ACID SULFATE SOILS MANAGEMENT PLAN (ASSMP)

STA BUS DEPOT MONA VALE
58 DARLEY STREET, MONA VALE, NSW, 2103

Prepared For:	**State Transit Authority (STA)**
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TABLE OF CONTENTS

LIST OF TABLES, FIGURES & APPENDICES

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Environment & Natural Resource Solutions (ENRS) was commissioned as independent environmental consultants by the State Transit Authority (STA) (the client) to prepare a contemporary Acid Sulfate Soil Management Plan (ASSMP) for the STA Bus Depot located at 58 Darley Street, Mona Vale, NSW, 2103 (herein referred to as the Site).

ENRS understand this ASSMP is required in anticipation of ground works with the potential to disturb acid sulfate soils (ASS). The proposal is to construct a Total Liquids Remediation System (TLRS) which will comprise a series of interconnected on and offsite recovery Wells with pumps extracting contaminated groundwater and hydrocarbon product, to be transferred by under and above ground piping to an onsite Wastewater Treatment System (WTS), to be located at the rear of the existing Bus Depot workshop garage. This ASSMP is required by the Northern Beaches Council for Development Approval of a category 1 remediation project under NSW Government SEPP55 planning guideline, given that the proposed remediation Wells and piping is to be installed within a potential acid sulfate zone. Previous Site investigations document the Site area where the TLRS is proposed adjacent Taronga Place comprises medium-coarse sand to depths of 4 m.

This report documents a site specific Acid Sulfate Soil Management Plan (ASSMP) in general accordance with the NSW Acid Sulfate Soils Management Advisory Committee (ASSMAC;1998) guidelines; the NSW EPA (2014) Waste Classification guidelines; and with consideration of the NSW RTA (2005) Guidelines for the Management of Acid Sulfate Materials, and where appropriate the WA Department of Environment and Conservation (DEC; 2013) guidelines for Identification and Investigation of Acid Sulfate Soils and Acidic Landscapes.

1.1 OBJECTIVES

The objective of this ASSMP is to provide a framework for the on-site monitoring, treatment and management of Potential Acid Sulfate Soils (PASS) and actual Acid Sulfate Soils (ASS) that may be disturbed during the proposed site works, and procedures for soil waste classification and offsite disposal.

1.2 SCOPE OF WORK

The scope of work for the preparation of this ASSMP included the review, assessment and reporting of existing site data under the following tasks:

- Review of previous environmental investigation reports;
- Review project proposal, nature or ground works, depths and extent of material which may be disturbed;
- Review ASS risk maps in context of the proposed development area and scope of works with potential to disturb soil and groundwater; and
- Prepare ASSMP with protocols for soil waste classification and management of potentially contaminated soil and groundwater.

1.3 ACID SULFATE SOIL DEFINITION

Acid Sulfate Soils (ASS) is the common name given to sediments and soils containing iron sulfides (usually pyrite), which when oxidised, release sulfuric acid which can have direct toxic effects and indirect effects through increased metal availability (e.g. iron and aluminium precipitation) and reduced nutrient availability. ASS are typically located in low-lying coastal regions including mangroves, salt marsh vegetation or tidal areas, and at the bottom of coastal rivers and lakes. Acid sulfate soils (where present) can be identified as being either 'potential' or 'actual' (**Table 1**).

Table 1: ASS Definitions

Potential Acid Sulfate Soils (PASS)
Soils which contain iron sulfides or sulfidic material which have NOT been exposed to air and oxidised. The field pH of these soils in their undisturbed state is ***pH 4 or more*** and may be neutral or slightly alkaline. However, they pose a potential environmental risk when disturbed, as they will become acidic when exposed to air and oxidised.
actual Acid Sulfate Soils (ASS)
Soils containing highly acidic soil horizons or layers resulting from the aeration of soil materials that are rich in iron sulfides, primarily sulfide. This oxidation produces hydrogen ions in excess of the sediment's capacity to neutralise the acidity resulting in soils of ***pH of 4 or less*** when measured in dry conditions. These soils can sometimes be identified by the presence of ***pale yellow*** mottles and coatings of jarosite.

ASS is commonly managed during excavation works by ***neutralisation*** where alkaline materials are physically incorporated into the soil. Sufficient neutralising agent(s) needs to be used to ensure that there is the capacity to neutralise all existing acidity that may be present and all potential acidity that could be generated from complete oxidation of the sulfides over time. The preferred agent for treating ASS is Agricultural Lime (Aglime) as $CaCO_3$. However, there can be difficulties in effectively mixing fine Aglime with wet, lumpy, clayey or cohesive sediments. Alternatively liquid lime may be applied or similar alkaline material.

1.4 CONTAMINATED LAND MANAGEMENT

The proposal is to establish a Total Liquids Remediation System (TLRS) to remove hydrocarbon contaminated groundwater at the Site under management of the NSW EPA. Groundwater monitoring has delineated a groundwater plume across the east-northeast portion of the bus depot and areas adjacent Taronga Place. Site works are to be supported by:

- Lower Explosive Level (LEL) monitoring and hotworks permits; and
- Personal Protective Equipment (PPE) for soil vapour, and to prevent dermal contact.

Soil and groundwater management procedures will be required for excavated material and any dewatering. Controls are required to ensure appropriate containment with no leachate or discharge from the site. Any material required to be disposed offsite must be classified in accordance the NSW EPA guidelines for Waste Classification, and disposed offsite at a facility licensed to receive the specified class of waste.

2.0 SITE DESCRIPTION

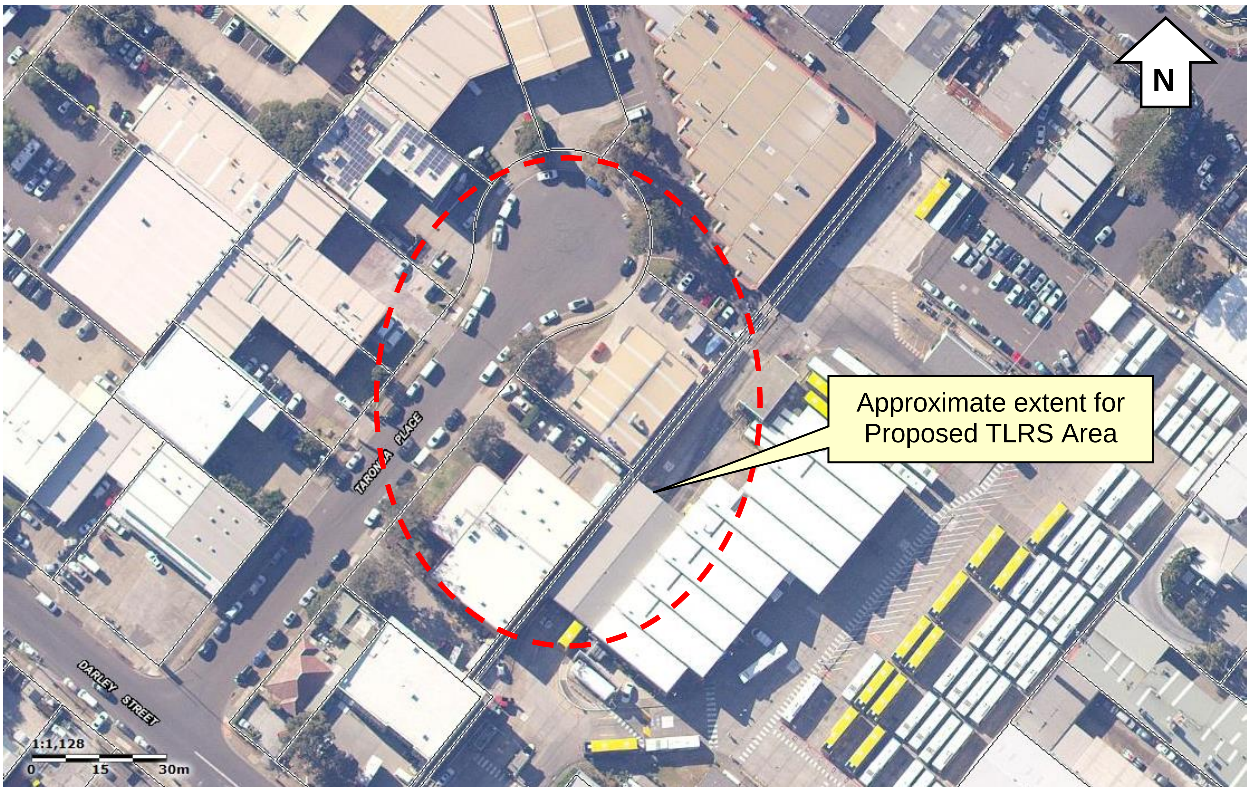
2.1 LOCATION

The Site location is shown in **Figure 1**. The key features required to identify the Site are summarised in **Table 2**

Table 2: Site Identification

SITE	DESCRIPTION
Street Address	58 Darley Street, Mona Vale, NSW, 2103
Lot / Deposited Plan	Lot 2 / DP 542640
LGA	Pittwater Council
Zoning	4(b1) Light Industrial B1
STA Site Area	17,100 m^2 (approximately)

Figure 1: Site Location Map



2.2 TOPOGRAPHY

A review of the site topography was conducted with reference to the current series Mona Vale 1:25,000 topographic map sheet 9130-1S and Sydney series soil landscape sheet. The surrounding area is characterised by low relief less than 10 metres with level to gently undulating terrain, depressions and in-filled lagoons. The site is relatively level with a subtle slope towards the northwest approaching an open stormwater channel which ENRS understands drains west into Winnererremy Bay.

Survey plans (Degotardi;1999) confirm the site gradient is northwest from a high of ~3 mAHD along the southern boundary towards a low of ~2.5 mAHD in the northwest corner of the site.

2.3 GEOLOGY

A review of the geological setting was conducted with reference to the Sydney 1:100,000 geological series sheet. The mapped geology shows the site is located within a localised northwest channel infilled with quaternary (Qha) alluvial deposits described as silty to peaty quartz sand, silt and clay, with ferruginous and humic cementation in places, and common shell layers. Drilling during installation of monitoring bores by ENRS intercepted brown silty sands to a maximum depth of 3 metres below ground level.

2.4 HYDROGEOLOGY

Groundwater in the area is associated with two (2) primary forms of aquifer systems;

- *Shallow unconfined* systems hosted in unconsolidated alluvial deposits, generally less than 5 m in depth with moderate to high yields, and water table strongly controlled by rainfall recharge; and
- *Deep fractured rock* and dual porosity aquifers hosted by the underlying Narrabeen Group (Rnn) sedimentary sequences described as shale, sandstone and claystone. Typically, deeper than 20 m with low to moderate yields, high iron and variable salinity.

A review of the online registered bore database (NOW cited 12/09/17) identified numerous bores in the area east of Barrenjoey Road and south of Darley Street registered for various uses including, waste disposal, monitoring, recreation and domestic. Bores report a Standing Water Level (SWL) between 2.0 metres and 4.5 metres below ground level (mbgl) did not identify any groundwater users within a one (1) kilometre radius of the Site. It is noted that the nearest bore (10WA107460) is registered for waste disposal to the south adjacent the site at 10 Darley Street. The registered bores do not identify any groundwater users down-gradient of the site. Further discussion of groundwater conditions in offsite monitoring bores is provided in the results section of this report.

3.0 ASSESSMENT CRITERIA

3.1 ACID SULFATE SOILS

3.1.1 Field Indicators

Field indicators for potential (PASS) and actual (ASS) should be applied to support identification in the field and trigger further laboratory testing if required:

Table 3: ASS Field Indicators

TYPE	FIELD INDICATORS
Acid Sulfate Soils(ASS)	dominance of mangroves, reeds, rushes and other marine/estuarine or swamp-tolerant vegetation.
	low lying areas, back swamps or scalded/bare areas in coastal estuaries and floodplains.
	sulfurous smell after rain following a dry spell or when the soils are disturbed.
Actual Acid Sulfate Soil (ASS)	**Soil characteristics**
	field **$pH_F \leq 4$** in soils.
	field **$pH_{FOX} < 3$** in soils.
	any jarositic horizons or substantial **iron oxide mottling**. Jarosite is a characteristic **pale yellow** mineral deposits which can be precipitate as pore fillings and coatings on fissures. In the situation of a fluctuating watertable, jarosite may be found along cracks and root channels in the soil. However, jarosite is not always found in ASS.
	Water characteristics
	water of pH < 5.5 in adjacent streams, drains, groundwater or ponding on the surface.
	unusually clear or milky blue-green drain water flowing from or within the area (aluminium released by the acid sulfate soils acts as a flocculating agent.).
	extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits.
Potential Acid Sulfate Soils (PASS)	**Soil characteristics**
	waterlogged soils - unripe muds (soft, buttery, blue grey or dark greenish grey) or **estuarine** silty sands or sands (mid to dark grey) or bottom sediments of estuaries or tidal lakes (dark grey to black).
	presence of **shell**.
	soil pH usually neutral but may be acid - positive Peroxide Test.
	Water Characteristics
	water pH usually neutral but may be acid.

3.1.2 ASSMAC Guidelines

The Acid Sulfate Soils Assessment Guidelines (ASSMAC;1998) have been endorsed by the NSW EPA and Department of Planning & Infrastructure, however the Queensland (QASSIT;2015 and WA (DoE;2006) draft Guidelines provide the most up-to-date manuals at the national level and should be referred to in addition to ASSMAC. The guidelines provide action criteria for field testing and Suspension Peroxide Oxidation Combined Acidity and Sulfur (SPOCAS) laboratory analysis. ASS and PASS assessment of SPOCAS results is based on two (2) lines of evidence. ASS or PASS conditions are identified to be present when both the **'acid trail'** and the **'sulfur trail'** lines of evidence show indicative concentrations. If either the ‘acid trail’ or the ‘sulfur trail’ lines of evidence are incomplete (e.g. below detection or action criteria) then ASS or PASS are not confirmed. The highest lab results should be compared against the action criteria to determine if the disturbance of ASS at the site will need to be treated and managed.

Table 4: ASS Field Indicators

Indicator	SCR & SPOCAS Result	Action Criteria
Acid Trail	pH (KCl), TAA, TPA, TSA.	18 mol H+/tonne
Sulfur Trail	pH (ox), S (KCl), S(P), S(RAS), SPOS.	0.03 %S

Where a project may disturb more than 1,000 tonnes of ASS with a sulphur trail ≥0.03%S (Spos) or acid trail ≥18 mol H+/tonne equivalent acidity (TPA or TSA), a detailed management plan is required.

3.2 WASTE CLASSIFICATION CRITERIA

Liquid and non-liquid waste designated for disposal shall be assessed in accordance with the NSW EPA Waste Classification Guidelines (EPA;2014). Guidelines are defined for the specific contaminant concentration (SCC) and the toxicity characteristics leaching procedure (TCLP). To establish soil waste classification using both SCC and TCLP, the test values for each chemical contaminant must be compared with the threshold values set in Table 2 of Part 1 of the guidelines:

Table 5: Waste Classification Criteria

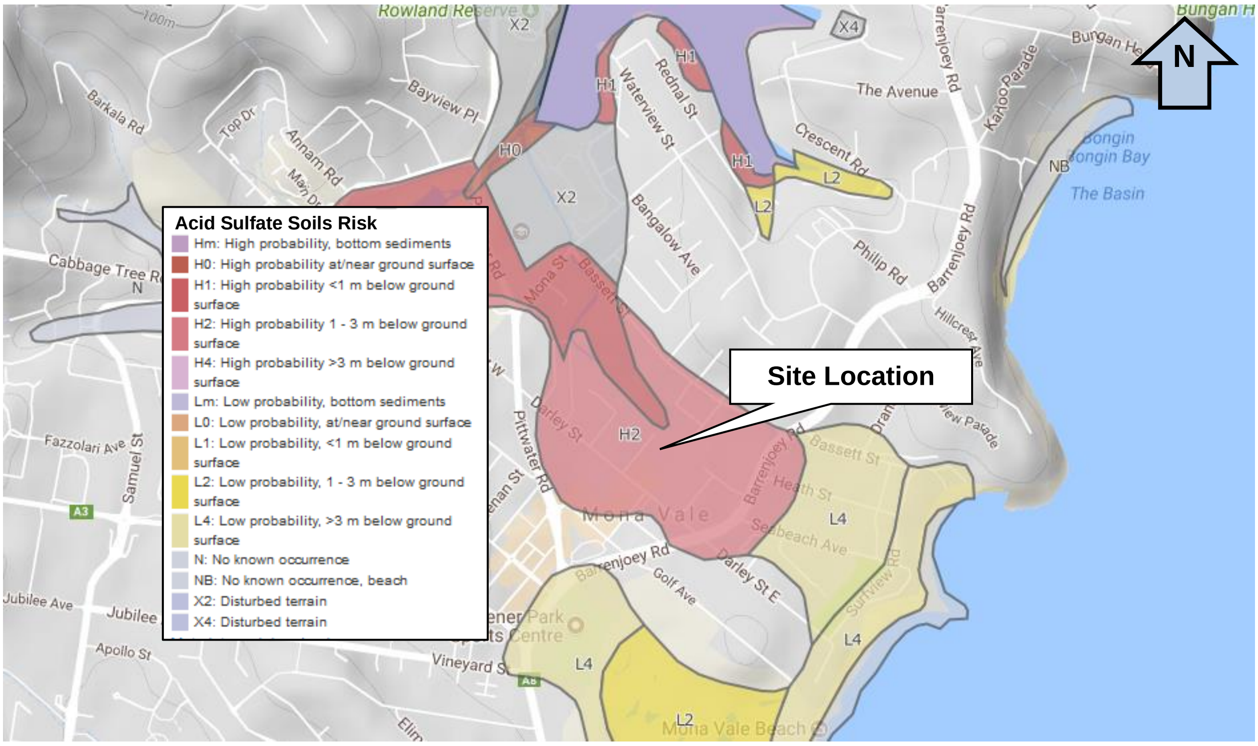
Classification	SCC value	TCLP value
General solid waste	≤ SCC1	≤ TCLP1
Restricted solid waste	≤ SCC2	≤ TCLP2
Hazardous waste	> SCC2	> TCLP2

4.0 ASS INVESTIGATION

4.1 RISK MAP

A pre-commencement assessment was conducted for Potential Acid Sulfate Soil (PASS) with reference to the online Acid Sulfate Soil Risk maps. The Site is mapped in an area classified as ***High Probability*** of occurrence (H2) or High Risk, refer to **Figure 2**.

Figure 2: ASS Risk Map



Source: http://www.environment.nsw.gov.au/eSpade2Webapp (cited 8.06.2020)

4.2 FIELD SCREENING

Where practical field screening for ASS is conducted by a trained Environmental Professional to support assessment of the likelihood of ASS. Field pH peroxide tests for both pH_F and pH_{FOX} should be conducted at 0.25-0.5 m intervals ensuring at least one test per soil horizon type. Where testing is not completed in the field they should be conducted within 24 hours of soil sample collection, ensuring appropriate sample handling procedures.

Samples should be submitted to a NATA accredited laboratory for SCR & SPOCAS testing to calculate neutralisation liming rates where **$pH_F<4$** or **$pH_{FOX} <3$**.

No field screening was conducted during preparation of this ASSMP due to access limitation and underground services. Previous Site reports document borelogs (BH21 enrs;2016) with coarse sand depths of 4 m with no field indicators for PASS/ASS.

4.3 LABORATORY ANALYSIS

Where laboratory confirmation is needed or a liming rate required samples should be submitted to the laboratory for the chromium reducible suite (Scr) and SPOCAS. It is noted the Suspension Peroxide Oxidation Combined Acidity and Sulfate (SPOCAS) testing may report elevated liming rates where samples comprise shell fragments.

SCR and SPOCAS testing should be conducted for any excavated material or drill cuttings which are proposed to be stockpiled, retained on Site or open excavations.

4.4 ASS RISK ASSESSMENT

Review of the Site location and Risk Maps indicate the site has a high potential for PASS and ASS which will require SCR & SPOCAS testing to inform liming rates.

Field testing should be undertaken on excavated soils and drilling spoil as soon as material is accessible during works. Where results exceed field indicators, samples should be submitted to a NATA laboratory for SCR & SPOCAS testing to inform liming rates. The material should then be treated by mixing with lime at 1.5x the laboratory reported liming rate and re-tested in the field to confirm neutralisation status.

5.0 SOIL MANAGEMENT PLAN

5.1 EXTENT OF WORKS

ENRS understand the project involves Drilling works for groundwater Well installation, and trenching to install underground pipelines and serves. Given the relatively shallow groundwater table in the area, the maximum depth of excavation is expected to be less than 1 m which is unlikely to intersect PASS/ASS. Drilling to depths of 4 m present some potential for PASS/ASS.

Where necessary temporary stockpiling maybe required during liming prior to waste classification and offsite disposal. Given the depth of the works it is anticipated that the groundwater table will be intercepted, creating the potential for groundwater discharge which will be required to be captured and tested to assess suitability for discharge or classification for offsite disposal.

5.2 PRE-EXCAVATION MEASURES

Prior to commencement the project manager shall ensure the following measures have been carried out:

- Ensure the works plan is designed to minimise the potential disturbance of ASS material;
- Establish stockpile areas and/or sealed containers;
- Establish suitable quantity of Aglime based on liming rates to be reported by NATA laboratory testing as soon as material is accessible for sampling;
- Establish drainage controls to capture any leachate or off site runoff and prevent any direct discharge to water ways;
- Designated project environment officer responsible for ensuring environmental monitoring, field testing and reporting in accordance with this ASSMP; and
- Induct project staff to ensure familiarity with this ASSMP including; ASS field indicators; site controls; liming procedures; materials handling protocols, waste classification and licensed disposal.

5.3 TREATMENT & RE-INSTATEMENT

Where soils are excavated the exposed surface of the soils shall be covered as soon as practicable with clean fill to prevent oxidation.

5.3.1 Guard Layer

Should the fill be proposed for re-instatement without stockpile treatment a ***guard layer of Aglime*** should be spread on the base of the subject area prior to placement or re-instatement. Guard layers may need to be applied between each compacted ASS layer as a precaution in environmentally sensitive areas, areas with high levels of sulfides or where soils are difficult to mix.

The ASSMAC guidelines recommend a minimum of 5 kg of fine Aglime should be applied per m^2 per vertical metre of fill. Assuming the project may re-instate approximately 0.3-0.5 metres a guard layer of ***1.5 kg to 2.5 kg per*** m^2 ***of Aglime*** should be applied.

5.3.2 Liming Methodology

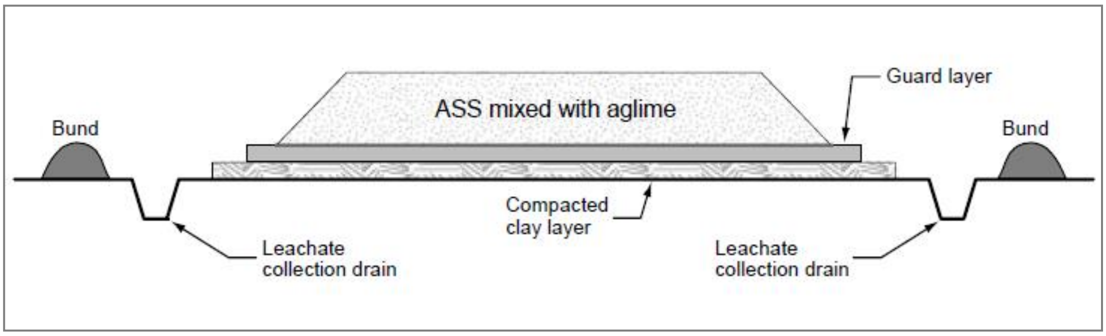
ASS material shall require neutralising to manage acidity and **maintain a soil pH >5**. Aglime is the preferred agent for neutralising ASS. Aglime has an acid neutralising value of approximately 97% $CaCO_3$. An Effective Neutralising Value (ENV) correction factor of 1.5 should be applied to calculate the reported liming rates.

ASS material should be placed in <300mm thick layers to allow drying. The appropriate amount of neutralising agent, including a **safety factor of 1.5** to allow for incomplete mixing, should be spread once the ASS are sufficiently dry. The ASS may require reworking several times to achieve adequate mixing of the neutralising agent and/or drying of the soil. Initial liming rates may be refined based on post-treatment monitoring results. Sampling and testing shall be undertaken by a suitably qualified person to verify the neutralisation treatment. Depending on the results of testing, reapplication of lime may be necessary to gain adequate neutralisation.

5.4 STOCKPILE PROTOCOL (IF REQUIRED)

The stockpile areas shall comprise specially prepared treatment (or liming) pads on hardstand, compacted clay or be prepared by lining the base with two (2) layers of thick impermeable plastic or stockpile material should be contained within designated containers. Stockpiles shall be bunded with impervious plastic, silt fencing or hay bales. Temporary cover is required when the stockpiles are not in use to minimise oxidation and leachate potential. Where practical, material types should be separated to avoid mixing. All stockpiles shall be maintained in an orderly and safe condition. Batters shall be formed with slope angles which are appropriate to prevent collapse or sliding of the stockpiled material.

Figure 3 Schematic Treatment Pad



Source: QLD ASS Technical Manual, Soil Management Guidelines (2015)

5.5 DISPOSAL OF ASS (IF REQUIRED)

Excess soil or waste may be disposed off site to an appropriately licensed facility following waste classification in accordance with NSW EPA Waste Classification Guidelines (EPA 2014). The waste classification should take into account the acid sulfate soil requirements and should NOT be assessed as Virgin Excavated Natural Material (VENM). Documentation should be maintained by the Site manager.

5.6 WATER MANAGEMENT

The Site comprises of an open level block. Shallow and wide drains shall be constructed at the Site perimeter to capture any leachate or runoff. Should monitoring results of any leachate and drainage water indicate a low pH (below 6.5), the addition of lime will be required to demonstrate no risk to the environment in accordance with the Protection of the Environment (*POE) Act* (1997) and Council requirements. Water from the Site assessed as suitable (by a suitably qualified environmental professional) shall be discharged to infiltration and evaporation drains. At no point shall water from the Site be allowed to flow into water ways. Alternatively, the water may be disposed offsite as liquid waste in accordance with the NSW EPA Waste Classification Guidelines (EPA 2017) to an appropriately licensed facility. Copies of disposal dockets shall be maintained with Site records.

5.7 MONITORING PROTOCOL

Monitoring and field testing will be required during the Site works to assess conditions prior to disturbance. Monitoring shall be conducted by a qualified environmental professional with experience in soil and water quality testing.

Table 6: Monitoring Protocol

Monitoring	Protocol	Action
Pre-excavation	Field pH testing conducted before excavation or immediately after excavation to document field pH prior to treatment. Assess each stage of works or every 100m linear section at 200mm depth intervals.	Conduct field testing, if pH_F <4; or pH_{FOX} <3 Submit samples for SCR&SPOCAS testing and conduct liming at 1.5 reported lime rate.
During Works	Weekly field testing of treated material and any Site water recovered from the excavation to ensure treatment and neutralising rates are effective and to assess the pH of any leachate or Site water. 1. Weekly Soil field pH 2. Daily Water pH and EC until pH conditions are consistently >6.5	If soil field pH <5 re-treat and consider installation of groundwater monitoring and increase testing frequency If water pH <6.5 treat and contain. Re-assess treatment and Site control procedures.

Monitoring	Protocol	Action
Post Treatment	soil pH after two weeks and again after four weeks Laboratory testing for SCR & SPOCAS after four weeks.	Review results against guidelines. Actions relevant to results.

5.8 WASTE DISPOSAL

5.8.1 Soil Waste

Potential ASS must be kept wet at all times during excavation and subsequent handling, transport and storage, until they can be disposed of safely. They must be received at the proposed disposal point within 16 hours of being dug up.

Where potential ASS cannot be classified as VENM or a licenced underwater disposal site is not available, the soil must be treated in accordance with the neutralising techniques in this ASSMAC. The soil must be chemically assessed in accordance with Step 5 in Part 1 of the Waste Classification Guidelines to determine whether any other contaminants are present in the material. When the classification has been established, the soil should be disposed of to a landfill that can lawfully accept that class of waste.

All material leaving the site shall be completely and securely covered to prevent loss of loose material from the vehicle and tracked appropriately. Only vehicles which are appropriately licensed, have clean exterior bodywork and which will not pollute the offsite transportation corridors shall be permitted to leave the site.

Any material removed from the Site shall be transported in accordance with government regulations and the requirements of the SafeWork Authority. All offsite truck movements shall occur during normal working hours. All trucks carrying loads of impacted soil material off-site shall be licensed to transport the materials and tracked in accordance with EPA requirements and State Government regulations.. Disposal of waste materials shall only be undertaken at appropriate NSW EPA licensed facilities which have been approved by the Project Manager.

5.8.2 Liquid Waste

All water discharge and dewatering must be captured, tested and assessed against ANZECC guidelines to document suitability for disposal to stormwater in accordance with Council requirements and the POE Act. Should the waters be assessed as unsuitable for release to stormwater the water should be classified as liquid waste and disposed in accordance with EPA requirements. Copies of disposal receipts should be retained by the project manager and provided to ENRS to document the validation process.

5.9 UNEXPECTED FINDS PROTOCOL

Measures for soil and water quality management during the project are outlined below:

- Implement the protocols outlined in this ASSMP;
- If works encounter groundwater contact an environmental professional to assess conditions and review procedures;

- Ensure an adequate supply of agricultural grade lime is stockpiled and available for use on Site; and
- Ensure project staff are made aware of this ASSMP in order to minimise any potential impact from disturbing ASS. Evidence of induction shall be maintained with project records.

6.0 REPORTING

Records shall be maintained to document the tracking of soil excavations, treatment and re-instatement, including details of locations, volumes, profiles (depths), treatment methods/ liming rates and environmental monitoring results.

Should any material be disposed off Site, complete details of transport procedures and disposal records are required including individual truck details and quantity transport, receipts and soil/ water quantities.

A monitoring report may be required at completion of Site works to substantiate treatment processes.

7.0 REFERENCES

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8.0 GLOSSARY

(Acid) Fizz test: The field test used for soils to test for the presence of carbonate minerals, whereby dilute hydrochloric acid is added to the soil. An effervescent fizzing reaction indicates the presence of carbonate minerals.

Acid Base Accounting (ABA): The process by which the various acid-producing components of the soil are compared with the acid neutralising components so that the soil's net acidity can be calculated.

Action criteria: The critical net acidity values (expressed in units of equivalent % pyrite sulfur, or equivalent mol H+/t) for different soil texture groups and sizes of soil disturbance that trigger the need for ASS management.

Actual Acidity: A component of existing acidity. The soluble and exchangeable acidity already present in the soil, often as a consequence of previous oxidation of sulfides. It is this acidity that will be mobilised and discharged following a rainfall event. It is measured in the laboratory using the TAA method. It does not include the less soluble acidity (ie. Retained acidity) held in hydroxy-sulfate minerals such as jarosite.

ANC: Acid neutralising capacity. A measure of a soil's inherent ability to buffer acidity and resist the lowering of the soil pH.

ANCBT: Acid neutralising capacity by back titration. Acid neutralising capacity measured by acid digest followed by back titration of the acid that has not been consumed.

ANCE: Excess acid neutralising capacity. Found in soils with acid neutralising capacity in excess of that needed to neutralise the acidity generated by oxidation of sulfides. The soil is oxidised with peroxide, then a titration is performed with dilute hydrochloric acid to a pH of 4, followed by a second peroxide digestion. If a soil has a positive ANCE result then the TPA result is zero and vice versa.

CaHCl: Calcium soluble in 4 M HCl, which includes soluble and exchangeable calcium as well as calcium found in certain carbonate minerals (eg. dolomite, calcite, aragonite).

CaKCl: Potassium chloride extractable calcium measured following the TAA analysis, which includes soluble and exchangeable calcium as well as calcium from gypsum.

CaNAS: Net acid soluble calcium. The calcium soluble in 4 M HCl that is not soluble in 1 M KCl. (CaHCl – CaKCl). It can be used (in combination with MgNAS) to provide an estimate of the soil carbonate content, but may be an overestimate if calcium is dissolved from non-carbonate or non-acid-neutralising minerals.

CaP: Peroxide calcium. Calcium measured following the TPA analysis, which includes soluble and exchangeable calcium, calcium from gypsum, as well as calcium (eg. from carbonates) dissolved as a result of acid produced due to oxidation of sulfides by peroxide.

Chromium Suite: The acid base accounting approach used to calculate net acidity which uses the chromium reducible sulfur method to determine potential sulfidic acidity. A decision tree approach based on the pHKCl result is then used to determine the other components of the acid base account.

CIN: Inorganic carbon. (CT – CTO). It is used to estimate the carbonate content of the soil.

CRS: The acronym often given to the Chromium Reducible Sulfur method.

CT: Total carbon. A measure of the total carbon content of the soil, encompassing both organic and inorganic forms.

CTO: Total organic carbon. The carbon in sample measured following a sulfurous acid digestion procedure used to remove carbonate carbon.

Existing Acidity: The acidity already present in acid sulfate soils, usually as a result of oxidation of sulfides, but which can also be from organic material or acidic cations. It can be further sub-divided into actual and retained acidity, ie. Existing Acidity = Actual Acidity + Retained Acidity.

Fineness factor: A factor applied to the acid neutralising capacity result in the acid base account to allow for the poor reactivity of coarser carbonate or other acid neutralising material. The minimum factor is 1.5 for finely divided pure agricultural lime, but may be as high as 3.0 for coarser shell material.

Jarosite: Jarosite is a characteristic pale yellow mineral deposit that can precipitate as pore fillings and coatings on fissures. Where there is a fluctuating watertable, jarosite may be found along cracks and root channels in the soil. However, jarosite is not always found in AASS.

MgA: Reacted magnesium. The magnesium soluble after the peroxide digest and TPA titration that was not soluble following KCl-extraction and TAA titration. (MgP – MgKCl). It can be used (in combination with CaA) to provide an estimate of the soil carbonate content, but may be an underestimate if the HCl-titration to pH 4 has not been performed as part of the TPA/ANCE procedure.

MgHCl: Magnesium soluble in 4 M HCl, which includes soluble and exchangeable magnesium as well as magnesium found in certain carbonate minerals (eg. dolomite, magnesite).

MgKCl: Potassium chloride extractable magnesium measured following the TAA analysis, which includes soluble and exchangeable magnesium.

MgNAS: Net acid soluble magnesium. The calcium soluble in 4 M HCl that is not soluble in 1 M KCl. (MgHCl – MgKCl). It can be used (in combination with CaNAS) to provide an estimate of the soil carbonate content, but may be an overestimate if magnesium is dissolved from noncarbonated or non-acid-neutralising minerals.

MgP: Peroxide magnesium. Magnesium measured following the TPA analysis, which includes soluble and exchangeable magnesium, as well as magnesium (eg. from carbonates) dissolved as a result of acid produced due to oxidation of sulfides by peroxide.

Monosulfides: The term given to the highly reactive iron sulfide minerals found in ASS that have the approximate formula ‘FeS’ and which are soluble in hydrochloric acid (as opposed to iron disulfides such as pyrite that are not appreciably soluble in hydrochloric acid).

Net Acidity: The result obtained when the values for various components of soil acidity and acid neutralisin capacity are substituted into the Acid Base Accounting equation. Calculated as: Net Acidity = Potential sulfide Acidity + Existing Acidity – (Acid Neutralising Capacity/Fineness Factor)

PASS: Potential Acid Sulfate Soil.

pHF: Field pH. Field determination of pH in a soil:water paste.

pHFOX: Field peroxide pH. Field determination of pH in a soil:water mixture following reaction with hydrogen peroxide.

pHKCl: Potassium chloride pH. pH in a 1:40 (W/V) suspension of soil in a solution of 1 M potassium chloride measured prior to TAA titration.

pHOX: Peroxide oxidised pH. pH in a suspension of soil in a solution after hydrogen peroxide digestion in the SPOCAS method.

POCAS: An acronym standing for Peroxide Oxidation Combined Acidity and Sulfate method (Method Code 21). This method has been superseded by the SPOCAS method.

POCASm: An acronym standing for the modified Peroxide Oxidation Combined Acidity and Sulfate method. This method has been superseded by the SPOCAS method.

Potential (sulfidic) acidity: The latent acidity in ASS that will be released if the sulfide minerals they contain (eg. pyrite) are fully oxidised. It can be estimated by titration (ie. TSA) if no acid neutralising material is present, or calculated from SPOS or SCR results.

Retained Acidity: The ‘less available’ fraction of the existing acidity (not measured by the TAA) that may be released slowly into the environment by hydrolysis of relatively insoluble sulfate salts (such as jarosite, natrojarosite, and other iron and aluminium hydroxy-sulfate minerals).

SCR: The symbol given to the result from the Chromium Reducible Sulfur method (Method 22B). The SCR method provides a measure of reduced inorganic sulfide content using iodometric titration after an acidic chromous chloride reduction. This method is not subject to interferences from organic sulfur.

SHCl: Sulfur soluble in 4 M HCl which includes soluble and adsorbed sulfate, sulfate from gypsum, as well as sulfate from hydroxy-sulfate minerals such as jarosite and natrojarosite.

SKCl: Potassium chloride extractable sulfur measured following the TAA analysis, which includes soluble and adsorbed sulfate as well as sulfate from gypsum.

SNAS: Net acid soluble sulfur. (SHCl – SKCl). The sulfur soluble in 4 M HCl that is not soluble in 1 M KCl. It provides an estimate of the sulfate contained in jarosite and similar low solubility hydroxy-sulfate minerals (and can be used to estimate retained acidity).

SP: Peroxide sulfur. Sulfur measured following the TPA analysis, which includes soluble and exchangeable sulfate, sulfate from gypsum, as well as sulfide converted to sulfate and that released from organic matter as a result of peroxide oxidation.

SPOS: Peroxide oxidisable sulfur from the SPOCAS method. The sulfur soluble after the peroxide digest and TPA titration that was not soluble following KCl-extraction and TAA titration. (SP – SKCl). It provides an estimate of the soil sulfide content, but is affected by the presence of organic sulfur.

SRAS: Residual acid soluble sulfur. The sulfur measured by 4 M HCl extraction on the soil residue remaining after peroxide digestion and TPA titration of the SPOCAS method. It provides an estimate of the sulfate contained in jarosite and similar low solubility hydroxy-sulfate minerals (and can be used to estimate retained acidity).

ST: Total sulfur. A measure of the total sulfur content of the soil, encompassing both organic and inorganic forms.

STOS: Total oxidisable sulfur. An estimate of soil oxidisable sulfur made from determining the sulphur not soluble in 4 M HCl. (ST – SHCl). It tends to provide an overestimate of soil sulfide content.

Self-neutralising soils: This term is given to ASS where there is sufficient acid neutralizing capacity (with the relevant safety factor applied) to neutralise the potential sulfidic acidity held in the soil (ie. the net acidity from the Acid Base Account is zero or negative). Soils may be ‘self-neutralising’ due to an abundance of naturally occurring calcium or magnesium carbonates (eg. crushed shells, marine animal exoskeletons, coral) or other acid-neutralising material.

SPOCAS: An acronym standing for Suspension Peroxide Oxidation Combined Acidity and Sulfur method (Method Code 23), the peroxide-based method that supersedes the previous POCAS and POCASm methods.

SPOCAS Suite: The acid base accounting approached used to calculate net acidity based on the Suspension Peroxide Oxidation Combined Acidity and Sulfur method. A decision tree approach based on the values of pHKCl and pHOX is used to decide what analytical path is followed in order to allow calculation of net acidity.

TAA: Titratable actual acidity. The acidity measured by titration with dilute NaOH following extraction with KCl-solution in the SPOCAS method. Previously referred to as Total Actual Acidity in the POCAS and POCASm methods.

TPA: Titratable peroxide acidity. The acidity measured by titration with dilute NaOH following peroxide digestion in the SPOCAS method. Previously referred to as Total Potential Acidity in the POCAS and POCASm methods.

TSA: Titratable sulfidic acidity. The difference in acidity measured by titration with dilute NaOH following extraction with KCl-solution and the acidity titrated following peroxide digestion in the SPOCAS method. (TPA – TAA). Previously referred to as Total Sulfidic Acidity in the POCAS and POCASm methods.

9.0 LIMITATIONS

This report and the associated services performed by ENRS are in accordance with the scope of services set out in the contract between ENRS and the Client. The scope of services was defined by the requests of the Client, by the time and budgetary constraints imposed by the Client, and by the availability of access to Site.

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The data, findings, observations, conclusions and recommendations in the report are based solely upon the state of Site at the time of the investigation. The passage of time, manifestation of latent conditions or impacts of future events (e.g. changes in legislation, scientific knowledge, land uses, etc) may render the report inaccurate. In those circumstances, ENRS shall not be liable for any loss or damage that may be occasioned directly or indirectly through the use of, or reliance on, the contents of the report.

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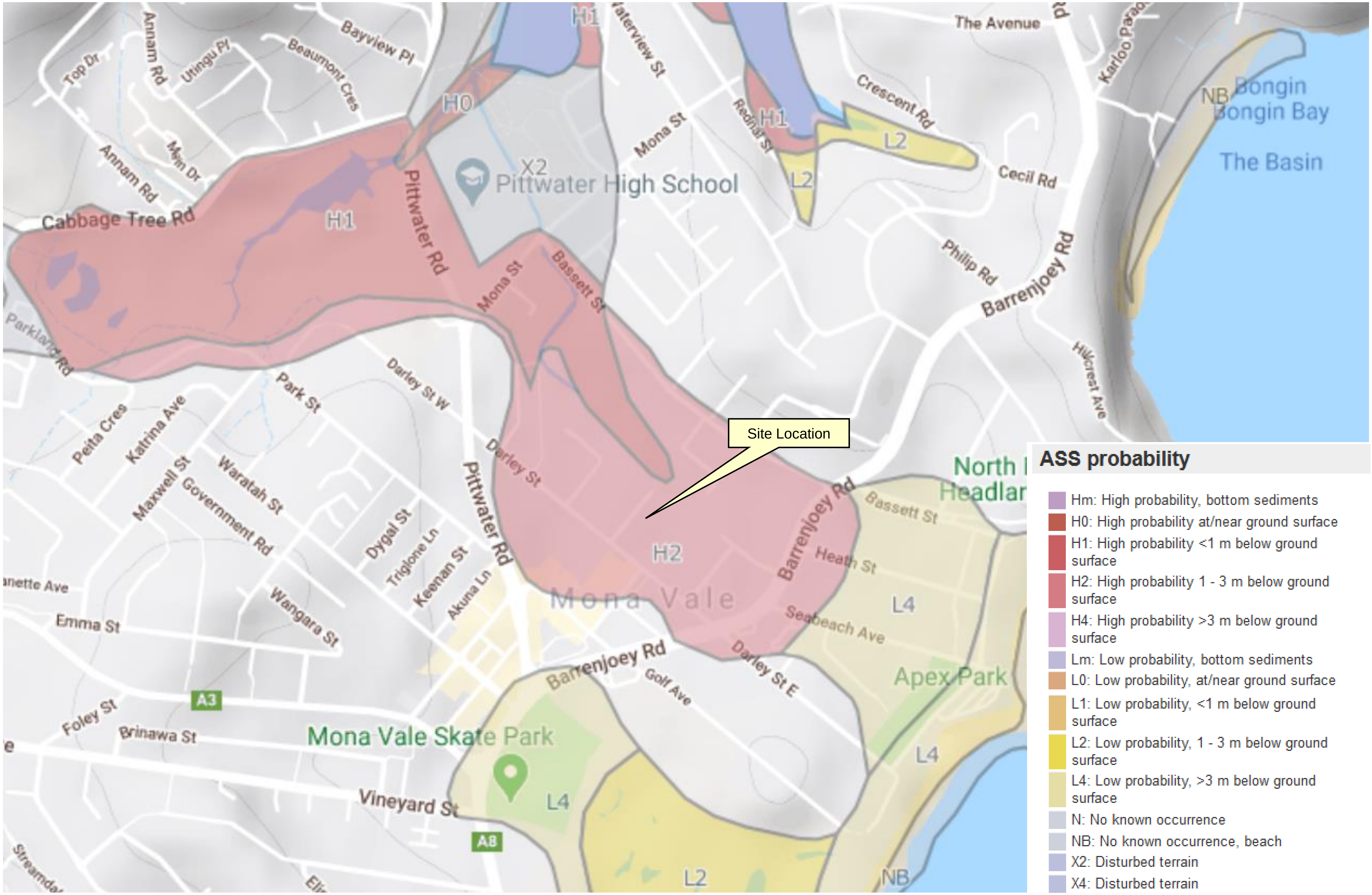

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Client:	**STA**	Drawn:	**R.L.**	Figure:	**4**
Project:	**ENRS0212**	Source:	**NSW SEED**	Date:	**09/06/2020**
Location:	**Mona Vale Bus Depot, NSW**	Scale:	**ScaleBar**	Title:	**Acid Sulfate Soil Risk Map**
		Status:	**Rev 1**		

Appendix 1
Laboratory Certificates of Analysis

(To be appended)

Appendix 2
Example ASSMP Flow Chart

STEP 1 Site inductions. Ensure staff are familiar with this ASSMP especially field indicators of ASS, treatment procedures, & Waste Classification.

STEP 2 Designate Environmental Officer responsible for ASS management.

Establish Site controls, drains, Aglime stockpile.

STEP 3 Stockpile separately any excavated material/Piling spoil. Do not mix with natural soils.

STEP 4 Field test soil prior to disturbance or as soon as accessible to identify Actual or Potential ASS. If $pH_F<4$ or $pH_{FOX}<3$ submit samples for SCR & SPOCAS testing. If ASS is present continue monitoring as per Step 8

STEP 5 Treat ASS. Apply Aglime to ASS soil areas prior or during excavation/piling at 1.5x NATA laboratory reported lime rate.

STEP 6 Establish guard layer of Aglime prior to placement of ASS material on nonsealed ground at rate of $5kg/m^2$ per vertical metre.

STEP 7 Cover disturbed ASS with clean fill/plastic as soon as practical

STEP 8 Monitoring:

- Submit samples for waste classification if required to be disposed offsite.
- Test water pH & EC daily if present in drains and treat with lime if <6.5
- Field test soil 1 week, 2 weeks and 4 weeks after disturbance or dispose offsite.
- Apply monitoring results to adjust liming rates.
- Laboratory SPOCAS & SCR testing after 4 weeks if field tests indicate ongoing risk.

STEP 9 Compile results and submit final report to Council/Regulator with record of ASS placement, waste disposal if any, liming rates and monitoring results.