General Guidance on Managing Acid Sulfate Soils

Department of Environment

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Abbreviations

The abbreviations used in this guidance are as follows:

Ag WA	Department of Agriculture
CALM	Department of Conservation and Land Management
DIR	Department of Industry and Resources
DoE	Department of Environment
EP Act	*Environmental Protection Act 1986*
EPA	Environmental Protection Authority
WAPC	Western Australian Planning Commission
DPI	Department for Planning and Infrastructure

Contents

1. Introduction

1.1 The purpose of this guidance

This guidance provides an introduction to the subject of acid sulfate soils (ASS) and general direction to local government, State agencies, organisations and individuals involved with managing development and carrying out works in areas where ASS are present. It leads the reader to sources of information and provides a framework for decision-making associated with managing development proposals and ground disturbing activities in ASS risk areas. The document also serves to increase public awareness of ASS as an issue of environmental importance, with economic and social implications, and to provide an overview of ASS in Western Australia.

The guidance applies to the State of Western Australia and should be read in conjunction with the Western Australian Planning Commission's (WAPC) Planning Bulletin No. X, *Acid Sulfate Soils*, and the Department of Environment's (DoE) Acid Sulfate Soils Management Series at www.environ.wa.gov.au under 'contaminated sites' and 'acid sulfate soils'.

Appendix 1 provides a checklist to assist in identifying developments, works and activities that may disturb ASS, and Appendix 2 suggests appropriate procedures to be followed in ASS risk areas.

1.2 About ASS

1.2.1 ASS formation

Acid sulfate soil is the common name given to naturally occurring soil or sediment containing iron sulfides over extensive low lying areas under waterlogged or highly reducing conditions (i.e. anaerobic conditions). These soils may be found close to the natural ground level but may also be found at depth in the soil profile. When sulfides are exposed to air, oxidation takes place and sulphuric acid is produced when the soil's capacity to neutralise the acidity is exceeded.

For the purposes of this guidance, the term 'acid sulfate soils' (ASS) includes both actual acid sulfate soils and potential acid sulfate soils:

- Actual acid sulfate soils (AASS) are soils or sediments that contain iron sulfides and/or other sulfidic minerals that have been oxidised, producing highly acidic soil horizons or layers. These materials are characterised by bright yellow or straw coloured mottles of the mineral jarosite and often contain dark reddish coloured streaks. AASS have a soil pH 4 or less.

The impacts of ASS leachate may persist over a long time, or peak seasonally (after dry periods with the first drought-breaking rains). In some areas of Australia, ASS drained 100 years ago is still releasing acid (Sammut 2000).

- Potential acid sulfate soils (PASS) are soils or sediments which contain iron sulfides and/or other sulfidic minerals that have not been oxidised by exposure to air. The field pH of these soils in their undisturbed state is more than pH 4 and commonly neutral pH (approximately 7). These soils or sediments are invariably saturated with water in their natural state. The waterlogged layer may be peat, clay, loam or silty sand and is usually dark grey and soft.

  PASS are not known to be associated with environmental problems in their undisturbed state. While the natural exposure of these soils or sediments to air (e.g. during severe droughts) is associated with the generation of acid, the acidity tends to occur as low frequency, low magnitude, short duration events after drought breaking rains (ASSMAC, 1998).

1.2.2 ASS impacts

ASS have the capacity to directly impact upon the basic natural assets of soil, water, biota and air, and thus upon most human endeavours, including agriculture, fishing, aquaculture, recreation, tourism, as well as human health and visual amenity. The environmental, social and economic consequences that may result include:

- Accumulation of sulfates, sulfides, iron oxides and salinity from rising groundwater and perched water tables;
- Adverse changes to the water quality of the soil, groundwater, surface water, wetlands, watercourses and estuaries;
- Soil acidification;
- Degradation of water-dependant ecosystems and ecosystem services;
- Loss of habitat and biodiversity;
- Invasion and dominance of wetlands and waterways by acid tolerant water plants and plankton species.
- Loss of plant yield;
- Poor quality water sources for stock, irrigation and human use;
- Bared soil surfaces in discharge areas;
- Increased human health risks associated with arsenic, aluminium and other heavy metal contamination in surface and groundwater, and acid dust;
- Loss of visual amenity from rust coloured stains, scums and slimes from iron precipitates;
- Corrosion of metallic and concrete structures (concrete cancer) such as roads, bridges, pumps, drainage pipes and foundations;
- Blockage of perforated plastic pipe drainage systems by iron precipitates; and
- Financial burden of treating and rehabilitating affected areas, and maintenance of infrastructure.

1.2.3 ASS generation

Projects and developments in AAS risk areas that involve excavation, lowering the water table or compacting saturated soils or sediments and/or laterally displacing previously saturated sediments, resulting in groundwater extrusion and aeration of ASS, may result in soil, groundwater and/or surface water acidity and the release of metals and precipitates.

Examples of activities that may generate ASS include:

- Coastal developments, such as canal estates, marinas, golf courses;
- Dewatering and drainage;
- Groundwater pumping;
- Artificially deepened lakes, waterways and wetlands;
- Removing sulfidic peat;
- Infrastructure projects, such as bridges, roads, dredging, port facilities and flood mitigation works;
- Mining and quarrying operations;
- Aquaculture developments, such as prawn farms in mangrove communities; and
- Filling activities.

1.2.4 ASS locations

ASS are widespread around coastal Australia, particularly in association with mangrove swamps. The extent of inland ASS is largely unknown and research into their behaviour is limited.

In Western Australia, ASS are known to have formed in the following general locations:

- Estuarine areas and coastal lowland areas such as mangroves, tidal flats, salt marshes and swamps;
- Wetland areas;
- Saline inland areas; and
- Near mining operations.

Particular areas of concern in Western Australia include:

- Estuarine, floodplain and wetland areas between Perth and Busselton, such as the Peel-Harvey estuarine system and the Vasse River area;
- The northern coastline, including the Pilbara and Kimberley coasts;
- The Scott River Plain, including Toby Inlet; and
- Parts of the Wheatbelt where land salinisation has occurred.

In the Perth region, some of the identified locations of ASS disturbance and exposure include:

- Garrett Road and Guildford bridges on the Swan River;
- Riverside Drive development in Perth CBD;
- Stirling, Bassendean, Guildford and Bayswater; and

- Lake Gnangara and Lake Yangebup wetlands.

1.3 National and State positions on ASS

1.3.1 National position on ASS

In recognition of the need for a nation-wide co-ordinated approach to managing ASS, the National Working Party on Acid Sulfate Soils was set up and has developed a National Strategy for the Management of Coastal Acid Sulfate Soils (NWPASS 2000).

The National Strategy identifies four objectives:

- **Identify and define coastal ASS in Australia**

An accurate environmental hazard assessment process at the catchment level and a reliable property assessment method are needed to help establish whether particular properties are at risk, and if so, the extent and severity of ASS.

- **Avoid disturbance of coastal ASS**

Undisturbed ASS pose few problems for the environment. To refrain from exposing ASS avoids environmental damage and obviates the need for expensive remedial works. Avoiding ASS impacts is most likely to be achieved through a combination of research, education, well considered development and planning controls and promotion of best management practices.

- **Mitigate impacts when ASS disturbance is unavoidable**

If ground disturbing activity must be undertaken on ASS soils, it should be undertaken in a manner that ensures that there is no resultant acid water discharge into streams and waterways. While management does present difficulties and some risk, expensive treatment technologies can enable major developments and projects to proceed.

- **Rehabilitate disturbed ASS and acid drainage**

Where past land use practices, such as excavation and drainage, have disturbed areas of ASS, rehabilitation of these areas will be necessary to improve water quality and minimise on-going adverse effects.

1.3.2 State position on ASS

A draft Western Australian State Strategy for Managing Acid Sulfate Soils and a draft Planning Bulletin on Acid Sulfate Soils are in preparation soon to be released for public comment .

1.3.3 EPA position on ASS

The EPA has identified ASS as an environmental factor requiring evaluation, where relevant, through the environmental impact assessment process. The EPA's objective for

this factor is to minimise the risk to the environment resulting from ASS, to be achieved by implementing appropriate detection and management strategies (EPA 1999).

1.4 WA statutory framework and relevant decision-making authorities

The legislation, processes and agencies directly concerned with ASS management in Western Australia are outlined in this section. The Land and Water Quality Branch of the Department of Environment is the lead agency proving advice on ASS issues, in association with the Department for Planning and Infrastructure.

1.4.1 *Environmental Protection Act 1986* (EP Act)

Development proposals and ground disturbing activities that are likely to disturb ASS may be subject to the provisions of the EP Act and policies developed pursuant to that Act. In pursuing its objectives to:

- protect the environment, and
- prevent, control and abate pollution,

the EPA may also publish statements and guidance on factors such as ASS.

Part III of the EP Act
Part III of the EP Act authorises the EPA to prepare and publish Environmental Protection Policies (EPPs) which, following Parliamentary approval and gazettal, have the force of law. The following EPPs have been gazetted and their requirements should be considered when planning development or undertaking works in their areas of application:

- Peel Inlet-Harvey Estuary;
- Swan Coastal Plain Lakes;
- Gnangara Mound Crown Land;
- Swan and Canning Rivers;
- South West Agricultural Zone Wetlands; and
- Western Swamp Tortoise Habitat.

Part IV of the EP Act
Under Part IV of the EP Act a proposal that appears likely, if implemented, to have a significant effect on the environment should be referred to the EPA for a decision on whether or not it should be subjected to the environmental impact assessment process. See section 3 of this document for an expansion of the referral and assessment process.

Part V of the EP Act
Where pollution arising from the disturbance of ASS has occurred or is likely to occur, the general pollution prevention provisions of Part V of the EP Act may be applicable (see section 1.4.2).

1.4.2 Department of Environment

Groundwater extraction and dewatering in declared public drinking water source areas are subject to licensing by DoE, including underground water pollution control areas, water reserves and public water supply catchment areas declared under the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* and the *Country Areas Water Supply Act 1947*.

1.4.3 Department for Planning and Infrastructure

The land use planning process is the source of initial guidance on new developments. The Western Australia Planing Commission, with assistance from the Department of Environment, has prepared Planning Bulletin on ASS. This document provides advice and guidance on rezoning, subdivision and development of land that may disturb ASS.

1.4.4 Department of Industry and Resources

Protocols for assessing mining proposals have been developed by the Department of Industry and Resources and are subject to the *Mining Act 1978.*

1.4.5 Other Government agencies and management authorities

Developments within and abutting the Swan River Trust management area generally require the approval of the Swan River Trust. Similarly, other management and decision making authorities eg local governments may require formal approval for developments within their respective jurisdictions.

Other agencies that may provide advice in relation to ASS include:

- Department of Agriculture Western Australia – agricultural land developments;
- Department of Fisheries – aquaculture projects; and
- Department of Conservation and Land Management (CALM) – projects impacting on lands managed by CALM, including wetlands in the conservation estate.

2. Department of Environment guidance

The DoE has developed a series of draft guidelines to assist with the investigation and management of ASS. These may be accessed through the Department's website www.environ.wa.gov.au and are entitled:

- Identification and Investigation of Acid Sulfate Soils and Groundwater;
- Treatment and Management of Disturbed Acid Sulfate Soils and Ground and Surface Waters; and
- Preparation of an Acid Sulfate Soil Management Plan.

The guidelines are based on procedures developed for Queensland and New South Wales and focus on investigation, treatment and management techniques that are appropriate for Western Australian conditions.

The WAPC draft Planning Bulletin on ASS (No. X) is also available on the DoE website.

2.1 Management objective for ASS

The DoE management objective for ASS is for potentially ASS disturbing development and activities to be planned and managed to avoid adverse effects on the natural and built environment and on human health and activities. This objective is consistent with the aims of the National Strategy for the Management of Coastal Acid Sulfate Soils (NWPASS 2000) and the position of the EPA (EPA 1999).

2.2 Guiding principles for management of ASS

The DoE's guiding management principles are:

1. Adverse ASS impacts on key elements of the biophysical environment, e.g. conservation areas and public drinking water supplies, are unacceptable.

2. ASS should be considered as an issue for all projects that involve ground disturbing activities.

3. Where possible, development projects should avoid soils and sediments exhibiting ASS characteristics.

4. A precautionary approach should be adopted in the management of ASS.

5. Community awareness of ASS issues should be promoted.

2.3 Framework for management of ASS

To avoid unacceptable ASS impacts, the following approach should be adopted:

1. Become familiar with the draft ASS risk map and ASS risk areas available on the DoE's website www.environ.wa.gov.au..

2. Undertake a preliminary site assessment where a project or proposal involves ground disturbing activity in an ASS risk area.

3. If disturbance of ASS is unavoidable, identify the precise location of ASS in areas to be disturbed, together with the maximum amount of existing and potential acidity (see section 2.4).

4. Consider a range of mitigation and management strategies, and demonstrate that:
   - every reasonable step has been taken to minimize and avoid the disturbance of ASS and adverse environmental impacts; and
   - there are no unacceptable risks to the natural or the built environment or human health as a result of ASS disturbance (see section 2.5).
5. Prepare and implement an approved Acid Sulfate Management Plan in accordance with the State-wide guidance provided in this document (see section 2.6).

Throughout this process,

- engage qualified people to carry out investigations and analyses, using an acceptable methodology, and
- consult with relevant agencies, such as DoE.

Local authorities and other responsible agencies with advisory and regulatory functions should advise the DoE of likely ASS in development areas, and ensure that the community is aware of the issue.

2.4 Identification and investigation of acid sulfate soils and groundwater

Adequate information on the extent and nature of ASS is the basis for ASS management. It needs to be established at the onset whether or not a proposed development site is in an area of ASS risk. DoE guidelines on the Identification and Investigation of Acid Sulfate Soils and Groundwater are available on DoE's website www.environ.wa.gov.au. Appropriate information-gathering methods include onsite indicators, field pH tests and chemical analysis. This process will ensure that ASS issues are considered at the early planning phase of a project. If it is possible that the proposed development will undergo environmental impact assessment, the information requirements of the EPA should be considered at this stage (see section 3).

2.5 Treatment and management of acid sulfate soils and acidic ground and surface water

The management of ASS does present difficulties and some risk. If development must occur on ASS, it should be carried out in a manner that ensures that there is no resultant acid water discharge that may adversely affect the biophysical environment and human health and amenity. DoE draft guidance on the Treatment and Management of Disturbed Acid Sulfate Soils and Ground and Surface Waters is available on the DoE's website www.environ.wa.gov.au.

2.6 Acid Sulfate Soil Management Plan

In the event that particular ASS disturbance is considered acceptable, it is generally expected that an Acid Sulfate Soil Management Plan will be prepared and implemented. The details will be dependent on the scale and characteristics of the particular development, the potential on-site and off-site environmental impacts, the sensitivity of the environment likely to be affected, and the level of certainty associated with the proposed mitigation strategy. Draft DoE guidance on the Preparation of an Acid Sulfate Soil Management Plan is available on the DoE's website www.environ.wa.gov.au.

2.7 ASS and the land use planning process

The WAPC has developed a draft Planning Bulletin on ASS (No. X). The purpose of the Planning Bulletin is to provide advice and guidance on matters that should be considered in the rezoning, subdivision and development of ASS risk areas. The draft Planning Bulletin is available on DEP's website www.environ.wa.gov.au

2.8 Works that may not require planning, environmental or government agency approval

Some excavation, drainage and dewatering works may not be subject to environmental impact assessment and approval processes. It is nonetheless very important that these works are well managed to avoid disturbance of ASS in areas at risk.

Works that may be in this category include:

- Road works, drainage works and works in public open space, by local authorities;
- Works by public authorities in regional reserves;
- Works for main roads and railways;
- Works for sub-surface infrastructure, e.g. for gas, water, effluent disposal, oil, power and telecommunication services;
- Agricultural developments, e.g. drainage works; and
- Bore water extraction in areas that do not require a licence.

3. Referral to the EPA

3.1 Referral of a proposal to the EPA under Part IV of the *Environmental Protection Act 1986*

Under section 38(1) of the EP Act, a proposal that appears likely, if implemented, to have a significant effect on the environment, or a proposal of a prescribed class, shall be referred by a decision-making authority, and may be referred by the proponent or a third party, to the EPA for assessment. The *Environmental Impact Assessment Administrative Procedures 2002* (Administrative Procedures) (Government of WA 2002) sets out the procedures adopted by the EPA in dealing with the referral and assessment of proposals and includes an explanation of environmental significance (section 4.1.2 of the Administrative Procedures) and the responsibilities of proponents and decision-making authorities.

Correlating to this, a proposal associated with minor potential environmental impacts, or with impacts that can be managed under Part V of the EP Act or other approval processes, is unlikely to require referral to the EPA.

Proposals that are likely to require referral to the EPA under Part IV of the EP Act include those where ASS drainage may directly or indirectly affect:

- Native vegetation areas of high conservation value;
- Significant wetlands;
- Waterways;
- Groundwater regimes that support natural features of high conservation value;
- Groundwater regimes that are used for public drinking water supply or other significant use;
- Any other environments eg marine environment, with high conservation value; and
- Human health, activities and amenity (where impacts may be significant).

3.2 Formal assessment of a scheme or proposal

The EPA makes a decision on whether or not to assess a proposal or scheme based on the information in the referral and any additional information it has obtained from the proponent, relevant government agencies or interest groups. The EPA may decide not to assess a proposal or scheme because the environmental impact is minor, or there is sufficient control under Part V of the Act or other approval processes . Where the EPA decides not to assess a proposal or scheme, the EPA nevertheless expects the proponent and relevant agencies to ensure that appropriate measures are taken to minimise environmental impacts. Depending on the circumstances, the EPA may provide public advice indicating what action should be taken to address environmental issues.

Where the EPA decides that a proposal or scheme will be assessed, the EPA will determine that one of the levels of assessment outlined in clause 5 of the Administrative Procedures will apply to the proposal. These are:

- Assessment on Referral information;
- Proposal Unlikely to be Environmentally Acceptable;
- Environmental Protection Statement;
- Public Environmental Review; and
- Environmental Review and Management Programme.

3.3 Information required at the time of referral

Where ASS is a factor in a scheme or proposal referred to the EPA, information that may assist the EPA to set an appropriate level of assessment on the referral, includes:

- The results of any desktop and onsite field tests, or laboratory tests that indicate the likelihood of ASS;
- Any further investigations that the proponent expects to carry out;
- The potential impacts on the physical environment and biota, and human health and activities;
- The proposed management strategies and measures to avoid or minimise adverse impacts on the environment and human health and activities;
- Advice on any consultation carried out with stakeholders, government agencies, experts and the community; and
- The statutory approvals required before the proposal may be implemented.

4. References and sources of information on ASS

4.1 Australia (national) and overseas

Dent, D and Dawson, B *The acid test: An expert system for acid sulfate soils.* Loughborough University, England. http://www-staff.lboro.ac.uk/~cobrd/identman.pdf
(A relatively easy to use methodology for identifying the likelihood of ASS by using site evidence)

Sammut, Jesmond 2000 *An introduction to acid sulfate soils.* National Heritage Trust, Australia. http://www.ea.gov.au/coasts/programs/cassp/booklet.html
(Introductory information on how ASS formed naturally in Australia, and their serious impacts)

National Working Party on Acid Sulfate Soils, on behalf of the Agriculture and Resource Management Council of Australia and New Zealand, the Australia and New Zealand Environment and Conservation Council and the Ministerial Council Forestry Fisheries and Aquaculture 2000 *National Strategy for the Management of Coastal Acid Sulfate Soils*. NSW Agriculture, Wollongbar, NSW.
http://www.affa.gov.au/docs/operating_environment/armcanz/pubsinfo/ass/ass.html
(The National Strategy includes a recommended reading list)

http://www.ea.gov.au/coasts/programs/cassp
(Environment Australia's ASS website, with links to other websites)

Fitzpatrick, RW, Merry, RH, Williams, J, White, I and Taylor, G 1998 *Acid Sulfate Soil Assessment: Coastal, Inland and Minespoil Condition.* National Land and Water Resources Audit Methods paper.

4.2 Queensland

http://www.dnr.qld.gov.au/resourcenet/fact_sheets
(Useful information on the issue in Queensland)

Ahern, CR, Ahern, MR and Powell, B 1998 *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland.* Queensland Acid Sulfate Soils Investigation Team, Department of Natural Resources, Resource Sciences Centre, Indooroopilly, Queensland http://www.nrm.qld.gov.au/resourcenet/land/landplan/lp-ass/ass-guidelines.pdf
(The sampling and chemical analysis methods set out in the above guidelines as established by the Queensland Department of Natural Resources are the de facto national standards)

Dear, SE, Moore, NG, Dobos, SK, Watling, KM and Ahern, CR 2002 , Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines.
(The guidelines are written from a risk management perspective. It is not a regulatory or policy document but an aid for stakeholders on ASS management issues)

Queensland Government 2002 *State Planning Policy 2/02: Planning and managing development involving acid sulfate soils.* Department of Communication and Information, Local Government, Planning and Sport, Department of Natural Resources, Queensland.

4.3 New South Wales

Stone, Y, Ahern, CR and Blunden, B 1998 *Acid Sulfate Soil Manual*. Acid Sulfate Soil Management Advisory Committee, Wollongbar, NSW.
(A comprehensive manual with guidelines for planning, management, laboratory methods, drainage, groundwater, management plans and industry)

Woodhead, A, Jenkins, A and Wood, M 2000 *Acid sulfate soils: Keys to success.* Acid Sulfate Soil Management Advisory Committee and NSW Agriculture, NSW.
(A user friendly book for people who want to identify ASS in NSW)

http://www.agric.nsw.gov.au
(search on ASS)

4.4 Victoria

EPA August 1999 *Acid Sulfate Soil and Rock* EPA Information Bulletin Publication 655, Victoria.

4.5 Western Australia

Environmental Protection Authority 1999 *Derby Tidal Power Project: Derby Hydro Power Pty Ltd: Report and Recommendations of the Environmental Protection Authority.* Bulletin 942, June 1999, Environmental Protection Authority, Perth, Western Australia.

Government of Western Australia 2002 *Focus on the Future: The Western Australian State Sustainability Strategy Consultation Draft*. Department of the Premier and Cabinet, Perth, Western Australia.

Government of Western Australia 2002 *Environmental Impact Assessment (Part IV Division 1) Administrative Procedures 2002*. Procedures pursuant to the *Environmental Protection Act 1986* published in the Western Australian Government Gazette No. 26, 8 February 2002, Government Printer, Perth, Western Australia.

Weber, Paul *Acid Sulfate Soils in Western Australia – An Introduction*. Research Paper, Ian Wark Research Institute, University of South Australia, Adelaide.

Water and Rivers Commission, Department of Environmental Protection and Department of Agriculture Western Australia December 1999 *Acid sulfate soils in coastal Western Australia*. Unpublished Brochure, Perth, Western Australia.

5. Glossary

Acid sulfate soils (ASS)
Soil or sediment containing iron sulfides or highly acidic horizons or layers.

Actual acid sulfate soils (AASS)
Soil or sediment containing highly acidic soil horizons or layers affected by the oxidation of iron sulfides, primarily pyrite. This oxidation produces hydrogen ions in excess of the sediment's capacity to neutralise the acidity, resulting in soils of pH 4 or less. These soils can usually be identified by the presence of jarosite.

Potential acid sulfate soils (PASS)
Soil or sediment containing iron sulfides or sulfidic material that have not been exposed to air and oxidised. The field pH of these soils in their undisturbed state is pH 4 or more, and may be neutral or slightly alkaline.

Note: The term acid sulfate soil generally includes actual and potential acid sulfate soils. Actual and potential acid sulfate soils are often found in the same soil profile, with actual acid sulfate soils generally overlying potential acid sulfate soil horizons.

Anaerobic conditions
Conditions whereby air (oxygen) is excluded, usually by waterlogging.

Acid sulfate soils risk map
Risk map units have been classified on the basis of the geomorphological and hydrological properties of the relevance to the formation of acid sulfate soils, including the depth to groundwater and height above sea level in Australian Height Datum.

Dewatering
The deliberate pumping siphoning, draining or other diversion of waters to render a site or area dry.

Estuary (Estuarine)
Numerous definitions have been given for estuaries. The standard definition for an estuary only describes the interaction between river and marine currents ' …a widened mouth of a river valley where freshwater intermixes with seawater and where tidal effects occur' (Lapidus 1990).

Extracting groundwater
Includes drainage, pumping or otherwise removing groundwater.

Groundwater
Subsurface water in the zone of saturation, including water below the watertable and water occupying cavities, pores and openings in underlying soil and rock.

Jarosite
An acidic pale yellow iron sulfate mineral: KFe3(SO4)2(OH)6. Jarosite is a by-product of the acid sulfate soil oxidation process, formed at pH less than 3.7; commonly found precipitated along root channels and other soil surfaces exposed to air.

Oxidised
Process of chemical change involving the addition of oxygen following exposure to air.
pH: a measure of the acidity of alkalinity of a soil of water body on a logarithmic scale of 0 to 14; a pH <7 is acid, pH 7 is neutral, and pH >7 is alkaline. Note that one unit change in pH is a tenfold change in acidity.

Pyrite
Pale-bronze or brass-yellow, isometric mineral: FeS2; the most widespread and abundant of the sulfide minerals.

Soil and sediment
The natural accumulation of unconsolidated mineral particles (derived from weathered rocks) and organic matter that covers much of the earth's surface. The chemical and physical composition varies greatly between soil and sediment types. Clays, silts, sands, gravels, peats, muds and indurated sands (e.g. 'coffee rock') are all examples of soil and sediment.

Waters
Includes river, stream, lake, lagoon, pond, swamp, wetland, unconfined surface water, unconfined water natural or artificial watercourse, bed and bank of any waters, dams, non-tidal or tidal waters (including the sea), stormwater channel, stormwater drain, roadside gutter, stormwater run-off, and any under groundwater, any part-thereof.

Appendix 1: Checklist for the identification of works that may disturb acid sulfate soils in Western Australia

It is recommended that works be judged as 'works in an area where there is a risk of disturbing acid sulfate soils' if at least one 'yes' is ticked in each of Parts A and B of the following table. If works are so identified, the flowchart at Appendix 2 should be referred to for suggested procedures.

PART A

Are the proposed works in any of the following areas?	**YES**	**NO**
ASS risk areas (identified by DoE and other government agency mapping or ASS risk mapping).		
Areas identified as Holocene swamp, tidal and estuarine deposits, marshes and floodplains (Environmental Geology maps published by the DIR)		
Geologically recent and shallow tidal, estuarine, marine, wetland, floodplain or waterlogged areas where deposition of fine sediments may have occurred or may be occurring, or mangroves or wetland dependant vegetation such as reeds and paperbarks (Land System and Soil-Landscape System mapping by Ag WA; soil, geology or geomorphology mapping; and vegetation mapping)		
Areas bearing sulfide minerals such as former marine or estuarine shales and sediments, mineral sand deposits (as identified in geological descriptions or in maps)		
Any area, particularly coastal, where the following pre-disposing factors exist: • Peat or a build up of organic material;		
• Near bores, where bore stratigraphy records may indicate peat or other organic deposits (DoE, Local Government, DIR);		
• Permanently inundated wetlands;		
• Seasonally or occasionally saturated or inundated floodplains and sumplands;		
• Mangrove areas;		
• Tidal swamps, wetlands and shallow estuarine areas receiving alluvium;		
• Artificial lakes excavated in peaty material;		
• Sites which may contain carbonaceous or pyritic material, such as fill, municipal waste, food industry waste, mining and metal waste, animal waste and industrial sites,		
• High water table (within 3 metres of the surface);		
• pH of soil or water less than 5; • Rising saline groundwater containing sulphides or sulphates; • Proximity to mining operations.		
Any areas where field tests, visual signs and other methodologies indicate that there is a likelihood of ASS (see section 4: Dent & Dawson; Woodhead *et al*). Visual indicators of ASS include;		
• Swamp/wetland vegetation, such as rushes and melaleucas;		
• Surface waters that are crystal clear (indicates soluble aluminium at pH 3-4), blue-green (indicates aluminium floc at pH 4-5), milky-white (indicates high aluminium at pH 5-6), yellow-brown (indicates dissolved iron at pH below 3.8) or contain red/brown or brown/yellow floc (indicates iron at pH less than 4);		
• Soils that are gooey black, or grey to greeny/bluish grey (PASS);		
• Silty black organic oozes (indicates iron monosulfides);		
• Soils that display red/orange mottling, straw yellow blotches or have a rotten egg gas odour (AASS); or		
• Soil surfaces displaying salt crusts or scalds (bare patches).		
Works proposed within approximately 500 metres of any of the above will require the lowering of the water table		

PART B

Do the proposed works involve any of the following disturbances?	**Yes**	**No**
Ground disturbing works in or near an area of high conservation significance (eg conservation category wetland), or affecting the drainage of an area of high conservation significance (via surface water or groundwater)		
Excavation of more than 100 cubic metres of material and the excavation depth is more than 2 metres below natural ground surface		
Temporary or permanent lowering of the groundwater table, e.g. dewatering, drainage works, or pumping		
Filling, where there is the potential for the fill to compact saturated soils or sediments and/or laterally displace previously saturated sediments, resulting in groundwater extrusion and aeration of ASS		

Appendix 2: Suggested procedures for works and development projects where acid sulfate soils may be disturbed