Water Corporation Acid Sulfate Soil and Dewatering Management Strategy

July, 2007

Water Corporation

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NCSI Certified Quality System ISO 9001

2145253A-PR2:16781 Rev C

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Date:	26 April 2007..
Distribution:	WC (2), PB (2) ....

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Executive summary

The maintenance and installation of water supply, wastewater and drainage, and irrigation assets by the Water Corporation, by necessity, results in the disturbance of soils with the potential requirement for dewatering of the superficial aquifer water table to facilitate site works. During maintenance and development of these assets, there is a need for the Water Corporation to demonstrate the best practice acid sulfate soil and dewatering management that achieves sound environmental outcomes. This *Acid Sulfate Soil and Dewatering Management Strategy* has been prepared by Parsons Brinckerhoff, on behalf of the Water Corporation, to address the environmental management commitments that will be made by the Water Corporation to ensure that management and development of these assets do not cause any long-term environmental harm.

Water Corporation will adopt a risk-based management approach to acid sulfate soils and dewatering. The risk assessment process is depicted diagrammatically in Figure E.1. Several risk factors have been considered with regards to deriving appropriate risk-based management strategies. These include:

- PROJECT RISK - The project risk assessment considered the scope of work of the project including project duration, volume of soil disturbing activities, depth to groundwater, type and proximity of environmental receptors, and beneficial use of groundwater.

- RISK OF ACID SULFATE SOIL OCCURRENCE - The risk of acid sulfate soil occurrence considers indicative parameters including geology, site elevation, depth to groundwater, wetlands and vegetation sensitivity and WAPC ASS risk rankings, to assess the likelihood of acid sulfate soils being present in a given environment.

- RISK OF ACID GENERATION – The acid generation risk assessment is undertaken post field work to determine the likelihood of given soil types to generate acidity if disturbed. The risk assessment considers parameters such as depth of soil in the profile, soil type, pH_F and pH_{FOX} results, sulfide content, and metals concentrations.

- DEWATERING RISK – The dewatering risk assessment considers factors such as duration of dewatering, depth of drawdown and proximity to nearest receptors to determine the relative risk of dewatering activities.

The aforementioned risk assessments are used collectively to derive a MANAGEMENT LEVEL for acid sulfate soil handling and dewatering activities. The management levels adopt the following principles:

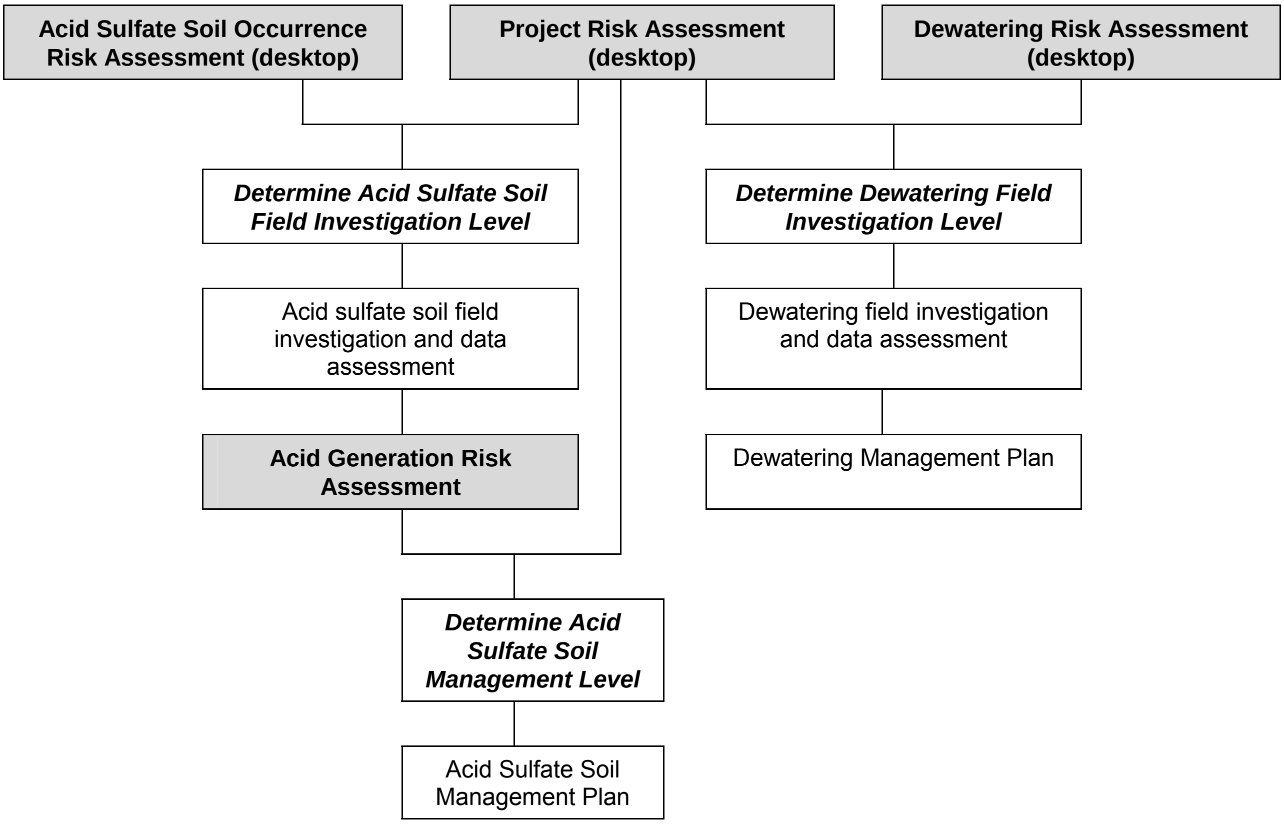
- Level 1 –- represents a low risk to the environment whereby measurable environmental impacts are unlikely. No active management practices will be adopted.

- Level 2 – represents a moderate risk to the environment in that impacts may occur but are not certain to occur. Management practices will focus on routine monitoring to identify change, and adopt active management strategies as a contingency.

- Level 3 – represents a high risk to the environment whereby impact to the environment is likely without management. Active management practices will be undertaken to ensure protection of environmental values.

This risk-based management strategy is considerate of the spirit and intent of relevant guidelines while considering the risk/cost benefit of investigation and management activities at each level of site development.

Figure E.1: Risk assessment process



1. Introduction

The maintenance and installation of assets by the Water Corporation, by necessity, results in the disturbance of soils with the potential requirement for dewatering of the superficial aquifer water table to facilitate site works. There is a need for the Water Corporation to demonstrate the best practice acid sulfate soil and dewatering management that achieves sound environmental outcomes. The Water Corporation is committed to conducting works in an environmentally responsible manner.

This document details the Water Corporation's commitments for the preparation and implementation of acid sulfate soil and/or dewatering management plans. All management plans will be prepared in accordance with the spirit and intent of relevant guidelines, with a focus on not causing any long-term, serious environmental harm.

1.1 Asset management undertaken by Water Corporation

The Water Corporation manages a variety of assets to achieve its core business of water supply and waste water disposal, namely:

- Water – collect, treat, transfer and deliver drinking quality and non-drinking-quality water.
- Wastewater and Drainage – collect, transport, treat, dispose and return wastewater and drainage water to the water cycle.
- Irrigation – bulk supplier of water for irrigation.

The following summarises the different infrastructure components that must be developed and maintained to successfully operate these systems.

1.1.1 Linear infrastructure

The water and wastewater systems that service Perth comprise thousands of kilometres of pipelines that link supply reservoirs, bores, water treatment plants and wastewater treatment plants, with approximately 600,000 connected properties. There are over 9,000 km of wastewater pipe alone.

The pipelines range in size from small drinking water delivery pipes to major sewers. They include 'normal' and pressure mains and are located at all depths from "above ground" to 10 metres below ground, and in all environments including soils adjacent to wetland systems and adjacent to Perth's river systems. Some pipes also cross river systems (or are buried below them).

1.1.2 Non-linear infrastructure

The Water Corporation has some $10 billion of infrastructure that controls the collection, treatment and transfer of water.

Non-linear infrastructure includes water treatment plants (including chlorine dosing facilities), reservoirs, dams, weirs, tanks, valve pits, dosing plants, overflow systems and ocean outfalls associated with the water supply systems.

In the wastewater treatment system, non-linear infrastructure includes:

- wastewater treatment plants, of which there are currently 3 in the metropolitan area and 92 in regional Western Australia;
- pumping stations, of which there are 550 in the metropolitan area (112 are located near rivers). Pumping stations are typically located in low-lying areas; and
- overflow storage tanks, that are typically located adjacent to pumping stations.

Perth's reticulated systems are located at topographical peaks and designed for gravity-feed where possible. In some cases reticulated systems are supported by pump stations that, by necessity, are generally located in low-lying areas.

Depending on the capacity of the system, non-linear infrastructure installations can range in size from 400 m^2 to 5,000 m^2, with earthwork activities ranging from a few weeks, on smaller projects, up to several months for larger projects. Due to the low-lying locations of many of the infrastructure components, dewatering is often required. Further, construction works are commonly undertaken in close proximity to sensitive receptors including residential water supplies, wetlands and rivers.

2. Regulatory requirements

The management of acid sulfate soils and dewatering discharge by the Water Corporation must be compliant in principle with guidelines and licencing requirements of various state regulatory organisations, as listed in the following sections.

2.1 Licences

Dewatering licences – general

Advice from the Department of Water (DoW) has indicated that the Water Corporation is not required to obtain either a Section 5C or Section 26D licence under the *Rights in Water and Irrigation Act (1914)* in regards to dewatering. The power given to the Water Corporation by Section 83(2)(b) of the *Water Agencies (Powers) Act 1984* overrides the generic requirements of Sections 5C and 26D of the *Rights in Water and Irrigation Act* and therefore the Water Corporation **is exempt** from the requirement to obtain a dewatering licence.

Swan River Trust development applications

Under Part 5 of the *Swan River Trust Act (1988)*, where dewatering associated with works is required within the Swan River Trust Act management area, the works (including dewatering) require the approval of the Swan River Trust. However, by agreement, the Water Corporation **is exempt** from submitting development applications for dewatering.

Local authority development applications

Local government authorities can require a dewatering and/or acid sulfate soil management plan as a part of their environmental management. This is more often a requirement when discharging excess dewater into the local authority controlled drainage system. The local government should be contacted prior to site works to confirm requirements.

Dewatering discharge disposal

A disposal licence is required under the *Waterways Conservation Act 1936*, if any dewatering discharge is proposed to be disposed of within any waterway covered under this Act (e.g. Peel-Harvey Estuary).

2.2 Relevant guidelines

The Water Corporation will comply with the following guidelines, or updated versions thereof, where appropriate:

- Water Quality Protection Note 13 – *Dewatering of soils at construction sites* (DoW, April 2006)
- Policy SRT/DE6 – *Dewatering* (Swan River Trust, August 2001)
- WAPC Bulletin #64 – *Acid Sulfate Soils* (WAPC, 2003)
- *Acid Sulfate Soil Guidelines Series* (DEC, 2004 – 2006)
- *Dewatering Effluent and Groundwater Monitoring Guidance for Acid Sulfate Soil Areas* (DEC, June 2006).

2.3 Agreed management approach

Notifying consultants of exemptions

The Water Corporation will ensure that relevant consultants and contractors are made aware of its exemption from requiring dewatering licences.

Management plans

Regardless of the fact that a dewatering licence is not required, there is a need for the Water Corporation to prepare and implement an acid sulfate soil and dewatering management plan for all sites that require dewatering to ensure that the environment is managed responsibly.

Management plans will be held on file at the Water Corporation for a period not less than 5 years and will be available for audit by the DEC upon request.

Notifying the Department of Environment and Conservation

Communication between the Water Corporation and DEC will be maintained to ensure the regional offices are aware of Water Corporation activities in their area:

- On high-impact projects, this will be undertaken through the formal assessment process;
- On low-impact projects, communication will be in the form of a notification letter to the relevant DEC regional manager. The letter shall include details of any proposed significant deviations from the guidelines listed in Section 2.2.

The DEC shall provide response where required within 10 working days of correspondence where they require further information. Water Corporation will assume that if a response is not received from the DEC in this timeframe that the DEC consents to the management approach.

3. Methodology for assessment

The Water Corporation will adopt a risk-based approach that is consistent with the intent of the guidelines presented in Section 2.2 to determine the level of assessment necessary prior to construction with regards to acid sulfate soils and dewatering.

All projects undertaken by the Water Corporation will document the outcomes of the project risk assessment on the *Project Acid Sulfate Soil and Dewatering Risk Assessment Form* provided in Appendix A.

3.1 Scope of project

Determination of the level of assessment to be undertaken to define acid sulfate soils and dewatering management requires a clear understanding of the scope of the project and the environmental setting in which it is located. The following aspects of project scope will need to be defined prior to site investigation:

- Proposed duration of project;
- Volume, area and depth of soil disturbance activities;
- Anticipated depth to groundwater;
- Type and proximity of sensitive environmental receptors; and
- Beneficial use of groundwater in the project area.

Once project scope factors have been defined, each factor will be assigned a risk ranking based on the likelihood for the activity to result in a measurable risk to the environment. Table 3.1 defines risk levels for each of the aforementioned project scope factors.

Table 3.1: Project scope risk assignment

Project Factors	Project Risk Level		
	LOW	**MEDIUM**	**HIGH**
Duration of Project	Less than 1 month	1-3 months	Greater than 3 months
Volume of excavation	Less than 100 m^3	100 m^3 – 1000 m^3	Greater than 1000 m^3
Depth of excavation	Less than 3 mBGL	3 – 10 mBGL	Greater than 10 mBGL
Depth to groundwater	Depth to groundwater > depth of excavation	Depth of excavation < 3 m below depth to groundwater	Depth of excavation > 3 m below depth to groundwater
Distance to Sensitive Receptors	Greater than 500 m	200 – 500 m	Less than 200 m
Sensitivity of Environmental Receptors	Unclassified water body	Multiple Use	Environmental Protection Policy or Conservation Category
Beneficial Use of Groundwater Resource	Irrigation or lower quality	Priority 3 resource	Priority 1/2 resource

The overall project scope risk will be defined by the highest factor risk assuming that two or more risk factors have been allocated that risk. Where only one risk factor defines the risk category, the project risk will be downgraded by one risk level.

For example:

- A project will be designated HIGH risk if the “duration of project” and “distance to sensitive receptors” are identified as HIGH, but all other project factors have a MEDIUM or LOW risk.
- A project will be designated MEDIUM risk if the “depth of excavation” is designated HIGH but all other project factors have a MEDIUM or LOW risk.

It is noted that in accordance with the requirements of the DEC (2006), sites where the total excavation volume is less than 100 m^3 will be considered to have NO RISK with regards to acid sulfate soils and therefore further assessment for acid sulfate soils does not need to be undertaken. However, a dewatering risk assessment will still need to be undertaken to determine the field investigation level and appropriate management strategies.

3.2 Acid sulfate soils

3.2.1 Desktop data review

Despite knowledge on the general areas characteristic of acid sulfate soils, detailed risk maps in Western Australia have not been produced for the whole state. Risk maps exist predominantly for costal areas (DEC, 2006). These risk maps provide information on the potential depth of occurrence of acid sulfate soils but do not provide information on the magnitude of the risk of acidification of soils due to their disturbance.

For sites outside the defined risk map areas, desktop assessment of regionally available information will be undertaken using key indicators of acid sulfate soils to identify the likelihood of occurrence outside the regionally mapped areas, and to confirm the risk of specific activities disturbing acid sulfate soils and shallow groundwater.

3.2.2 Data sources

Perth region

The Perth area encompasses land extending from Gingin to Dunsborough where regional acid sulfate soil mapping has been undertaken. The following data sources may be used to complete a desktop review for the Perth area:

- WAPC Bulletin 64 - South Metropolitan Region Scheme Acid Sulfate Soil Map
- Perth Metropolitan Region 1:50,000 Environmental Geology Series Maps.
- Geological Maps of Australia Series, 1: 250,000
- WRC, Perth Groundwater Atlas

Regional areas with ASS risk map

Regional areas that have had a detailed acid sulfate soil risk map produced are:

Wyndham, Dampier, Peedamulla and Mardie, Onslow, Exmouth, Coral Bay and Carnarvon, Denham, Geraldton, Gingin, Estuaries Kimberley, Mandurah, Peel, Greater Bunbury, Busselton, Dunsborough, Augusta, Walpole and Denmark, Albany – Torbay, Derby, Broome, Goldsworthy, Port Headland, Sherlock / Balla Balla / Mundabullangana, Point Samson, Wickham, Roebourne, and Karratha.

The following data sources may be used to complete a desktop review for sites that fall into the regions listed above:

- WAPC Bulletin 64 - Acid Sulfate Soil Risk Maps
- Geological Maps of Australia Series, 1: 250,000
- Department of Environment WIN Database for depth to groundwater

Regional areas without an ASS risk map

The following data sources may be used to complete a desktop review for regional areas:

- Department of Environment WIN Database for depth to groundwater
- Department of Environment Statewide River Water Quality Assessment (2004) for surface water quality.
- Shuttle Radar Topography Mission (SRTM) for Digital Elevation Model (DEM) and water bodies
- AGSO National Geoscience Dataset for regional regolith mapping
- Integrated dataset of Agricultural Land Cover Change (ALCC95), Forests of Australia 2003, 1996/97 Land Use of Australia, and the National Vegetation Information System 2000 (NVIS00) for regional vegetation cover.
- Geological Maps of Australia Series, 1: 250,000

3.2.3 Determination of risk of acid sulfate soil presence

Data from each of the aforementioned sources will be collated for each site where proposed excavation or dewatering works are planned. The potential for occurrence of acid sulfate soils at the site will be assessed through the use of key indicators such as topography, geology, wetlands, depth to groundwater, and vegetation and classified as HIGH (almost certain), MEDIUM (likely), MEDIUM-LOW (possible in isolated circumstances), and LOW (unlikely).

The following general principles (DEC, 2006) regarding the occurrence of acid sulfate soil have been used to determine a risk ranking of the key indicators, namely that acid sulfate soils can be found in:

- Areas depicted on geology and/or geomorphological maps as geologically recent (e.g. shallow tidal flats or tidal lakes, coastal alluvial valleys, wetlands, floodplains, waterlogged areas, swamps);
- Areas identified in geological descriptions or maps as bearing acid sulfide minerals, former marine or estuarine shales and sediments, recent quartz sand units, iron cemented organic rich sands (coffee rock), coal deposits, or mineral sand deposits;
- Areas known to contain peat or a build-up of organic material;
- Areas of known acidic soils with pH values ≤4.5 particularly in areas where organic matter and carbonaceous materials have depleted over time;
- Areas where the highest known watertable level is within 3 m of the surface; and
- Areas depicted in vegetation mapping as mangroves, wetland dependent vegetation (e.g. Melaleuca spp.), or salt/acid dependent vegetation (e.g. Casuarina spp.)

Table 3.2 summarises the acid sulfate soil risk classification used for the Perth region.

Table 3.3 summarises the acid sulfate soil risk classification used for the Albany-Torbay region.

Table 3.4 summarises the acid sulfate soil risk classification used for other regional areas.

It is noted that in regional areas of high surface elevation (>100m AHD), due to their geomorphological setting, risk classifications of MEDIUM or HIGH based on geological information requires supporting information from a secondary source (wetland, vegetation, water table) to be characterised as having a MEDIUM or HIGH risk of containing acid sulfate soils.

Table 3.2: Acid sulfate soil risk classification criteria – Perth region

Site Elevation	Geology	Wetland Classification	Depth to Groundwater	WAPC ASS Risk Map Ranking	Acid Sulfate Soil Risk Classification
>20 mAHD	LIMESTONE GRANITES and GNEISSES LATERITE DOLERITE CALCAREOUS SAND SAND of colluvial origin SAND derived from limestone	None	>10 mBGL	Low to No Risk	LOW
5 – 20 mAHD	SAND of eolian origin SILT of colluvium origin	Multiple Use	5-10 mBGL	Moderate to Low Risk	MEDIUM-LOW
5 – 20 mAHD	SAND of eolian origin SILT or CLAY of alluvium origin	Multiple Use	<5 mBGL	Moderate to Low Risk	MEDIUM
<5 mAHD	PEAT and PEATY SAND SILT of lacustrine origin	Resource Enhanced or Conservation Category	<5 mBGL	High Risk	HIGH

1. Based on the GSWA 1:50,000 Environmental Geology Series metropolitan maps

Table 3.3: Acid sulfate soil risk classification criteria – Albany-Torbay region

Topography	Geology[1]	Wetland Classification	Depth to Groundwater	WAPC ASS Risk Map Ranking	Acid Sulfate Soil Risk Classification
>40 mAHD	LIMESTONE GRANITES, MIGMATITES and GNEISSES SANDS and GRAVELLY SANDS of granitic origin LATERITE and LATERITIC GRAVELS SAND of alluvium origin (tertiary) SILTSTONE and SPONGOLITE Beach and dune SAND	None	>10 mBGL	Low to No Risk	LOW
5 – 40 mAHD	SAND of alluvium origin (quaternary)	Multiple Use	5-10 mBGL	Moderate to Low Risk	MEDIUM-LOW
5 – 40 mAHD	SAND of alluvium origin (quaternary)	Multiple Use	<5 mBGL	Moderate to Low Risk	MEDIUM
<5 mAHD	PEATY SAND of lake and swamp origin SANDY SILT and SILTY SAND, and CLAYEY SILT of lacustrine origin	Resource Enhanced or Conservation Category	<5 mBGL	High Risk	HIGH

1. Based on the GSWA 1:50,000 Environmental Geology Series ALBANY and TORBAY maps

Table 3.4: Acid sulfate soil risk classification criteria – Regional areas

Topography	Geology/Lithology			Vegetation, Wetlands and Water Bodies		Depth to Groundwater	Acid Sulfate Soil Risk Classification
	Regolith	Geology	Soil Types	Vegetation	Water Bodies		
>100 mAHD	MODERATELY WEATHERED BEDROCK	DURICRUST (CALCRETE/ SILICRETE/ UNDIFFERENTIATED) SEDIMENTARY ROCKS (MESOZOIC) SEDIMENTARY ROCKS (PALEOZOIC) GRANITIC ROCKS (ARCHEAN-PROTEROZOIC)	DUPLEX SOILS RED AND YELLOW EARTHS HARD SETTING LOAMY SANDS WITH RED CLAYEY SUB SOILS	NATIVE GRASSLANDS NATIVE SHRUBS AND HEATHS CROPS NATIVE FORESTS AND WOODLANDS	NONE CREEKS – fresh to brackish RIVERS – fresh to brackish WATER BODIES – fresh to brackish	>10 mBGL	LOW
20 – 50 mAHD	TERRESTRIAL SEDIMENTS ALLUVIAL SEDIMENTS AEOLIAN SANDS	QUATERNARY DEPOSITS DURICRUST (FERRUGINOUS)	EARTHY SANDS LEACHED SANDS	NATIVE GRASSLANDS NATIVE SHRUBS AND HEATHS CROPS NATIVE FORESTS AND WOODLANDS	RIVERS –saline WATER BODIES – saline	5 – 10 mBGL	MEDIUM-LOW
5 – 20 mAHD	TERRESTRIAL SEDIMENTS ALLUVIAL SEDIMENTS AEOLIAN SANDS	QUATERNARY DEPOSITS DURICRUST (FERRUGINOUS)	EARTHY SANDS LEACHED SANDS	MALALEUCAS, EUCALYTUS	SEASONAL WETLANDS	<5 mBGL	MEDIUM
<5 mAHD	LACUSTRINE SEDIMENTS	QUATERNARY DEPOSITS in low-lying, wetland areas	LEACHED SANDS in low lying areas. CRACKING CLAYS, UNDERLAIN IN AREAS BY HARD PAN AREAS	MALALEUCAS, EUCALYTUS	WETLANDS	<5 mBGL	HIGH

3.2.4 Field investigation

Field investigations will be undertaken prior to the commencement of earthworks with sufficient time to enable laboratory results to be provided and assessment of suitable management strategies to be made.

The intensity of the field investigation undertaken will be commensurate with the risk of the project to cause environmental harm (as determined in Table 3.1) and the likelihood of acid sulfate soils occurrence (as determined in Tables 3.2 – 3.4). The field investigation level can be determined by completing the *Project Acid Sulfate Soil and Dewatering Assessment Form* provided in Appendix A. The field approach detailed below will be adopted as a minimum but higher order action will be considered if there is insufficient information to fully characterise potential acid generating soils. Table 3.5 presents the risk matrix for determining the acid sulfate soil field investigation level.

Table 3.5: Field investigation level risk matrix

Acid Sulfate Soil Risk	Project Scope Risk		
	LOW	MEDIUM	HIGH
LOW	Level 1	Level 1	Level 2
MEDIUM-LOW	Level 1	Level 2	Level 3
MEDIUM	Level 2	Level 3	Level 4
HIGH	Level 3	Level 4	Level 4

Level 1 investigation

The Level 1 investigation level relates to those scenarios where acid sulfate soils are not expected to be present, and if present their disturbance is unlikely to pose a risk to the environment due to the low volume of material to be excavated, short exposure times, and/or a lack of interaction of the soils with groundwater.

Standard geotechnical investigation and site walkover will be undertaken prior to site development. If the results of the geotechnical investigation indicate a deviation to the preliminary project risk assessment, the desktop risk assessment will be amended based on the new information and the need for acid sulfate soil investigation will be reassessed.

Level 2 investigation

The Level 2 investigation level relates to those scenarios where acid sulfate soils may be present but if present are unlikely to pose a risk to the environment due to the low volume of material to be excavated, short exposure times, and/or a lack of interaction of the soils with groundwater. These scenarios may also relate to sites proximal to environmental receptors where a degree of caution is warranted to ensure environmental values are protected.

Standard geotechnical investigation and site walkover will be undertaken prior to site development. In addition the follow acid sulfate soils screening investigation will be undertaken:

- Field analysis of pH_F and pH_{FOX} (pH after oxidation) will be undertaken in each bore from each lithology, or at 1 m intervals, whichever is greater.
- For those samples where pH_F is less than 3.5 or pH_{FOX} less than 3, laboratory analysis using Chromium Reducible Sulfur Suite (S_{CR}) or SPOCAS will be undertaken.

Level 3 investigation

The Level 3 investigation level relates to those scenarios where acid sulfate soils are likely to be present and may be present below the water table. Due to the nature of the acid sulfate soils (e.g. high risk in environmentally sensitive areas) and/or potential for occurrence below the water table, responsible management of acid sulfate soils will be required. Acid sulfate soils likely to be encountered in these scenarios are strongly lithologically controlled and dependent on groundwater levels. Consequently therefore development of a suitable management strategy is reliant on lithological and hydrologically considerate soil delineation.

In addition to the standard geotechnical investigation, the following acid sulfate soil investigation will be undertaken:

Linear infrastructure

- Soil boreholes will be drilled at a frequency of 1 per 200 m to 1 per 500 m, or a minimum of 2 boreholes per excavation length for excavations less than 500 m.

Non-linear infrastructure

- Soil boreholes will be installed at a frequency of 4 soil boreholes per excavation or at a frequency of 4 boreholes for the first hectare and 2 boreholes per hectare for each subsequent hectare (for developments less than 10 Ha). Boreholes will be installed to a depth of 2 m below the depth of the excavation (to account for potential dewatering drawdowns).

Field analysis

Field analysis of pH_F and pH_{FOX} (pH after oxidation) will be undertaken in each borehole:

- from each lithology above the water table, or at 1 m intervals, whichever is greater;
- at 0.5 m intervals though the zone of water table fluctuation (nominally 1 m above and below the current water table); and
- from each lithology below the water table, or at 1 m intervals, whichever is greater.

Laboratory analysis

Laboratory analysis using Chromium Reducible Sulfur Suite (S_{CR}) or SPOCAS will be undertaken for:

- the highest risk soil sample from each soil bore based on pH_F/pH_{FOX} results;
- 1 in every 10 bores, or one bore per site, whichever is greater at 0.5 m intervals through the soil profile; and
- at least two samples from each lithology, for continuous soil lithologies greater than 0.5 m thick.

In addition, select samples will be analysed for metals (Al, As, Cd, Cr, Fe, Pb, Mo, Ni, Se, and Zn) to assist in determining risk of metals mobilisation to groundwater and suitable options for material disposal if required.

Level 4 investigation

The Level 4 investigation level relates to those scenarios where acid sulfate soils are likely to be present both above and below the water table and occurs in environments recognised as having a high acid generating potential. Due to the tendency for these environments to occur in close proximity of sensitive environmental receptors, close management of acid sulfate soils will be necessary to ensure that harm to the environment does not occur. To facilitate the development of appropriate management strategies, a detailed acid sulfate soil investigation will be undertaken.

In addition to the standard geotechnical investigation, the following acid sulfate soil investigation will be undertaken:

Linear infrastructure

- Soil boreholes will be drilled at a frequency of 1 per 100 m or a minimum of 2 per excavation length for excavations less than 200 m.
- This grid may be tightened where warranted (e.g. – proximal to sensitive receptors, in areas of variable acid generating potential or complex geology) to ensure complete characterisation of the soil profile is achieved.

Non-linear infrastructure

- Soil boreholes will be installed at a frequency of 4 per excavation to a depth of at least 2 m below the depth of the excavation (to account for potential dewatering drawdowns).

Field analysis

Field analysis of pH_F and pH_{FOX} (pH after oxidation) will be undertaken in each bore:

- at 0.5 m intervals through the soil profile; and
- from each lithology in the soil bores.

Laboratory analysis

Laboratory analysis using Chromium Reducible Sulfur Suite (S_{CR}) or SPOCAS will be undertaken for:

- the highest risk soil sample from each bore and 1 in every 5 bores at 0.5 m intervals through the bore profile for linear infrastructure greater than 500 m;
- at 0.5 m intervals through the soil profile for non-linear excavations and linear excavations less than 500 m;
- from each lithology in the soil profile.

In addition, select samples will be analysed for metals (Al, As, Cd, Cr, Fe, Pb, Mo, Ni, Se, and Zn) to assist in determining risk of metals mobilisation to groundwater and suitable options for material disposal if required.

3.2.5 Determination of risk of acid generation

The determination of risk for acid generation for soil types present at the site can be determined after the field investigation (including field and/or laboratory analysis) has been completed. The actual risk for acid generation to occur as a result of soil disturbance, regardless of the nature of the project, is dependent on several factors including:

- soil type
- depth of soil in the profile;
- volume of soil to be excavated;
- pH_F and pH_{FOX};
- sulfide content in the soil; and
- metals content in the soil.

Table 3.6 summarises the risks of acid generation associated with each of these soil parameters. The acid generation risk assessment will be considered for each soil type in conjunction with the project risk to define a suitable management strategy as discussed in Section 4.1.

Table 3.6 applies to soils that exceed the DEC action criteria for sulfide content (0.03%S or 18 mol H^+/tonne) only (DEC, 2006). Those soils with sulfide content less than the action criteria will be considered NO risk, regardless of their other soil parameters, and will therefore not require any special management during the construction stage.

Table 3.6: Acid generation risk assessment

Soil parameter	Acid generation risk		
	LOW	**MEDIUM**	**HIGH**
Depth in the soil profile	Upper 3 m of the soil profile	3 mBGL to the water table	Soils collected from below the water table
Volume of soil to be excavated	Less than 100 m^3	100 – 1000 m^3	Greater than 1000 m^3
Field pH indicators[1]	pH_F>5 pH_{FOX}>4	4<pH_F<5 3<pH_{FOX}<4	pH_F<4 pH_{FOX}<3
Soil type and sulfide content[2]	Medium to heavy clays and silty clays with <0.1%S OR Sandy loams/peat to light clays and cemented gravels < 0.07%S	Medium to heavy clays and silty clays with >0.1%S OR Sandy loams/peat to light clays and cemented gravels 0.07%S – 0.1%S OR Sands to loamy sands <0.07%S	Sandy loams/peat to light clays and cemented gravels >0.1%S OR Sands to loamy sands >0.07%S
Metals concentrations	[Metals] < EILs[3] [Fe] approx < 100 mg/kg [Al] approx < 100 mg/kg	HIL[4]>[Metals] > EILs 1000 >[Fe] < 100 mg/kg 1000 >[Al] < 100 mg/kg	[Metals] > HIL [Fe] approx > 1000 mg/kg [Al] approx > 1000 mg/kg

1. Based on the mean of all pH_F and pH_{FOX} values taken for the soil type.
2. Sulfide content will be defined by the maximum sulfide content measured for that soil type.
3. EIL – ecological investigation levels (DEC, 2003)
4. HIL – health investigation level for applicable landuse (DEC, 2003)

The risk of acid generation for all soils that exceed the action criteria will be defined by:

- The highest criteria in each of the soil parameter categories will define the risk level for that category;
- The acid sulfate soil risk will be defined by the highest soil parameter risk assuming that two or more risk factors have been allocated that risk. Where only one risk factor defines the risk category, the project risk will be downgraded by one risk level. For example:
  - The soil type will be designated HIGH risk if the "soil type/sulfide content" and "volume of soil to be excavated" are identified as HIGH, but all other soil parameters have a MEDIUM or LOW risk.
  - The soil type will be designated MEDIUM risk if the "soil type/sulfide content" is designated HIGH but all other soil parameters have a MEDIUM or LOW risk.
- Metals concentrations will only be considered for MEDIUM and HIGH field pH indicators and soil type/sulfide content categories. In this case, the higher of the risk rankings will apply. For example:
  - if a soil is ranked as having a MEDIUM risk of Field pH indicators or Soiltype/sulfide content but metals concentrations are ranked as HIGH, the acid generating potential of the soil will be considered HIGH).

3.3 Dewatering

To ensure suitable risk assessment and management of dewatering activities, pre-construction dewatering investigations and predictions of drawdown impacts should be undertaken. The aims of the dewatering investigations are to:

- Determine the likely quality of dewatering discharge
- Determine the appropriate dewatering and disposal method
- Enable prediction of dewatering quantities
- Enable predictions of the extent of drawdown (cone of depression)

3.3.1 Field investigation

The complexity of the field investigation for dewatering purposes will be related to the risk of the dewatering activities to cause environmental harm. Risk will be characterised on the following factors:

- Duration of dewatering;
- Proximity of dewatering to sensitive receptors; and
- Potential for oxidation of acid sulfate soils.

Table 3.7 summarises the risk ranking for each of these environments.

Table 3.7: Dewatering risk matrix

Dewatering Factor	Dewatering Risk Ranking		
	LOW	MEDIUM	HIGH
Duration	Less than 1 month	1 – 3 months	> 3 months
Proximity to sensitive receptors	Greater than 500 m	200 – 500 m	<200 m
Acid sulfate soil environment[1]	LOW or MEDIUM-LOW ASS risk	MEDIUM ASS risk	HIGH ASS risk

1. Based on the acid sulfate soil risk defined by Tables 3.2 – 3.4.

The level of field investigation for dewatering will be based on the highest risk component as determined in Table 3.7. Table 3.8 defines the minimum dewatering field investigation for each risk level.

Table 3.8: Dewatering investigation program matrix

Risk Level	Dewatering investigation program
LOW	▪ Determination of soil types during geotechnical investigation ▪ Determination of water table level from soil bore installations ▪ Collection of a groundwater sample from soil bores (no dedicated groundwater monitor bore) and analysis for a suitable suite of analytes ▪ Estimation of hydraulic parameters of the aquifer through review of published information
MEDIUM	▪ Determination of soil types during geotechnical investigation ▪ Installation of 1-2 temporary groundwater monitor wells down-hydraulic gradient of the excavation and/or between the excavation and the receptor where the risk ranking has been defined due to receptor proximity ▪ Determination of water table level from the soil bore and monitor well installation ▪ Collection of a groundwater sample from the monitor well and analysis for the acid sulfate soil groundwater suite[1] and other relevant water quality parameters ▪ Estimation of hydraulic parameters of the aquifer through review of published information
HIGH	▪ Determination of soil types during geotechnical investigation ▪ Installation of a suitable number of groundwater monitor wells around the excavation ▪ Determination of hydraulic parameters (permeability, storage, transmissivity) of the soils through pump testing ▪ Monitoring of groundwater levels from the groundwater monitor bores (seasonal levels if lead time permits) ▪ Collection of groundwater samples from the monitor wells and analysis for the acid sulfate soil groundwater suite[1] and other relevant parameters ▪ Collection of water quality samples from nearby sensitive receptors if relevant.

1. pH, EC, TDS, TDS, DO, redox, total acidity, total alkalinity, sulfate, chloride, total Al and Fe, dissolved Al, As, Cr, Cd, Fe, Mn, Ni, Se, Zn, ammoniacal nitrogen, hydrogen sulfide, total N, total P, filterable reactive P (FRP)

3.3.2 Modelling of dewatering requirements

In all dewatering cases modelling of the impacts of dewatering will be undertaken by a qualified hydrogeologist to predict the volume of water to be extracted and the groundwater drawdown radius.

The complexity of the model, and parameters modelled, will be considerate of the risk associated with dewatering activities, as summarised in Table 3.9.

Table 3.9: Modelling requirements

Dewatering Risk Level	Model requirements
LOW	▪ Maximum drawdown cone estimated using published tables for common soil types ▪ Calculation of dewatering volumes and rates
MEDIUM	▪ Maximum drawdown cone estimated using recognised methods (Theis, Sichardt, etc) ▪ Calculation of dewatering volumes and rates ▪ Calculation of aquifer recharge rates
HIGH	▪ Modelling of drawdown cone over time based on site-specific aquifer properties ▪ Calculation of dewatering volumes and rates ▪ Modelling of aquifer recharge rates and impacts over time ▪ Prediction of settlement impacts due to dewatering

4. Acid sulfate soil and dewatering management

Appropriate management of acid sulfate soils and dewatering activities will be undertaken to ensure that there are no long-term adverse impact to the environment. The degree of management undertaken by the Water Corporation and their contractors during construction works will be commensurate with the potential for immediate risk to the environment.

4.1 Acid sulfate soils

The management principles adopted by Water Corporation in their handling of acid sulfate soils will be considerate of the risk of acid sulfate soils causing harm to the environment based on the risk of acid generation as determined through field and laboratory testing (as determined in Table 3.6) and project risk (as determined in Table 3.1). Table 4.1 summarises the risk management levels that will be adopted.

Table 4.1: Management level – risk matrix

Acid Generation Risk Level	Project Risk Level		
	LOW	**MEDIUM**	**HIGH**
LOW	Level 1	Level 1	Level 2
MEDIUM	Level 1	Level 2	Level 3
HIGH	Level 2	Level 3	Level 3

A **LEVEL 1** management ranking represents those earthworks scenarios where acid sulfate soils are absent or are present in low concentrations above the water table or where earthworks activities are sufficiently short term to minimise the opportunity for oxidation of acid sulfate soils. As a result, disturbance of these materials is unlikely to result in any environmental impacts that would not naturally occur in the environment. Due to the low level of risk, no active acid sulfate soil management will be undertaken for those sites with a Level 1 management ranking.

A **LEVEL 2** management ranking represents those earthworks scenarios where acid sulfate soils are likely to be present in with a moderate acid generating potential or with a high acid generating potential but in low volumes. Management of these soils will adopt a monitor and react strategy if signs of oxidation occur.

A **LEVEL 3** management ranking represents those earthwork scenarios where acid sulfate soils are likely to be present in abundance and have a high likelihood of generating acidity during the period of earthworks. Active management of these soils will be undertaken based on the assumption that oxidation of the soils will occur during the course of the earthworks.

The following sections describe the minimum management strategies, and the management principles that will be adopted by the Water Corporation for the management of acid sulfate soils.

4.1.1 Excavation management

Table 4.2 summarises the excavation management practices that will be followed for each of the management levels to minimise the risk of oxidation of acid sulfate soils due to construction activities.

Table 4.2: Excavation management practices

Management Level	Linear Infrastructure	Non-linear Infrastructure
Level 1	▪ Standard construction management practices to be adopted. No specific acid sulfate soil considerations required.	▪ Standard construction management practices to be adopted. No specific acid sulfate soil considerations required.
Level 2	▪ Where possible, trench segments will be excavated in lengths that permit the opening and closing of the trench within 48 hours. ▪ Where in-situ PASS is exposed for a period exceeding 5 days, neutralisation of the sides and base of the excavation will be undertaken prior to backfilling.	▪ Where in-situ PASS is exposed for a period exceeding 5 days, neutralisation of the sides and base of the excavation will be undertaken prior to backfilling.
Level 3	▪ Implementation of alternate construction methods (e.g. horizontal directional drilling (HDD)) will be considered. ▪ Where soils must be disturbed, trench segments will be excavated in the shortest practicable lengths. ▪ Where in-situ PASS is left exposed, neutralisation of the sides and base of the excavation (e.g. barriers of high grade aglime, spraying with liquid neutralising agents) will be undertaken routinely as appropriate throughout the duration of the exposure.	▪ Implementation of construction methods that exclude the availability of oxygen (e.g. sheet-piling) will be considered. ▪ Where in-situ PASS is left exposed, neutralisation of the sides and base of the excavation (e.g. barriers of high grade aglime, spraying with liquid neutralising agents) will be undertaken routinely as appropriate throughout the duration of the exposure.

4.1.2 Soil stockpiling and neutralisation

Soil neutralisation may be required for soils identified as potentially acid generating during the pre-construction field investigations (i.e. those soil types identified in Table 3.6 as having a MEDIUM or HIGH sulfide content). Table 4.3 summarises the practices that will be adopted for stockpiling and treatment (neutralisation) of soils for each of the management levels. The requirement for stockpiling and neutralisation will be dependent on the risk management level for the soil type and the duration of stockpiling.

Table 4.3: Management of soil stockpiles

Management Level	Short-term stockpiles (less than 5 days)	Medium-term stockpiles (5 days to 1 month)	Long-term stockpiles (greater than 1 month)
Level 1	Untreated soils will be stockpiled direct to ground	Untreated soils will be stockpiled direct to ground	Untreated soils will be stockpiled direct to ground
Level 2	Untreated soils will be stockpiled direct to ground	Untreated soils will be stockpiled on a containment pad	Untreated soils will be stockpiled on a containment pad
Level 3	Untreated soils will be stockpiled on a containment pad	Treated soils will be stockpiled on a containment pad	Treated soils will be stockpiled on a containment pad

Stockpile construction

Stockpile construction will adhere to the following principles:

- Where practicable (i.e. – adequate space is available) soil types with different acid generating capacities will be stockpiled separately and managed according to their individual risk level.
- Soils will be stockpiled as far away from environmental receptors and drains as practicable to minimise potential for mobilisation of the soils, and impacts from the soils into these waterways.
- The amount of neutralising agent will be based on 0.2 times the maximum acidity for every metre depth of the soil to be treated. The amount of neutralising agent required for the containment pad will be calculated using the *Containment Pad Calculation Worksheet* provided in Appendix B.
- Where the acid generating potential of the soils is not known, the containment pad will be constructed of a guard layer of crushed, compacted limestone or equivalent neutralising agent to a minimum thickness of 300 mm.
- The stockpile containment will be constructed so that all leachate and run-off is collected and the ingress of surface water is prevented. This may necessitate the construction of containment bunds and diversion banks. The containment bunds/diversion banks will be constructed on non-acid-generating, low-permeability soils.
- The stockpile containment unit will be constructed so that all leachate and run-off can infiltrate through the neutralising guard layer. Where infiltration to ground is impracticable, leachate and run-off will be diverted to a containment pond and tested for water quality and need for treatment prior to disposal to the environment.
- The surface area of the stockpile will be minimised to reduce the extent of material exposed to atmospheric oxygen. This may involve:
  - Shaping the stockpile and/or capping or lining it with a material that will minimise drying by wind and sun and prevent the ingress of rainfall. This management practice will apply to soils collected from above the water table;
  - Spraying the surface of the stockpile to keep it moist using iron-free water or neutralising solution. The spray will need to be carefully managed to prevent over-wetting of the stockpile material and should comprise a fine mist to prevent desegregation of the soil from the stockpile surface. This management practice will be suitable for soils collected from below the water table.

Neutralisation agent

Aglime or lime sands are the preferred neutralising materials for the treatment of acid sulfate soils. Neutralising materials obtained for use by the site will be accompanied by information pertaining to its effective neutralising value (ENV), which is a measure of the soils neutralising capacity in consideration of particle size distribution of the neutralising material.

Where ENV information is not provided by the supplier, Calcium Carbonate Equivalence by a NATA accredited laboratory to determine the neutralising value (NV) of the material and particle size distribution (PSD) will be determined. (The calcium carbonate equivalence method is applicable for calcium carbonate only and cannot be used for determination of NV for calcium oxides or calcium hydroxides). The number of samples to be laboratory tested will be consistent with the DoE *Guidelines for Acceptance of Solid Waste to Landfill* (2001). The NV used for calculating the neutralisation material dosing ratio for the treatment of soils is based on the average NV value obtained from the laboratory analysis. The calculation for ENV will be determined using the *ENV Calculation Worksheet* provided in Appendix C.

Other neutralising agent such as magnesite, dolomite, sodium bicarbonate, soda ash, hydrated lime/slaked lime, or quicklime may be considered. Use of alternative neutralising agents will need to be justified based on consideration of NV and ENV, solubility, pH, chemical constituents and impurities, moisture content and method of application.

Methods of neutralisation

The method of neutralisation will adhere to the following principles:

- **Where untreated soils have been stockpiled** on a containment pad, soil neutralisation will occur at the time of backfilling by backfilling the excavation with both the untreated soils and the neutralising agent present in the pad. Approximate mixing of the acid generating soils and the neutralising agent during backfilling will occur by vertically “cutting back” the stockpile and “raking in” the neutralising agent within the excavation.
- **Where treated soils are to be stockpiled** on a containment pad, the excavated material will be neutralised using a suitable neutralising agent. The amount of neutralising agent required will be based on the highest percent sulfur concentration for that soil type and will be calculated using the *Neutralising Agent Calculation Worksheet* provided in Appendix D.
- Neutralisation will be undertaken by mechanical application on the containment pad to achieve uniform blending of the neutralising material and the acid generating soils.
- Where excavation works are undertaken in areas of limited space, alternative neutralisation options, such as treatment of soil within a neutralisation unit, off-site neutralisation, in-situ injection of the neutralising agent prior to excavation, or injection of neutralising agent into stockpiles will be considered.

The method of neutralisation will need to be considerate of the soil type to be neutralised. In particular:

- Uniform blending of sands and sandy silts can typically be accomplished using mechanical tilling or “bucket blending” methods;
- Uniform blending of peats, silts and clays is usually difficult to achieve using standard earthworking equipment. These materials are generally more suitable for off-site disposal. If treated on-site the treatment method will need to include crushing or fragmenting of the soil (whilst minimising oxygen exposure) prior to treatment.

4.1.3 Disposal

Soils that are unsuitable for reuse at the site for geotechnical purposes will be disposed off-site to a suitable facility, as is appropriate for the project. The options for disposal in order of preference are:

- Untreated to a treatment facility capable of undertaking the required soil treatment and disposal;
- Untreated to a Class 2 landfill facility, in accordance with the specific requirements of the designated facility;
- Treated and validated in accordance with the requirements of Section 3.1.3 after which soil will be considered inert and may be disposed as day cover to a Class 1 landfill or reused for alternative purposes (e.g. landscaping).

4.1.4 Validation and performance criteria

The following validation and monitoring will be undertaken:

Linear infrastructure

- **Untreated soils** will be checked daily for visual signs of acid generation (e.g. – formation of jarosite or iron oxides). Representative soil samples will be collected daily from the surface of the stockpile (minimum 2 samples per stockpile face) and tested for pH_F.
- **Treated soils** will be sampled at a rate of 1 sample/50 m^3 soil and tested for pH_F and pH_{FOX} following treatment to validate the effectiveness of the neutralisation process. When pH_F and pH_{FOX} is found to be within the performance criteria (Table 4.4), soils will be considered suitable for backfill into the trench.
- **Leachate and run-off** from the stockpiles will be field tested for pH, EC, temperature and total acidity prior to release to the environment, to determine if neutralisation is necessary.

Non-linear infrastructure

- **Untreated soils** that are identified as potentially acid generating will be checked daily for visual signs of acid generation (e.g. – formation of jarosite or iron oxides). Representative soil samples will be collected twice weekly from the surface of the stockpile (minimum 2 samples per stockpile face) and tested for pH_F.
- **Treated soils** will be sampled at a rate of 1 sample/50 m^3 soil and tested for pH_F and pH_{FOX} following treatment to validate the effectiveness of the neutralisation process. When pH_F and pH_{FOX} are found to be within the performance criteria, and soils are expected to be stockpiled for longer than two weeks, 1:10 field samples will be sent to the laboratory for confirmatory analysis by SPOCAS or the S_{CR} Suite, prior to use as backfill. When the soil will be reused within two weeks, field results will be used as the basis for confirming neutralisation.

Performance criteria

Table 4.4 summarises the performance criteria to be adopted for the stockpiles during the monitoring programme.

Table 4.4: Stockpile performance criteria

Medium	Acceptable Threshold
Untreated soils	$pH_F > 4$
Treated soil	$pH_F > 6.5$ $pH_{FOX} > 6.5$ TPA[1]+TAA[2] <18 mol H^+/tonne
Leachate and run-off	8.5>pH>6.5 TTA[3] < 40 mg/L

1. TPA – Titratable Peroxide Acidity
2. TAA – Titratable Actual Acidity
3. TTA – Total Titratable Acidity

4.1.5 Contingency plans

Contingency plans will be developed on a site-specific basis to address actions to be undertaken where performance criteria are not met. Contingency plans will consider, but not be limited to, implementation of the following:

- If due to unforseen circumstances, the duration of the earthworks activities is extended, a reassessment of the management strategies will be undertaken and implementation of a higher level of soil management will be adopted if warranted.
- If any soils are encountered during excavation works that are not representative of the soils previously identified, these soils will be treated in accordance with the procedures adopted for the highest risk soil previously identified at the site.
- If the aforementioned stockpile performance criteria are exceeded, the following points will be implemented:
  - If pH_F results of the untreated soils are outside the acceptable thresholds, the soil stockpile will be covered with a guard layer of neutralising agent or irrigated with a liquid neutralising agent.
  - If pH_F and pH_{FOX} results of treated soil validation samples are outside the acceptable thresholds, further lime treatment of soils will be undertaken prior use as backfill (linear infrastructure) or submission of samples to the laboratory (non-linear infrastructure);
  - If laboratory analysis of treated stockpile soils (non-linear infrastructure) are outside of the TPA+TAA criteria, further lime treatment of soils will be undertaken prior to re-use on-site or soils will be disposed to an appropriate off-site facility; and
  - If leachate and run-off exceed the performance criteria, neutralisation of the leachate and run-off to achieve the performance criteria will be undertaken prior to release to the environment.

4.2 Dewatering

4.2.1 Dewatering method

The aim of the preferred dewatering method should be to minimise the radius of influence of the cone of depression. Any dewatering activity should strive to minimise impacts to surrounding water bore users and sensitive surface water receptors. Common options for dewatering methods include:

- SUMP PUMPS: Sump pumping is the simplest method of dewatering excavations. Sumps are usually sited at the lowest point of the excavation and made big enough to hold sufficient water for pumping and to keep the floor of the excavation dry. A pump is provided for each sump and connected to a discharge pipe. Sump pumps are generally suitable for low-flow, short-term dewatering with small dewatering volumes
- WELL-POINT SYSTEMS: Well-point systems comprise a series of closely spaced wells connected to a header-pipe and usually pumped by a collective suction lift pump. Dewatering using well-points is generally suitable for low to moderate flow, medium-term dewatering. Some continuity of the permeability is required for maximum effectiveness, although this can be mitigated by varying the spacing and vertical distribution of the wells.
- POSITIVE CUT OFF (e.g. SHEET PILING): Sheet piling involves the installation of impermeable steel walls around the edge of the excavation to limit groundwater influx. Sheet piling will generally be necessary for deep excavations with significant drawdown of the water table to limit the cone of depression of the dewatering activities. Sheet piling is often used in combination with well-point systems to stabilise pressures around the excavations.

Other water exclusion methods such as soil refrigeration and impervious soil barriers can be considered where standard methods are deemed unsuitable.

4.2.2 Dewatering discharge treatment

Dewatering discharge may require treatment to ensure that it does not have any adverse impact to receiving water bodies. Treatment may include but is not limited to sediment filtration or settlement, neutralisation, and/or contaminant removal. The need for dewatering discharge treatment is determined through monitoring of the dewatering discharge, groundwater and/or surface waters in the area as described in Section 4.2.4.

It is noted that treatment of groundwater in all environments to near neutral pH (6.5 to 8.5) is generally required by the DEC to ensure future mobilisation of metals in the soil profile is not promoted. Table 4.5 summarises some of the key treatment methods and the groundwater quality indicators that should trigger treatment methods.

Table 4.5: Dewatering discharge treatment options

Water Quality Trigger	Treatment Method
pH < 5.0	Neutralisation treatment using calcite pellets. Lime sands, or hydrated lime, as appropriate for the project.
pH of dewatering discharge more than 1 pH unit less than pH of receiving water body	pH adjustment (e.g. neutralisation)
Total Titratable Acidity > 40 mg/L	Neutralisation treatment and aeration and settlement to precipitate dissolved metals
Total Suspended Solids – visible	Sediment filtration through geofabric or hay-bales if discharging to an open water body. No treatment required if reinfiltrating through an infiltration basin because the aquifer will work as a sediment filtration system
Metals/toxicants concentration in dewatering discharge could result in an increase of the seasonal background concentration of the receiving body by	Suitable toxicant filtration/flocculation method to be employed.

Water Quality Trigger	Treatment Method
>10%	
Nutrient concentrations in dewatering discharge could result in an increase of the seasonal background concentration of the receiving body by >10%	Nutrient-stripping containment basin (aerobic/anaerobic "wetland")

4.2.3 Dewatering discharge disposal

Options of discharging excess water should be considered in the following order of priority:

- DUST SUPPRESSION: Dewatering discharge should in the first instance be used for dust suppression during construction works. As dewatering discharge volumes will generally exceed dust suppression requirements, additional discharge disposal methods will typically need to be employed.
- INFILTRATION SYSTEM: This is the preferred option as it recharges the water into the environment from which it has been removed. Its effectiveness is limited by the hydraulic properties of the soil strata to which the water is discharged (hydraulic conductivity, depth to groundwater table). Infiltration systems must generally include installation of an infiltration basin to prevent flooding of the surrounding environment, although in some select environments discharge to ground may be considered acceptable. This option will require monitoring of the water quality to ensure reinfiltrated discharge does not degrade the water quality of the receiving environment.
- DRAINAGE SYSTEM: This method may be considered where dewatering discharge volumes are high and space available for reinfiltration is limited. Employment of a drainage system is generally limited by the hydraulic capacity of the drainage system. This option will require monitoring of the water quality to ensure reinfiltrated discharge does not degrade the water quality of the receiving environment.
- SURFACE WATER BODIES: Discharge to surface water bodies must be undertaken in a manner that ensures no loss of amenity (odour or visual impacts), or change to the water quality in the receptors to ensure that the ecosystem of the receiving water body is sustained. Most surface water bodies have a high social significance and discharge to significant lakes and wetlands is typically controlled through regulatory licences. Prior to discharges going into these environments the Water Corporation Environment Branch must be contacted, all appropriate stakeholders notified, and applicable discharge licences obtained. Appropriate standards will be determined on a case by case basis in accordance with regulatory environmental guidelines.
- SEWER: Disposing of excess dewatering discharge to sewer is generally the last option. Both the Water Corporation Region and Industrial Waste Branch must be contacted for relevant guidelines. The region determines the hydraulic capacity of the system while the Industrial Waste Branch deals with water quality. Discharge to sewer generally also requires a Licence to Discharge from the Department of Water.

4.2.4 Monitoring and performance criteria

Where dewatering occurs in the presence of acid sulfate soils or where discharge is to occur to an environmentally sensitive environment, a combination of dewatering discharge, surface and or groundwater monitoring will be undertaken to ensure that long-term environmental harm does not occur in the receiving environment.

Dewatering discharge monitoring

Monitoring of dewatering discharge will occur when dewatering activities are expected to exceed one week (7 days) in a given area, when groundwater treatment systems are employed, or at sites where the cone of depression is predicted to extend to within 200 m of an environmentally sensitive area.

Where treatment of dewatering discharge occurs, monitoring of the water quality will occur both before and after any treatment process. Table 4.6 summarises the minimum monitoring to be undertaken by the dewatering contractor and acceptable performance criteria for the dewatering discharge (pre-treatment). Where dewatering discharge exceeds the performance criteria (pre- or post-treatment), it is an indication that treatment of the discharge is necessary prior to discharge to the environment.

Table 4.6: Dewatering discharge monitoring

Analyte	Frequency	Acceptable Performance Criteria
Acid Sulfate Soil Environments		
Field pH, EC, Total Titratable Acidity (TTA)	Daily for the duration of dewatering.	Pre-treatment pH > 5.5 Post-treatment pH between 6.5 – 8.5 EC within 10% of receiving environment TTA < 40 mg/L
Field Fe^{2+}, Fe^{3+}	Weekly	Fe^{2+} < 10 x applicable guidelines for the receiving environment Fe^{3+} stable
Laboratory pH, EC, TTA	Fortnightly	Laboratory results within 0.5 pH units and EC and TA within 20% of field values
Other Environments		
Visual water clarity where discharge to a surface water body occurs	Daily	Visual Water Clarity is "Clear"
TSS and TDS where discharge to a surface water body occurs	Weekly	TSS and TDS < 10% greater than the seasonal background of the receiving environment
Toxicants and nutrients	Twice-weekly	Performance criteria to be established on a site specific basis based on predicted loading to the receiving environment.

Groundwater and/or surface water monitoring

In addition to dewatering discharge monitoring, monitoring of suitable groundwater and/or surface water sites (e.g. at and along the pathway to the receptor) will be undertaken for dewatering activities with a duration greater than 4 weeks or at sites where the cone of depression is predicted to extend to within 200 m of an environmentally sensitive area.

Table 4.7 summarises the minimum frequency of monitoring to be undertaken by a suitably qualified site supervisor and acceptable performance criteria. These criteria may be modified in consideration of site-specific criteria as considered appropriate.

Table 4.7: Groundwater and/or surface water monitoring

Analyte	Frequency	Acceptable Performance Criteria
All environments		
Water Levels	Twice-weekly during dewatering	Performance criteria to be established on a site-by-site basis to ensure drawdown does not adversely impact surrounding bore users or environmental receptors
Water Levels	Weekly to fortnightly post-dewatering	Monitoring to continue until water levels reach pre-dewatering levels in consideration of seasonal water table fluctuations
Acid Sulfate Soil Environments		
Field pH, EC, Total Titratable Acidity (TTA), DO, redox	Twice-weekly during dewatering	∆pH <0.5 pH units in one week EC and TA within 15% of background water quality
Field Fe^{2+}, Fe^{3+}	Fortnightly during dewatering	Fe^{2+} < 10 x applicable guidelines for the receiving environment Fe^{3+} stable
Laboratory pH, EC, TTA	Fortnightly during dewatering	Laboratory results within 0.5 pH units and EC and TA within 20% of field values
Laboratory analysis of pH, SO_4, Cl total alkalinity, total acidity, total Al and Fe, dissolved Al, As, Cr, Cd, Fe, Mn, Ni, Zn, and Se, Total-N, Total-P, NH_4-N, H_2S	End of dewatering program, when water table level recovers and 1 month after groundwater level recovery	Analytes below applicable water quality guidelines for the resource or within 20% of background water quality where background concentrations already exceed applicable guidelines.
Other Environments		
Visual inspection of surface water bodies where discharge to a surface water body occurs	Daily during dewatering	GROUNDWATER: not applicable
		SURFACE WATER: Discharge causes no visible floating oil, foam, grease, scum, flocculant, or deposition of sediment or turbidity
TSS and TDS where discharge to a surface water body occurs	Fortnightly during dewatering	GROUNDWATER: not applicable
		SURFACE WATER: TSS and TDS < 10% greater than the seasonal background of the receiving environment
Toxicants and nutrients	Fortnightly during dewatering	GROUNDWATER: Analytes below applicable water quality guidelines for the resource or within 20% of background water quality where background concentrations already exceed applicable guidelines.
		SURFACE WATER: Analytes within 10% of the seasonal background concentration of the analyte in the receiving body.

4.2.5 Contingency plans

Contingency plans will be developed on a site-specific basis to address actions to be undertaken where performance criteria are not met. Contingency plans will consider, but not be limited to, implementation of the following:

- Additional treatment methods in the event that performance criteria are not met;
- Alternative disposal options in the event the preferred method is considered to cause environmental harm;

- A reduction of dewatering rates in the event that extent of drawdown is considered to be causing environmental harm;
- Addition of a comprehensive suite of groundwater monitoring at an appropriate frequency where dewatering discharge, groundwater or surface water quality varies significantly (and adversely) compared to pre-dewatering conditions;
- Additional assessment the causes of water quality deterioration in the event that long-term water quality is considered to have degraded for reasons directly attributable to dewatering. This may include assessment of soil and groundwater quality, and development of a suitable management strategy.

5. Report requirements

A Project Acid Sulfate Soil and Dewatering Risk Assessment Form (Appendix A) will be completed for all sites.

For those sites where acid sulfate soil and/or dewatering investigations are determined to be required, results from the acid sulfate soil and/or dewatering investigation and suitable management plans will be reported by a suitable consultant in accordance with the DEC reporting requirements as defined in the *Draft Identification and Investigation of Acid Sulfate Soils* (DEC, 2006) and *Preparation of Acid Sulfate Soil Management Plans* (DoE, 2003). The following reporting components will be included:

Site setting

This section will include descriptions of the following:

- Identification of the land parcel over which the project will be undertaken;
- Maps showing the location of the project and the extent of works;
- Regional geology and hydrogeology;
- Surrounding land use; and
- Surrounding environmental receptors.

Project description

This section will include a detailed project description including:

- Proposed start date;
- Duration of the project;
- Expected depth of earthworks and volume of soils to be disturbed;
- Prediction as to whether dewatering will be required; and
- Assessment of the PROJECT RISK using the information from Section 3.1 and the *Project Acid Sulfate Soil and Dewatering Assessment Form* contained in Appendix A of this document.

Investigation methodology

This section will describe the methodology adopted for the acid sulfate soil and groundwater investigations, and will include:

- Acid sulfate soil investigation level and dewatering investigation level risk assessments;
- Description of the soil bore installation and sampling activities undertaken including bore depths, number of samples taken, and laboratory analyses;
- Description of the groundwater investigations undertaken;
- Description of QA/QC field procedures; and
- Adopted assessment criteria for the investigations.

Acid sulfate soil investigation results

This section will detail the results of the acid sulfate soil investigation including:

- Site specific geology;

- Results of pH_F and pH_{FOX} testing;
- Laboratory results;
- Discussion of QA/QC results and impact on data assessment;
- Location map and/or cross-sections of acid generating soils compared to excavation footprints;
- Summary of acid generating soil types, and volumes of material likely to be disturbed; and
- Risk assessment of acid generating potential and implications for site management.

Groundwater investigation results

This section will detail the results of the groundwater investigation including:

- Site specific hydrogeology including aquifer description, flow directions, flow rates; and
- Groundwater quality.

Acid sulfate soil management strategies

This section will detail the specific management strategies that will be adopted for the site including:

- A discussion of the management level as determined in Table 4.1;
- Excavation management;
- Soil handling;
- Soil treatment;
- Disposal;
- Validation and performance criteria; and
- Contingency plans.

Dewatering management strategies

This section will detail the specific management strategies that will be adopted for the site, including:

- Discussion of the volume and rate of dewatering;
- Dewatering methods;
- Dewatering discharge treatment;
- Dewatering discharge disposal;
- Monitoring and performance criteria; and
- Contingency plans.

6. Responsibilities and timing

Table 6.1 summarises the responsibilities and preferred timing for the implementation of the acid sulfate soil and dewatering management strategy at a project level.

Table 6.1: Responsibilities and timing

EMS Component	Responsible Party	Timeframe
Project Investigation Phase		
Project scope definition	Project manager/design engineer	Post-design
Acid sulfate soil desktop risk assessment	Environmental officer/consultant	Post-design
Dewatering desktop risk assessment	Environmental officer/consultant	Post-design
Project Acid Sulfate Soil and Dewatering Assessment Form	Environmental officer/consultant	Post-design
Acid sulfate soil investigation	Geotechnical consultant	3 months prior to contract tender issue
Dewatering investigation	Geotechnical/environmental consultant	3 months prior to contract tender issue
Determine acid sulfate soil and dewatering management levels	Geotechnical/environmental consultant	Post-investigation
Prepare acid sulfate soil and dewatering management plan including determination of management strategies	Geotechnical/environmental consultant	Completed 1 month prior to contract tender issue
Prepare correspondence to DEC regarding management	Environmental officer/consultant	1 month prior to construction
Project Execution Phase		
Select and source suitable neutralisation agent	Construction manager	Pre-construction
Calculate required volumes of neutralising agent for acid sulfate soil treatment	Construction manager	Pre-construction
Calculate volume of neutralising agent required for containment pads to enable stockpiling	Construction manager	Pre-construction
Conform with stockpile construction requirements	Construction contractor	During construction
Conform with soil disposal requirements	Construction contractor	During construction
Conduct soil stockpile testing	Construction contractor or environmental consultant	During construction
Manage dewatering discharge	Construction contractor	During construction
Daily dewatering discharge monitoring	Construction contractor	During construction
Collect groundwater/surface water samples for laboratory water quality analysis	Environmental consultant	During/post construction
Review data for exceedences and advise of need to implement contingency plans	Construction manager/environmental officer or environmental consultant	During construction
Implement contingency plans	Construction contractor	During construction

7. References

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Appendix A

Project Acid Sulfate Soil and Dewatering Risk Assessment Form

Project Acid Sulfate Soil and Dewatering Assessment Form – Perth and Albany-Torbay Regions

Project Description

Project Commencement Date:	

Project Risk Assessment

Project Scope Item	Description	Project Risk Ranking (Table 1)
Duration of project		
Planned depth of excavation		
Expected depth to groundwater		
Distance to environmental receptors		
Sensitivity of environmental receptors		
Beneficial use of groundwater resource		
	PROJECT RISK[1]	

1. The overall project scope risk will be defined by the highest factor risk assuming that two or more risk factors have been allocated that risk. Where only one risk factor defines the risk category, the project risk will be downgraded by one risk level.

Desktop Review Outcomes and Acid Sulfate Risk Assessment

Site Characteristic	Description	Risk Rating (Table 2 or 3)
Site Elevation		
Geology		
Wetlands		
Depth to Groundwater		
WAPC ASS Risk Classification		
	ACID SULFATE SOIL RISK[2]	
	ACID SULFATE SOIL FIELD INVESTIGATION LEVEL[3]	

2. The acid sulfate soil risk will be defined by the highest risk ranking of all site characteristics.
3. The acid sulfate soil field investigation level will be defined by the risk matrix presented in Table 5.

Dewatering Risk Assessment

Dewatering Factor	Description	Risk Rating (Table 6)
Duration of dewatering activities		
Distance to environmental Receptors		
Acid sulfate soil risk		
	DEWATERING RISK[4]	

4. The dewatering risk will be defined by the highest risk ranking of all dewatering factors.

Project Acid Sulfate Soil and Dewatering Assessment Form – Regional Areas

Project Description

Project Commencement Date:	

Project Risk Assessment

Project Scope Item	**Description**	**Project Risk Ranking (Table 1)**
Duration of project		
Planned depth of excavation		
Expected depth to groundwater		
Distance to environmental receptors		
Sensitivity of environmental receptors		
Beneficial use of groundwater resource		
	PROJECT RISK[1]	

1. The overall project scope risk will be defined by the highest factor risk assuming that two or more risk factors have been allocated that risk. Where only one risk factor defines the risk category, the project risk will be downgraded by one risk level.

Desktop Review Outcomes and Acid Sulfate Risk Assessment

Site Characteristic	**Description**	**Risk Rating (Table 4)**
Site Elevation		
Regolith		
Geology		
Soil Type		
Vegetation		
Water Bodies		
Depth to Groundwater		
	ACID SULFATE SOIL RISK[2]	
	ACID SULFATE SOIL FIELD INVESTIGATION LEVEL[3]	

2. The acid sulfate soil risk will be defined by the highest risk ranking of all site characteristics. It is noted that in regional areas of high surface elevation (>100 mAHD), risk classifications of MEDIUM or HIGH based on geology/regolith/soil type requires supporting information from a secondary source to be characterized as having a MEDIUM or HIGH risk.
3. The acid sulfate soil field investigation level will be defined by the risk matrix presented in Table 5.

Dewatering Risk Assessment

Dewatering Factor	**Description**	**Risk Rating (Table 6)**
Duration of dewatering activities		
Distance to environmental Receptors		
Acid sulfate soil risk		
	DEWATERING RISK[4]	

4. The dewatering risk will be defined by the highest risk ranking of all dewatering factors.

Project Risk Assessment – Risk Ranking Tables

Table 1: Project risk assessment

Project Factors	**Risk Level**		
	LOW	**MEDIUM**	**HIGH**
Duration of Project	Less than 1 month	1-3 months	>3 months
Depth of excavation	<3 mBGL	3 – 10 mBGL	>10 mBGL
Depth to groundwater	Depth to groundwater > depth of excavation	Depth of excavation < 5 m below depth to groundwater	Depth of excavation > 5 m below depth to groundwater
Distance to Sensitive Receptors	> 500 m	200 – 500 m	<200 m
Sensitivity of Environmental Receptors	Unclassified water body	Multiple Use	EPP or CC
Beneficial Use of Groundwater Resource	Irrigation or lower quality	Priority 3 resource	Priority 1/2 resource

Table 2: Acid sulfate soil risk classification - Perth region (see following page)

Table 3: Acid sulfate soil risk classification - Albany-Torbay region (see following page)

Table 4: Acid sulfate soil risk classification - Regional areas (see following page)

Table 5: Acid sulfate soil field investigation level

Acid Sulfate Soil Risk	**Project Scope Risk**		
	LOW	**MEDIUM**	**HIGH**
LOW	Level 1	Level 1	Level 2
MEDIUM-LOW	Level 1	Level 2	Level 3
MEDIUM	Level 2	Level 3	Level 4
HIGH	Level 3	Level 4	Level 4

Table 6: Dewatering risk level

Risk Ranking	**Duration**	**Proximity to Sensitive Receptors**	**Acid Sulfate Soil Environment**
LOW	Less than 1 month	Greater than 500 m	Low ASS risk
MEDIUM	1 – 3 months	200 – 500 m	Medium ASS risk
HIGH	> 3 months	<200 m	High ASS risk

Table 2: Acid sulphate soil risk classification criteria – Perth region

Site Elevation	Geology	Wetland Classification	Depth to Groundwater	WAPC ASS Risk Map Ranking	Acid Sulfate Soil Risk Classification
>20 mAHD	LIMESTONE GRANITES and GNEISSES LATERITE DOLERITE CALCAREOUS SAND SAND of colluvial origin SAND derived from limestone	None	>10 mBGL	Low to No Risk	LOW
5 – 20 mAHD	SAND of eolian origin SILT of colluvium origin	Multiple Use	5-10 mBGL	Moderate to Low Risk	MEDIUM-LOW
5 – 20 mAHD	SAND of eolian origin SILT or CLAY of alluvium origin	Multiple Use	<5 mBGL	Moderate to Low Risk	MEDIUM
>5 mAHD	PEAT and PEATY SAND SILT of lacustrine origin	Resource Enhanced or Conservation Category	<5 mBGL	High Risk	HIGH

1. Based on the GSWA 1:50,000 Environmental Geology Series metropolitan maps

Table 3: Acid sulphate soil risk classification criteria – Albany-Torbay region

Topography	Geology[1]	Wetland Classification	Depth to Groundwater	WAPC ASS Risk Map Ranking	Acid Sulfate Soil Risk Classification
>40 mAHD	LIMESTONE GRANITES, MIGMATITES and GNEISSES SANDS and GRAVELLY SANDS of granitic origin LATERITE and LATERITIC GRAVELS SAND of alluvium origin (tertiary) SILTSTONE and SPONGOLITE Beach and dune SAND	None	>10 mBGL	Low to No Risk	LOW
5 – 40 mAHD	SAND of alluvium origin (quaternary)	Multiple Use	5-10 mBGL	Moderate to Low Risk	MEDIUM-LOW
5 – 40 mAHD	SAND of alluvium origin (quaternary)	Multiple Use	<5 mBGL	Moderate to Low Risk	MEDIUM
>5 mAHD	PEATY SAND of lake and swamp origin SANDY SILT and SILTY SAND, and CLAYEY SILT of lacustrine origin	Resource Enhanced or Conservation Category	<5 mBGL	High Risk	HIGH

1. Based on the GSWA 1:50,000 Environmental Geology Series ALBANY and TORBAY maps

Table 4 Acid sulfate soil risk classification criteria – Regional areas

Topography	Geology/Lithology			Vegetation, Wetlands and Water Bodies		Depth to Groundwater	Acid Sulfate Soil Risk Classification
	Regolith	Geology	Soil Types	Vegetation	Water Bodies		
>100 mAHD	MODERATELY WEATHERED BEDROCK	DURICRUST (CALCRETE/ SILICRETE/ UNDIFFERENTIATED) SEDIMENTARY ROCKS (MESOZOIC) SEDIMENTARY ROCKS (PALEOZOIC) GRANITIC ROCKS (ARCHEAN-PROTEROZOIC)	DUPLEX SOILS RED AND YELLOW EARTHS HARD SETTING LOAMY SANDS WITH RED CLAYEY SUB SOILS	NATIVE GRASSLANDS NATIVE SHRUBS AND HEATHS CROPS NATIVE FORESTS AND WOODLANDS	NONE CREEKS – fresh to brackish RIVERS – fresh to brackish WATER BODIES – fresh to brackish	>10 mBGL	LOW
20 – 50 mAHD	TERRESTRIAL SEDIMENTS ALLUVIAL SEDIMENTS AEOLIAN SANDS	QUATERNARY DEPOSITS DURICRUST (FERRUGINOUS)	EARTHY SANDS LEACHED SANDS	NATIVE GRASSLANDS NATIVE SHRUBS AND HEATHS CROPS NATIVE FORESTS AND WOODLANDS	RIVERS –saline WATER BODIES – saline	5 – 10 mBGL	MEDIUM-LOW
5 – 20 mAHD	TERRESTRIAL SEDIMENTS ALLUVIAL SEDIMENTS AEOLIAN SANDS	QUATERNARY DEPOSITS DURICRUST (FERRUGINOUS)	EARTHY SANDS LEACHED SANDS	MALALEUCAS, EUCALYTUS	SEASONAL WETLANDS	<5 mBGL	MEDIUM
<5 mAHD	LACUSTRINE SEDIMENTS	QUATERNARY DEPOSITS in low-lying, wetland areas	LEACHED SANDS in low lying areas. CRACKING CLAYS, UNDERLAIN IN AREAS BY HARD PAN AREAS	MALALEUCAS, EUCALYTUS	WETLANDS	<5 mBGL	HIGH

Appendix B

Containment Pad Calculation Worksheet

Containment Pad Calculation Worksheet

This worksheet can be used to determine the amount of neutralising agent (aglime or lime sands) required to construct a containment pad suitable for the stockpiling of acid sulfate soils and to assist in determining suitable dimensions of the containment pad. This worksheet may require modification for use with alternative neutralising agents.

Step 1: Gather the relevant information project information

Parameter	Definition	Project Specific Value
A	Area of excavation (m^2)	
H	Depth of excavation (m)	
V	Volume of excavated material (A x H m^3)	
δ	Density of soil (T/m^3)	
B	Bulking factor post excavation	
%S	Maximum total sulfide concentration of soil to be stockpiled (%S)	
ENV	Effective neutralizing value of the neutralizing agent used for containment pad construction (expressed as a decimal percent)	
CP	Area of the containment pad (m^2)	

Step 2: Calculate the height of the stockpile (SPH expressed as metres)

V (m^3) x *B* / *CP (m^2)* = *SPH (m)*

__________ x __________ / __________ = __________

Step 3: Calculate the quantity of neutralising agent required (NA expressed as kg $CaCO_3$)

3.1 Calculate the neutralisation rate (NR expressed as kg $CaCO_3$/tonne of soil)

[0.2 x SPH (m)] x *[%S x 30.59]* / *ENV* = *NR (kg $CaCO_3$/T)*

__________ x __________ / __________ = __________

3.2 Calculate the volume of neutralising agent required

NR (kg $CaCO_3$/T) x *V (m^3)* / *δ (T/m^3)* = *NA (kg $CaCO_3$)*

__________ x __________ / __________ = __________

Step 4: Calculate the thickness of the containment pad (T expressed as metres)

[NA (kg $CaCO_3$) / 2000] / *CP (m^2)* = *T (m)*

__________ / __________ = __________

Appendix C

ENV Calculation Worksheet

ENV Calculation Worksheet

DEFINITIONS

Parameter	Definition	Units
NV	Neutralising value of the soil as determined through laboratory analysis using the Calcium Carbonate Equivalence method	%
S	Number of samples analysed	none
NV_{AVE}	Average neutralizing value of the soils	%
PSD	Particle size proportion as determined through laboratory analysis	%
UF	Utilisation factor for different particle sizes	none
ENV	Effective neutralizing value	%

Step 1: Calculate the average NV of the soil

SUM [NV of all samples] / *S* = NV_{AVE} *(%)*

____________________ / ____________ = [ ]

Step 2: Determine the Utilisation Value of the soil (% $Value_{Total}$)

Step 2.1: Determine the untilisation value for each of the particle size distribution categories.

Particle size	PSD Proportion (%)	x	Utilising Factor	=	%Value
>0.850 mm			0.1		
0.300 – 0.850 mm			0.6		
<0.300			1.0		

Step 2.2: Determine the %Value for the soil

$\%Value_{>0.850}$ + $\%Value_{0.300-0.850}$ + $\%Value_{<0.300}$ = *%Value*

____________ + ____________ + ____________ = [ ]

Step 4: Calculate the ENV of the soil

NV_{AVE} / *&Value/100* = *ENV (%)*

____________________ / ____________ = [ ]

Appendix D

Neutralising Agent Calculation Worksheet

Neutralising Agent Calculation Worksheet

This worksheet can be used to calculate the total amount of neutralising agent required for a site. It can also be used to calculate the total amount of neutralising agent required to treat individual soil units. The worksheet is designed to assist with calculations for aglime and lime sand neutralising agents only and may require modification for use with other neutralising agents.

Step 1: Gather the relevant information project information

Parameter	Definition	Project Specific Value
A	Area of excavation (m^2)	
T	Thickness of soil unit (m)	
V	Volume of soil to be treated (A x T m^3)	
δ	Density of soil (T/m^3)	
%S	Maximum total sulfide concentration of soil unit(%S)	
ENV	Effective neutralizing value of the neutralizing agent used to treat the soil (expressed as a decimal percent)	

Step 2: Calculate the neutralisation rate (NR expressed as kg $CaCO_3$/tonne of soil)

%S x *45.885* / *ENV* = *NR (kg $CaCO_3$/T)*

__________ x __________ / __________ = [ ]

Step 3: Calculate the quantity of neutralising agent required

NR (kg $CaCO_3$/T) x *V (m^3)* x *δ (T/m^3)* = *NA (kg $CaCO_3$)*

__________ x __________ x __________ = [ ]