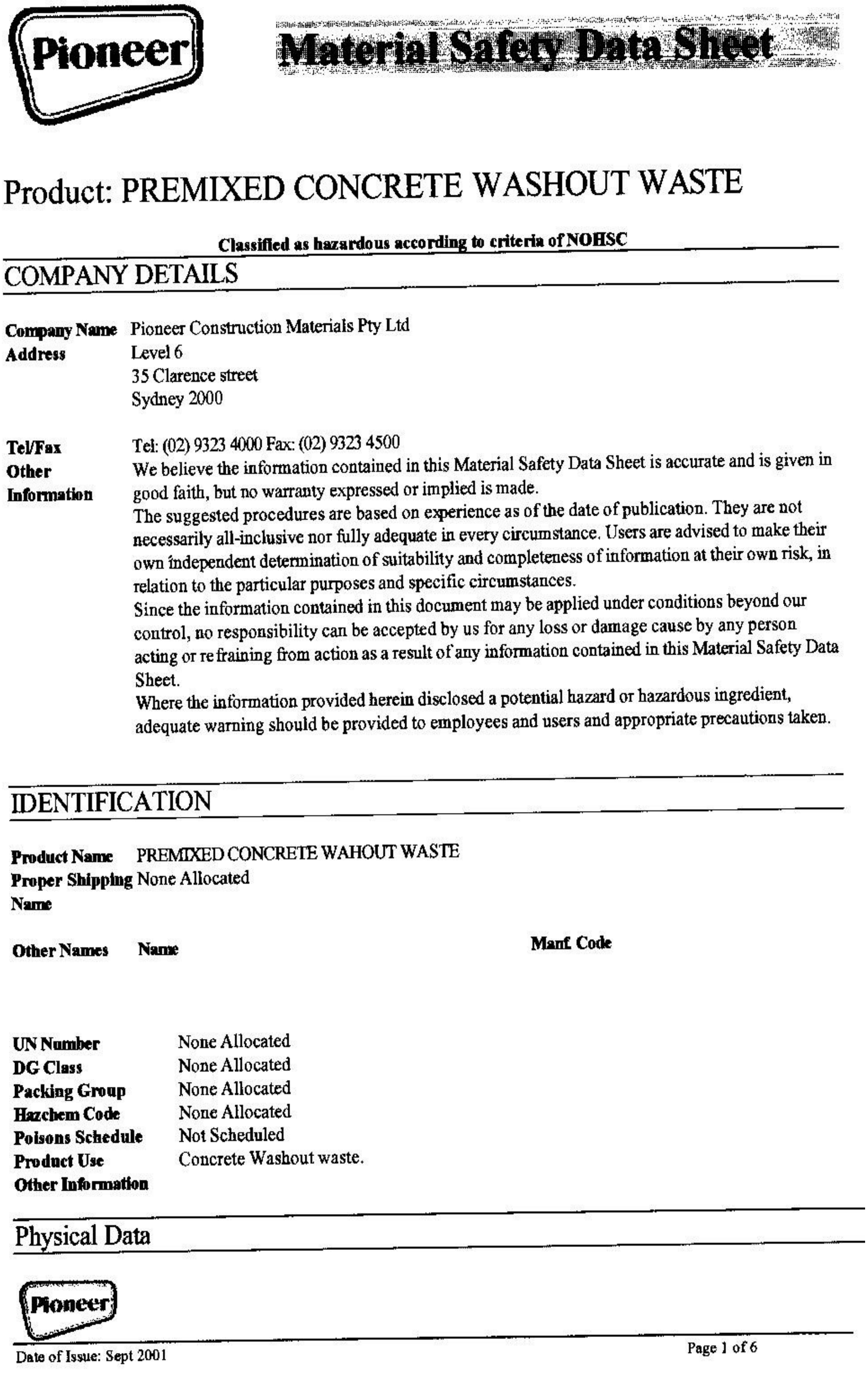
Prevent spillages from entering natural waters.

Contact Point:

Laboratory Manager
Unimin Australia Limited
Attunga Plant
Garthowen Road,
Attunga NSW 2345

Phone:	02 67695501
24hr Emergency:	02 67695501
Emergency Services:	Dial 000

Figure E1 continued



Pioneer **Material Safety Data Sheet**

Product: PREMIXED CONCRETE WASHOUT WASTE

Classified as hazardous according to criteria of NOHSC

COMPANY DETAILS

Company Name	Pioneer Construction Materials Pty Ltd
Address	Level 6 35 Clarence street Sydney 2000
Tel/Fax	Tel: (02) 9323 4000 Fax: (02) 9323 4500
Other Information	We believe the information contained in this Material Safety Data Sheet is accurate and is given in good faith, but no warranty expressed or implied is made. The suggested procedures are based on experience as of the date of publication. They are not necessarily all-inclusive nor fully adequate in every circumstance. Users are advised to make their own independent determination of suitability and completeness of information at their own risk, in relation to the particular purposes and specific circumstances. Since the information contained in this document may be applied under conditions beyond our control, no responsibility can be accepted by us for any loss or damage cause by any person acting or refraining from action as a result of any information contained in this Material Safety Data Sheet. Where the information provided herein disclosed a potential hazard or hazardous ingredient, adequate warning should be provided to employees and users and appropriate precautions taken.

IDENTIFICATION

Product Name	PREMIXED CONCRETE WAHOUT WASTE
Proper Shipping Name	None Allocated

Other Names	**Name**	**Manf. Code**

UN Number	None Allocated
DG Class	None Allocated
Packing Group	None Allocated
Hazchem Code	None Allocated
Poisons Schedule	Not Scheduled
Product Use	Concrete Washout waste.
Other Information	

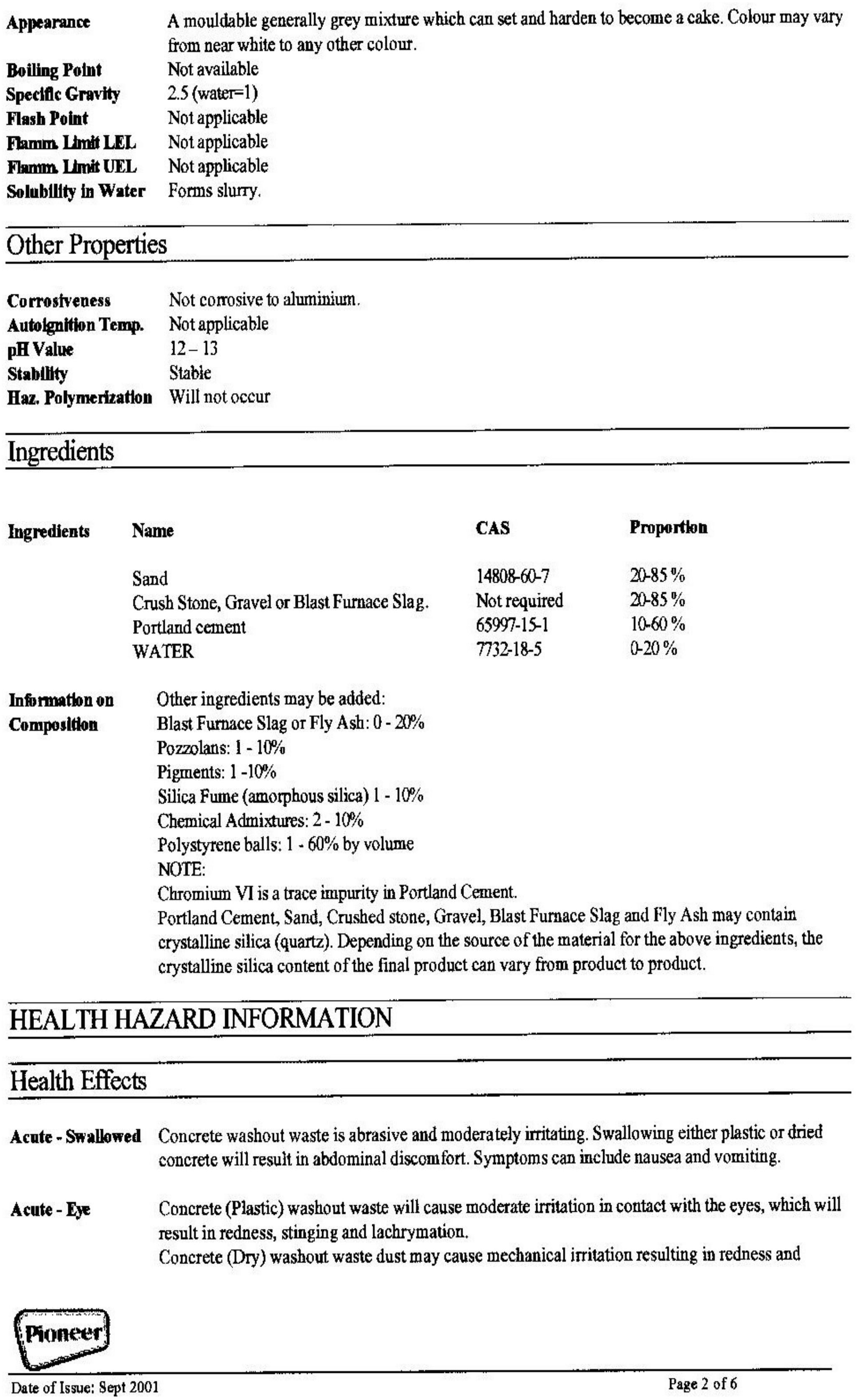
Physical Data

Pioneer

Date of Issue: Sept 2001

Page 1 of 6

Figure E2: Premixed Concrete Washout Material Safety Data Sheets



Appearance	A mouldable generally grey mixture which can set and harden to become a cake. Colour may vary from near white to any other colour.
Boiling Point	Not available
Specific Gravity	2.5 (water=1)
Flash Point	Not applicable
Flamm. Limit LEL	Not applicable
Flamm. Limit UEL	Not applicable
Solubility in Water	Forms slurry.

Other Properties

Corrosiveness	Not corrosive to aluminium.
Autoignition Temp.	Not applicable
pH Value	12 – 13
Stability	Stable
Haz. Polymerization	Will not occur

Ingredients

Ingredients	**Name**	**CAS**	**Proportion**
	Sand	14808-60-7	20-85 %
	Crush Stone, Gravel or Blast Furnace Slag.	Not required	20-85 %
	Portland cement	65997-15-1	10-60 %
	WATER	7732-18-5	0-20 %

Information on Composition

Other ingredients may be added:
Blast Furnace Slag or Fly Ash: 0 - 20%
Pozzolans: 1 - 10%
Pigments: 1 -10%
Silica Fume (amorphous silica) 1 - 10%
Chemical Admixtures: 2 - 10%
Polystyrene balls: 1 - 60% by volume
NOTE:
Chromium VI is a trace impurity in Portland Cement.
Portland Cement, Sand, Crushed stone, Gravel, Blast Furnace Slag and Fly Ash may contain crystalline silica (quartz). Depending on the source of the material for the above ingredients, the crystalline silica content of the final product can vary from product to product.

HEALTH HAZARD INFORMATION

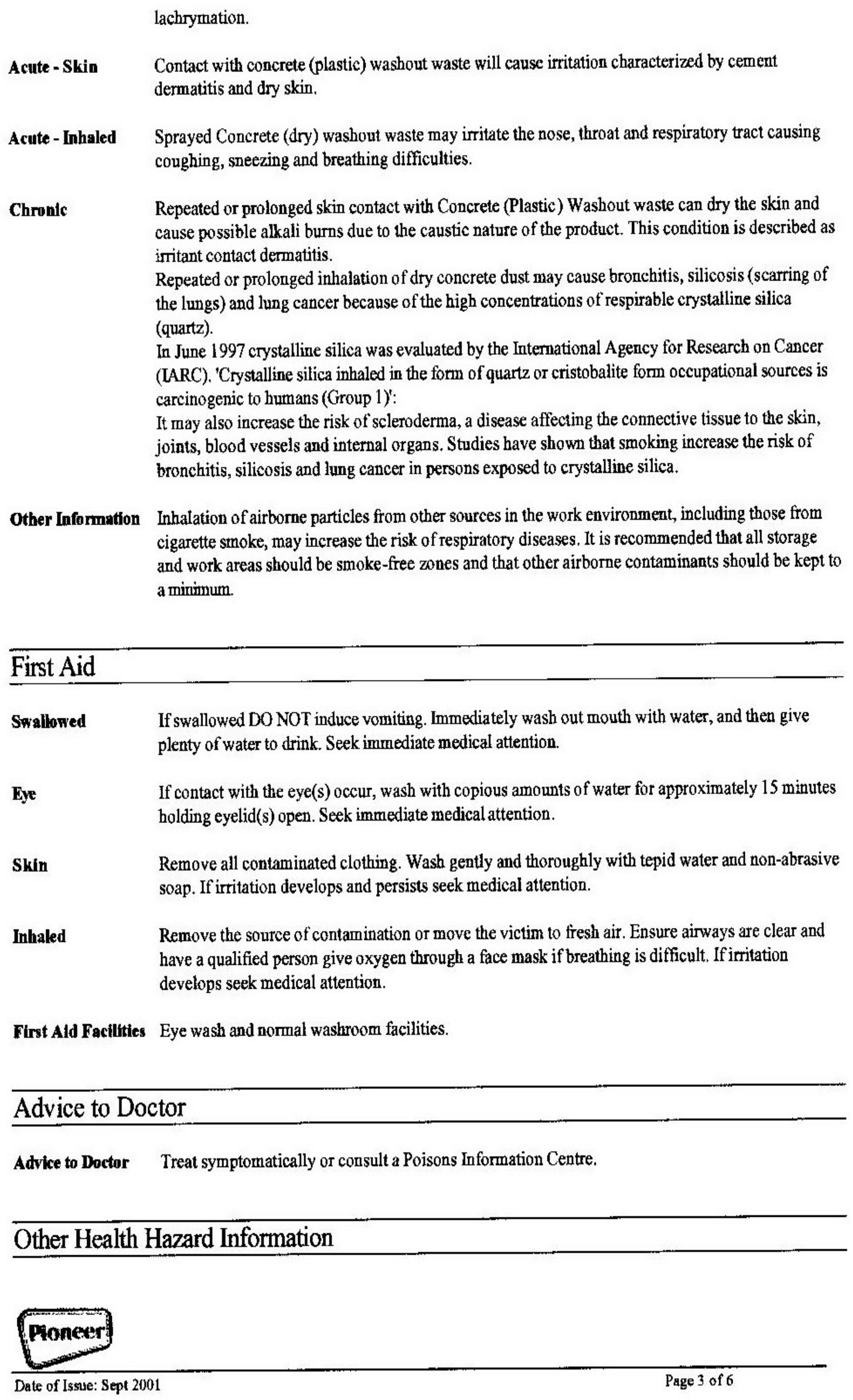
Health Effects

Acute - Swallowed Concrete washout waste is abrasive and moderately irritating. Swallowing either plastic or dried concrete will result in abdominal discomfort. Symptoms can include nausea and vomiting.

Acute - Eye Concrete (Plastic) washout waste will cause moderate irritation in contact with the eyes, which will result in redness, stinging and lachrymation.
Concrete (Dry) washout waste dust may cause mechanical irritation resulting in redness and

Pioneer

Figure E2 continued



lachrymation.

Acute - Skin Contact with concrete (plastic) washout waste will cause irritation characterized by cement dermatitis and dry skin.

Acute - Inhaled Sprayed Concrete (dry) washout waste may irritate the nose, throat and respiratory tract causing coughing, sneezing and breathing difficulties.

Chronic Repeated or prolonged skin contact with Concrete (Plastic) Washout waste can dry the skin and cause possible alkali burns due to the caustic nature of the product. This condition is described as irritant contact dermatitis.

Repeated or prolonged inhalation of dry concrete dust may cause bronchitis, silicosis (scarring of the lungs) and lung cancer because of the high concentrations of respirable crystalline silica (quartz).

In June 1997 crystalline silica was evaluated by the International Agency for Research on Cancer (IARC). 'Crystalline silica inhaled in the form of quartz or cristobalite form occupational sources is carcinogenic to humans (Group 1)':

It may also increase the risk of scleroderma, a disease affecting the connective tissue to the skin, joints, blood vessels and internal organs. Studies have shown that smoking increase the risk of bronchitis, silicosis and lung cancer in persons exposed to crystalline silica.

Other Information Inhalation of airborne particles from other sources in the work environment, including those from cigarette smoke, may increase the risk of respiratory diseases. It is recommended that all storage and work areas should be smoke-free zones and that other airborne contaminants should be kept to a minimum.

First Aid

Swallowed If swallowed DO NOT induce vomiting. Immediately wash out mouth with water, and then give plenty of water to drink. Seek immediate medical attention.

Eye If contact with the eye(s) occur, wash with copious amounts of water for approximately 15 minutes holding eyelid(s) open. Seek immediate medical attention.

Skin Remove all contaminated clothing. Wash gently and thoroughly with tepid water and non-abrasive soap. If irritation develops and persists seek medical attention.

Inhaled Remove the source of contamination or move the victim to fresh air. Ensure airways are clear and have a qualified person give oxygen through a face mask if breathing is difficult. If irritation develops seek medical attention.

First Aid Facilities Eye wash and normal washroom facilities.

Advice to Doctor

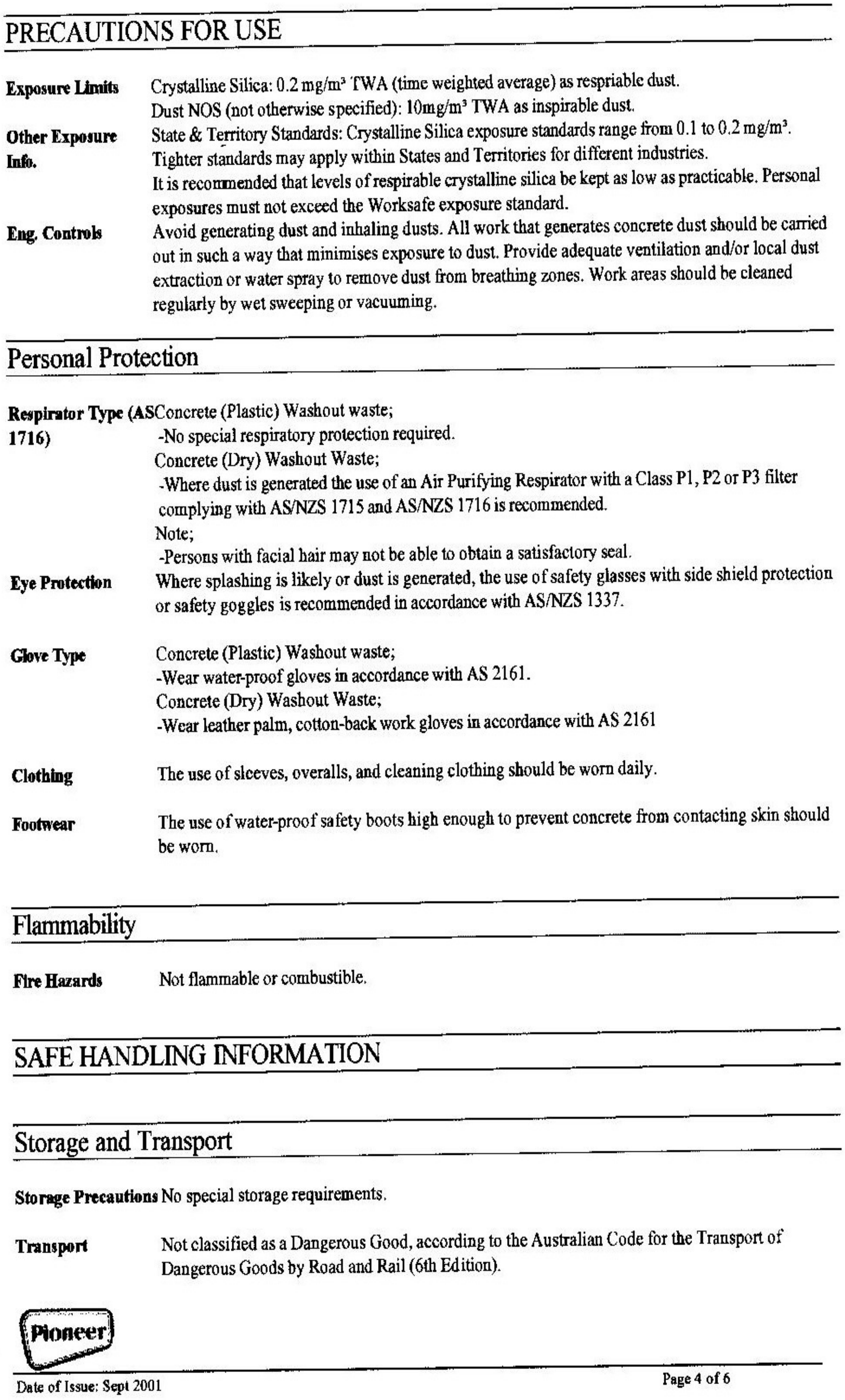
Advice to Doctor Treat symptomatically or consult a Poisons Information Centre.

Other Health Hazard Information

Date of Issue: Sept 2001

Page 3 of 6

Figure E2 continued



PRECAUTIONS FOR USE

Exposure Limits	Crystalline Silica: 0.2 mg/m³ TWA (time weighted average) as respriable dust. Dust NOS (not otherwise specified): 10mg/m³ TWA as inspirable dust.
Other Exposure Info.	State & Territory Standards: Crystalline Silica exposure standards range from 0.1 to 0.2 mg/m³. Tighter standards may apply within States and Territories for different industries. It is recommended that levels of respirable crystalline silica be kept as low as practicable. Personal exposures must not exceed the Worksafe exposure standard.
Eng. Controls	Avoid generating dust and inhaling dusts. All work that generates concrete dust should be carried out in such a way that minimises exposure to dust. Provide adequate ventilation and/or local dust extraction or water spray to remove dust from breathing zones. Work areas should be cleaned regularly by wet sweeping or vacuuming.

Personal Protection

Respirator Type (AS 1716)	Concrete (Plastic) Washout waste; -No special respiratory protection required. Concrete (Dry) Washout Waste; -Where dust is generated the use of an Air Purifying Respirator with a Class P1, P2 or P3 filter complying with AS/NZS 1715 and AS/NZS 1716 is recommended. Note; -Persons with facial hair may not be able to obtain a satisfactory seal.
Eye Protection	Where splashing is likely or dust is generated, the use of safety glasses with side shield protection or safety goggles is recommended in accordance with AS/NZS 1337.
Glove Type	Concrete (Plastic) Washout waste; -Wear water-proof gloves in accordance with AS 2161. Concrete (Dry) Washout Waste; -Wear leather palm, cotton-back work gloves in accordance with AS 2161
Clothing	The use of sleeves, overalls, and cleaning clothing should be worn daily.
Footwear	The use of water-proof safety boots high enough to prevent concrete from contacting skin should be worn.

Flammability

Fire Hazards	Not flammable or combustible.

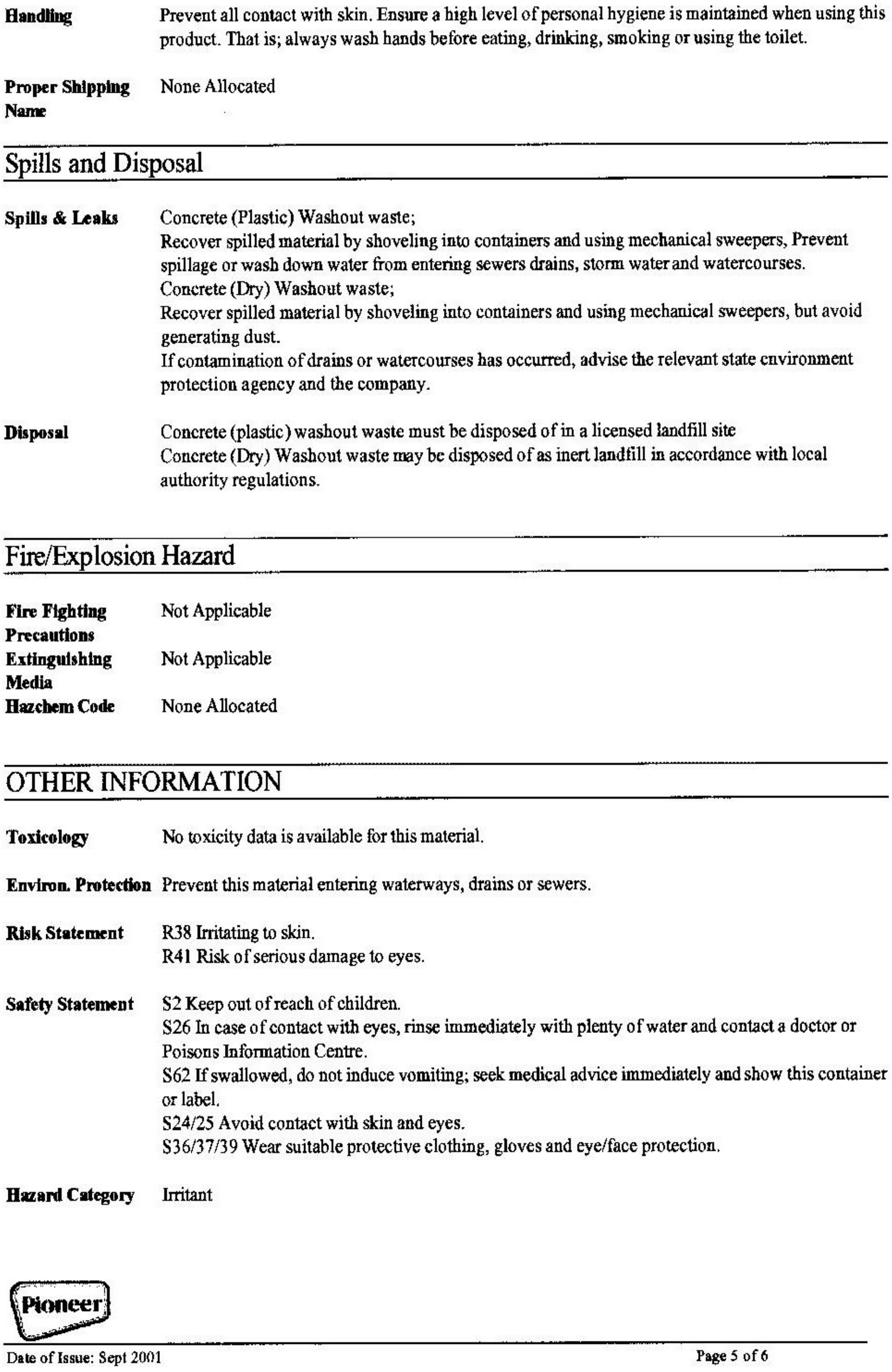
SAFE HANDLING INFORMATION

Storage and Transport

Storage Precautions	No special storage requirements.
Transport	Not classified as a Dangerous Good, according to the Australian Code for the Transport of Dangerous Goods by Road and Rail (6th Edition).

Pioneer

Figure E2 continued



Handling	Prevent all contact with skin. Ensure a high level of personal hygiene is maintained when using this product. That is; always wash hands before eating, drinking, smoking or using the toilet.
Proper Shipping Name	None Allocated

Spills and Disposal

Spills & Leaks	Concrete (Plastic) Washout waste; Recover spilled material by shoveling into containers and using mechanical sweepers, Prevent spillage or wash down water from entering sewers drains, storm water and watercourses. Concrete (Dry) Washout waste; Recover spilled material by shoveling into containers and using mechanical sweepers, but avoid generating dust. If contamination of drains or watercourses has occurred, advise the relevant state environment protection agency and the company.
Disposal	Concrete (plastic) washout waste must be disposed of in a licensed landfill site Concrete (Dry) Washout waste may be disposed of as inert landfill in accordance with local authority regulations.

Fire/Explosion Hazard

Fire Fighting Precautions	Not Applicable
Extinguishing Media	Not Applicable
Hazchem Code	None Allocated

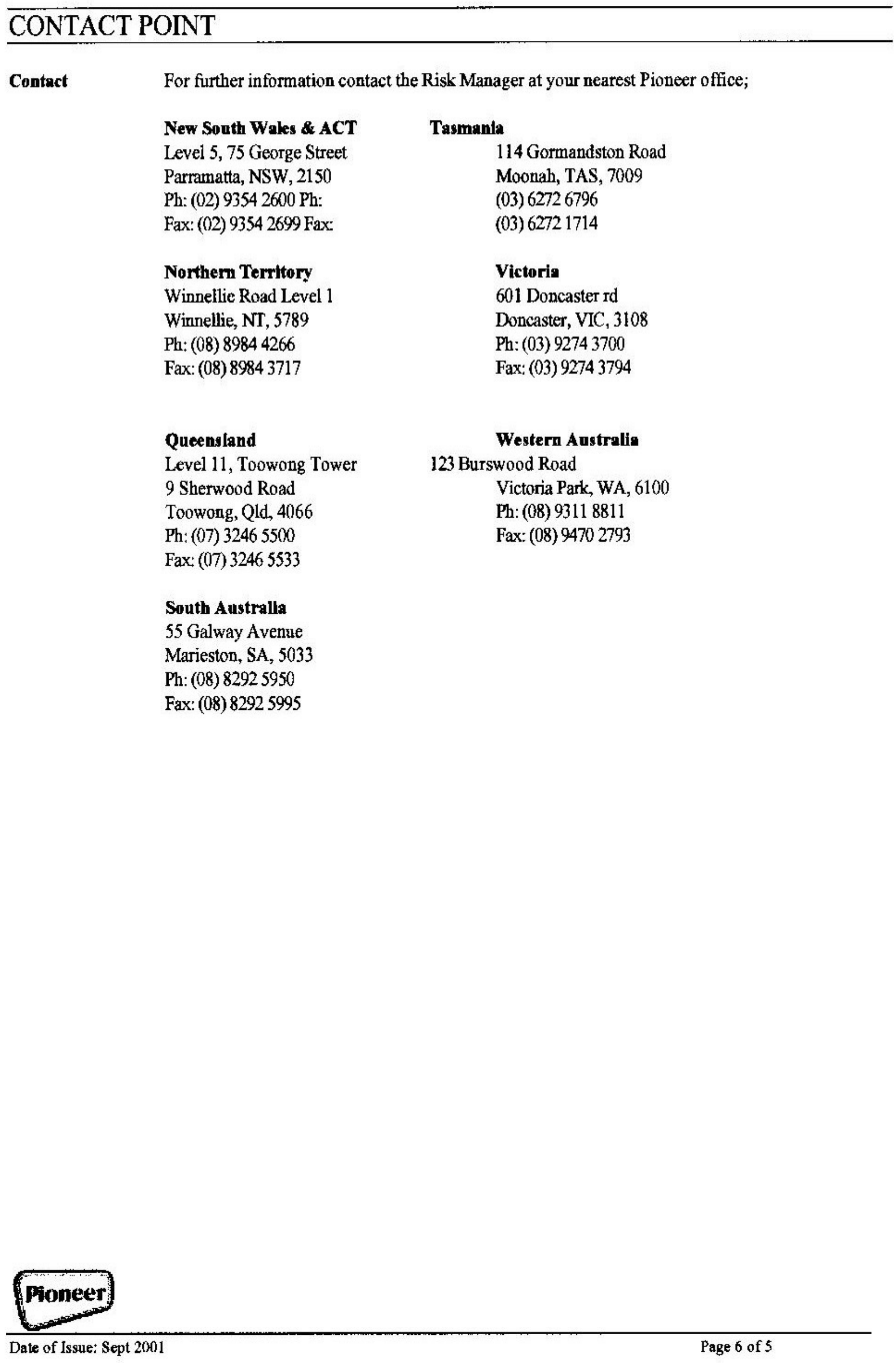
OTHER INFORMATION

Toxicology	No toxicity data is available for this material.
Environ. Protection	Prevent this material entering waterways, drains or sewers.
Risk Statement	R38 Irritating to skin. R41 Risk of serious damage to eyes.
Safety Statement	S2 Keep out of reach of children. S26 In case of contact with eyes, rinse immediately with plenty of water and contact a doctor or Poisons Information Centre. S62 If swallowed, do not induce vomiting; seek medical advice immediately and show this container or label. S24/25 Avoid contact with skin and eyes. S36/37/39 Wear suitable protective clothing, gloves and eye/face protection.
Hazard Category	Irritant

Pioneer

Date of Issue: Sept 2001 Page 5 of 6

Figure E2 continued



CONTACT POINT

Contact For further information contact the Risk Manager at your nearest Pioneer office;

New South Wales & ACT
Level 5, 75 George Street
Parramatta, NSW, 2150
Ph: (02) 9354 2600 Ph:
Fax: (02) 9354 2699 Fax:

Tasmania
114 Gormandston Road
Moonah, TAS, 7009
(03) 6272 6796
(03) 6272 1714

Northern Territory
Winnellie Road Level 1
Winnellie, NT, 5789
Ph: (08) 8984 4266
Fax: (08) 8984 3717

Victoria
601 Doncaster rd
Doncaster, VIC, 3108
Ph: (03) 9274 3700
Fax: (03) 9274 3794

Queensland
Level 11, Toowong Tower
9 Sherwood Road
Toowong, Qld, 4066
Ph: (07) 3246 5500
Fax: (07) 3246 5533

Western Australia
123 Burswood Road
Victoria Park, WA, 6100
Ph: (08) 9311 8811
Fax: (08) 9470 2793

South Australia
55 Galway Avenue
Marieston, SA, 5033
Ph: (08) 8292 5950
Fax: (08) 8292 5995

Date of Issue: Sept 2001

Page 6 of 5

Figure E2 continued

Appendix F

Graph of Leachate pH versus Incubation time

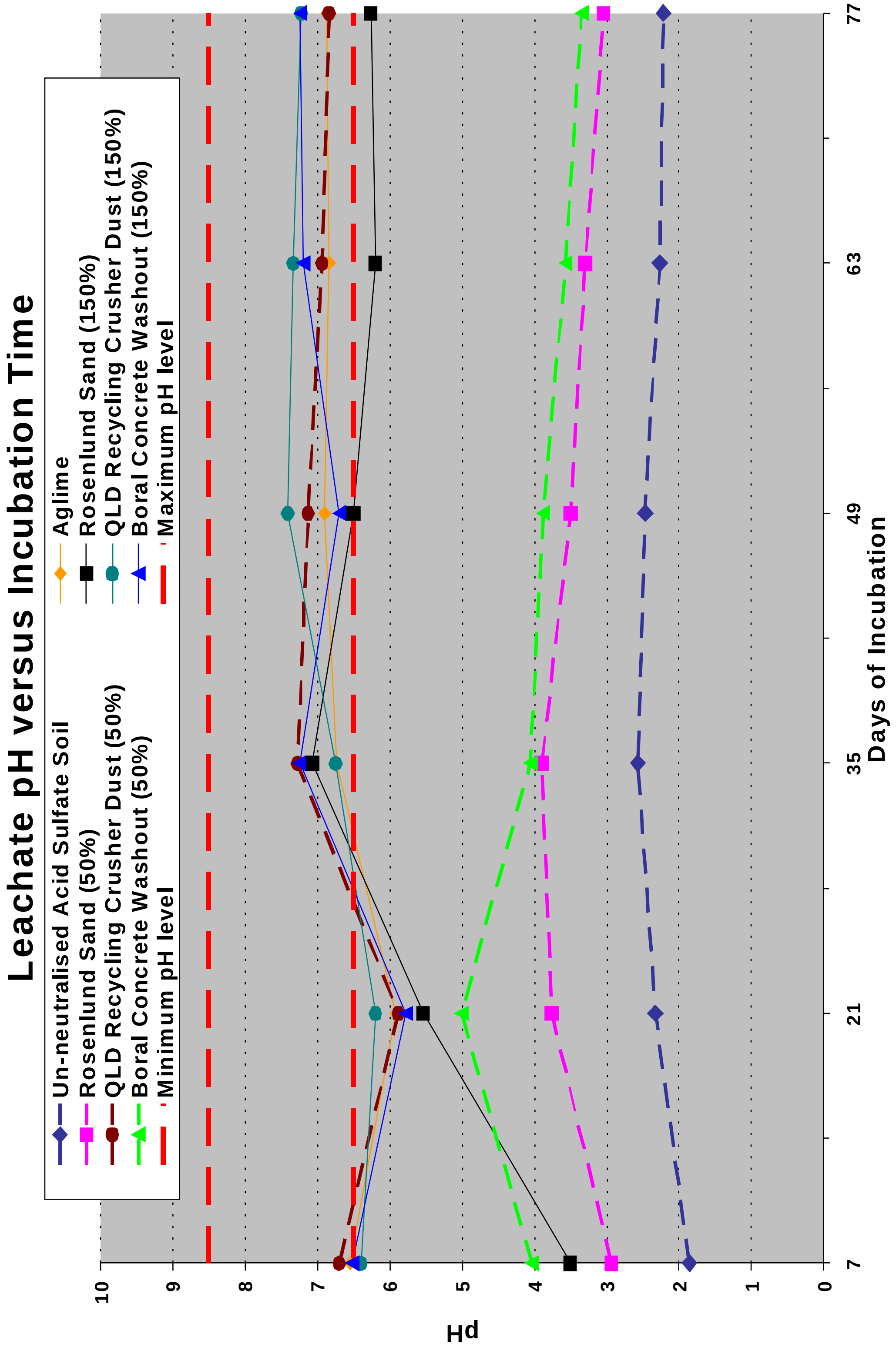


Figure F1: Line graph of Leachate pH versus incubation time for leaching column experiment