Guidelines for the Management of Acid Sulfate Materials:

Acid Sulfate Soils, Acid Sulfate Rock and Monosulfidic Black Ooze

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Note: This document supersedes the RTA's Acid Sulphate Soil: Policy and Procedures 1995; and Acid Sulphate Soil: Guidelines 1996.

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Amendment Register

This is Version 1 of the RTA's Guidelines for the Management of Acid Sulfate Materials: Acid Sulfate Soils, Acid Sulfate Rock and Monosulfidic Black Ooze.

To ensure that your copy of this guideline remains current, check the amendments register regularly on the RTA internet site.

The RTA has not published hard copies of this guideline. Any printed copies of this guideline are uncontrolled.

Amendment Number	Amendments		Comments	Date
	Chapter number	Page Number		
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The RTA would like to thank the people who provided comment during the review of the document.

Foreword

The RTA is committed to improving its management systems to achieve sustainable environmental outcomes for road development, construction and asset management. The *Guidelines for the Management of Acid Sulfate Materials: Acid Sulfate Soils, Acid Sulfate Rock and Monosulfidic Black Ooze* provide procedures for the environmental impact assessment, identification, investigation and management of Acid Sulfate Materials.

I commend these guidelines for use by all RTA staff, contractors and consultants.

Paul Forward
Chief Executive

TABLE OF CONTENTS

Introduction 1

Who needs to use this Guideline 3

When to use this Guideline 3

Structure of the Document 4

Part 1: Management Context 4

Part 2: Management of ASM 5

Part 3: Technical References 5

Technical Support 5

PART 1

1.0 RTA ASM Management Aim 7

2.0 Management System Context of this Guideline 7

3.0 Statutory and Policy Context 8

4.0 Acid Sulfate Materials and Acid Sulfate impacts on the Environment and Structures 8

4.1 Acid Sulfate Soils 8

4.1.1 Inland Acid Sulfate Soils 8

4.1.2 Other Coastal Acid Soils that are not Acid Sulfate 9

4.2 Monosulfidic Black Ooze 9

4.3 Acid Sulfate Rock 10

5.0 How does the presence of ASM affect the RTA's environmental performance? 11

PART 2

6.0 Management Principles 13

7.0 RTA ASM Procedures 14

7.1 Acid Sulfate Material Procedure No. 1: Identification of Acid Sulfate Material 18

7.2 Acid Sulfate Material Procedure No. 2: Environmental Impact Assessment. 27

7.3 Acid Sulfate Material Procedure No. 3: ASM Management Planning Process 32

7.4 Acid Sulfate Material Procedure No. 4: Selection of ASM Controls 38

PART 3

8.0 Glossary.. 49

9.0 References.. 54

APPENDICES

1 National Water Quality Management Strategy - Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)

2 Summary of Policies and Statutes affecting RTA activities in ASM areas

3 Impacts of Acid Sulfate Materials

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Introduction

This Guideline addresses the management of Acid Sulfate Soil (ASS), Acid Sulfate Rock (ASR) and Monosulfidic Black Ooze (MBO), jointly described as Acid Sulfate Materials (ASM). The Guideline updates and replaces the RTA's *Acid Sulphate Soil Policies and Procedures* (1995) and *Acid Sulphate Soil Guidelines* (1996).

This Guideline is intended for use by RTA personnel, project consultants and contractors in conjunction with the NSW *Acid Sulfate Soil Manual* (ASSMAC 1998). The ASSMAC Manual is the overriding ASM management guideline in New South Wales. This Guideline applies information contained in the ASSMAC Manual specifically to RTA activities and management processes. The ASSMAC Manual contains additional guidance for issues such as laboratory methods, drainage, groundwater, and advice to industry that have not been covered in detail within this Guideline.

The National Strategy for the Management of Coastal Acid Sulfate Soils (1999) provides a definition for ASS that is repeated in most other ASS management publications:

> *"Acid Sulfate Soil" is the common name given to naturally occurring soil and sediment containing iron sulfides, principally the mineral iron pyrite, or containing acidic products of the oxidation of sulfides. When sulfides are exposed to air, oxidation takes place and sulfuric acid is ultimately produced when the soil's capacity to neutralize the acidity is exceeded. As long as the sulfide soils remain under the water table, oxidation cannot occur and the soils are quite harmless and can remain so indefinitely."*

Although ASS is concentrated in coastal environments, there is potential for other ASM to have widespread distribution in the landscape. If disturbed, all forms of ASM can cause unacceptable environmental impacts, including acidification of waterways, major fish kills, habitat destruction, loss of agricultural productivity, geotechnical instability and corrosion of concrete and steel structures.

The RTA is committed to best practice environmental management in all its activities. The recognition and sustainable management of ASM during road planning, construction and maintenance is an important element of the RTA's procedures to achieve and maintain its position as a sound environmental manager.

Table 1 summarises the nature, distribution and potential impacts of ASM. Additional information is provided in **Sections 4.0** and **5.0**.

Table 1 - Characteristics of ASM

Material	Distribution	Potential impacts
ASS and Potential Acid Sulfate Soils (PASS)	Widespread in estuaries and coastal floodplains, backswamps and coastal wetlands. Inland ASS is rarer and may occur in combination with ASR and in soils derived from former marine sediments.	Discharges of very low pH (acidic) waters, biochemical barriers, fish kills, loss of habitat (scalding), loss of agricultural productivity, structural and engineering issues.
ASR	Potentially in all sedimentary, metamorphic and igneous rock types associated with higher risk metalliferous ores, coal and sulfate/sulfide minerals.	Leachate affects concrete structures, road surfaces and road railings, potential destabilisation of fill. Potential habitat impacts.
Monosulfides and MBO	Drains and waterways in acid sulfate areas, saline areas (coastal, inland and urban).	Rapid deoxygenation and acidification of waters, elevated release of heavy metals. Fish (and other fauna) kills.

The Guideline has been prepared in consultation with RTA project management, technology and environmental personnel, to ensure that it takes into consideration the RTA's extensive recent experience in the management of road construction and maintenance projects in areas affected by ASS and ASR.

Who needs to use this Guideline

The Guideline is relevant to both road construction projects and road maintenance projects that are part of the RTA's responsibility.

This guideline is intended for use by:

- RTA project managers and construction staff under their supervision;
- RTA environmental advisors and environmental officers who provide scientific and environmental advice to project managers;
- RTA geotechnical engineers, design engineers and project engineers, responsible for the assessment of potential road routes, construction methods, construction materials and maintenance procedures; and
- Professional service contractors to the RTA.

RTA project managers should also require that project consultants and contractors document and implement these procedures when carrying out projects in ASS or ASR risk areas. This requirement is to be incorporated into each contract.

When to use this Guideline

This guideline should be used for all projects where there is potential to disturb ASM (ASS, sediments, MBO or ASR).

The types of activities that may disturb or be affected by these materials include:

- excavation of cuttings exposing ASR;
- unintentional use of excavated ASR as fill material or for other road making purposes;
- excavation in coastal floodplain and wetland areas. Excavation includes minor disturbance of soil for installation of signs and traffic signals, through to major earthworks;
- building embankments across low strength swamp sediments;
- dredging of coastal rivers (estuarine reaches) for roadmaking materials;
- sinking bridge and roadworks piles;
- importing materials for fill from areas of potential ASS;
- lowering the water table by installing subsoil drains, deepening table drains or pumping water out of excavations in ASS areas. This is unlikely to have a significant impact on ASR;
- raising the water table by filling in drains;
- directing additional runoff onto adjacent properties so that enhanced drainage is required; and
- maintenance activities as identified in *RTA QA Specification G34 Environmental Protection Works (Management Plan), Annexure 3A – Road Maintenance Environmental Safeguard Matrix* including the maintenance of road verges, road pavement and safety rails etc in ASS and ASR areas.

Structure of the Document

The RTA ASM Guideline contains three parts:

- Part 1: Management Context;
- Part 2: Management of ASM; and
- Part 3: Glossary and Technical References.

Part 1: Management Context

Part 1 shows how this Guideline relates to the RTA's environmental management system, including the RTA Environmental Policy and environmental management planning processes. **Part 1** also includes the statutory and policy context of ASM management and introductory technical information about ASM and the risks they present to the environment.

Part 2: Management of ASM

Part 2 contains the procedural guidance on managing ASM. This includes guidance on the identification of ASM, environmental impact assessment, development of controls and treatments and ASM management planning. The ASM management requirements within each stage have been identified as a series of clear steps which indicate the extent of investigation, analysis and management controls that are necessary for effective management of ASM issues of all scales. The procedures reference relevant technical information such as the Acid Sulphate Soil Management Advisory Committee (ASSMAC) Manual and the Queensland Acid Sulfate Soils Investigation Team (QASSIT) Manual as necessary.

Part 3: Technical References

Part 3 contains a glossary of terms used in the assessment and management of Acid Sulfate Soil and rock materials. **Part 3** also contains a full list of technical references which are either directly referred to in **Parts 1** and **2** of the Guideline or are additional references which provide further information on ASS management.

Technical Support

This document is not principally a technical reference on the nature of ASS, ASR and MBO. Excellent technical information can be sourced in several State agency publications. Key technical references are:

- Acid Sulfate Soils Management Advisory Committee (ASSMAC) 1998. Ahern C R, Blunden B and Stone Y (eds). NSW Acid Sulfate Soil Manual;

- NSW Acid Sulfate Soil risk maps and Acid Sulfate Soil planning maps are available from the Department of Infrastructure, Planning and Natural Resources;

- Queensland Acid Sulfate Soils Investigation Team (QASSIT), Department of Natural Resources, Resources Sciences Centre, Indooroopilly – Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland. Ahern C R, Ahern M R and Powell B (1998a); and

- QASSIT – Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines Version 3.8 (2002) Authors: S E Dear, N G Moore, S K Dobbs, K M Watling and C R Ahern.

The ASSMAC Manual was released in 1998 and is currently under consideration for review by NSW Department of Infrastructure, Planning and Natural Resources (DIPNR). The Queensland (QASSIT) Guidelines provide the most up-to-date manual at the national level, and where there is any difference, the Queensland Guideline is referred to in these procedures rather than the NSW (ASSMAC) Manual. It is anticipated that the review of the ASSMAC Manual will result in full consistency between the two documents.

References to the current best technical information and to research that underpin current best practice are provided throughout the Guideline and summarised in **Part 3** of the Guideline.

This guideline will be reviewed and updated to take into account of new legislative requirements and technical references as they emerge.

PART 1

Management Context

1.0 RTA ASM Management Aim

The RTA's broad objective for the management of ASM during all aspects of its road network activities is noted below.

> *The RTA will use best practical environmental procedures for its road network activities which involve potential acid sulfate environments or pyritic materials from these environments.*
>
> *Activities in acid sulfate or pyritic environments will be managed in a manner that minimises adverse impacts on the environment, achieves relevant water and sediment quality objectives and meets community expectations.*

Definitions of Terms in the Policy:

Best practice environmental procedures means procedures that refer to and are consistent with the most recent policy and technical advice adopted by State agencies in Australia.

Water quality and sediment quality objectives refer to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000). Relevant objectives are noted in **Appendix 1**.

Minimise adverse impacts on the environment means that the RTA will use due diligence to ensure that its activities are conducted in accordance with best practice procedures and national environmental standards.

Meet community expectations refers to commitments made to the community during consultation about projects and/or referred to in consent conditions for road construction and maintenance projects. This may include water quality outcomes and ongoing information or consultation outcomes. Where no specific commitments to the community have been made, or consent conditions issued, the minimum requirement is to meet the commitments of our Environmental Policy.

2.0 Management System Context of this Guideline

This ASM Guideline is part of the RTA's Environmental Management System. The ASM policy and procedures are part of the material developed at the corporate level to drive environmental protection measures at the directorate and business area level.

The use of the Guideline by project managers and others involved in road construction and maintenance will underpin the RTA's demonstration of due diligence and the adoption of best management practice in relation to ASM.

The Guideline provides step-by-step procedures for the identification and management of risks associated with the presence of ASM in project areas. Understanding and familiarity with these procedures will contribute to the prevention of incidents such as increased acid leachate from RTA construction and maintenance projects.

3.0 Statutory and Policy Context

Numerous pieces of State and Federal legislation, as well as a number of environmental policies and strategies, must be taken into consideration when planning and implementing works in acid sulfate areas. A full list of current relevant legislation and policy, together with brief notes on how they apply to the RTA's management of ASS, is provided in **Appendix 2**.

4.0 Acid Sulfate Materials and Acid Sulfate impacts on the Environment and Structures

This section presents basic technical information about ASS, ASR and MBO. Technical references are presented in **Part 3**.

4.1 Acid Sulfate Soils

ASS include "**Actual ASS**" and "**Potential ASS**" and both types may be found in one soil profile.

Actual ASS are soils containing highly acidic soil horizons or layers, resulting from the oxidation of soil materials that are rich in iron sulfides. This oxidation produces hydrogen ions in excess of the sediment's capacity to neutralise the acidity, resulting in soils of pH of 4 or less when measured in dry season conditions. These soils can usually be recognised by the presence of pale yellow mottles and coatings of jarosite.

Potential ASS are soils which contain iron sulfides or sulfidic material which has not been exposed to air and oxidised. The field pH of these soils in their undisturbed state is usually 4 or more (and may be neutral or even slightly alkaline).

ASS occurs predominantly on coastal lowlands, with elevations generally below 5 m Australian Height Datum (AHD). The NSW ASSMAC Manual notes that ASS are generally associated with the Holocene age (last 10,000 years) sediments deposited in specific conditions such as within mangrove areas, saltmarsh, floodplain backswamps, coastal flats, seasonal or permanent freshwater swamps that were once saline or brackish and open tidal waters such as the beds of coastal rivers or lakes.

In NSW, maps of ASS distribution in the coastal zone were prepared by the then Department of Land and Water Conservation in 1998. NSW has approximately 4000 square kilometres of ASS, with incidences reported from every estuary along the coast.

Apart from acidification of pasture and waterways, the environmental consequences of drainage of ASS include discharge of waters with elevated concentrations of aluminium, iron and zinc. Hicks *et al* (2002) also report significant emissions of greenhouse gases such as carbon dioxide and nitrogen dioxide from wetland drainage.

4.1.1 Inland Acid Sulfate Soils

Although ASS generally occur in and around estuarine floodplains in the coastal zone, they can also occur in inland environments. These "**Inland Acid Sulfate**

Soils" have been described in studies by CSIRO, NSW DLWC and Southern Cross University. Inland ASS has been reported from locations in NSW (around Yass), Victoria, Western Australia and the Eyre Peninsula in South Australia (see Fitzpatrick Fritsch and Self 1996 and Fitzpatrick, Hudnall, Self and Naidu 1993). CSIRO suggests two possible origins for these pyrite rich sediments. Some areas have been marine sediments in the geological past, some may be from deposition of wind blown sediment containing pyrite, and some may come from groundwater contact with primary pyrite in the underlying geological strata (see **Section 4.3** for information about ASR). Heavy metals in concentrations that are toxic to plants and animals may be released when these sediments are oxidised.

In Western Australia, some peaty deposits associated with groundwater dependent wetlands (eg. on the Swan Coastal plain) are locally very sulfidic. They also contain high levels of arsenic and other heavy metals. pH values as low as 2.4 have been reported in groundwater down gradient from wetlands where these peat deposits have been drained.

4.1.2 Other Coastal Acid Soils that are not Acid Sulfate

Acidic soil and water conditions can occur in soils that do not contain iron sulfide sediments, but do contain organic acids (such as humic acid). The field pH of these soils is often 4-4.5, but they do not have the capacity to generate additional acidity due to oxidation.

4.2 Monosulfidic Black Ooze

Monosulfides are also known as acid volatile sulfur (ie. they release hydrogen sulfide when in contact with strong acid) and are also often characterised by high concentrations of heavy metals.

Sullivan and Bush (2002) describe MBO as follows (p 14):

> *"Monosulfidic Black Ooze (MBO) are gels (moisture contents usually >70%), black, often oily in appearance, greatly enriched in monosulfide (ie up to 27% compared to a maximum of 1% for estuarine sediments), high in organic matter (usually >10% organic carbon) and can form thick (ie >1 m accumulations in waterways (eg drains) within ASS landscapes… MBOs are easily mobilised during runoff events and can be distributed into rivers or if flooding occurs, distributed over surrounding landscapes… They have the capability to cause both severe acidification and/or severe deoxygenation of flood waters."*

The formation of MBO needs a combination of acid sulfate runoff, carbon (eg from plants) and a low flow environment. This combination explains why they tend to be commonly found in drains in coastal ASS areas. Backwater areas that are periodically inundated by salt water are particularly prone to MBO accumulation. MBO can also form in inland areas where salinisation is occurring.

MBO has been identified in the Macquarie Marshes wetlands, as well as in drains in inland areas affected by salinity (eg. Griffith, Cohuna, Waikerie). Recent work by Sullivan, Bush and Ward (Southern Cross University, reported in the University News) has revealed substantial changes to the ecology of freshwater systems, particularly in irrigated landscapes, due to sulfate salinisation. In the widespread areas where sulfate salinisation is occurring, sulfides occur as monosulfidic ooze, and as accumulation of monosulfide and pyrite. These monosulfidic sediments have the same acidification and deoxygenation potential as those associated with estuarine waterways.

An important distinction between MBO and other ASM is that MBO may continue to form in drains, even after treatment, if conditions are favourable. This means that the presence of MBO presents an ongoing management and maintenance risk that may extend well beyond the road construction period.

4.3 Acid Sulfate Rock

ASR includes diverse lithologies that contain sulfide and sulfate minerals. Although the concentration of sulfide/sulfate minerals in most rocks is relatively low, elevated concentrations are associated with most ore deposits (metalliferous and coal).

Geologists, engineers and environmental managers working in the mining industry have been aware for many years of the association of metalliferous ores and coal with concentrations of sulfate and sulfide minerals. Acid generation from mine wastes is a major environmental management issue for most sectors of the mining industry.

More recently it has become apparent that the wider distribution of metal sulfide and sulfate minerals in geological units across the landscape also has potential to affect the environmental performance and structural integrity of other types of earthworks and construction. For instance, a high pyritic content is documented in sandstones in the lower part of the Sydney Basin (Permian units).

ASR has only recently been identified as an issue during road construction projects in south eastern Australia. One of the factors contributing to the emergence of the issue is changing road design and scale of excavation or filling earthworks. For example, to maintain multi lane roads at low gradients, very deep cuttings may be required in steep terrain. This means that cuttings may intersect rock (in cuttings and as fill) that has previously been protected below the water table, so that opportunities for the oxidation of pyrite occur due to the road project.

Reid et al (2001) provide an overview of the management risks associated with the presence of both sulfide and sulfate minerals in rocks that are disturbed during construction:

> *"Sulfur compounds occur in a number of different forms in natural and artificial materials. In the reduced form, they occur as sulfides such as pyrite in a wide range of rocks and soils and less commonly as mineral ores of lead (galena), zinc (sphalerite) and other metals. These minerals generally have very low solubility and are not in themselves a hazard to construction materials. However, weathering of reduced sulfur species leads to the production of soluble sulfate minerals which may cause attack of construction materials. Weathering also often leads to an increase in acidity, which besides increasing the solubility of sulfates may also be involved in the corrosion of construction materials."*

> *"However, much higher concentrations of sulfate can occur under acid conditions, or where unweathered materials with sulfides or soluble sulfate minerals are excavated and placed in spoil tips (as with mining waste) or used as structural backfills in civil engineering works. In both cases, the free*

access of air and water to the materials allows rapid oxidation of sulfide minerals and leaching of sulfates. This can lead to corrosion of construction materials and the production of leachate, which can pollute surface waters and groundwaters."

5.0 How does the presence of ASM affect the RTA's environmental performance?

The presence of these materials indicates potential risks to surface and groundwater quality, soil strength and stability, habitat character and agricultural productivity on adjoining lands. The presence of ASS or other sulfidic materials also presents design and materials challenges such as the selection of appropriate steel and concrete for acid risk environments, and the development of maintenance schedules for infrastructure in acid sulfate environments.

A range of impacts associated with disturbance and oxidation of ASM (drawn principally from the literature on ASS) appears in **Appendix 3**. These include:

- Aquatic and wetland/ terrestrial ecosystem impacts;
- Release of heavy metals from contaminated soils;
- Human and animal health;
- Corrosion and structural damage to steel and concrete structures;
- Soil structure and subsidence;
- Soil erosion, clogging of aquifers and subsoil drains; and
- Other impacts, issues and risks.

PART 2

Management of Acid Sulfate Materials

6.0 Management Principles

The *Queensland Acid Sulfate Soil Technical Manual, Soil Management Guidelines* (2002) provides a set of eight key management principles for dealing with ASS situations. These are noted in **Table 6.1**. These management principles are noted where relevant to each of the ASM management procedures in **Section 7**.

Table 6.1 – Eight Key Management Principles for Dealing with ASS Situations

1.	The disturbance of ASS should be avoided wherever possible.
2.	Where disturbance of ASS is unavoidable, preferred management strategies are: - Minimisation of disturbance; - Neutralisation; - Hydraulic separation of sulfides either on its own or in conjunction with dredging; and - Strategic reburial (reinterment). Other management measures may be considered but must not pose unacceptably high risks.
3.	Works should only be performed when it has been demonstrated that the potential impacts of works involving ASS are manageable to ensure that the potential short and long term environmental impacts are minimised.
4.	The material being disturbed (including *in situ* ASS) and any potentially contaminated waters associated with ASS disturbance, must be considered in developing a management plan for ASS and/or complying with general environmental due diligence.
5.	Receiving marine, estuarine, fresh or brackish waters are not to be used as a primary means of diluting and/or neutralising ASS or associated contaminated waters.
6.	Management of disturbed ASS is to occur if the ASS Action criteria (noted in Attachment 1 to ASM Procedure No. 2 of the guidelines) is exceeded or reached.
7.	Stockpiling of untreated ASS above permanent ground water table with (or without) containment is not an acceptable long-term management strategy. For example, soils that are to be stockpiled, disposed of, used as fill, placed as a temporary or permanent cover on land or in waterways, sold or exported off the treatment site or used in earth bunds, that exceed the Action Criteria should be treated or managed (see Attachment 1 to ASM Procedure No. 4).
8.	The following issues should be considered when formulating ASS management strategies: - the sensitivity and environmental values of the receiving environment. This includes the conservation, protected or other relevant status of the receiving environment (eg. Fish Habitat Area, Marine Park, or protected/threatened species); - whether ground waters and/or surface waters are likely to be directly or indirectly affected; - the heterogeneity, geochemical and textural properties of soil on site; and - the management and planning strategies of local government and/or state government, including Regional or Catchment Management Plans/Strategies and State and or Regional Coastal Policies/Plans

ASSMAC 1998 describes a series of ASS mitigation and management strategies that were prepared jointly by NSW and Queensland State agency experts. These have been incorporated into Attachment 1 to ASM Procedure 4.

7.0 RTA ASM Procedures

Five main phases of project planning and implementation are identified in **Table 7.1**. This figure also summarises the steps in ASM management that must be included in each phase, and relevant procedures and reference material for each phase.

The management of ASM by RTA personnel and contractors is required to be in accordance with four procedures which cover the conduct of RTA activities from route selection to operation and maintenance.

- ASM Procedure No. 1: Identification of Acid Sulfate Materials;
- ASM Procedure No. 2: Environmental Impact Assessment;
- ASM Procedure No. 3: ASM Management Planning Process; and
- ASM Procedure No. 4: Selection of ASM Controls.

These procedures are presented in **Sections 7.1** to **7.4**, together with flow charts to show where decisions need to be made and how information feeds back through the procedure. It is important to note that these procedures are not stand-alone processes, but run concurrently and provide input into each other.

An important component of effective ASM management is the communication of technical and management information between each phase of the project planning and implementation.

Note: RTA projects are delivered with different contracting arrangements including Build Own Operate Transfer (BOOT) and Design Construct Maintain (DCM) schemes. Although the responsibility for managing each project phase may vary between projects, the procedures outlined in Part 2 of this Guideline are to apply irrespective of who the responsible party is.

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Table 7.1 - Overview of ASM management steps in road planning and construction

Project Management Life Cycle

Phase 1: Network analysis
Identification and initial, broad "scoping" of proposed project(s)

- Development of overall strategy (route strategy or equivalent)
- → *Route Strategy (or equivalent)*

Phase 2: Option investigation
Selection of preferred route/preferred option

- Initial project-specific studies and consultations (desktop research etc) to identify broad options
- → *Project Development Proposal (or equivalent)*
- Determination of preferred route/ preferred broad option
- → *Preferred Option Report*

Phase 3: Design development and approval
Concept design development and refinement, approvals and preparation of performance requirements for tender documentation

- Initial concept design for preferred option
- → *Initial Concept Design Report*
- Refinement of concept design
- → *Concept Design Report and EIS or REF*
- EIS or REF displayed, design responses to submissions
- → *Planning approval*
- Concept design refinement and finalisation
- → *Final Concept Design Report*

Phase 4: Detailed design and implementation
Detailed design and documentation and project delivery within agreed cost and time limits

- Tendering, detailed design and documentation, and land acquisitions
- → *Detailed design completed*
- Construction
- → *Construction completed*

Phase 5: Handover and operation

- Handover
- → *Project opening*
- Operation and maintenance
- → *Monitoring and review of performance*

ASM Management Steps

Phase 2:

- Preliminary identification of ASM
- Preliminary risk assessment
- Feedback / Consider in project design

Phase 3:

- Review preliminary assessment results and risk analysis from project design stage
- Review project design
- Detailed identification of ASM
- Environmental impact assessment
- Preliminary identification of controls
- Obtain development consent

Phase 4:

- Review EIA, development consent and any other approvals, project design
- Obtain any further relevant licences and approvals
- Detailed design of ASM controls
- Conduct detailed risk assessment
- Identify community consultation requirements for construction stage
- Develop ASM Management Plan
- Communicate / provide Management Plan to contractor
- Conduct required training / communicate ASM Management Plan
- Implement ASM controls / treatments as specified in Management Plan
- Conduct inspections and monitoring and relevant reporting as specified in Management Plan
- Conduct community consultation as required in the Management Plan
- Handover to Road Operation and Maintenance

Phase 5:

- Review Management Plan and other relevant records from construction stage
- Prepare information for inclusion in the Maintenance Plan or the OEMP
- Implement ongoing maintenance requirements as detailed in the Management Plan
- Conduct inspections, audits, monitoring and reporting as detailed in the Management or Maintenance Plan
- Review inspection and monitoring results
- Consider performance/effectiveness of controls/ treatments in past projects in design of future controls

ASM Guideline

- Phase 1: Refer to RTA policy for ASS management throughout its road network
- ASM Procedure 1 (Phase 2 to Phase 4)
- ASM Procedure 2 (Phase 2 to Phase 3)
- ASM Procedure 3 (Phase 4 to Phase 5)
- ASM Procedure 4 (Phase 4 to Phase 5)
- ASM Management Plan (Phase 4 to Phase 5)
- RTA QA G34 / G35 / G36 (Phase 4)
- RTA EIA Guidelines (Phase 3 to Phase 4)
- Community Involvement Practice Notes and Resource Manual (Phase 3 to Phase 4)

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7.1 Acid Sulfate Material Procedure No. 1: Identification of Acid Sulfate Material

Application:

Applies to the identification of Acid Sulfate Material (including Acid Sulfate Soils [ASS], Potential ASS [PASS], Acid Sulfate Rock [ASR] and Monosulfidic Black Ooze [MBO]) during both road network planning (preliminary) and environmental impact assessment phases (detailed) of road infrastructure planning. The procedure is also relevant to the preparation of environmental management plans for both small and large scale works. This procedure applies to all RTA activities undertaken by RTA personnel and/or contractors engaged by the RTA to undertake activities on their behalf.

Management Principles:

Identification of the occurrence of ASM where it may be impacted by proposed works.

Utilise a phased approach to identify and quantify potential risks.

Responsibility:

Project Manager, Road Network Planner, Environmental staff, and geotechnical personnel.

Inputs:

Base data – geochemical information that may help establish the possible presence of ASM.

PROCESS

Actions
Stage 1: Preliminary Identification of ASM (to be undertaken during Options Investigation or Environmental Impact Assessment).
1. Conduct desktop review of available information to identify and document potential ASS risk areas which may include: • Review ASS Risk maps developed by the Department of Land and Water Conservation (1998); • Identify any areas less than 10 m above mean sea level; • Identify any wetland areas; • Determine if the site has alluvial or estuarine sediments; • Vegetation types including mangroves, paperbarks, swamp oak, reeds, rushes or other marine or swamp tolerant vegetation; • Presence of scalded soil surfaces; • Review results of any soil/water/rock testing previously carried out in area; and • Store data for later reference.

Actions
2. Conduct desktop review of available information to identify and document potential ASR risk areas including: • Review geology maps to identify rock types containing metal sulfides or sulfates and coal bearing deposits. In most cases petrological studies will be required to confirm risks associated with ASR; • Identification of ASR is not clear cut. Some geotechnical investigation is required, including drilling and sampling of fresh unoxidised rock; and • Review results of any soil/water/rock testing previously carried out in area (include review of results of any previous testing for RTA projects in the area).
3. Consult relevant agencies (Local Council, NSW Department of Infrastructure, Planning and Natural Resources and the NSW Department of Environment and Conservation) and land owners about their knowledge of ASS and ASR on the subject land.
4. Conduct a field inspection to examine the area for field indicators of ASS or ASR as outlined in Section 4.4 of the RTA ASM Guideline. Note; there is potential for ASR to be overlooked if no fieldwork is undertaken.
5. Document results on a map and accompanying briefing paper showing; • areas assessed, and • known or potential ASS and ASR identified in road network planning study area.
6. If no actual or potential ASS or ASR is identified then no further action is required and results are reported in the environmental impact assessment. If actual or potential ASS or ASR is identified then proceed to Procedure 1 Stage 2.
Stage 2: Detailed Identification of ASS and ASR (to be undertaken during the Design Development and Approval phase). Note; it is recommended that ASM investigations be undertaken at the earliest stage of project development. Detailed identification of ASM could be undertaken post EIA, where the EIA references the potential of ASM and identifies that further investigations are required prior to proceeding with the Proposal.
1. Review Stage 1 results.
2. Establish whether the site to be disturbed is considered minor or major. • Minor – disturbing less than 1000 tonnes of soil, non-linear [spatially confined] and does not affect groundwater – Proceed to Action 3. • Major – disturbing greater 1000 tonnes of soil, linear pattern [not spatially confined] and affects groundwater – Proceed to Action 4.
3. Conduct at site sampling for minor disturbances. • Test substrates to be disturbed in accordance with: - Section 6, Qld Govt., 2002, *State Planning Policy 2/02 Guideline – Planning and Managing Development involving ASS.* For ASR it is important to test unoxidised material.
4. Sampling for all major disturbances to be undertaken by appropriately qualified personnel in accordance with the following guidelines: • ASS – Ahern, C R, Ahern, M R & Powell, B, 1998, *Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland 1998;*

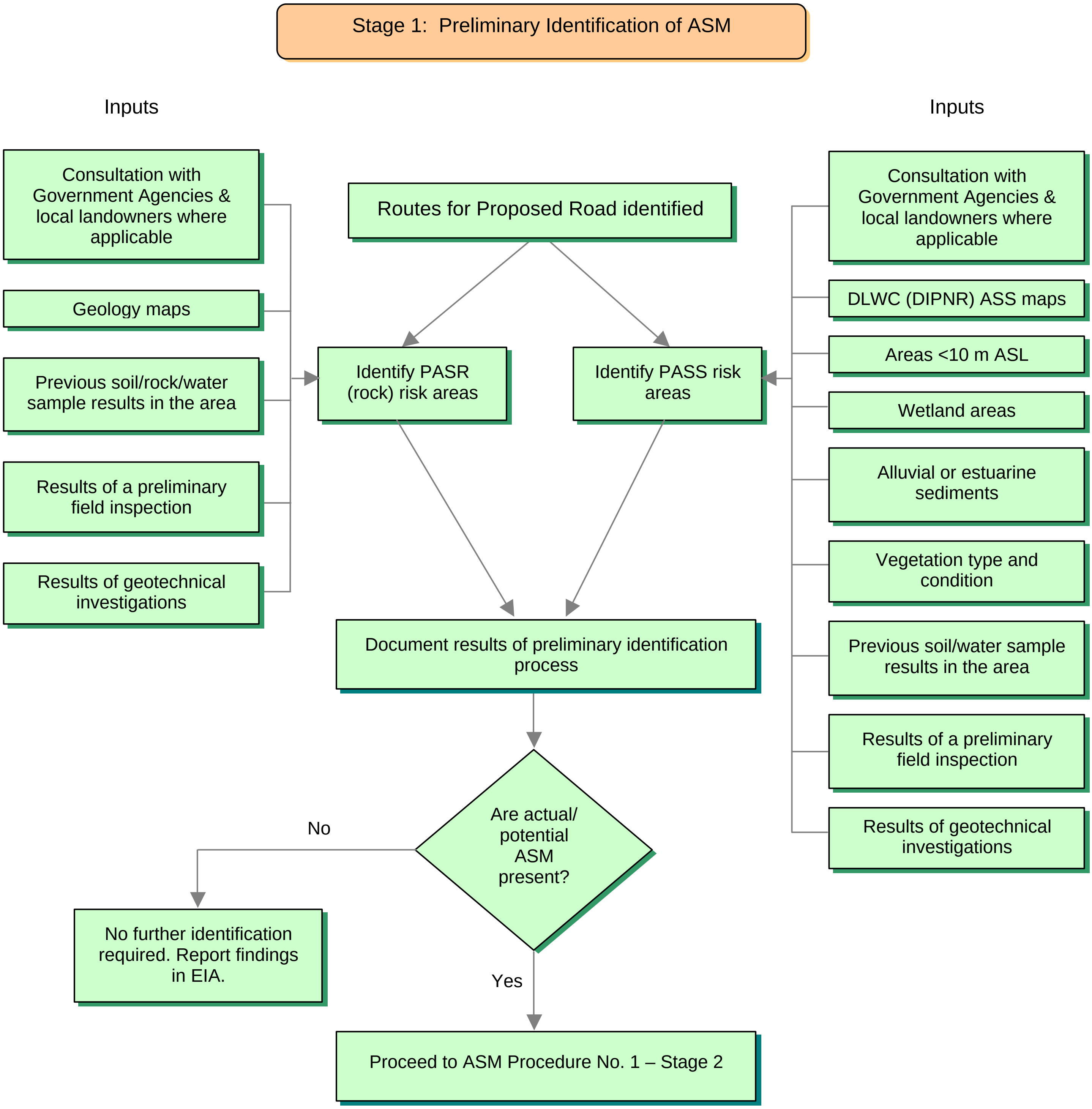
- ASR – Reid, J M, Czerewko, M A & Cripps, J C, 2001, *Sulfate Specification for Structural Backfills*; and
- Groundwater – Section 7, Qld Govt., 2002, *State Planning Policy 2/02 Guideline – Planning and Managing Development involving ASS.*

5. Document results in a detailed report including:
   - description of methods and sampling regime;
   - sampling results;
   - mapping of ASS and ASR constraints;
   - analysis of level of risk (environmental, structural etc.) associated with disturbance of each area; and
   - description of required treatments, controls and management strategies to address ASS and ASR issues.

Outputs:

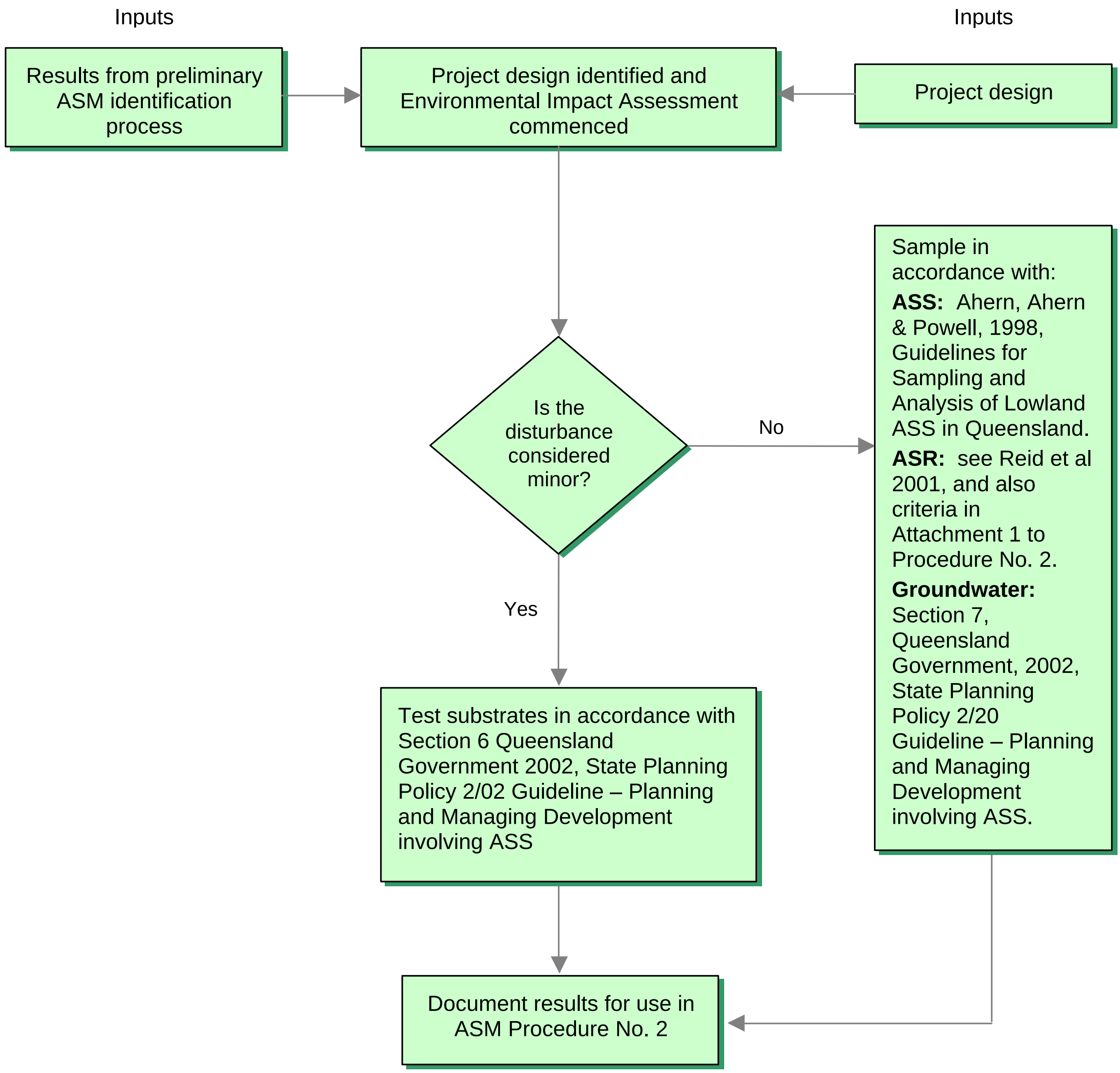
- Stage 1 Outputs:
  - A map and accompanying briefing paper.
- Stage 2 Outputs:
  - Detailed report.

ASM Procedure No. 1: Identification of Acid Sulfate Material



ASM Procedure No. 1: Identification of Acid Sulfate Material

Stage 2: Detailed Identification of ASM



ASM Procedure No. 1 – Attachment 1

Action criteria for management intervention – ASM

Recognising ASM in the Field – Preliminary Indicators

The following are preliminary indicators of ASS that may be observed during initial site inspections.

White and Melville (2000) highlight ten preliminary indicators of ASS that may be observed during initial site inspections. These are noted below, together with some broad indicators of ASM noted in the Queensland Guidelines. ARUP Geotechnics (pers comm.) and the Victorian Environment Protection Authority (1999) provide some field indicators of the presence of actual ASR. Where an indicator also relates to ASR, it is noted below:

- for ASS, surface elevation of less than ten metres above mean sea level (with a higher risk below five metres above mean sea level). Most commonly, these will be associated with coastal wetlands or backswamp areas, interdune swales etc.);
- soils and sediments of recent (Holocene and modern) age;
- areas where the dominant vegetation is tidally affected eg. mangroves, marine couch, saline scalds or swamp tolerant reeds, rushes and grasses (eg. *Phragmites australis*), paperbarks (eg. *Melaleuca spp*) and she oak (*Casuarina spp*). In inland areas, the dominance of acid tolerant vegetation is an indicator of ASR, or of areas undergoing sulfate salinisation;
- scalded or bare low lying areas (note that scalding may be due to saline conditions as well as acid conditions);
- acid surface waters, drain, stream or groundwater with pH less than 4. ARUP Geotechnics (pers comm) suggest that surface water pH of less than 4.5 (in elevated inland areas) is also an indicator of ASR;
- acidic soil, which when saturated has pH less than 4. Surface soil in inland areas with pH less than 4 may also indicate the presence of ASR, however MBO usually have a pH greater than 4;
- unusually clear or milky green drain water coming from or within a site. This is indicative of both ASS and ASR;
- a sulfurous smell after rains following a dry spell or when the soil is disturbed;
- extensive iron stains on drain surfaces or stream banks, or iron stained drain water and orange red ochre deposits in and around drains and streams;
- pale yellow surface encrustations or nodules (jarosite) on soil clods or on spoil heaps left exposed after dredging or excavation. Surface encrustations of jarosite may also occur due to the presence of ASR;

- augered soil or excavated pits indicating any pale yellow or orange red iron oxide deposits in fissures and old root channels or iron oxide mottling. This is also an indicator of ASR, but note that jarosite is not always found in Actual ASR or ASS;

- excessive corrosion or etching of concrete and/or steel structures exposed to ground and drainage waters, or rapid corrosion of fresh steel in or on the soil. Corrosion of concrete or steel structures is also indicative of the presence of ASR;

- presence of sulphide minerals (pyrite) in rock outcrops or drill samples. In fresh exposures, these may have a shiny or metallic appearance, but they may appear tarnished or rusty in weathered samples/exposures;

- presence of significant concentrations of sulfide minerals, in rocks with a low presence of potentially neutralising carbonates;

- areas identified in geological descriptions or in maps as bearing sulfide minerals, coal deposits, or marine shales/sediments (the scale of these maps means that this information will generally need to be checked in the field). In addition, the presence of pyrite will generally require a detailed petrological investigation;

- deep older estuarine sediments below ground surfaces of either Holocene or Pleistocene age (where deep excavation or drainage is proposed);

- blue-grey, blue-green or grey waterlogged soils which smell of rotten egg gas; and

- black, organic gels in drains, pH less than 4, with a slightly oily appearance (MBO).

ASM Procedure No. 1 – Attachment 2

Action criteria for management intervention – ASS

The *Queensland ASS Technical Manual, Soil Management Guidelines* presents Soil Action Criteria. These are presented in the following Table. The Soil Action Criteria consider soils according to their texture (texture class and approximate clay content) and the combined existing and potential acidity of the material. Action criteria also take into account the volume of soil to be disturbed (greater or less than 1000 tonnes).

Texture-based Acid Sulfate Soil action criteria (after Ahern *et al.* 1998a)

Type of Material		***Action Criteria* if 1 to 1000 tonnes of material is disturbed**		***Action Criteria* if more than 1000 tonnes of material is disturbed**	
		Existing + Potential Acidity		**Existing + Potential Acidity**	
Texture range (McDonald *et al.* 1990)	Approx clay content (%)	Equivalent sulphur (%S) (oven-dry basis)	Equivalent acidity (mol H^+/tonne) (oven-dry basis)	Equivalent sulphur (%S) (oven-dry basis)	Equivalent acidity (mol $H^{+/}$tonne) (oven-dry basis)
Coarse texture *Sands to loamy sands*	= 5	0.03	18	0.03	18
Medium texture *Sandy loams to light clays*	5 – 40	0.06	36	0.03	18
Fine texture *Medium to heavy clays and silty clays*	= 40	0.1	62	0.03	18

Oven-dried basis means dried in a fan-forced oven at 80° - 85°C for 48 hours.

Note that the ***action criteria*** refer to existing plus potential acidity for given volumes of ASS. The highest result(s) should always be used to assess if the relevant ***action criteria*** level has been met or exceeded; using the average or mean of a range of results is not appropriate. This issue is discussed in the *Sampling Guidelines*.

Note: If a soil shows evidence of self-neutralising or self-buffering eg. Titratable Potential Acidity (TPA) = 0 and the acid neutralising capacity (ANC) > 5% using equivalent units, then a case may be made for reduced or no treatment (see ASS Tip 14 of the *Queensland ASS Technical Manual, Soil Management Guidelines* on self-neutralising soils).

Acid Rock Criteria from Victorian EPA and Environment Australia

These criteria relate to tests for Net Acid Producing Potential (NAPP) and Net Acid Generation (NAG). These tests require the rock sample to be crushed to a paste. The number of samples required will depend on the geological complexity of the area and the likelihood that pyrite minerals occur in the geological sequence.

Victorian EPA Criteria for Acid Sulfate Rock

(EPA Victoria 1999)

Final Net Acid Generation	Net Acid Generation Value (kg H_2 $S0_4$/tonne)	Net Acid Producing Potential (kg H_2 $S0_4$/tonne)
<4.5	>5	positive

Environment Australia Criteria for Acid Sulfate Rock

(EA 1997)

Classification	NAPP	Final NAG pH	Saturated Paste pH	Electrical conductivity (dS/m)
Potentially acid forming	Positive	4 or lower	<4	
Non acid forming	Zero or negative	>4		
High level of soluble constituents (indicative of oxidation)				>2

7.2 Acid Sulfate Material Procedure No. 2: Environmental Impact Assessment

Application: This procedure applies to all RTA environmental impact assessments (EIA) undertaken by RTA personnel, consultants or contractors.

Management Principles:

For all proposed RTA activities (including maintenance activities) an EIA is to be undertaken in accordance with the *RTA EIA Guidelines* and *ASSMAC Manual Assessment Guidelines*.

To identify the environmental aspects and impacts of RTA activities such that environmental impacts can be minimised.

Risks should be fully identified, quantified and documented.

Risk should be reduced to as low as reasonably practicable taking into account technological and economic constraints. Avoid or minimise disturbance of ASM where practical.

Responsibility:

Project Manager, Environmental staff, Environmental Assessment Team or Contractors.

Inputs:

Base data, including GIS/mapping data, criteria for ASS/PASS etc.

Conceptual design details.

Outputs of ASM Procedure No. 1.

PROCESS

	Actions
1.	Determine if known or potential ASM are present at proposed activity site by undertaking a Preliminary Identification of ASM in accordance with *ASM Procedure No. 1: Identification of ASM – Stage 1*.
2.	If ASM are present conduct Preliminary Risk Assessment to identify the risk to the environment of the RTA activity in relation to ASM. Document results to be considered in project design decisions, otherwise undertake EIA in accordance with *RTA EIA Guidelines*.
3.	Risk assessments are to consider potential impacts on: • surface waters; • groundwater (including licensed groundwater users); • flora and fauna; • agriculture; • soil structure and subsequent impacts on infrastructure stability; • infrastructure integrity (corrosion etc.); and • community and government agency perceptions.
4.	Undertake a detailed identification of ASM in accordance with *ASM Procedure No. 1:*

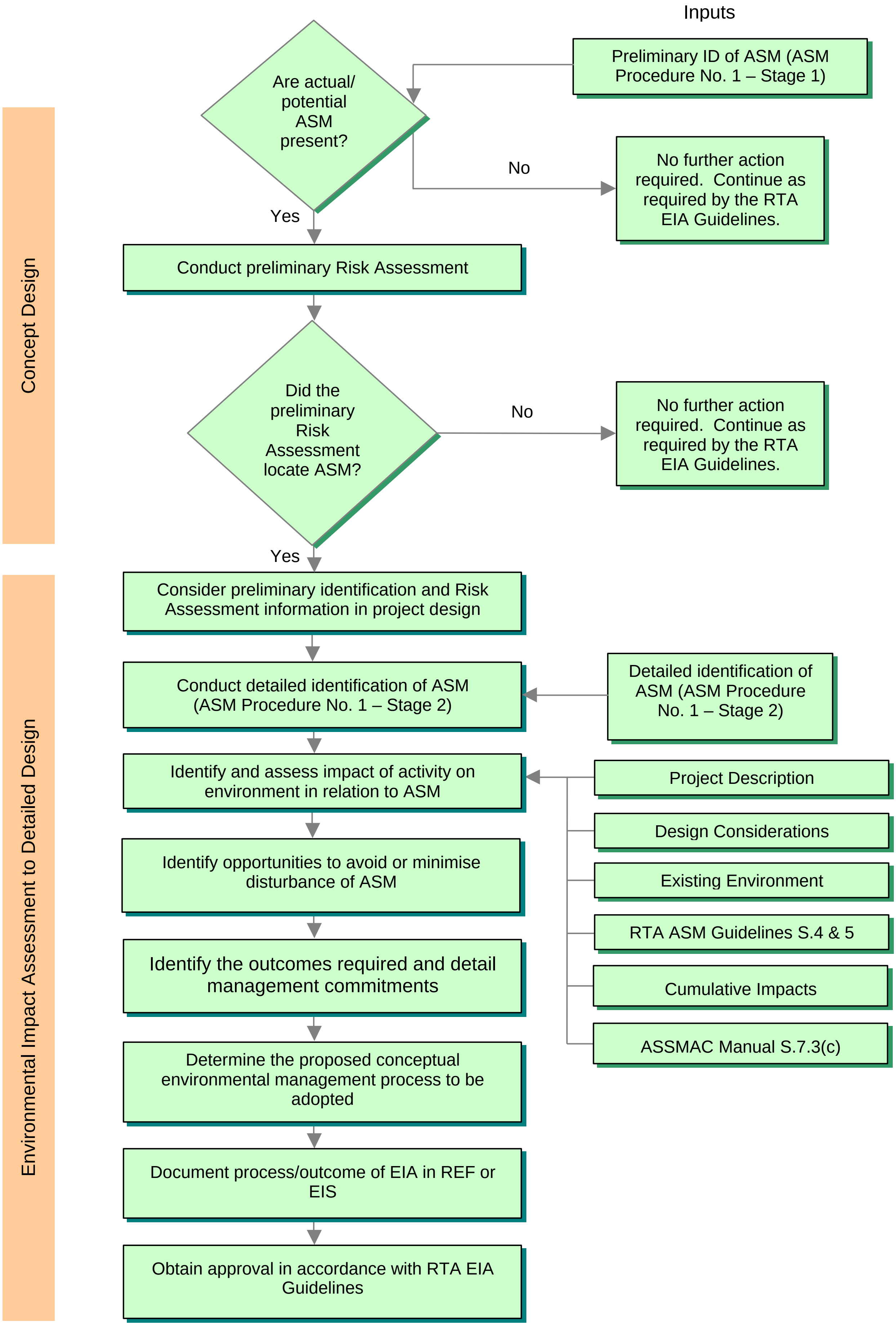
Actions
Identification of Acid Sulfate Materials – Stage 2.
5. Identify and assess the level of impact of activity on site and surrounding environment giving consideration to: • results of the identification process; • preliminary risk assessment results; • design considerations (all RTA activities including avoidance); • existing environment; • maximum possible quantity and concentration of leachate from ASM based on the worst case scenario; • potential impact of ASM as outlined in RTA ASS Guidelines Section 5.0 including surface waters, groundwater, flora and fauna, agriculture, soil structure and subsequent impacts on infrastructure stability, infrastructure integrity and community and government relations; and • cumulative impacts and other indirect environmental impacts such as increased salinity in the soil and water quality. Further guidance on the assessment of the level of the impact is contained in the *ASSMAC Manual*, Section 7.3(c) Assessment of Potential Impacts.
6. Identify the outcomes required and detail management commitments: • to meet all relevant water quality requirements for water within or adjacent to the project area; • to treat or manage ASM to ensure it will not impact on infrastructure structural integrity; and • to treat ASM to allow effective rehabilitation of areas disturbed by construction/maintenance works.
7. Document EIA process and outcome in REF or EIS as required by RTA EIA Guidelines. Attachment 1 to this procedure provides guidance on the structure and content of the REF/EIS. The level of detail required will be relative to the assessed level of ASM impact.

Outputs:

Preliminary Risk Assessment Documentation

EIA Documentation (REF or EIS). This information will support the preparation of an ASM Management Plan (ASM Procedure No. 3).

ASM Procedure No. 2: Environmental Impact Assessment



ASM Procedure No. 2 – Attachment 1

Issues to be addressed in an ASM REF or EIS

1.0 PROPOSAL DESCRIPTION

- Note the presence of actual or potential ASM.
- Description of works to be undertaken including excavation/drainage/filling.

2.0 CONCEPT STAGE

- Include preliminary ASM identification and preliminary risk assessment in substantiating why preferred option has been adopted.

3.0 DETAILED ASSESSMENT STAGE

- Description of design considerations – include design features relevant to control and management of ASM, such as drains, construction process, additional borrow material – unexpected geotechnical conditions.
- Description of site and surroundings:
  - geology and soils, actual or potential ASM as determined by *ASM Procedure No. 1: Identification of ASM;* and
  - identify the environmental sensitivity of land adjacent to the project site.
- Description of potential environmental impacts and the level of impact.

4.0 IMPLEMENTATION STAGE

- Identify the outcomes required and management commitments devised by *ASM Procedure No. 4: Identification of ASM Controls.*
- Description of the conceptual environmental management process to be undertaken once activity is approved as determined by *ASM Procedure No. 3: Management Planning Process.*
- Include details of contingency measures proposed in the event of failure of proposed control measures and management strategies, or identification of unexpected ASM issues.
- Measures to address non-conformances against the ASM Management Plan.
- Include project review and ongoing monitoring that may be required and matters that may require ongoing maintenance.

5.0 OUTCOMES AND JUSTIFICATION

If applicable, include any ASM matters that affect major biophysical, social or economic project outcomes.

7.3 Acid Sulfate Material Procedure No. 3: ASM Management Planning Process

Application:

The ASM Management Planning Process is required to be implemented for projects that are identified as impacting on known or potential ASM. The management plan specifies the controls that must be implemented and the specific issues for each project. The ASM Management Plan will form part of the Contractors Environmental Management Plan and Project Environment Management Plan.

Management Principles:

Works should be performed in accordance with best practice environmental management to ensure that the potential short and long term environmental impacts are minimised.

Where disturbance of ASS, MBO or ASR is unavoidable, preferred management strategies include minimisation of disturbance.

The material being disturbed (including *in situ* ASM) and any potentially contaminated waters associated with ASM disturbance, must be considered when developing a management plan for ASM.

Management of disturbed ASS is to occur if the ASS Action Criteria (see Attachment 1 to ASM Procedure No. 1) of the guidelines is exceeded or reached.

Risks should be fully identified, quantified and documented.

Risk should be reduced to a low as reasonably practicable taking into account technological and economic constraints.

Responsibility:

Project Manager, Environmental staff, Asset Manager, Contractor.

Inputs:

- Information from the Environmental Impact Assessment process (refer to ASM Procedure No. 2).
- ASS and ASR controls identified in accordance with ASM Procedure No. 4.
- Community consultation strategy information developed in accordance with the *RTA Community Involvement Practice Notes and Resource Manual*.

Process:

Actions
1. Identify legal requirements relating to ASM including (as applicable): • ASM management objectives and performance targets; • Conditions of Approval; • DEC Environment Protection Licence conditions; and • Conditions of other permits/licences/approvals.

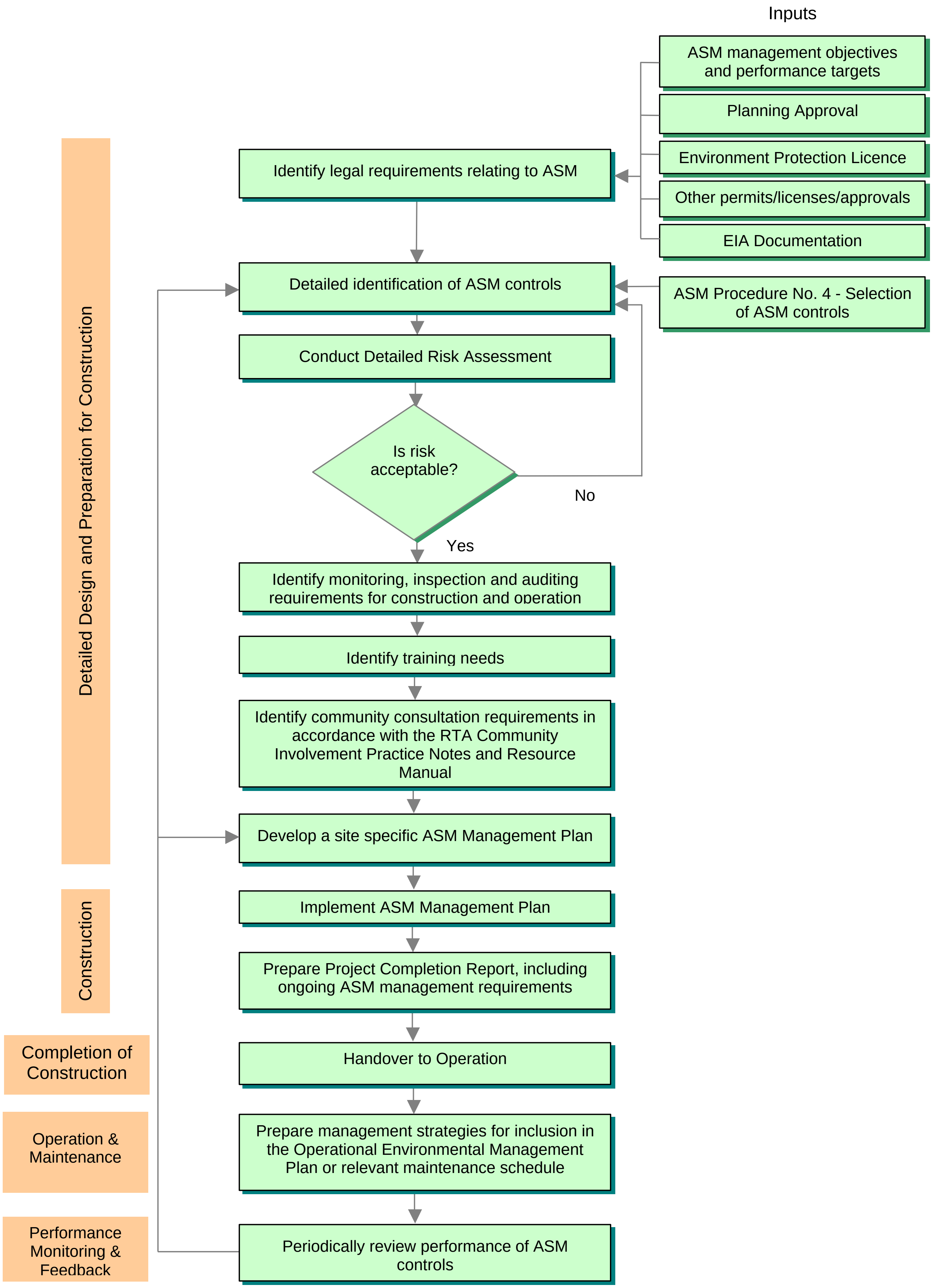
Actions
2. Identify potential ASM impacts and implement outcomes and commitments documented in the Environmental Impact Assessment as part of the detailed design process. Describe in detail the management strategies to be included in the ASM Management Plan for both construction and operation.
3. Conduct Detailed Risk Assessment to identify the risk to the environment of the activity in relation to ASM in accordance with the RTA Risk Management Manual and document results to be considered in detailed design. Risk assessments are to consider potential impacts on: • surface waters; • groundwater (including licensed groundwater users); • flora and fauna; • agriculture; • soil structure and subsequent impacts on infrastructure stability; • infrastructure integrity (corrosion etc.); and • community and government agency perceptions. Further details on how ASM impacts on the above parameters can be found in Section 5 and Appendix 3 of this Guideline. The following should also be considered: • the level of residual risk associated with each potential impact (refer to list in Stage 1 process above) with the proposed controls and/or management strategies in place; • the risk of controls and/or management strategies not being properly implemented and any required management measures; • the risk of failure of the proposed controls and any required contingency measures; • the performance/effectiveness of controls/treatments on past projects; and • the risk that construction materials imported to the site (e.g. gravels) are impacted by ASM.
4. Identify monitoring, inspection and auditing requirements relating to ASM for the construction and maintenance phases, in accordance with the outcomes of the Environmental Impact Assessment phase and risk assessments. Monitoring, inspection and auditing requirements may include: • water quality monitoring; • inspections of ASM storage and containment practices; • inspection of ASM treatment/management practices; • monitoring of the effectiveness of ASM treatments (eg. pH and acid generating potential of treated ASM); • auditing the effectiveness of design controls to address ASM; and • auditing the effectiveness of contractor management of ASM.
5. Identify any project specific training needs in relation to ASM in accordance with the outcomes of the Environmental Impact Assessment phase and risk assessments.
6. Identify community consultation needs for the construction and maintenance phases of the project in accordance with the RTA Community Involvement Practice Notes and Resource Manual.

Actions
7. Develop a project ASM Management Plan to address the construction phase and provide input into operational management and maintenance. The Plan is to address all the above actions and is to include contingency measures. A generic list of issues to be addressed in the ASM Management Plan is included as Attachment 1 to ASM Procedure No. 3. However, it is important that each ASM Management Plan provides detailed guidance on site-specific issues.
8. Implement ASM Management Plan.
9. On completion of the construction phase, the ASM management details are to be included in the Project Completion Report (refer to Section 9.9.3 of the RTA Environmental Impact Assessment Policy, Guidelines, Procedures). Issues to be detailed include: • details of compliance with the ASM Management Plan and any legal requirements (e.g. Conditions of Approval); • details of any unforeseen issues and contingency measures implemented; and • an assessment of the effectiveness of ASM treatments/management strategies and implications that this may have for other projects (i.e. a description of 'lessons learnt').
10. The relevant components of the ASM Management Plan and any additional details from Action 9 above are handed over to the RTA Regions' Asset Management section.

Outputs:

- Detailed Risk Assessment documentation.
- ASM Management Plan (refer to Action 7).
- ASM management details to be included in the Project Completion Report (refer to Action 9).
- Relevant details of ASM Management Plan to be used by Regional Asset Managers (refer to Action 10).

ASM Procedure No. 3: ASM Management Planning Process



ASM Procedure No. 3 - Attachment 1

Issues to be addressed in an ASM Management Plan

1.0 Background

- Description of ASM outcomes and commitments from the EIA phase.
- Description of legal requirements including project specific requirements (eg. Conditions of Approval) and where they are addressed in the Plan.

2.0 Objectives and Performance Targets

- Purpose of the Management Plan.
- Any appropriate water quality objectives, or other objectives required by consent conditions.

3.0 Description of ASM Aspects and Impacts

- Detailed description and assessment of ASM aspects and impacts determined as part of the detailed design phase.

4.0 Controls and Management Strategies

- Detailed description of proposed control measures and management strategies for the project.

5.0 Contingency measures

- Details of contingency measures proposed in the event of failure of proposed control measures and management strategies or identification of greater than expected ASM issues.
- Measures to address non-conformances against the ASM Management Plan.

6.0 Training

- Details of any project specific training requirements in relation to ASM.

7.0 Consultation

- Outline of proposed ASM consultation program at different phases of the project.

8.0 Monitoring and Auditing

- Physical monitoring requirements (water, soil, rock etc.)
- Audit of detailed design as it relates to ASM.
- Construction phase inspection requirements (material handling and treatment).
- Audit of ASM management practices (against Management Plan requirements).

9.0 Communication and Reporting

- Identification of key communication channels utilised by the Management Plan.
- Summary of reporting requirements relating to ASM management.

10.0 Responsibility

- Summary of responsibilities for implementation of the management plan.

11.0 Resources

- Summary of resources required for the implementation of the management plan.

7.4 Acid Sulfate Material Procedure No. 4: Selection of ASM Controls

Attachment 1 to ASM Procedure No. 1 provides guidance when intervention is necessary to reduce risks associated with Acid Sulfate Materials.

Attachment 1 to ASM Procedure No. 4 provides guidance on a range of ASM management strategies.

Attachment 2 to ASM Procedure No. 4 provides guidance on lime application rates to treat ASM.

All three of these attachments are drawn from the Queensland Acid Sulfate Soil Technical Manual - Soil Management Guidelines, version 3.8 (2002)

Application:

This procedure provides guidance for determining appropriate ASM controls and management strategies during both the EIA phase (conceptual) and the detailed design phase (detailed). It is envisaged that in most cases this process will be implemented by personnel who are appropriately qualified and experienced in dealing with ASM management. This procedure applies to all RTA activities undertaken by the RTA personnel and/or contractors engaged by RTA to undertake activities on their behalf.

Management Principles:

The disturbance of ASM should be avoided wherever possible.

Where disturbance of ASM is unavoidable, preferred management strategies are:

- minimisation of disturbance;
- neutralisation;
- hydraulic separation of sulfides either on its own or in conjunction with dredging; and
- strategic reburial (reinterment).

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

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

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

Stockpiling of untreated ASS above permanent ground water table with (or without) containment is not an acceptable long-term management strategy. For example, soils that are to be stockpiled, disposed of, used as fill, placed as a temporary or permanent cover on land or in waterways, sold or exported off the treatment site or used in earth bunds, that exceed the Action Criteria should be treated or managed (see Attachment 1 to ASM Procedure No. 4).

The following issues should be considered when formulating ASM management strategies:

- the sensitivity and environmental values of the receiving environment;
- whether ground waters and/or surface waters are likely to be directly or indirectly affected;
- the heterogeneity, geochemical and textural properties of soil on site; and
- the management and planning strategies of local government and/or state government, including Regional or Catchment Management Plans/Strategies and State and or Regional Coastal Policies/Plans.

Responsibility:

Project Manager, Environmental Officer, Contractors.

Inputs:

- Project design details (either conceptual or detailed depending on phase of project).
- Details of ASM present in the study area based on detailed report prepared in accordance with ASM Procedure 1.
- Results from preliminary risk assessment completed in accordance with ASM Procedure 2 and detailed risk assessment described in ASM Procedure 3.

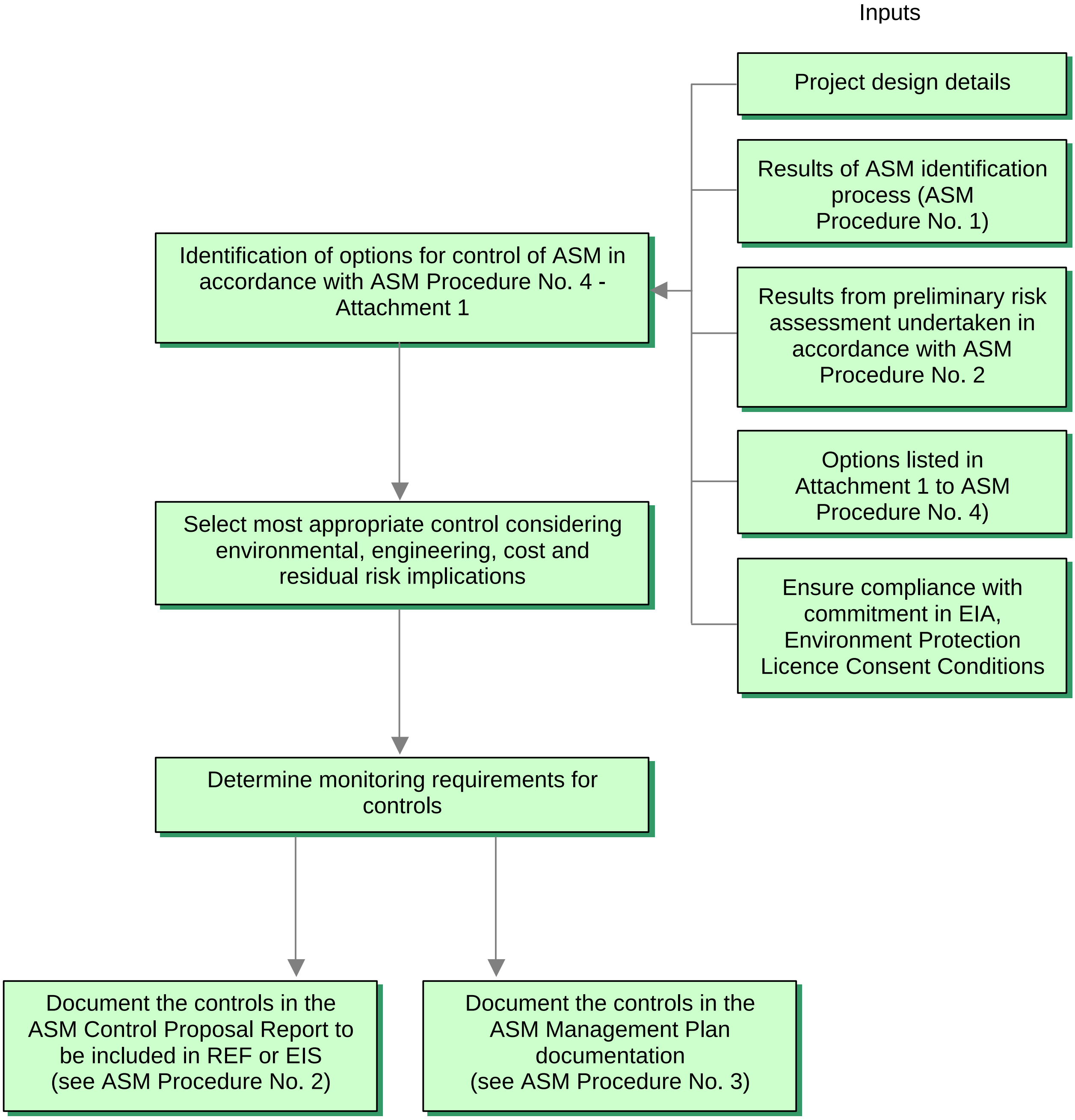
Process:

Actions
1. Identify control options (refer to ASM Procedure No. 4 – Attachment 1).
2. Select most appropriate control option taking into account: • scale of project; • environmental impacts; • engineering impacts; • costs; • residual risk; and • performance/effectiveness of controls used on past projects.
3. Determine monitoring requirements for each control option (including pre-disturbance monitoring as appropriate), as per *ASSMAC* 1998, Chapter 6.4.
4. Document the proposed control options in detail, including: • identifying the particular material targeted by that treatment/management option; • providing sufficient detail for the treatment/management option to achieve practical implementation (eg. rates of lime per tonne of material to achieve neutralisation); • a description of any limitations of the proposed treatment/management option; • a description of monitoring requirements; • a description of performance targets so that success can be assessed (eg. target pH of treated ASS); and • contingency measures in the event that monitoring shows that the selected treatment/management options are ineffective (refer to *ASSMAC* 1998, Chapter 6.5).

Outputs:

- A detailed ASM control proposal report outlining the information specified in Action 4 above, to be included in REF or EIS (refer to ASM Procedure No. 2) and the ASM Management Planning Process (ASM Procedure No. 3).

ASM Procedure No. 4: Selection of ASM Controls



ASM Procedure No. 4 – Attachment 1

Acid Sulfate Soil Controls

The management strategies/treatment options outlined below are adopted from the *Queensland Acid Sulfate Soil Technical Manual – Soil Management Guidelines* Version 3.8 (Dear, S E, Moore, N G, Dobos, S K, Watling, KM and Ahern, C.R., 2002), with other secondary references included as appropriate. The *Queensland ASS Technical Manual* is the most up to date State government technical reference. It is anticipated that the NSW *ASSMAC Guidelines*, currently being reviewed and updated, will be consistent with the Queensland guidelines.

In order of preference:

Management/Treatment Strategy	Brief Description	Limitations	References
Avoidance Strategies			
Planning to avoid ASS	Avoidance of ASS in all cases is the preferred option.	It is unlikely that this will be a viable option for most infrastructure projects.	Chapter 6.1, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.1.
Cover *in situ* soils with clean fill	If groundwater levels are not affected, it may be possible to cover in situ PASS with clean fill to provide adequate depths for infrastructure excavations without disturbing PASS.	May disturb in situ ASS by: • bringing ASS into contact with the groundwater table; • displacing and thereby aerating previously saturated PASS above the groundwater table; and/or • raising acidic groundwater tables with the short-term release of acid into waterways.	Chapter 6.2, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.2.
Minimisation of disturbance			
Redesign earthworks layout	Redesign the earthworks layout where possible to avoid/minimise impacts on areas with high levels of sulphides, concentrating development activities in areas with low levels of sulphides.	Requires detailed understanding of ASS distributions including stratigraphic mapping. Following the commencement of construction, redesigning earthworks may not be possible.	Chapter 7.1, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.2.

Management/Treatment Strategy	Brief Description	Limitations	References
Shallow disturbances	Where ASS is overlain with non-ASS sediments, the depth of earthworks can be altered so that the ASS remains undisturbed.	Requires detailed understanding of ASS distributions including stratigraphic mapping. Following the commencement of construction, redesigning earthworks may not be possible.	Chapter 7.2, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.2.
Redesign existing drains	Drains can be designed to be wider and shallower and therefore do not penetrate the sulphide layers.	Requires detailed understanding of ASS distributions including stratigraphic mapping. Is effective only where ASS is overlain with non-ASS sediments.	Chapter 7.3, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.2.
Minimise groundwater fluctuations	Activities which result in groundwater table fluctuations should be avoided (drainage structures, changes in vegetation, dewatering, construction of water storages etc).	Some projects may require works which result in groundwater table fluctuations. In this case, treatment options should be pursued.	Chapter 7.4, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.2 & Chapter 3.2.3.
Neutralisation of Acid Sulfate Soils			
Neutralisation of ASS	Incorporation of alkaline materials (eg. aglime) into ASS. Sufficient neutralising agent needs to be used to ensure that all existing and potential acidity can be neutralised. Establishing appropriate performance criteria and undertaking verification testing is essential.	There can be significant risks to the environment if a neutralisation treatment is poorly managed (refer to Chapter 8 for further detail).	Chapter 8, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.4, 3.5, 3.6 & 3.7.

Management/Treatment Strategy	Brief Description	Limitations	References
Hydraulic Separation			
Hydraulic separation	Involves the partitioning of sediment or soil fragments or minerals using natural or accelerated differential settling based on differences in grain size and grain density. Separates sulphide grains from other sediments to create 'clean fill' and sulfidic fines requiring treatment.	Separation will be poor if the sulphide grains are well cemented or the soil contains too much clay (generally only suitable for sediments with <20% clay and silt content). 'Cleaned' sediment will still have some acid generating potential and will require supplementary treatment. Significant risks to the environment may also occur during the hydraulic separation process (refer to Chapter 9 for further detail).	Chapter 9, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.5.
Strategic Reburial			
	Requires a void into which PASS are placed. The void must be covered by either surface or standing water or must be beneath the groundwater table (below compacted non-ASS or neutralised material).	Oxidation must be permanently precluded (eg. must allow for groundwater or standing water fluctuations). Areas must be protected from future disturbances (eg. dredging, drainage works etc.). This may represent a future land use constraint. Strategic reburial is inappropriate for ASS unless the existing acidity has been neutralised.	Chapter 10, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.3.

Management/Treatment Strategy	Brief Description	Limitations	References
Higher Risk Management Strategies			
Stockpiling ASS	Stockpiling ASS after excavation and prior to treatment. Stockpiling should be minimised by preparing a detailed earthworks strategy that documents the timing of soil removal, treatment locations, and treatment and disposal locations.	The risks of stockpiling untreated ASS may be very high even over a short period. Significant quantities of acid may build up, especially in porous sandy soils. Mixing of soil horizons make appropriate neutralisation treatment difficult. If stockpiling occurs for a sufficient period for oxidation to occur, leachate and runoff must be collected and treated.	Chapter 11.1, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.3 & 3.7.
Strategic reburial of soils with existing acidity	As previously discussed for Strategic Reburial, except that soils have potential and existing acidity.	Large-scale use of this management strategy is not recommended. There are also difficulties in incorporating suitable neutralising agents due to solubility issues (drying of ASS for treatment will result in more acid generation).	Chapter 11.2, *Queensland Acid Sulfate Soil Technical Manual*.
Large-scale dewatering or drainage	Earthworks and/or pumping that result in localised drainage or lowering of groundwater and the exposure of sulfidic soils.	This activity is high risk and should not be undertaken without detailed assessment and identification of appropriate management measures. May be acceptable for short-term small scale works (eg. shallow infrastructure trenching).	Chapter 11.3, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.2.
Vertical mixing	A high risk technique that relies on using the buffering capacity of non-AS horizons to dilute and neutralise the ASS horizon.	Suitable only for soil profiles which have a calcareous shelly horizon at shallow depths (eg. a high proportion of fine crushed shells, coral or finely ground limestone). Use of technique requires effective mixing of profiles which requires a high level of earthworks skill and effort. Requires detailed understanding of soil properties to ensure sufficient buffering.	Chapter 11.4, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.4.

Management/Treatment Strategy	Brief Description	Limitations	References
Generally Unacceptable Management Strategies			
Above ground capping	Placing untreated ASS above ground and encapsulating under a non-porous cap.	Failure of cap will lead to oxidation and acid generation (failure may occur due to poor design or construction, drought, disturbance etc.). Long-term monitoring is required.	Chapter 12.1, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.3.
Hastened oxidation	Hastened oxidation through regular wetting and mechanical aeration of the soil.	There are significant time delays associated with this technique. System must be fully contained (including from flooding etc.) so that acidic leachate (high in heavy metals) can be collected and suitably treated. Extensive sampling is required and may prove costly.	Chapter 12.2, *Queensland Acid Sulfate Soil Technical Manual*. *ASSMAC*, 1998, Chapter 3.2.4.

Acid Sulfate Rock Controls

There is substantial literature on the management of acid mine drainage, which results from the disturbance of one type of acid rock.

Key controls to prevent or minimise impacts from ASR include:

- avoidance; and
- minimisation of disturbance (requires detailed understanding of distribution).

Arup Geotechnics (pers comm.) summarise a further seven measures that will generally provide control of acid generated from ASR.

<u>Preferred Options (prevent acid generation):</u>

- Ensure that suitable material characterisation has been conducted (see ASM Procedure No. 2), so that sulfidic material is not used for fill, ballast or site remediation works.
- Prevent oxidation. This may include placing ASR in an anaerobic environment, usually below water.
- Minimise oxidation rate and isolate higher risk materials from exposure.
- Manage stockpiled materials. This will include minimising the quantity and duration of storage, minimising surface area exposed to air, covering to avoid infiltration, diverting stormwater, etc.

Less Preferred Options (treat discharge)

- Contain or treat acid drainage to minimise risk of significant off site impacts – install leachate collection and treatment system.

- Provide a neutralising agent.

- Speed up oxidation, collect and treat leachate.

ASM Procedure No. 4 – Attachment 2

Estimating treatment levels and aglime required to treat the total weight of disturbed Acid Sulfate Soil – based on soil analysis (after Ahern et al 1998, *Queensland Acid Sulfate Soil Technical Manual, Soil Management Guidelines*)

The tonnes (t) of pure fine aglime, $CaC0_3$ 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) (» m³ x BD) ‡	**Soil Analysis# - Existing Acidity plus Potential 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
10000	14	28	47	94	187	281	374	468	702	936	1170	1404	1872	2340

L	**Low treatment**: (≤0.1 tonnes lime)	**M**	**Medium treatment:** (>0.1 to 1 tonne lime)	**H**	**High treatment:** (>1 to 5 tonnes lime)	**VH**	**Very High treatment:** (>5 to 25 tonnes lime)	**XH**	**Extra High treatment:** (>25 tonnes lime)

Note: Lime rates are for pure fine aglime, $CaC0_3$ assuming an NV of 100% and using a safety factor of 1.5. A factor that accounts for Effective Neutralising Value is needed for commercial grade lime. (See the *Information Sheets on Neutralising Agents – Neutralising Considerations*).

‡ An approximate soil weight (tonnes) can be obtained from the calculated volume by multiplying volume (cubic m) by bulk density (t/m^3). (Use 1.7 if BD is not known). Dense fine sandy soils may have a BD up to 1.7, and hence $100m^3$ of such soil may weigh up to 170t. In these calculations, it is necessary to convert to dry soil masses, since analyses are reported on a dry weight basis.

Potential acidity can be determined by Chromium Reducible Sulfur (S_{CR}), Peroxide Oxidisable Sulfur (S_{POS}) and Total Oxidisable Sulfur (S_{TOS}). For samples with pH <5.5, the existing acidity must also be determined by appropriate laboratory analysis eg. Titratable Actual Acidity (TAA). Soils with retained acidy eg. jarosite or other similar insoluble compounds have a less available acidity and will require more detailed analysis. The amount of treatment required may be reduced if the self-neutralising capacity of the soil is appropriately measured. Consult the ***Queensland Acid Sulfate Soils Technical Manual, Laboratory Methods Guidelines.***

PART 3

Glossary and Technical References

8.0 Glossary

This section provides information about the terminology of Acid Sulfate Soil and Acid Sulfate Rock management, together with a reference list for further information about all aspects of ASM that may be relevant to RTA personnel.

Updates of ASM references will be issued on a regular basis via the RTA's Intranet.

Acid export – drains are often the means for acid export from an ASS area. Eliminating or reducing the number of drains will reduce the amount of acid exported.

Acid Sulfate Material (ASM) – a general term used in this guideline to refer to all types of acid sulfate environments – soils, rock and Monosulfidic Black Ooze.

Acid Sulfate Rock (ASR) – geological units that contain sulfide or sulfate minerals (commonly pyrite) which have the potential to oxidise during construction and produce acid that can affect structural integrity or environmental conditions.

Acid Sulfate Soil (ASS) - a soil or soil horizon which contains acid sulfides or an acid soil horizon affected by oxidation of sulfides. This is the definition used in Queensland's Environmental Protection Policy.

Actual Acidity – Soluble and exchangeable acidity readily available for reaction, including pore waters containing metal species capable of hydrolysis (eg. Fe or Al3+ ions)

Actual Acid Sulfate Soil – a term sometimes used for an Acid Sulfate Soil in which the sulfides have started to oxidise; this is to distinguish it form a *potential Acid Sulfate Soil* (qv).

Action Level of oxidisable sulfur is the level for that textures class (ASM Procedure 4 - Attachment 2) above which active management or treatment of the material will be required if disturbed.

Aerobic Conditions – conditions in which oxygen is readily available from either the atmosphere or from water containing oxygen.

Anaerobic Conditions – conditions in which oxygen is not readily available.

Aquifer – a porous soil or rock layer which stores and allows transmission of water.

ASS – acronym for Acid Sulfate Soil.

ASSMAC – acronym for Acid Sulfate Soils Management Advisory Committee.

Aspect – an element of an organisation's activities, products or services that can interact with the environment.

Best Practice Environmental Management (BPEM) - Section 18 DEC: the management of the activity to achieve an ongoing minimisation of the activity's environmental harm through cost-effective measures assessed against the measures currently used nationally and internationally for the activity.

Biochemical Barrier – changes in biochemical conditions (e.g. acidity and metals concentrations) in waterways that restrict movement of aquatic species.

Broadacre Agriculture – farming of large areas of land, as is usually practiced in Australia; the term is sometimes used to distinguish this type of farming from intensive agriculture such as the hand-feeding of large numbers of cattle in small feedlots.

Buffering Capacity – this is a measure of the ability of a sample to resist changes in pH. In ASS this ability arises because of reactions between sediment components and the hydrogen ions produced by oxidisation. These buffering components include alkaline material such as shells made from calcium carbonate and the clay and organic fractions of the sediment.

Concentration – is the amount of a substance contained per unit amount of sample. Concentrations in liquids are expressed in amount per volume: moles of substance per litre of solution, (M/l); millimoles (mM/l); milligrams per litre, (mg/l); or in amount per unit weight: parts per million, (ppm). Concentrations in solids are expressed in amount per unit weight: kilograms of substance per kilogram of sample x 100, (%); moles or millimoles per kilogram (M/kg, mM/kg); or parts per million, (ppm), milligrams per kilogram (mg/kg).

Cone of Depression – this is the volume of soil around a dewatering point that becomes unsaturated (eg. partially drained) during dewatering. Before dewatering ASS, the extent, location and soil characteristics of the cone of depression should be determined.

Density, Bulk Density – the dry mass (weight) of a material per unit total volume of material (including pore space). Units are tonnes per cubic metre, t/m^3.

Drainage – is water flowing under the force of gravity in or from permeable sediment. Drainage flows can either be vertical flows, such as flow to the water table, or lateral flows to streams or drains.

Ecologically Sustainable Development (ESD) – Section 3 DEC: allowing development that improves the total quality of life, both now and in the future, in a way that maintains the ecological processes on which life depends.

Estuary – the lowest reaches of a river where tidal ocean water mixes with fresh water from the river flows.

Environmental Evaluation – Section 71 DEC: an environmental audit or investigation of an activity to decide the source, cause or extent of environmental harm caused by the activity, and the need for an environmental management program.

Environmental Harm – Section 14 DEC: any adverse effect, or potential adverse effect (whether temporary or permanent and of whatever magnitude, duration or frequency) on an environmental value. May be caused by direct or indirect result of an activity.

Environmental Management Program – an environmental management program approved under Chapter 3, Part 6 of the EPA, to achieve compliance with the Act by reducing environmental harm, or detailing the transition to an environmental standard.

Environmental Protection Policies (EPPs) – environmental protection policy approved under Chapter 2 of the DEC.

Environmental Value – Section 9 DEC: a quality or physical characteristic of the environment that is conducive to ecological health or public amenity; or another quality of the environment identified and declared to be an environmental value under an environmental protection policy or regulation.

Environmentally Relevant Activities (ERAs) – an activity in Schedule 1 of the Environmental Protection Regulation, 1998.

Equivalent - for acids and alkalis an equivalent is the weight of substance necessary to give one mole of hydrogen ion, H^+, or one mole of hydroxyl ion, OH^-, in a neutralisation reaction. For an oxidising or reducing agent it is a mole of substance divided by the number of electrons in the half reaction for reduction or oxidisation.

Existing acidity – includes actual acidity and retained acidity.

Fish Habitat Area – Sections 120 and 121, Fisheries Act 1994 giving statutory protection to key habitats to ensure long-term fisheries production.

Floc – a mass of material that has precipitated as a result of chemical or physical interactions (short or floccule).

Flocculation – the formation of flocs (qv).

Gel – a soft, jelly-like mass.

Geomorphic – relating to the form of the earth or its solid surface features.

Heavy Metals – are metallic ions in trace quantities in the environment. They can accumulate in organisms such as plants, fish, birds, animals, and humans and in sufficient concentration, can impair the function of those organisms or be toxic to them.

Heterogeneity – the condition or state of being different in kind or nature.

Holocene – the most recent geologic epoch of the Quaternary period. The Holocene is the most recent of the seven epochs which make up the Cainozoic Era. It covers events occurring from the end of the last glacial event, about 11,000 years ago.

Hydrocyclone – a machine for separating particles or fluids of different densities by rapid rotation.

Impact – any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organisation’s activities, products or services.

Inland Acid Sulfate Soils – ASS can form under freshwater conditions in saline discharge areas where sulfur, iron and clay have accumulated after mobilisation. These soils may form as a result of land clearing, excess discharge of sulfate rich saline groundwater and erosion, forming scalds.

Jarosite – a sulfate of iron and potassium forming a yellowish or brownish mineral.

Marine Plant – Section 8 Fisheries Act 1994: includes a plant that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing or fallen.

Mole, gram-molecule – a mole, or gram-molecule, is the weight of a substance in grams, numerically equal to its atomic or molecular weight. A mole contains 6.023×10^{23} molecules of the substance. A molar solution is one which contains one mole of the substance per litre of solution.

Oxidation – an increase in the oxidation state or number of an element; the removal of one or more electrons from an atom or ion or group of atoms; to combine with oxygen. eg. The oxidation of ferrous, (Fe^{2+}) ions to ferric, (Fe^{3+}) ions:

$Fe^{2+} \Rightarrow Fe^{3+} + e^-$

ironII ⇨ ironIII + electron

The oxidation of organic matter, represented as CH2O, to carbon dioxide:
$CH_2O + O_2 \Rightarrow CO_2 + H_2O$

Organic matter + oxygen -> carbon dioxide + water

In these equations the ironII and organic matter are oxidised. The agent which causes the oxidisation is itself reduced.

Oxidation State or Number – the absolute value of the electronic charge on an ion or molecule; the charge on an atom which is assumed to account for the number of electrons involved in the oxidation or reduction of an atom in an ion or molecule to the free element. eg. Fe^{3+} has oxidation number +3. Elemental sulfur, S^0, has oxidation number 0. The sulfur in H_2S, S^{2-} has oxidation number -2.

pH – is a measure of the concentration of hydrogen ions (H+) in solution. It is defined as pH = -log10(H+) in moles per litre. Note that this is a logarithmic scale. A tenfold change in (H+) produces a change of 1 pH unit. When the pH of an aqueous solution is 7, that is the hydrogen ion activity and concentration are 10-7 moles/l, the solution is neutral. Pure water in equilibrium with carbon dioxide in the atmosphere has a pH less than 6 at 25ºC. Acidic solution may be neutralised by the addition of alkaline materials or solutions.

Potential Acid Sulfate Soil – a term sometimes used for an Acid Sulfate Soil (qv) in which the sulfides have not yet started to oxidise; this is to distinguish it from an actual Acid Sulfate Soil. (qv).

Potential acidity – acidity associated with the complete oxidation of sulfides (mainly pyrite).

Pyrite – iron sulfide.

Reduction – the removal of oxygen from a substance, or the addition of hydrogen to it; see also, oxidation.

Retained acidity – acidity retained from sparingly and insoluble sulfur compounds (other than sulfides) that slowly produce acid (eg. jarosite, natrojarosite and tamarugite).

Secondary sulfate salts – secondary sulfate salts (eg. Jarosite) may dissolve and produce acid with wetting and drying of soil stockpiles. Different testing procedures are necessary to identify the presence of different salts (see Queensland Laboratory Methods Guidelines).

Self-neutralising soils – these soils contain abundant natural calcium or magnesium carbonate which contributes to the neutralising capacity of the soil. Related factors are shell size, (fine shell fragments are more effective due to larger surface area). Self neutralising soils may still require the application of additional neutralising agents, and the amount should be determined on a site by site basis.

Soil Scalding – chemical or physical actions that severely reduce the ability of soils to support vegetation.

Soil Ripening – the converting of Acid Sulfate Soils to their final condition after all the sulfides have oxidised; such soils tend to have smaller volumes and poorer water holding capacities than originally.

Sulfates – salts resulting from the chemical action of sulfuric acid; in the context of ASS the term refers to various iron sulfates.

Sulfides – in the context of ASS this term refers to unoxidised mineral compounds containing sulfur, namely iron sulfide, iron monosulfide and organic sulfides.

Water Balance – an account of the quantitative inputs and outputs of water to and from a storage such as a wetland or an aquifer,; if there is little net change in the storage volume over a period of time the total inputs during that period should be equal to the total of the outputs.

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APPENDIX 1

National Water Quality Management Strategy – Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)

Appendix 1

National Water Quality Management Strategy - Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000)

The current process for determining appropriate water quality outcomes in Australia is presented in the *Australian and New Zealand Guidelines for Fresh and Marine Waters* (2000) and involves a risk based assessment of ecosystem condition.

The following tables, drawn from the *Australian and New Zealand Guidelines for Fresh and Marine Waters* (2000) summarise firstly the process for determining the appropriate level of protection in relation to biological indicators, physical and chemical stressors, toxicants and sediments (Table 3.2.1 of the Guideline). Secondly, Tables 3.3.2 and 3.3.3 of the Guideline provide default water quality values for natural waters in south eastern Australia. Default triggers are noted for salinity, turbidity, a variety of nutrients, dissolved oxygen and pH.

Of these, the values that are provided for lowland rivers and estuarine/marine ecosystems are likely to be relevant to RTA staff managing ASS issues. Whilst coastal wetlands may also be impacted by road works in ASS areas, the guideline notes that no reliable data is available to set default triggers for the water quality parameters under consideration.

Table 1: Recommended Levels of Protection Defined for Each Indicator Type (Table 3.1.2 from ANZECC, 2000)

	Level of Protection			
Ecosystem Condition	**Biological Conditions**	**Physical and Chemical Stressors**	**Toxicants**	**Sediments**
1. High conservation/ ecological value	• No change in biodiversity beyond natural variability. Recommend ecologically conservative decision criteria for level of detection. • Where reference condition is poorly characterised, actions to increase the power of detecting a change recommended. • Precautionary approach recommended for assessment of post-baseline data through trend analysis or feedback triggers.	• No change beyond natural variability recommended, using ecologically conservative decision criteria for detecting change. Any relaxation of this objective should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered. • Where reference condition is poorly characterised, actions to increase the power of detecting a change recommended. • Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.	• For toxicants generated by human activities, detection at any concentration could be grounds for investigating their source and for management intervention[1]; for naturally occurring toxicants, background concentrations should not be exceeded. *Where local biological or chemical data have not yet been gathered,* apply the default values provided in Section 3.4.2.4. Any relaxation of these objectives should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered. • In the case of effluent discharges, direct toxicity assessment (DTA) should also be required. • Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.	• No change from background variability characterised by the reference condition. Any relaxation of this objective should only occur where comprehensive biological effects and monitoring data clearly show that biodiversity would not be altered. • Precautionary approach taken for assessment of post-baseline data through trend analysis or feedback triggers.
2. Slightly to moderately disturbed systems	• Negotiated statistical decision criteria for detecting departure from reference condition. Maintenance of biodiversity still a key management goal. • Where reference condition is poorly characterised, actions to	• Always preferable to use data on local biological effects to derive guidelines. *If local biological effects data unavailable,* local or regional site data used to derive guideline values using suggested approach	• Always preferable to use data on local biological effects (including DTA) to derive guidelines. *If local biological data unavailable,* apply default, low-risk trigger values from Section 3.4.2.4. • Precautionary approach may be	• The sediment quality guidelines provided in Section 3.5 apply. • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback

[1] For globally distributed chemicals such as DDT residues, it may be necessary to apply background concentrations, as for naturally occurring toxicants.

	increase the inferential strength of the monitoring program suggested. • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers.	in Section 3.3.2.3. Alternatives to the default decision criteria for detecting departure from reference condition may be negotiated by stakeholders but should be ecologically conservative and not compromise biodiversity. *Where local reference site data not yet gathered,* apply default, regional low-risk trigger values from Section 3.3.2.5. • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers.	required for assessment of post-baseline data through trend analysis or feedback triggers. • In the case of effluent discharges DTA may be required.	triggers.
3. Highly disturbed systems	• Selection of reference condition within this category based on community desires. Negotiated statistical decision criteria for detecting departure from reference condition may be more lenient than the previous two condition categories.	• Local or regional reference site data used to derive guideline values using suggested approach in Section 3.3.2.3. Selection of reference condition within this category based on community desires. Negotiated statistical decision criteria may be more lenient than the previous two condition categories. *Where local reference site data not yet gathered,* apply default, regional low-risk trigger values from Section 3.3.2.5; or use biological effects data from the literature to derive guidelines.	• Apply the same guidelines as for 'slightly-moderately' disturbed systems. However, the lower protection levels provided in the Guidelines may be accepted by stakeholders. • DTA could be used as an alternative approach for deriving site-specific guidelines.	• Relaxation of the trigger values where appropriate, taking into account both upper and lower guideline values. • Precautionary approach may be required for assessment of post-baseline data through trend analysis or feedback triggers.

Table 2: Default Trigger Values for Physical and Chemical Stressors (Table 3.3.2 from ANZECC, 2000)

Default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems. Trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types. Data derived from trigger values supplied by Australian states and territories. Chl *a* = chlorophyll *a*, TP = total phosphorous, FRP = filterable reactive phosphate, TN = total nitrogen, NO_x = oxides of nitrogen, NH_4^+ = ammonium, DO = dissolved oxygen.

Ecosystem Type	**Chl *a*** ($\mu g\ L^{-1}$)	**TP** ($\mu g\ P\ L^{-1}$)	**FRP** ($\mu g\ P\ L^{-1}$)	**TN** ($\mu g\ N\ L^{-1}$)	**NO_x** ($\mu g\ N\ L^{-1}$)	**NH_4^+** ($\mu g\ N\ L^{-1}$)	**DO (% saturation)** [l] Lower limit	**DO (% saturation)** [l] Upper limit	**pH** Lower limit	**pH** Upper limit
Upland river	na [a]	20 [b]	15 [g]	250 [c]	15 [h]	13 [i]	90	110	6.5	7.5 [m]
Lowland river [d]	5	50	20	500	40 [o]	20	85	110	6.5	8.0
Freshwater lakes & Reservoirs	5 [e]	10	5	350	10	10	90	110	6.5	8.0 [m]
Wetlands	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data
Estuaries [p]	4 [f]	30	5 [j]	300	15	15	80	110	7.0	8.5
Marine [p]	1 [n]	25 [n]	10	120	5 [k]	15 [k]	90	110	8.0	8.4

na = Not applicable

a = Monitoring of periphyton and not phytoplankton biomass is recommended in upland rivers – values for periphyton biomass (mg Chl *a* m^{-2}) to be developed;

b = Values are 30 μgL^{-1} for QLD rivers, 10 μgL^{-1} for VIC alpine streams and 13 μgL^{-1} for TAS rivers;

c = Values are 100 μgL^{-1} for VIC alpine streams and 480 μgL^{-1} for TAS rivers;

d = Values are 3 μgL^{-1} for Chl *a*, 25 μgL^{-1} for TP and 350 μgL^{-1} for TN for NSW & VIC East flowing coastal rivers;

e = Values are 3 μgL^{-1} for TAS lakes;

f = Value is 5 μgL^{-1} for QLD estuaries;

g = Value is 5 μgL^{-1} for VIC alpine streams and TAS rivers;

h = Value is 190 μgL^{-1} for TAS rivers;

i = Values is 10 μgL^{-1} for QLD rivers;

j = Value is 15 μgL^{-1} for QLD estuaries;

k = Values of 25 μgL^{-1} for NO_x and 20 μgL^{-1} for NH_4^+ for NSW are elevated due to frequent upwelling events;

l = Dissolved oxygen values were derived from daytime measurements. Dissolved oxygen concentrations may vary diurnally and with depth. Monitoring programs should assess this potential variability (see Section 3.3.3.2);

m = Values for NSW upland rivers are 6.5-8.0, for NSW lowland rivers 6.5-8.5, for humic rich TAS lakes and rivers 4.0-6.5;

n = Values are 20 μgL^{-1} for TP for offshore waters and 1.5 μgL^{-1} for Chl *a* for QLD inshore waters;

o = Values is 60 μgL^{-1} for QLD rivers;

p = No data available for TAS estuarine and marine waters. A precautionary approach should be adopted when applying default trigger values to these systems.

Table 3: Ranges of Default Trigger Values (Table 3.3.3 from ANZECC, 2000)

Ranges of default trigger values for conductivity (EC, salinity), turbidity and suspended particulate matter (SPM) indicative of slightly disturbed ecosystems in south-east Australia. Ranges for turbidity and SPM are similar and only turbidity is reported here. Values reflect high site-specific and regional variability. Explanatory notes provide detail on specific variability issues for ecosystem type.

Ecosystem Type	Salinity (μScm^{-1})	Explanatory Notes
Upland rivers	30-350	Conductivity in upland streams will vary depending upon catchment geology. Low values are found in VIC alpine regions (30 μScm^{-1}) and eastern highlands (55 μScm^{-1}), and high values (350 μScm^{-1}) in NSW rivers. Tasmanian rivers are mid-range (90 μScm^{-1}).
Lowland rivers	125-2200	Lowland rivers may have higher conductivity during low flow periods and if the system receives saline groundwater inputs. Low values are found in eastern highlands of VIC (125 μScm^{-1}) and higher values in western lowlands and northern plains of VIC (2200 μScm^{-1}). NSW coastal rivers are typically in the range 200-300 μScm^{-1}.
Lakes & reservoirs	20-30	Conductivity in lakes and reservoirs is generally low, but will vary depending upon catchment geology. Values provided are typical of Tasmanian lakes and reservoirs.
	Turbidity (NTU)	
Upland rivers	2-25	Most good condition upland streams have low turbidity. High values may be observed during high flow events.
Lowland rivers	6-50	Turbidity in lowland rivers can be extremely variable. Values at the low end of the range would be found in rivers flowing through well-vegetated catchments and at low flows. Values at the high end of the range would be found in rivers draining slightly disturbed catchments and in many rivers at high flows.
Lakes & reservoirs	1-20	Most deep lakes and reservoirs have low turbidity. However, shallow lakes and reservoirs may have higher natural turbidity due to wind-induced resuspension of sediments. Lakes and reservoirs in catchments with highly dispersible soils will have high turbidity.
Estuarine & marine	0.5-10	Low turbidity values are normally found in offshore waters. Higher values may be found in estuaries or inshore coastal waters due to wind-induced resuspension or to the input of turbid water from the catchment. Turbidity is not a very useful indicator in estuarine and marine waters. A move towards the measurement of light attenuation in preference to turbidity is recommended.

APPENDIX 2

Summary of Policies and Statutes affecting RTA activities in ASM areas

Summary of Policies and Statutes affecting
RTA activities in ASM areas

Statute, Policy, Strategic Plan	Summary	Application to RTA ASM Management
Environment Protection and Biodiversity Conservation Act 2000 Cwlth (EPBC Act)	The Commonwealth is the determining authority for proposed actions that are likely to have a significant impact on matters of national environmental significance. All proposed actions that impact on matters of national environmental significance must be referred to Environment Australia seeking a determination on whether the impact of the proposed action is considered significant.	Chapter 2.3.5, 5.2.1 and Appendix N of the *RTA EIA Guidelines* outline when a referral to Environment Australia is required for RTA activities that have ASM related impacts. Approximately 6 weeks should be allowed for the referral process.
Environmental Planning and Assessment Act 1979 and Regulations 2000 NSW (EP&A Act)	Approval for development and activities undertaken by the RTA needs to be obtained under either Part 4 or Part 5 of the Act. Where an Environmental Planning Instrument requires development consent to be obtained for RTA developments then the assessment process outlined in Part 4 of the EP&A Act must be followed. If not, as a public authority, the RTA must obtain approval under Part 5 for work classed as an activity.	Both Part 4 and Part 5 require an EIA be undertaken that considers environmental factors including the impact of leachate from ASM on surface and groundwaters, soil and vegetation. This process is documented in either an REF or EIS. EIA is to be conducted in accordance with the *RTA EIA Guidelines* and *ASM Procedure No.1*.
Protection of the Environment Operations Act (1997)	Certain polluting activities must hold an environment protection licence. Schedule 1 of the POEO Act lists activities for which an environment protection licence is required. Types of scheduled activities include Freeway or tollway construction, dredging works and extractive industries. The RTA is under a duty to notify the DEC of the occurrence of pollution incidents where material harm to the environment is caused or threatened. Material harm includes actual or potential harm to the health or safety of human beings or ecosystems that is not trivial or that results in actual or potential loss or property damage to an amount of $10,000.	Works undertaken to manage ASS specifically do not require an Environment Protection Licence unless undertaken in conjunction with a scheduled activity such as Freeway or tollway construction. However, the if RTA activities result in material harm to the environment being caused or threatened, then the RTA and individual employees of the RTA are under a duty to notify the DEC of such an incident as soon as practicable.
Coastal Protection Act 1979 NSW	Requires a public authority to obtain the concurrence of the Minister for Commerce to carry out any development or grant the right to carry out any development in the coastal zone if in the opinion of the Minister, the development or the use or occupation may in any way adversely impact on coastal water bodies (lakes, lagoons, wetlands estuaries etc).	If RTA conducts activities in the coastal zone then they must consult with the Minister for Commerce and obtain the concurrence of that Minister for activities which have an adverse impact before granting approval.
State Environmental Planning Policy No.14 – Coastal Wetlands (SEPP 14)	SEPP 14 aims to ensure that coastal wetlands are preserved and protected. Land clearing, levee construction, drainage works or filling may only be carried out within these wetlands with the consent of the local council and the agreement of the Director-General of DIPNR.	If works to manage ASM involve disturbance of a SEPP 14 wetland and are not part of existing development consent, consent must be sought from the local council. An EIS must accompany the development application.

Summary of Policies and Statutes affecting RTA activities in ASM areas (cont)

Statute, Policy, Strategic Plan	**Summary**	**Application to RTA ASM Management**
Water Management Act 2000 NSW (WMA)	Requires either a licence or approval to be obtained for activities that impact upon NSW water resources. Water access licences will replace existing water licenses under the *Water Act 1912*. Land based activities will be subject to four possible types of approval: water use approvals; water management work approvals; controlled activity approvals and aquifer interference approvals. Water use approvals authorise the use of water for a specified purpose for up to 10 years. Water management work approvals permit the construction and use of works for water supply, drainage or flood management for up to 20 years. Controlled activity approvals authorise 'controlled activity' on water front land, which includes building, carrying out of work, deposition of material, and removal of material. Aquifer interference activity approvals authorise the holder to conduct activities that damage or interfere with groundwater that are not for the primary purpose of extracting groundwater.	Upon commencement of the licensing and approvals provisions, the WMA will affect most land based activities. The detailed requirements of the Act should be considered where ASM management works involve: ▪ Taking and using water, ▪ Constructing or removing drainage or flood works, and ▪ Carrying out any works affecting the flow or quality of water in a water course, including depositing or removing material or removing vegetation. All necessary approvals will be obtainable through a single application from the DIPNR.
Water Act 1912 NSW	At present a licence is required for works including extraction of water, installation of bores and the diversion of watercourses.	The RTA must obtain a licence to extract water from any river, creek or bore or to construct works for the purpose of diverting a watercourse.
Fisheries Management Act 1994 NSW (FMA)	The *Fauna Management Act 1994* imposes a number of obligations, including: ▪ The requirement to provide written notice to the Minister at least 28 days prior to carrying out dredging or reclamation work, ▪ The requirement to notify the Minister of the proposal to construct, alter or modify a dam, weir or reservoir on a waterway, ▪ The need to consider habitat protection plans and to consider other documents in certain circumstances, ▪ The Act sets out the requirements for content where a Species Impact Statement is required under the EP&A Act, ▪ The requirements for permits in certain circumstances (e.g. for obstruction of fish passage), and ▪ The requirements relating to Threatened Species Recovery Plans and Threat Abatement Plans.	The Act is potentially relevant to ASM works affecting waterways with respect to the issues identified in the summary.
Environmentally Hazardous Chemicals Act 1985 NSW	The DEC has the power to regulate the management of certain chemicals by making Chemical Control Orders (CCO). CCO can prohibit specified activities or require them to be licensed, prohibit activities that don't comply with the conditions of the order, or permit an activity unconditionally.	CCO exist for certain chemicals such PCBs used by the RTA. Management of these chemicals should be undertaken in accordance with the CCO.

Summary of Policies and Statutes affecting RTA activities in ASM areas (cont)

Statute, Policy, Strategic Plan	Summary	Application to RTA ASM Management
National Parks and Wildlife Act 1974 NSW (NPW Act)	This Act provides for the preservation, protection and management of certain native fauna, flora and Aboriginal heritage. It is an offence to harm native fauna or pick native flora within wildlife protection areas, harm or pick any threatened species, population or ecological community unless licensed to do so or in accordance with a development consent . In relation to Aboriginal heritage, it is an offence to knowingly damage, deface or destroy an Aboriginal relic or Aboriginal Place without the consent of the NPWS under s.90. In addition, anyone who discovers an Aboriginal relic must report that discovery to the NPWS within a reasonable time unless that person has reason to believe that the NPWS already knows of its existence.	Relates to activities undertaken by the RTA that could result in harm to flora and fauna and are not undertaken in accordance with development consent. The NPW Act may also be relevant where works to manage ASM have the potential to adversely impact Aboriginal sites.
Threatened Species Conservation Act 1995	The *TSC Act* provides protection for threatened plants and animals native to NSW (excluding fish and marine vegetation) and integrates the consideration of threatened species into the planning process under the *EP&A Act*.	Could be relevant where works to manage ASS are not part of a development consent and have the potential to harm species listed under the Act.
Native Vegetation Conservation Act 1997 NSW	This Act provides a comprehensive system for conserving and managing native vegetation in NSW. The Act prohibits the clearing of certain land without development consent under the *EP&A Act* in certain circumstances.	In areas with approved regional vegetation management plans, vegetation management (as may be required during the management of ASM) should be undertaken in accordance with the plan, otherwise actions may require development consent. In areas where there is currently no plan, clearing of native vegetation is permissible if exemptions apply (a list is held by the local DIPNR office), or if approval has been given by DIPNR.
State Environmental Planning Policy No.71 – Coastal Protection (SEPP 71)	Clause 8 of SEPP 71 lists numerous matters to be considered by a consent authority when determining a development application located within the coastal zone. Water quality is listed as a matter for consideration. DIPNR is made responsible for the assessment of new development within the coastal zone classed as significant coastal development. Significant coastal development includes land within a sensitive coastal location and 100m below the high water mark of the sea. It was recently announced that SEPP 71 will be reviewed.	Works to manage ASM undertaken within the coastal zone and considered to be coastal significant development require approval from the DIPNR. A range of coastal environments in which ASM can be expected to occur are noted as sensitive coastal locations in the SEPP.

Summary of Policies and Statutes affecting RTA activities in ASM areas (cont)

Statute, Policy, Strategic Plan	Summary	Application to RTA ASM Management
Local Environmental Plans and ASS Model LEP	A model LEP has been developed to improve the management of works undertaken in ASS areas and has been adopted by many coastal local government areas. The model LEP contains provisions requiring development consent for works that might disturb ASS by subjecting the approval to environmental assessment under Part 4 of the EP&A Act, 1979.	A LEP in a coastal area is likely to require consent for RTA work undertaken within an ASS risk area in accordance with the provisions of the model LEP. However, in most cases the consent requirements will be overcome by the application of other statutory provisions and environmental impact assessment under Part 5 of the EP&A Act will apply.
NSW Catchment Blueprints	Catchment Blueprints provide a succinct and clear direction for activity and investment in natural resource management across the relevant catchment over the next 10 years. Blueprints contain objectives, catchment targets, management targets and a list of management actions to achieve the targets in order to guide natural resource management decisions.	Many Blueprints specifically address ASS issues on coastal floodplains. Therefore in managing ASM, the RTA should examine the relevant Catchment Blueprint and undertake activities consistently with the Blueprint targets.
State Water Management Outcomes Plan	Sets overall policy and strategic outcomes for water management in NSW. Target 30 relates specifically to ASM. It states that coastal floodplain areas with high water quality risk are to be addressed by no increase in acid drainage resulting from new developments in a mapped ASS hot spot.	All RTA works should be undertaken in accordance with the NSW SWMOP, in particular ASM related works are to be consistent with Target 30.
Estuary Management Plans	Prepared as joint initiatives of State and Local Government. Estuary Management plans provide actions to maintain and enhance estuary values, and generally include actions and targets relating to ASS as a key issue.	The impact of Estuary Management Plans should be considered during EIA.
Floodplain Management Plans	Prepared as a joint initiative of State and Local Government. May include actions relating to protection of water quality in floodplain habitats.	The impact of Estuary Management Plans should be considered during EIA.
NSW Coastal Policy 1997	Provides a strategic framework for the management of coastal environments, with 9 goals and 34 key actions. Action 2.1.4 of the Policy relates specifically to ASS. It states that initiatives will be taken to address the impacts of ASS through risk mapping, requiring an EIS for ASS related developments, monitoring ASS impacts, preparation of management plans, at the project level. It was announced in late 2002 that the NSW Coastal Policy is to be updated in consultation with relevant stakeholders.	RTA works undertaken in the coastal zone should be consistent with the objectives of the NSW Coastal policy and specifically Action 2.1.4.
National Strategy for the Management of Coastal Acid Sulfate Soils 2000	The National Strategy provides a national approach to the assessment and management of coastal ASS. It identifies priorities for better management of coastal ASS that include distribution mapping and the implementation of effective planning policy.	RTA works in ASS areas should be undertaken generally in accordance with the National Strategy.

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APPENDIX 3

Impacts of Acid Sulfate Materials

A range of impacts associated with disturbance and oxidation of ASM (drawn principally from the literature on ASS) is presented below.

1. Aquatic and Wetland/Terrestrial Ecosystem Impacts

White and Melville (2000) provide an overview of the impacts of poorly managed ASS on ecology. The most commonly reported impacts of acidification of estuarine waters relate to gilled fish, crustacean and aquaculture shellfish.

- Sammut, Melville and Callinan (1995) describe fish kills and fish diseases such as red spot disease that result from acidification of fish habitat. A major event that drew attention to the severity of acid sulfate impacts on coastal waterways occurred in 1987, when 23 km of the Tweed estuary was so severely acidified that it resulted in "death of all fish, prawns, crabs and many worms in this reach" (White and Melville 2000).

- A number of studies have reported decreased aquaculture production and shell thinning (eg. in oysters) in estuaries subject to chronic acidification episodes.

- NSW Fisheries (1985) reported a general decline in fish populations and fish health as well as potential changes to species structure in areas where acid drainage occurs. Although wild fish will generally move if possible to avoid low pH waters, they can become trapped in estuaries between floodgate structures and acidified waters.

Inappropriately managed drainage from actual ASS and from pyritic rocks that are uncovered in cuttings or used as fills can affect the growth of plants. White and Melville (2000) note that since the main period of floodplain drainage, now some 50 years ago in northern NSW, some low lying areas have become persistently scalded and devoid of vegetation. The peat that formerly overlaid the ASS in these areas has often been burnt after desiccation and the geochemistry of the scalded areas is toxic to plants (usually with a high aluminium concentration). Rossicky, Sullivan and Slavich (2002) report research on potential revegetation measures for these scalded areas.

In coastal agricultural lands, the extent of ASS impacts depends in part on the nature of the crop, with some species (such as bananas, sugarcane and pineapples) being much more tolerant of acid soil conditions than others. Johnson (2002) and others have also noted that some species of Melaleuca are acid tolerant and may provide preliminary indication of acid hot spots across a floodplain.

2. Release of Heavy Metals from Contaminated Soils

The reaction between acid and clay minerals releases dissolved aluminium, iron, manganese, heavy metals and other metal ions into soil and drainage waters (White and Melville, 2000; following van Breeman, 1973). At low pH (generally at pH less than 4.5) these ions will remain dissolved. The dissolved ions are highly toxic to aquatic life.

The impact of acid conditions can be particularly significant in situations where there is existing contamination of soils or sediments by heavy metal pollution. These situations could include estuarine sediments that have been polluted by stormwater or sewerage effluent containing metals or pesticides.

3. Human and Animal Health

Humans and domestic and wild animals are all sensitive to low pH environments, and particularly to potentially toxic concentrations of metals that may occur in acidified areas. White and Melville (1993) and Pearce (1995) refer to direct impacts such as stunted growth, mental impairment, heavy metal poisoning and respiratory problems. A further indirect impact is an increased risk of diseases that may be carried by acid tolerant organisms.

QASSIT (2000) note the potential for dust from disturbed ASM to cause eye irritation and direct contact with acid surface waters can trigger dermatitis in sensitive individuals.

4. Corrosion of and Structural Damage to Steel and Concrete Structures

This issue is widely reported from areas affected by ASS and ASR. White and Melville (2000) note that iron and steel (eg. in pipes, reinforcing steel) and aluminium (eg. in road guard rails, aluminium boats) are attacked by acid, although steel generally requires severe reducing conditions. As an example, Tweed Shire Council recently spent $4 million replacing cast iron water pipes that had been corroded by acid.

Lea (1970) describes the impact of acid sulfate conditions on cement. These impacts include etching, exposure of aggregate, volume increase due to chemical reactions and overall weakening/degradation.

Other aspects of the process of deterioration include:

- leaching, which removes part or all of the hardened cement paste from concrete;
- deterioration by exchange reactions and by removal of readily soluble compounds from the hardened cement paste; and
- swelling deterioration, largely due to the formation of new stable compounds in the hardened cement paste.

5. Soil Structure and Subsidence

White and Melville (2000) note that when ASS oxidise, there are significant structural changes to the soil, known as "ripening."

> *"Many of the unconsolidated backswamp, sulfidic sediments are essentially gels containing up to 80% water and they have a very small capacity to transmit water. Ripening flocculates these gels, producing soils with lower water contents and higher hydraulic conductivities. Ripening can also cause soil to shrink by almost 50% of their volume (see also White et al 1993). This together with the oxidation of peat top soils means that the soil surface elevations in drained backswamp areas are lower than in their undrained state."*

6. Soil Erosion, Clogging of Aquifers and Subsoil Drains

Where land and water uses cause dewatering of sand aquifers in ASS areas, the pyrite minerals can oxidise at depth in the stratigraphy, leading to the formation of iron flocs when fresh or neutral pH water meets iron rich ground waters. In addition, bacterial mats and filamentous bacteria may thrive in iron rich groundwaters. In both cases, there is potential for wells, drains and pumps to become clogged. Note also the potential for MBO to form as organic gels in drains in ASS areas.

In areas where surface soils are affected by acidification, vegetation may be very sparse and regeneration slow. These scalded soils are susceptible to both sheet erosion and wind erosion (note acid dust impacts on human health, in **Section 5.4**).

7. Other Impacts, Issues and Risks

The range and severity of these direct environmental and project management risks also raises the potential for a number of associated risks, including:

- geotechnical investigation and road design costs, including the development of alternative route scenarios;
- project cost implications associated with effective management of ASM (eg. additional materials costs or changes to design), and also with failure to recognise and deal with ASS effectively;
- potential additional environmental offset costs in terms of specific habitats under threat from road construction;
- risks of prosecution by the DEC if there is an ASM incident causing harm to the environment and the RTA cannot demonstrate due diligence; and
- poor community relations and organisational reputation for sustainable environmental management. Reduced perception of the RTA as a credible performer in sustainable environmental management.

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