



**Department of Environmental Protection  
Water and Rivers Commission**  
Amalgamating to form the Department of  
Environment, Water and Catchment Protection

## Acid Sulfate Soils Guideline Series

# Identification and investigation of acid sulfate soils and groundwater

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### 1.0 Introduction

The early identification of acid sulfate soils can provide a useful platform for developing and adopting effective measures to reduce the generation of acidic soils and water. Acid Sulfate Soils (ASS) are soils that contain iron sulfides which, when drained or disturbed, produce sulfuric acid and result in the release of soluble iron, sulfate, aluminium and other toxic metals. These soils commonly have a pH of between 4 and 6, and have the potential to produce acid if exposed to oxygen.

Proponents proposing to carry out developments that involve the disturbance of soil or the change of groundwater levels in areas susceptible to ASS, should require to conduct a preliminary site assessment and investigation to determine whether or not ASS are present. Inappropriate management of ASS by landowners or developers can result in environmental harm and the risk of litigation under the *Environmental Protection Act 1986*. Potential impacts from disturbing acid sulfate soils can be found in the draft *DEWCP and EPA guidance on managing acid sulfate soils (2002)*, available on the webpage [www.environ.wa.gov.au](http://www.environ.wa.gov.au).

### 2.0 Purpose of the Guidelines

The purpose of these guidelines is to provide information on the level of investigation required to:

- identify the presence or the absence of ASS in areas to be disturbed by a proposed development; and if present,
- define the location of ASS and the maximum amount of existing and potential acidity in order to determine appropriate management measures.

### 3.0 Investigations

A two-step investigation process will usually be required:

- Step 1: Soil sampling supported by desktop assessment and site investigation; and
- Step 2: Sample selection and laboratory analysis (supported by Step 1).

#### 3.1 Step 1: Desktop assessment and site investigation

Step 1 involves a desktop assessment and a site visit to identify indicators of ASS followed by soil sampling.

### 3.1.1 Desktop assessment

The desktop assessment is a preliminary appraisal of ASS risk within the property/landholding. This involves gathering information from ASS risk maps, generic soil maps, geological maps, topographic maps, aerial photographs and other local investigations or environmental impact reports, to assess the possibility of ASS occurrence.

Appendix 1 provides a draft ASS risk map based on existing geomorphological and hydrological properties of the relevant soil formation. The ASS risk map is a broad scale assessment for planning purposes. The ASS risk map provides an indication where acid sulfate soils may exist. Local variance in soil conditions will greatly influence the on-ground validation of key map units. The ASS risk map will not replace the need to undertake a detailed soil identification and on-ground assessment. Whilst information from this map should form part of the information presented in an investigation report, it cannot be used alone at the property scale to confirm absence of ASS, or define the amount of existing or potential acidity for a disturbance.

The following geomorphic or site description criteria should be used to determine if ASS are likely to be present:

- land with elevation less than 5 metres AHD;
- soil and sediment of recent geological age (Holocene);
- marine or estuarine sediments and tidal lakes;
- low-lying coastal wetlands or back swamp areas, waterlogged or scalded areas, stranded beach ridges and adjacent swales, interdune swales or coastal sand dunes;
- coastal alluvial valleys;
- areas where the dominant vegetation is tolerant of salt, acid and/or waterlogging conditions e.g. mangroves, saltcouch, swamp-tolerant reeds, rushes, paperbarks (*Melaleuca spp.*) and swamp oak (*Casuarina spp.*); and
- areas identified in geological descriptions or in maps as:
  - bearing sulfide minerals;
  - coal deposits or marine shales/sediments (geological maps and accompanying descriptions may need to be checked); and
  - deep older estuarine sediments below ground surface of either Holocene or pre-Holocene age.

### 3.1.2 Site investigation

Soil sampling locations should be guided by the desktop assessment and site characteristics. Relevant characteristics to consider include:

- nature of the disturbance (excavation, filling or groundwater extraction);
- specific location or locations of disturbance;
- total area of the site (in m<sup>2</sup> or hectares) to be disturbed;
- volume of material to be disturbed; and maximum depth of disturbance with reference to metres AHD (including any underground service pipes such as sewerage or drains).

Care should be taken to ensure representative samples are collected especially on sites with more than one type of geomorphological unit, or clearly different land surface elevations, so that sampling is representative of the area.

Appendix 2 provides a list of soil and water indicators that can be used (as a result of either site investigation or field soil tests) to identify if ASS are present. The site inspection should investigate for the presence of actual and potential ASS. Also note that it is common to have an actual ASS that also contains some un-oxidised iron sulfides or potential acidity.

### 3.1.3 Soil sampling

Soil sampling involves drilling or augering investigative boreholes to at least 3 metres depth, or at least 1 metre below the maximum depth of disturbance (whichever is the greater), describing and undertaking field soil tests on the soil profiles retrieved and collecting and storing samples for laboratory analysis. The information gathered from this step will be required to assist in selecting appropriate samples for laboratory analysis and enable both the proponent and the Department of Environment, Water and Catchment Protection (DEWCP) to review and assess the results. The following information should be provided as part of the soil sampling procedure:

- the full grid reference of each borehole using Australian Metric Grid ;
- the exact location of each borehole shown on an appropriately scaled map;
- an exact description of the vertical dimensions of the borehole relative to existing surface height AHD;
- a brief description of the equipment and/or methods used to retrieve the samples;
- a field description for each soil profile including soil texture, colour, mottling and other diagnostic features (e.g. jarosite, shell); and
- results from field soil tests (field pH ( $pH_F$ ), pH after oxidation with hydrogen peroxide ( $pH_{FOX}$ ) and reaction with peroxide) at 0.25 metre vertical intervals to the base of the soil profile (see Appendix 3 for notes on how to interpret these tests).

The number of boreholes required is dependant on the volume of ASS disturbance, or for disturbances greater than 1000 m<sup>3</sup>, the area (m<sup>2</sup> or hectares) to be disturbed. Table 1 summarises the minimum number of boreholes to be drilled, described, field tested and sampled for non-linear and linear disturbances.

**Table 1 – Minimum number of boreholes required for ASS investigation**

<b>Extent of site project</b>	<b>Number of boreholes</b>
<b>1. Area project</b>	
< 1 ha	4
1 – 2 ha	6
2 – 3 ha	8
3 – 4 ha	10
> 4 ha	2 for every hectare
<b>2. Volume of disturbance (m<sup>3</sup>)</b>	
≤ 250	2
251 – 1000	3
> 1000	1 for every 500m <sup>3</sup>
<b>3. Linear project</b>	
Minor width and volume and low S(%)	@ 100 m intervals
Major width and volume	@ 50 m intervals

*Note: The borehole density relates to the pre-development stage, as opposed to sampling requirements after disturbance – adapted from Queensland State Planning Policy 2/02 Guidelines .*

Once boreholes have been dug, the profiles described and soil field tests conducted, soil samples must be collected from each profile at a vertical maximum of 0.5 metre intervals. In deciding the appropriate sampling intervals, the field operator should refer to the field description notes and identify any significant changes with depth down the profile in field description properties (such as a change in pH, colour, texture etc.). Samples with clearly

different physical, visual or chemical properties should not be 'bulked' together, as this will reduce the precision of future laboratory results.

When collecting samples in the field it is important to prevent oxidation of the soil as much as possible. This can be achieved by immediately placing the sample in plastic bags or other suitable containers, excluding air, then placing in a field freezer or with ice in an esky. Samples should be kept out of direct sunlight even on ice. The samples should be carefully marked (using a waterproof pen) for easy identification, and be frozen or specially dried within 24 hours of collection.

All samples should be retained in storage (frozen or specially dried) until the field investigation report and any related ASS management strategy has been assessed for the purposes of the development, i.e. approval given. Further laboratory analysis may be required to clarify results, or provide a more accurate understanding of the soil for management purposes. Re-drilling is expensive.

Further information on how to conduct ASS sampling can be found in the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998* on the website [www.environ.wa.gov.au](http://www.environ.wa.gov.au)

It is important to note that there are occupational health and safety issues related to soil collection and field-testing, particularly in regard to handling hydrogen peroxide, digging soil inspection pits and dangers associated with hydrogen sulfide gas poisoning. A Health and Safety Plan should be prepared and communicate to all field staff prior to site investigation.

### **3.1.4 Using information gathered in step 1 to make a decision**

Appendix 3 outlines how to interpret field pH ( $\text{pH}_F$ ) and field peroxide pH ( $\text{pH}_{\text{FOX}}$ ) results. These tests are essential for indicating whether ASS are likely to be present or absent. If the proponent concludes that the desktop assessment, site and field indicators and pH test results all show that ASS are absent then this should be clearly stated.

Irrespective of the field test results, Step 2 (confirmatory laboratory analysis) is required in the majority of situations. The exception is when a non-linear disturbance up to 1000 m<sup>3</sup> which does not involve activities that may alter groundwater, is planned in one of the following situations:

- the area is mapped as low risk of ASS on a draft ASS Risk Map and the conclusions of Step 1 show that ASS are absent. The applicant may submit the results of Step 1 to the Land and Water Quality Branch, DEWCP for assessment without undertaking Step 2; and/or
- compelling geomorphic and geologic evidence (e.g. soils developed on basalt) supported by field pH tests on the soil provides strong evidence that ASS are absent from the areas to be disturbed. The proponent may submit this evidence (i.e. photographs, soil description and results from Step 1) to support non-completion of Step 2.

*NB: All soil samples should be retained until the application is approved. The DEWCP may call upon one or more of the samples to be confirmed by laboratory analysis.*

## **3.2 Step 2: Sample selection and laboratory analysis**

Step 2 outlines the selection of soil samples for laboratory analysis required to either prove that ASS are absent, or to quantify the maximum amount of existing and potential soil acidity that will require treatment and management. Sample selection for laboratory analysis should be guided by the field results obtained in Step 1 (particularly the field pH and field pH peroxide tests).

*NB: The DEWCP will likely compare the laboratory results with the field results and if dissatisfied with the sample selection, may request that additional samples be analysed.*

### 3.2.1 Sample selection for non-linear disturbance up to 1000 m<sup>3</sup>

The sampling protocol outlined below, together with Table 3, should be used as a guide to selecting samples for laboratory analysis where a non-linear disturbance up to 1000 m<sup>3</sup> is proposed. Use of this protocol assumes that high quality field investigations have been undertaken as outlined in Step 1.

1. Use Table 1 to determine the minimum number of boreholes required (based on the maximum volume of disturbance).
2. Collect samples at the required interval and collate field information (see Step 1).
3. Using the field results from Step 1, select the *soil profile* most likely to contain ASS.
4. From this soil profile, and using the field results as a guide, select one sample that is most likely to contain ASS from *each metre interval*.
5. Using the field results, select a single (one) sample most likely to contain ASS from *each* additional soil profile.
6. Submit the selected samples for laboratory analysis, and store the remaining samples frozen or specially dried for possible future use.

### 3.2.2 All other disturbances

For disturbances that are greater than 1000 m<sup>3</sup>, linear disturbances and activities involving alteration to groundwater, consult the Land and Water Quality Branch, DEWCP for advice.

**Table 2 shows the minimum soil samples to be initially selected for laboratory analysis for non linear disturbances less than 1000 m<sup>3</sup>**

	Maximum disturbance depth			
	<1 m	1 – 2 m	2 – 3 m	3 – 4 m
	Borehole depth 2 m	Borehole depth 3 m	Borehole depth 4 m	Borehole depth 5 m
Volume of disturbed soils ≤ 250 m <sup>3</sup>	3	4	5	6
Volume of disturbed soils 251 - 1000m <sup>3</sup>	4	5	6	7

*Number of samples to be analysed per total volume of soil to be disturbed, not per borehole.*

*Depth of disturbance from ground surface. Borehole depth must be 1m maximum of disturbance*

### 3.2.3 Laboratory analysis selection

Once the appropriate samples have been selected, the samples should be submitted to an approved accredited laboratory for analysis. The existing acidity and potential acidity of the soil should be analysed. Potential acidity can be determined by Chromium Reducible Sulfur (S<sub>CR</sub>), Peroxide Oxidation Combined Acidity and Sulfate (POCAS) and Total Oxidisable Sulfur (TOS). For samples with pH<sub>F</sub> <5.0, the existing acidity must also be determined by appropriate laboratory analysis e.g. Titratable Actual Acidity (TAA) if S<sub>CR</sub> and TOS analyses are to be conducted. Soils with jarosite or other similar insoluble compounds have a less available existing acidity and will require more detailed analysis. Refer to the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*.

Different laboratory analyses provide different types and levels of information on the chemistry of the soil e.g. Titratable Potential Acidity (TPA) and the full Suspension Peroxide Oxidation Combined Acidity and Sulfur (SPOCAS) methods have been developed by the Queensland Department of Natural Resources and Mines for ASS investigation. A combination of analyses may be required if a more detailed knowledge of the soil chemistry is necessary e.g. to determine the most appropriate neutralising agent or management technique, or if the proponent wants to minimise the amount of neutralising agent used (often

economical for larger scale disturbances). Advice from the Land and Water Quality Branch, DEWCP on an appropriate laboratory can be sought before analysis commences.

## **4.0 Using laboratory results from Step 2**

### **4.1 For all disturbances**

If no single laboratory result exceeds the texture-based ASS *Action Criteria* in Appendix 4 (i.e. absence of ASS has been confirmed), then the applicant can submit the application with the supporting information.

If any one of the laboratory results exceed the texture-based ASS *Action Criteria*, indicating that existing and potential acidity must be managed, then the appropriate level of treatment [low (L), medium (M), high (H), very high (VH) or extra high (XH)] can be determined using the highest single laboratory result and the total volume of disturbance together with Table 5. If the level of treatment is very high (VH) or extra high (XH) then additional laboratory analysis will normally be required to give a better quantification of the location, the maximum amount of existing acidity plus potential acidity and volume of ASS to be disturbed.

### **4.2 For non-linear disturbances up to 1000 m<sup>3</sup>**

If the combination of the disturbance volume and the highest laboratory result applied to Table 5 indicate that a very high (VH) or extremely high (XH) level of treatment is required, additional samples will need to be analysed in accordance with the full requirements of the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*. (i.e. one sample per 0.5 metre interval analysed). Treatment and management are discussed in the *Treatment and Management of Disturbed Acid Sulfate Soils DEWCP 2003* and the *Queensland Soil Management Guidelines – Acid Sulfate Soil Technical Manual 2002* available on [www.environ.wa.gov.au](http://www.environ.wa.gov.au). The results from these additional analyses can then be used to calculate average existing, plus potential acidity content, for each depth interval and develop a more refined cost-effective treatment plan.

### **4.3 For linear disturbance**

If the volume of soil to be disturbed between sampling points multiplied by the average S% of this volume is less than the VH category as shown in Table 5, then sampling at 100 m intervals is acceptable. Where this is not the case, then a greater sampling intensity would be expected (ie 50m intervals).

### **4.4 Conclusion**

Preliminary sampling intensities in Table 1 and 2 do not provide sufficient detail on the existing and potential acidity required for using different liming rates with different soil layers. Further analysis of the stored samples and/or more detailed justification will be required if the proponent wants to neutralise different layers of the soil with different amounts of neutralising agent, or use the average of all laboratory analyses as the basis for lime application rates. In such cases, more detailed calculations involving weight (using volume and bulk density) will be necessary by referring to the *Treatment and Management of Disturbed Acid Sulfate Soils DEWCP 2003* and the *Queensland Soil Management Guidelines – Acid Sulfate Soil Technical Manual 2002*.

There may be situations where ASS is found at the construction stage of a development even though the ASS investigation (undertaken in accordance with this Guideline) indicated otherwise. If such a situation occurs, the disturbed ASS will require treatment and management to minimise adverse environmental impacts.

## 5.0 Groundwater investigation prior to disturbance

At an early stage in the ASS investigation, it is important to consider any potential groundwater issues, particularly if groundwater is likely to be disturbed beyond normal seasonal fluctuations.

The hydrological regimes that operate in an area affect the behaviour of ASS and the transport of oxidation products. ASS which are permanently waterlogged remain benign, but if the groundwater level is lowered (either temporarily or permanently) then oxidation may occur resulting in acid formation and metal mobility. Vertical and horizontal groundwater flows transport oxidation products (acid, toxic by-products) to other areas and adjacent subsoil.

It is also vital to keep in mind that groundwater treatment *in situ* is usually not feasible. A suitably qualified professional person experienced in assessing and managing ASS and groundwater issues should undertake all investigations.

Groundwater should be investigated prior to soil disturbance and should demonstrate:

- the presence or absence of acidic groundwaters prior to works;
- that the proposed development will not result in previously saturated ASS (both onsite or offsite) being aerated through groundwater extraction or excavation;
- that if previously-saturated ASS will become aerated (as a result of the proposed development), this information will be used to assist in the production of effective treatment and management plans; and
- that any acidic groundwater will not migrate from the site and impact adjacent properties and sensitive environments.

### 5.1 Required information

Prior to on-site works, the groundwater investigations should include a description of water quality, including seasonal variations where applicable. Essential information that should be collected and documented as part of the groundwater investigation includes but is not limited to:

- field measurements of pH, electric conductivity, dissolved oxygen and redox. If field measurement of groundwater pH is less than 5, additional investigations for calcium, magnesium, total iron, dissolved iron, dissolved manganese, filtered aluminium, arsenic, chromium, cadmium, bicarbonate, carbonate, chloride and sulfate should be conducted;
- determine the depth to the watertable with an indication of the seasonal variation. The greater the groundwater depth, the risk of impacting the groundwater or changes to the watertable levels are lower;
- identify adjoining on and off-site groundwater related environments (e.g. wetlands, springs, rivers and creeks) and any likely recharge areas (e.g. areas of waterlogging). Sites that contain surface water linkages to the groundwater increase the likelihood of groundwater being affected; and
- identify any adjoining existing groundwater users, density of water extraction bores and uses of groundwater extraction.

A soluble chloride: soluble sulfate ( $\text{Cl}:\text{SO}_4^{2-}$ ) ratio should also be calculated to determine if sulfide oxidation has occurred in the past. Where the analysis indicates that there is an elevated level of sulfate ions relative to the chloride ions, these results may indicate the presence of ASS in the landscape. A  $\text{Cl}:\text{SO}_4^{2-}$  ratio by mass of less than four, and certainly a ratio less than two, is a strong indication of an extra source of sulfate from previous sulfide oxidation (Mulvey 1993).

## 5.2 Using the information

If groundwater investigations indicate that existing groundwaters do not conform to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ 2000) water quality criteria, then any extracted groundwater must be contained and treated before release.

If groundwater investigations indicate that existing groundwaters are acceptable by the ANZECC/ARMCANZ 2000 guidelines water quality criteria:

- daily monitoring for pH is still required prior to any release to receiving waters to ensure that there is no deterioration of water quality standards since previous measurements; and
- weekly monitoring for pH is still required if an on-site water storage (greater than 100 m<sup>3</sup> or 0.1 megalitre) interacts with groundwater to ensure that there is no deterioration of water quality standards since previous measurements. If the above monitoring indicates a pH result outside the acceptable range of the ANZECC guidelines, waters must be treated in accordance with the recommended liming rates.

While the treatment of relatively small quantities of water may appear to be quite straightforward, applicants should seek qualified professional assistance, as the chemistry of water quality can be a complex environmental issue.

In cases where excessive iron, aluminium and other salts are present, particularly in large volumes, sophisticated treatments may be required in consultation with the Land and Water Quality Branch, DEWCP.

Where iron is precipitating from the acidic water, very low dissolved oxygen levels may result. Wherever possible, dissolved oxygen should be measured over the full diurnal cycle for a period of a few days to establish the diurnal range in concentration.

## 6.0 Further information

The Land & Water Quality Branch of the Department of Environment, Water & Catchment Protection (DEWCP) is currently drafting this series of guidance notes related to ASS. These guidance notes will initially be in draft form, and comments are welcomed. The guidance notes will be made available on the Department of Environmental Protection website as they are developed.

It is recommended that reference is made to guidelines and manuals developed by the New South Wales and Queensland State governments, in particular;

- *NSW Acid Sulfate Soil Manual 1998*, Acid Sulfate Soil Advisory Committee;
- *Queensland Acid Sulfate Soil Technical Manual 2002, Soils Management Guidelines* Queensland Acid Sulfate Soils Management Advisory Committee;
- *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*, Queensland Acid Sulfate Soils Investigation Team;

Queries or comments relating to ASS or the guidance notes should be directed to one of the following officers of the Land & Water Quality Branch;

Steve Appleyard – 9222 8626 or [steve.appleyard@wrc.wa.gov.au](mailto:steve.appleyard@wrc.wa.gov.au)

Stephen Wong – 9222 7101 or [stephen.wong@wrc.wa.gov.au](mailto:stephen.wong@wrc.wa.gov.au)



## 7.0 Acknowledgements

The Land & Water Quality Branch would like to acknowledge the guidelines and manuals produced by the following committees and organisations which were used in the development of this guideline:

- NSW Acid Sulfate Soils Management Advisory Committee;
- Queensland Acid Sulfate Soils Investigation Team;
- Queensland Acid Sulfate Soil Management Advisory Committee; and
- Queensland Government (Department of Local Government & Planning and Department of Natural Resources and Mines).

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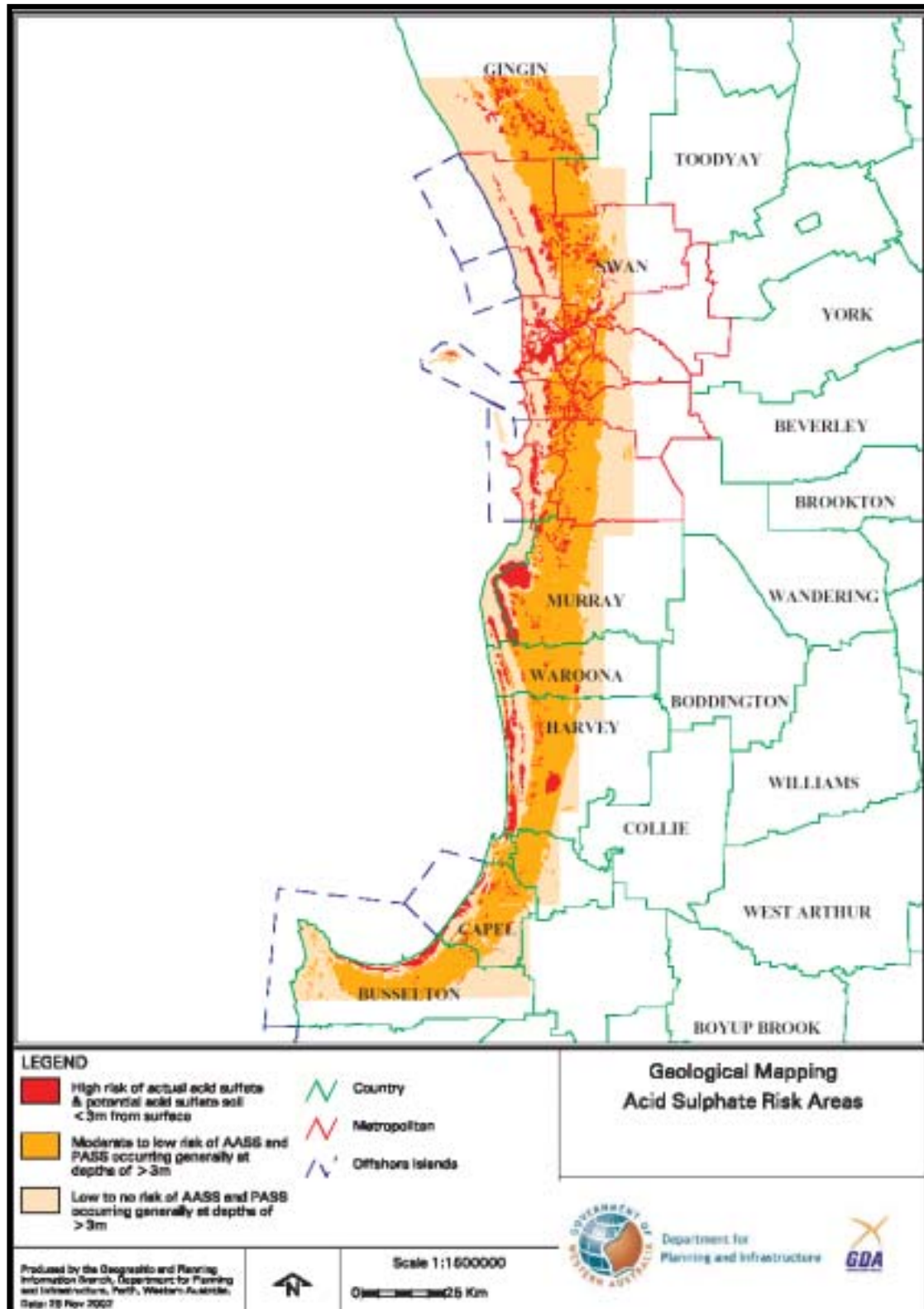
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## Appendix 1: Acid Sulfate Soil Risk Map



**NB: Inland areas (not shaded) have not been assessed. The precautionary approach is to use visual indicators and field tests to detect the presence of acid sulfate soils**

## Appendix 2: Soil and water indicators

The site investigation will involve the applicant undertaking a visual field investigation of soil and ground and surface water characteristics. Some helpful soil and water field indicators suggesting the presence of ASS are set out below. Some of the indicators will only be available when boreholes are augered.

<b>Soil Type</b>	<b>Indicators</b>
<b>Actual acid Sulfate soil (AASS)</b>	<p><b>Soil characteristics</b></p> <ul style="list-style-type: none"> <li>• field <math>pH_F \leq 4</math> (when field <math>pH_F &gt; 4</math> but <math>&lt; 5</math> may indicate some existing acidity and other indicators should be used to confirm presence or absence);</li> <li>• presence of corroded shell;</li> <li>• any jarositic horizons or substantial iron oxide mottling in surface encrustations or in any material dredged or excavated and left exposed; and</li> </ul> <p><b>NB:</b> <i>Jarosite is a characteristic pale yellow mineral deposit that can 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 actual ASS.</i></p> <ul style="list-style-type: none"> <li>• sulfurous smell e.g. hydrogen sulfide or 'rotten egg' gas.</li> </ul> <p><b>Water characteristics</b></p> <ul style="list-style-type: none"> <li>• water of <math>pH &lt; 5.5</math> (and particularly below 4.5) in adjacent streams, drains, groundwater or ponding on the surface (this is not a definitive indicator as organic acids may contribute to low pH in some environments such as melaleuca swamps);</li> <li>• unusually clear or milky blue-green drain water flowing from or within the area (aluminium released by ASS acts as a flocculating agent); and</li> <li>• extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits.</li> </ul> <p><b>Landscape and other characteristics</b></p> <ul style="list-style-type: none"> <li>• dead, dying, stunted vegetation*;</li> <li>• scalded or bare low-lying areas*;</li> <li>• corrosion of concrete and/or steel structures*.</li> </ul> <p><i>* May also be due to excessive salinity or to salinity in combination with AASS.</i></p>
<b>Potential acid sulfate soil (PASS)</b>	<p><b>Soil characteristics</b></p> <ul style="list-style-type: none"> <li>• waterlogged soils – unripe muds (soft, buttery, blue grey or dark greenish grey), silty sands or sands (mid to dark grey) or bottom sediments (dark grey to black e.g. monosulfides) possibly exposed at sides and bottoms of drains or cuttings, or in boreholes;</li> <li>• soil <math>pH_F &lt; 4</math> and commonly neutral (see also Appendix 3 for details on soil field pH tests);</li> <li>• soil <math>pH_{FOX} &lt; 3</math>, with a large unit change from <math>pH_F</math> to <math>pH_{FOX}</math>, together with a strong reaction to peroxide;</li> <li>• reaction to peroxide using semi-microscopic screening techniques;</li> <li>• presence of shell; and</li> <li>• a sulfurous smell e.g. hydrogen sulfide or 'rotten egg' gas.</li> </ul> <p><b>Water characteristics</b></p> <ul style="list-style-type: none"> <li>• water pH usually neutral but may be acid.</li> </ul> <p><b>NB:</b> Caution should be taken when inspecting highly altered landscapes in the field (e.g. where inert fill has been placed over ASS material). Soil, water and landscape indicators may be masked by past landscape and drainage modifications and this should be taken into consideration when defining borehole locations.</p>

## Appendix 3: Interpreting soil field pH tests

It is important to note that whilst a useful exploratory tool, soil field pH tests are indicative only and cannot be used as a substitute for laboratory analysis to determine the presence of ASS. Laboratory analysis is needed to quantify the amount of existing plus potential acidity. This appendix provides information on how to interpret the results from soil field pH tests. For further information on how to conduct and interpret these tests, consult the latest version of the *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*.

Field pH tests should be conducted on the soil profile at regular intervals (0.25 metres) using a field pH meter calibrated according to the manufacturer's instructions. All results ( $\text{pH}_F$  and  $\text{pH}_{\text{FOX}}$  values, peroxide reaction) should be tabulated and reported.

Other semi-field tests such as examination under a microscope for pyrite and its reaction with peroxide on the slide may be useful tools to identify pyrite presence, but they require experience and training.

### 1. Field pH test ( $\text{pH}_F$ ) i.e. pH of soil and water paste

The  $\text{pH}_F$  test measures the existing acidity of a 'soil:water' paste, and is therefore used to help identify if ASS are present. If the measured pH of the soil paste is  $\text{pH}_F \leq 4$ , oxidation of sulfides has probably occurred in the past, indicating the presence of AASS. Highly organic soils or heavily fertilised soils may also return a  $\text{pH}_F$  close to 4. A  $\text{pH}_F > 4$  but  $\leq 5$  indicates an acid soil, but the cause of the acidity will need to be further investigated by laboratory analysis. The  $\text{pH}_F$  test does not detect any unoxidised sulfides (i.e. PASS). For this reason, this test must be used in conjunction with the  $\text{pH}_{\text{FOX}}$  test.

### 2. Field pH peroxide test ( $\text{pH}_{\text{FOX}}$ ) i.e. pH of soil and peroxide mix and reaction with peroxide

The  $\text{pH}_{\text{FOX}}$  test is used to indicate the presence of iron sulfides or PASS. This test involves adding 30% hydrogen peroxide (pH adjusted to 4.5–5.5) to a sample of soil. If sulfides are present a reaction will occur. The reaction can be influenced by the amount of sulfides present in the sample, the presence of organic matter or the presence of manganese. Once the reaction has occurred, the pH is measured.

A combination of three factors is considered in arriving at a 'positive field sulfide identification':

**A reaction with hydrogen peroxide.** The strength of the reaction with peroxide is a useful indicator but cannot be used alone. Organic matter, coffee rock and other soil constituents such as manganese oxides can also cause a reaction. Care should be exercised in interpreting a reaction on surface soils and high organic matter soils such as peats and coffee rock, and some mangrove/estuarine muds and marine clays. This reaction should be rated, e.g. L = Low reaction, M = Medium reaction, H = High reaction, X = Extreme reaction.

**The actual value of  $\text{pH}_{\text{FOX}}$ .** If the  $\text{pH}_{\text{FOX}} < 3$ , and a significant reaction occurred, then it strongly indicates a PASS. The more the  $\text{pH}_{\text{FOX}}$  drops below 3 the more positive the presence of inorganic sulfides.

**A much lower  $\text{pH}_{\text{FOX}}$  than field  $\text{pH}_F$ .** The lower the final  $\text{pH}_{\text{FOX}}$  value and the greater the difference between the  $\text{pH}_{\text{FOX}}$  compared to the  $\text{pH}_F$ , the more indicative the presence of PASS. This difference may not be as great if starting with an already very acid  $\text{pH}_F$  (close to 4), but if the starting pH is neutral or alkaline then a larger change in pH should be expected. Where

fine shell, coral or carbonate, is present the change in pH may not be as large due to buffering. The 'fizz test' (effervescence with 1 M HCl) should be used to test for carbonates and shell.

**NOTE:** *Field techniques are useful exploratory tools, but are indicative only and definitely not quantitative. They are not a replacement for quantitative laboratory analyses. Although it is commonly assumed that a low %S value means a low risk, the situation is more complex: [%S] x [volume disturbed] = risk assessment. Lowering of groundwater is another level of complication that needs to be addressed.*

*Field and laboratory tests, sampling intensity and action levels (based on oxidisable sulfur results) relevant to the investigation of ASS are outlined in the Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland 1998. These guidelines, also available at [www.environ.wa.gov.au](http://www.environ.wa.gov.au), should be used to guide Western Australian investigations in combination with the Draft DEWCP and EPA Guidance on Acid Sulfate Soils (2002).*

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## APPENDIX 4: Texture-based ASS “Action Criteria”

The *Action Criteria* are based on the sum of existing plus potential acidity, calculated as equivalent sulfur (e.g. s-TAA + S<sub>CR</sub> in %S units) or equivalent acidity (e.g. TAA + a- S<sub>CR</sub> in mol H<sup>+</sup>/tonne). The highest laboratory result(s) is always used to assess against the action criteria. For further information refer to *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998*.

As clay content tends to influence a soil’s natural pH buffering capacity, the action criteria are grouped by three broad texture categories – coarse, medium and fine. The criteria are used to define when ASS disturbed at a site will need to be treated and managed.

For projects that disturb ≥1000 tonnes of ASS with ≥0.03 %S or ≥18 mol H<sup>+</sup>/tonne equivalent acidity, a detailed management plan and development consent will be required.

### Texture-based acid sulfate soils ‘action criteria’

Type of material		Action Criteria if 1-1000 tonnes of materials is disturbed Existing + Potential Acidity		Action Criteria if >1000 tonnes of materials is disturbed Existing + Potential Acidity	
Texture range McDonald et al. (1990)	Approx. clay content (%)	Equivalent sulfur (%S) (oven-dry basis)	Equivalent Acidity (mol H <sup>+</sup> /tonne) (oven-dry basis)	Equivalent sulfur (%S) (oven-dry basis)	Equivalent Acidity (mol H <sup>+</sup> /tonne) (oven-dry basis)
<b>Coarse Texture</b> Sands to Loamy sands	≤ 5	0.03	18	0.03	18
<b>Medium Texture</b> Sandy loams to light clays	5 – 40	0.06	36	0.03	18
<b>Fine Texture</b> Medium to Heavy clays and silty clays	≥ 40	0.1	62	0.03	18

The action criteria refer to existing and potential acidity for given volume of ASS. The highest result(s) should always be used to assess if the relevant action criteria level has been made or exceeded; using the average or mean of a range of results is no longer considered appropriate.

Total actual acidity (TAA) is determined by titration of a 1M KCl salt solution to pH 5.5 using NaOH. This is a measurement of the soil’s existing acidity prior to oxidation of sulfidic material.

Total potential acidity (TPA) is determined by peroxide double oxidation. This is estimated by titration to pH 5.5 of total acidity after oxidation of the soil with 30% hydrogen peroxide.

When determining lime requirements, subtracting TAA from Total Potential Acidity (TPA) to get Total Sulfidic Acidity (TSA) is acceptable.

**TABLE 5 Existing treatment levels and aglime required to treat the total weight of disturbed ASS based on soil analysis (adapted from Queensland SPP Guidelines 2/02)**

The tonnes (t) of pure fine agricultural lime ( $\text{CaCO}_3$ ) required to fully treat the total weight/volume of acid sulfate soils (ASS) can be read from the table at the intersection of the weight of disturbed soil [row] with the existing plus potential acidity [column]. Where the exact weight or soil analysis figure does not appear in the heading of the row or column, use the next highest value.

Disturbed ASS (tonnes) ( $\approx \text{m}^3$ ) †	Soil Analysis <sup>‡</sup> – Potential Acidity plus Existing Acidity (converted to equivalent S% units)													
	0.03	0.06	0.1	0.2	0.4	0.6	0.8	1	1.5	2	2.5	3	4	5
1	0	0	0	0	0	0.03	0.04	0.05	0.1	0.1	0.1	0.1	0.2	0.2
5	0	0	0	0.05	0.1	0.1	0.2	0.2	0.4	0.5	0.6	0.7	0.9	1.2
10	0	0.03	0.05	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.9	2.3
50	0.1	0.1	0.2	0.5	0.9	1.4	1.9	2.3	3.5	4.7	5.9	7.0	9.4	12
100	0.1	0.3	0.5	0.9	1.9	2.8	3.7	4.7	7.0	9.4	12	14	19	23
200	0.3	0.6	0.9	1.9	3.7	5.6	7.5	9.4	14	19	23	28	37	47
250	0.4	0.7	1.2	2.3	4.7	7.0	9.4	12	18	23	29	35	47	59
350	0.5	1.0	1.6	3.3	6.6	10	13	16	25	33	41	49	66	82
500	0.7	1.4	2.3	4.7	9.4	14	19	23	35	47	59	70	94	117
600	0.8	1.7	2.8	5.6	11	17	22	28	42	56	70	84	112	140
750	1.1	2.1	3.5	7.0	14	21	28	35	53	70	88	105	140	176
900	1.3	2.5	4.2	8.4	17	25	34	42	63	84	105	126	168	211
1000	1.4	2.8	4.7	9.4	19	28	37	47	70	94	117	140	187	234
2000	2.8	5.6	9.4	19	37	56	75	94	140	187	234	281	374	468
5000	7.0	14	23	47	94	140	187	234	351	468	585	702	936	1170
10 000	14	28	47	94	187	281	374	468	702	936	1170	1404	1872	2340

<b>L</b>	<b>Low treatment:</b> ( $\leq 0.1$ tonne lime)
<b>M</b>	<b>Medium treatment:</b> ( $> 0.1$ to 1 tonne lime)
<b>H</b>	<b>High treatment:</b> ( $> 1$ to 5 tonnes lime)
<b>VH</b>	<b>Very High treatment:</b> ( $> 5$ to 25 tonnes lime)
<b>XH</b>	<b>Extra High treatment:</b> ( $> 25$ tonnes lime)

Lime rates are for pure fine agricultural lime ( $\text{CaCO}_3$ ) using a safety factor of 1.5. A factor that accounts for Effective Neutralising Value is needed for commercial grade lime. An approximate soil weight (tonnes) can be obtained from the calculated volume by multiplying volume (cubic m) by bulk density ( $\text{t/m}^3$ ). (Use 1.7 if B.D. is not known.)

† Tonnes approximately equal  $\text{m}^3$  (volume) for soils with Bulk Density (BD) of 1 g/cc or  $\text{t/m}^3$ . Dense fine sandy soils may have BD up to 1.7. Thus 100  $\text{m}^3$  may weigh up to 170 t.

‡ Potential acidity can be determined by Chromium Reducible Sulfur ( $S_{\text{CR}}$ ), Peroxide Oxidisable Sulfur ( $S_{\text{POS}}$ ) and Total Oxidisable Sulfur ( $S_{\text{TOG}}$ ). Existing acidity can be determined by Titratable Actual Acidity (TAA). Soils with jarosite or other similar insoluble compounds have a less available existing acidity and will require more detailed analysis.