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Site 015 Kangaroo Island
Acid Sulphate Soil Risk

Figure:

BLUE CARBON ECOSYSTEM RESTORATION

ACID SULFATE MATERIALS PLAN OF MANAGEMENT FRAMEWORK

Blue Carbon S2C Pty Ltd

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Document History

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Revision	Purpose and Description	Originated	Checked	Reviewed	Authorised	Date
A	Acid Sulfate Materials Plan of Management Framework	RP	GW	GW	RP	07/02/2023

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Review

This document should be reviewed annually or, when required. It must be reviewed following significant incidents and updated where appropriate to ensure that it remains relevant and effective throughout Blue Carbon restoration projects and activities. All reviews, changes or updates are to be recorded using the Document History box provided above.

CONTENTS

LIST OF TABLES

GLOSSARY OF TERMS

Term	***Meaning / Definition***
Actual ASS	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 more than 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.
Ag lime	Agricultural lime
ASM	Acid Sulfate Material
ASS	Acid Sulfate Soils
BCER	Blue Carbon Ecosystem Restoration
BC-OC	BlueCarbon OnCountry
BC-S2C	Blue Carbon S2C Pty Ltd
Best practice environmental procedures	means procedures that refer to and are consistent with the most recent policy and technical advice adopted by State or Territory agencies in Australia.
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.
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
PASS	Potential Acid Sulfate Soils 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).
Framework	Plan of Management
Water quality and sediment quality objectives	means that BC-S2C will use due diligence to ensure that its activities are conducted in accordance with best practice procedures and national environmental standards. Refer to the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (2000).

1 Overview

This Acid Sulfate Materials Plan of Management Framework (herein referred to as the **Framework**) has been prepared by Blue Carbon S2C Pty Ltd (**BC-S2C**) to assist in addressing, identifying and managing Acid Sulfate Soils (**ASS**) or Potential Acid Sulfate Soils (**PASS**) at individual Blue Carbon Ecosystem Restoration (**BCER**) project sites. ASS or PASS are herein referred to as Acid Sulfate Materials (**ASM**). The Framework is intended for use by BlueCarbon OnCountry (**BC-OC**) personnel, project consultants and contractors involved in **BCER** activities on behalf of Blue Carbon S2C Pty Ltd (**BC-S2C**) to develop site specific ASM Management Plans using the information contained in Appendix A to H.

This Framework has been prepared in conjunction with:

- National guidance for the management of acid sulfate soils in inland aquatic ecosystems (Environment Protection and Heritage Council and the Natural Resource Management Ministerial Council, 2018).
- National Acid Sulfate Soils Guidance: Guidance for the dewatering of acid sulfate soils in shallow groundwater environments (Water Quality Australia, 2018a).
- National Acid Sulfate Soils Guidance: Guidelines for the dredging of acid sulfate soil sediments and associated dredge spoil management (Water Quality Australia, 2018b).
- National Acid Sulfate Soils Guidance: National acid sulfate soils sampling and identification methods manual (Water Quality Australia, 2018c).

1.1 Context

This Framework must be read in conjunction with the following BC-S2C document - Erosion and Sediment Control Guideline – BCO-PLN-200-2023-002

1.2 What are ASS?

ASS is the common name given to naturally occurring soil and sediment containing:

- iron sulfides derived from the mineral iron pyrite or,
- containing acidic products from 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 neutralise the acidity is exceeded.

If the sulfide soils remain under the water table:

- oxidation cannot occur, and the soils are quite harmless and can remain so indefinitely.

1.3 Characteristics of ASS

Material	Distribution	Potential impacts
ASS and PASS	Widespread in estuaries and coastal floodplains, backswamps and coastal wetlands.	Discharges of very low pH (acidic) waters, biochemical barriers, fish kills, loss of habitat, loss of agricultural productivity, structural and engineering issues.

1.4 Who needs to use this Plan?

This Plan is relevant to all BCER projects. It is intended for use by:

- BC-OC project site managers and construction staff under their supervision.
- BC-OC environmental advisors, sea and land ranger officers, and environmental consultants who provide cultural or scientific knowledge / advice to project managers.
- Professional service contractors to BC-OC.
- BC-OC project managers should also require that all consultants and contractors document and implement these procedures when carrying out projects in ASS or ASR risk areas. This requirement is incorporated into each contract.

1.5 When to use this Plan

This Framework should be used for all projects where there is potential to disturb ASS sediments. The types of activities that may disturb or be affected by ASS include:

- Excavation of drainage lines required for BCER. Excavation includes minor disturbance of soil to major earthworks.
- Deep re-use of excavated channel material containing ASS for topographical and hydrological restoration purposes.
- Sinking new bridge piles.
- Excavating new culvert foundations.

1.6 Governance

BC-S2C is committed to best practice environmental management in all its activities. The recognition and sustainable management of ASS during BCER planning, construction and maintenance is an important element for BC-S2C to achieve and maintain its values.

1.7 Document structure

Table 1-1 Document structure

Section No.	Title	Description
1	Overview	Provides an overview of ASS governance.
2	Management context	This Chapter describes how the ASM Framework relates to the BC-S2C' environmental management system, including its Environment & Sustainability Policy and, environmental management planning processes. It includes the statutory and policy context of ASM management and introductory technical information about ASM and the risks they present to the environment.
3	Managing ASS	This Chapter contains the procedural guidance for identifying and managing ASM. This includes guidance on environmental impact assessment, development of controls and treatments and, ASM management planning. The ASM management requirements have been identified as a series of clear steps which indicate the extent of investigation, analysis and management controls necessary for effective management of ASM issues
4	References	References cited in the Framework
Appendix A	Procedure No.1	Preliminary identification of ASM
Appendix B	Procedure No.2	ASM In-field indicators
Appendix C	Procedure No.3	Detailed identification of ASM flowchart
Appendix D	Procedure No.4	Trigger criteria for ASM management intervention
Appendix E	Procedure No.5	Environmental Impact Assessment for ASM
Appendix F	Procedure No.6	ASM management actions
Appendix G	Procedure No.7	ASS treatment priorities
Appendix H	Procedure No.8	Estimating soil treatment levels of ASS

2 Management Context

2.1 BC-S2C management aim

BC-S2C' broad objective for the management of ASM during its BCER projects is noted below.

BC-S2C will use best practical environmental procedures for its blue carbon restoration 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.

2.2 Management system context

This Framework is part of BC-S2C's Environmental Management System that is supported by an Environment & Sustainability policy developed at the corporate level to drive environmental protection measures at the directorate and business area level. The use of this Framework by project managers and others involved in BCER will underpin BC-S2C' 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 BCER project areas. Understanding and familiarity with these procedures will contribute to the prevention of incidents such as increased acid leachate from BC-S2C projects.

2.3 Statutory and policy context

Northern Territory and Commonwealth legislation, as well as several national environmental policies and strategies, must be taken into consideration when planning and implementing works in acid sulfate areas.

2.4 Acid sulfate soils

The environmental consequences of disturbing or draining ASS include discharge of waters with elevated concentrations of aluminium, iron, and zinc. Emissions of greenhouse gases such as carbon dioxide and nitrogen dioxide from wetland drainage can also occur. 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 4.0 to 4.5, but they do not have the capacity to generate additional acidity due to oxidation.

2.5 How does the presence of ASS affect BC-S2C environmental performance?

The presence of ASS 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 challenges and, the maintenance of infrastructure in acid sulfate environments.

A range of potential adverse environmental impacts associated with disturbance and oxidation of ASM. These potential impacts 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.
- Other impacts, issues, and risks.

3 Plan of management

3.1 Management principles for acid sulfate soils

The ASS management principles to be implemented by BC-S2C for its BCER were adopted from the *Queensland Acid Sulfate Soil Technical Manual, Soil Management Guidelines* (2014). They are noted in Table 3-1.

Table 3-1 Key ASS management principles

Principle No.	Key principle
1	The disturbance of ASS should be avoided wherever possible. BC-S2C will adopt Principle No.1 during project development and design.
2	Where disturbance of ASS is unavoidable, BC-S2C's preferred management strategies will be: a. Minimisation of disturbance. b. Neutralisation c. Hydraulic separation of sulfides either on its own or in conjunction with dredging. d. Strategic reburial (reinterment).
3	Works should only be performed when it has been demonstrated that the potential impacts of works involving ASS are manageable and, 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	The management of disturbed ASS is to occur if the ASS Trigger Action criteria is exceeded or reached (see Appendix D - Procedure No. 4).
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 Trigger Action Criteria (see Appendix D - 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 (e.g., 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. • The management and planning strategies of the appropriate authority including Regional or Catchment Management Plans/Strategies and State/ Territory Regional Coastal Policies/Plans.

3.2 Procedures for managing acid sulfate materials

The management of ASM by BC-OC personnel and contractors is required to be in accordance with the procedures listed below and contained in Appendix A to Appendix H.

- ASM Procedure No. 1: Preliminary identification of Acid Sulfate Materials (Appendix A).
- ASM Procedure No. 2: In-field indicators (Appendix B).
- ASM Procedure No. 3: Detailed identification of ASM flowchart (Appendix C).
- ASM Procedure No. 4: Trigger criteria for management intervention (Appendix D).
- ASM Procedure No. 5: Environmental Impact Assessment (Appendix E).
- ASM Procedure No. 6: Management actions (Appendix F).
- ASM Procedure No. 7: ASS treatment priorities (Appendix G).
- ASM Procedure No. 8: Estimating soil treatment options for ASS (Appendix H).

The Procedures cover the conduct of BC-S2C and BC-OC restoration activities from route selection to operation and maintenance. These procedures include 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.

4 References

Dear, S-E., Ahern, C. R., O'Brien, L. E., Dobos, S. K., McElnea, A. E., Moore, N. G. & Watling, K. M., 2014. Queensland Acid Sulfate Soil Technical Manual: Soil Management Guidelines. Brisbane: Department of Science, Information Technology, Innovation and the Arts, Queensland Government.

5 Appendices

Appendix A: Preliminary identification of ASM across all BCER sites and supporting information

ASM Procedure No. 1: Preliminary identification of Acid Sulfate Materials

Application:
Applies to the identification of ASM across all BC-S2C activities undertaken by BC-OC personnel and/or contractors engaged by BC-OC 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

BC-OC Project Manager, BC-OC Environmental Scientist, Environmental staff, and all on-site contractors.

Inputs

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

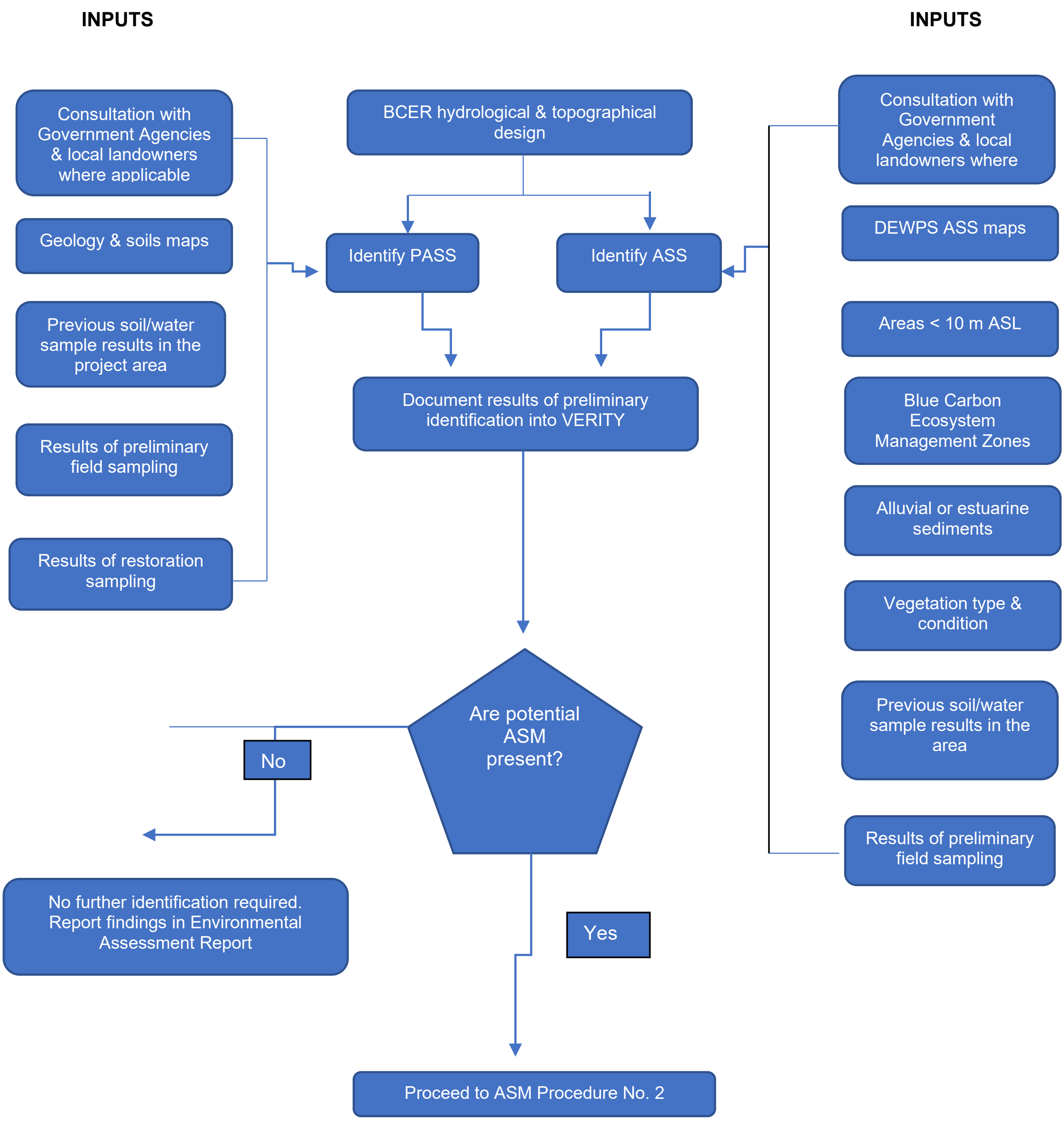
Process

The procedure is covered across two stages which involves preliminary investigation (Refer to Table A1 below) and detailed investigations (Procedure 3).

TABLE A1: Stages of identification for ASM

Action No.	Action
Preliminary identification of ASM to be undertaken during options investigation or preliminary environmental assessment	
1	Conduct desktop review of available information to identify and document potential ASS risk areas which may include: • Review ASS Risk maps relevant to the area. • Identify and map areas less than 10 m above mean sea level. • Identify and map wetland / blue carbon ecosystem management zones. • Determine if the site has alluvial or estuarine sediments. • Identify and map vegetation types including mangroves, paperbarks, swamp oak, reeds, rushes or other marine or swamp tolerant vegetation. • Review results of any soil/water/rock testing previously carried out in area. • Store data for later reference
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. • Review results of any soil/water/rock testing previously carried out in area.
3	Consult relevant agencies (Local Council, NSW Department of Infrastructure, Planning and Natural Resources and the NSW Department of Environment and Conservation) and landowners 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 (Procedure No.2)
5	Document results on a map and accompanying briefing paper showing: • Areas assessed. • 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
Detailed identification of ASS to be undertaken during the Design Development and Approval phase. ASM investigations be undertaken at the earliest stage of project development.	
1	Review Stage 1 results.
2	Establish whether the site to be disturbed is considered minor or major. • Minor – disturbing less than 1,000 tonnes of soil, non-linear [spatially confined] and does not affect groundwater – Proceed to Action 3. • Major – disturbing greater 1,000 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 *National Acid Sulfate Soils Guidance – National acid sulfate soils sampling and identification methods manual (June, 2018)*.
4	Sampling for all major disturbances to be undertaken by appropriately qualified personnel in accordance with the above Guideline.
5	Document results in a detailed report including: • Description of methods and sampling regime. • Sampling results. • Mapping of ASS a constraints. • Analysis of level of risk (environmental, structural etc.) associated with disturbance of each area. Description of required treatments, controls, and management strategies to address ASS issues.
Outputs	
Stage 1	A map and accompanying briefing paper or report identifying ASS (actual and potential).
Stage 2	Detailed report that includes any field sampling results.

Preliminary identification of Acid Sulfate Material Flowchart



Appendix B: In-field indicators of Acid Sulfate Material

ASM Procedure No. 2 - In-field indicators for Acid Sulfate Material

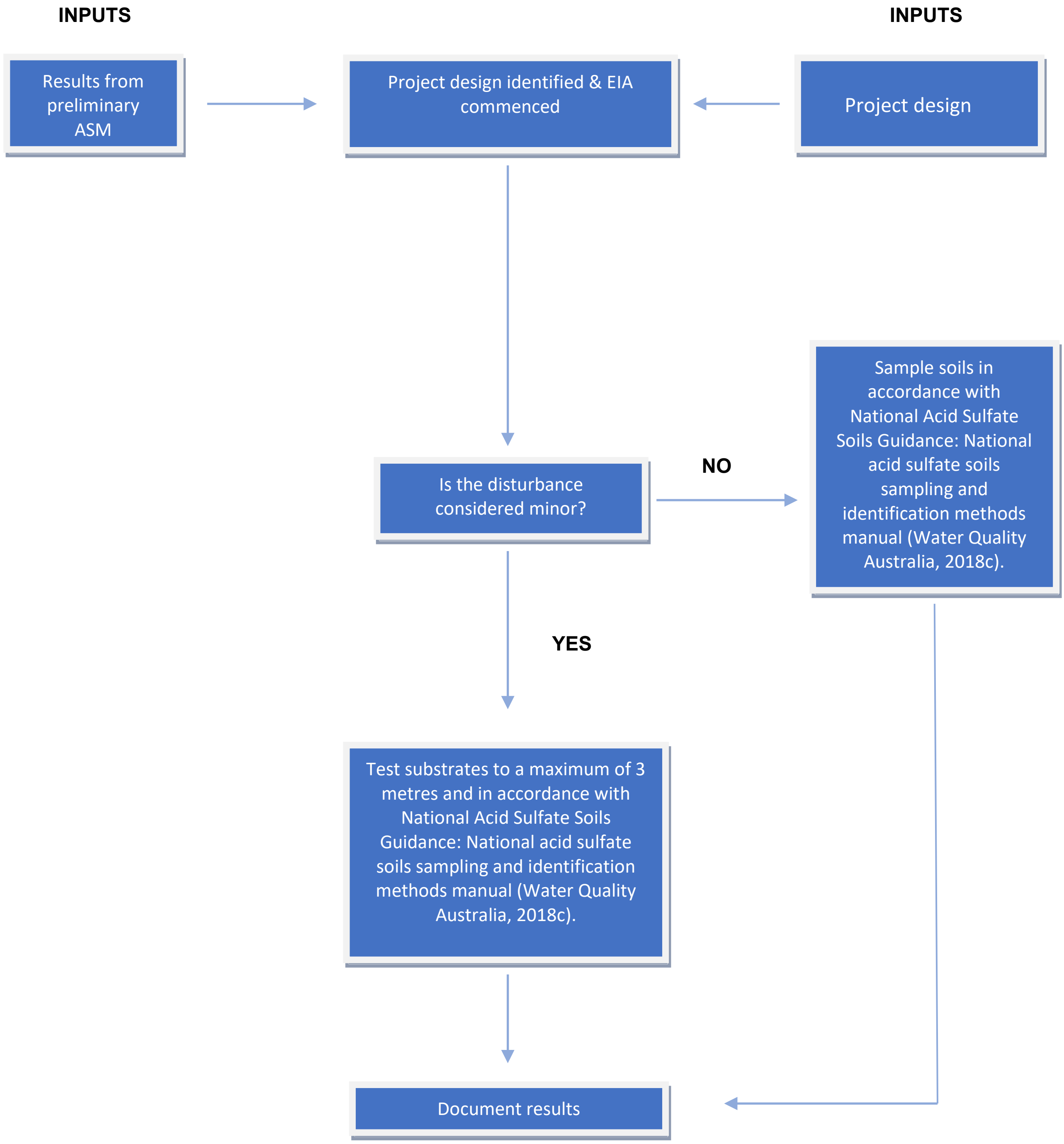
The following are preliminary indicators of ASS that may be observed during initial site inspections.

- 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.).
- Blue-grey, blue-green or grey waterlogged soils which smell of rotten egg gas.
- Soils and sediments of recent (Holocene and modern) age.
- Areas where the dominant vegetation is tidally affected e.g., mangroves, marine couch, saline scalds or swamp tolerant reeds, rushes, and grasses (e.g., *Phragmites australis*), paperbarks (e.g., *Melaleuca spp*) and *Casuarina spp*.
- Acid surface waters - pH less than 4.
- Acidic soil - when saturated has pH less than 4.
- Unusually clear or milky green drain water coming from or within a site.
- 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.
- Augured soil or excavated pits indicating any pale yellow or orange red iron oxide deposits or iron oxide mottling.
- Corrosion of concrete or steel structures.
- 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.
- Deep older estuarine sediments below ground surfaces of either Holocene or Pleistocene age (where deep excavation or drainage is proposed).

If any of the above are observed or recorded, **proceed to ASM Procedure No.3**

Appendix C: Detailed identification of Acid Sulfate Material flowchart

ASM Procedure No.3 - Detailed Identification of Acid Sulfate Material Flowchart



Appendix D: Trigger criteria for management intervention

ASM Procedure No.4 - Tigger criteria for management intervention

Trigger criteria for soils according to their texture (texture class and approximate clay content) and the combined existing and potential acidity of the material is shown in Table D1. Action criteria also considers the volume of soil to be disturbed (greater or less than 1,000 tonnes).

The ***trigger criteria*** refers to existing plus potential acidity for given volumes of ASS. The highest result(s) should always be used to assess if the relevant ***trigger criteria*** level has been met or exceeded.

Table D1 Texture-based ASS trigger criteria for management intervention

Type of soil material		Tigger Action Criteria if 1 to 1000 tonnes of material is disturbed		Tigger Action Criteria if 1 to 1000 tonnes of material is disturbed	
		Existing + Potential Acidity		Existing + Potential Acidity	
Texture range	**Approximate 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-dry basis means dried in a fan-forced oven at 80° - 85°C for 48 hours.

Note:
If a soil shows evidence of self-neutralising or self-buffering e.g., the Titratable Potential Acidity = 0 and the acid neutralising capacity > 5% using equivalent units, then a case may be made for reduced or no treatment.

Appendix E: Environmental Impact Assessment for Acid Sulfate Materials

ASM Procedure No. 5 - Environmental Impact Assessment

Application
This procedure applies to all BC-S2C environmental impact assessments (EIA) undertaken by BC-S2C or BC-OC personnel, consultants, or contractors.

Management Principles

- For all proposed BC-OC restoration activities (including maintenance activities) an EIA is to be undertaken in accordance with this Framework to identify the environmental aspects and impacts of restoration 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, BC-S2C environmental assessment team or BC-S2C/BC-OC contractors.

Inputs:

- Base data, including GIS/mapping data, criteria for ASS/PASS etc.
- Conceptual design details.
- Outputs of ASM Procedures No. 1, 2 and 3.

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 restoration activity in relation to ASM. Document results to be considered in project design decisions.
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. 4:
5. Identify and assess the level of impact of activity on site and surrounding environment considering:
    - results of the identification process; preliminary risk assessment results;
    - design considerations;
    - existing environment;
    - maximum possible quantity and concentration of leachate from ASM based on the worst case scenario;
    - potential impact of ASM including:
        - surface waters,

    - groundwater,
    - flora and fauna,
    - agriculture,
    - soil structure.
- 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.

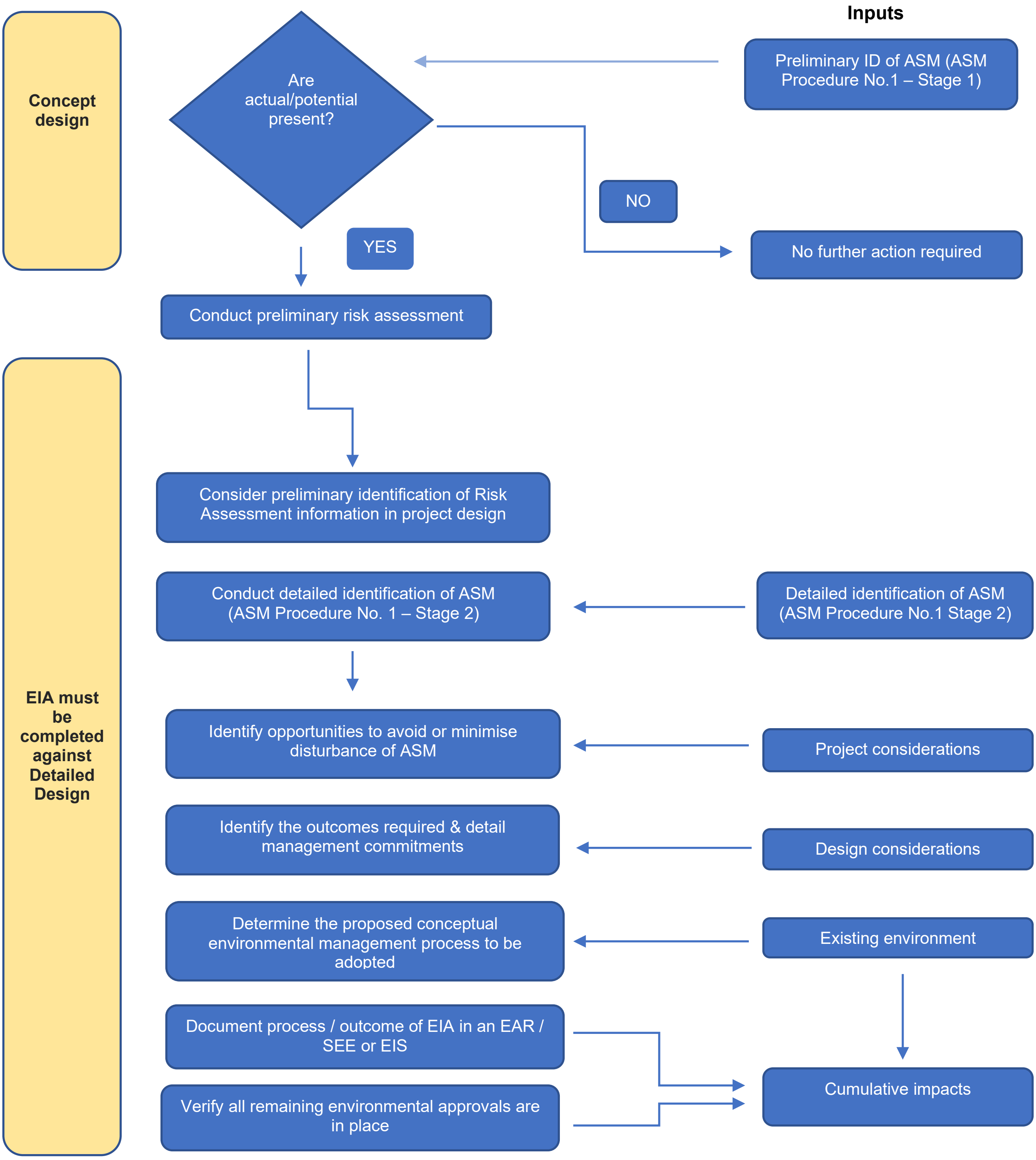
6. Identify the outcomes required and detail management commitments:

    - 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 project registration under the ERF or Verra methods.

Outputs
Risk assessment documentation.

Environmental Impact Assessment flowchart



Appendix F: ACID SULFATE MANAGEMENT ACTIONS

ASM Procedure No.6 - ASM Management Actions

Actions

1. Identify legal requirements relating to ASM including (as applicable):
    - ASM management objectives and performance targets.
    - Conditions of Project Registration and/or Approval.
    - Environment Protection Licence conditions.
    - Conditions of other permits/licences/approvals.
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.
4. 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.

The following should also be considered:

- the level of residual risk associated with each potential impact 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; and
- the performance/effectiveness of controls/treatments on past projects.

5. 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 (e.g. 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.

6. Identify any project specific training needs in relation to ASM in accordance with the outcomes of the Environmental Impact Assessment phase and risk assessments.

7. Identify community consultation needs for the construction and maintenance phases of the project in accordance with BC-S2C **Community Engagement Policy** and **Stakeholder Engagement Communication Plan**.

8. Develop a project specific ASM Framework that provides detailed guidance on site-specific issues.

9. Implement ASM Framework.

10. On completion of the construction phase, the ASM management details are to be included in the Project Completion Report. Issues to be detailed include:

    - details of compliance with the ASM Framework 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').

11. The relevant components of the ASM Framework and any additional details from Action 9 above are handed over to the RTA Regions' Asset Management section.

Outputs

- Detailed Risk Assessment documentation.
- Project specific ASM Framework (refer to Action 8).
- ASM management details to be included in the Project Completion Report.

Appendix G: Acid Sulfate Soil Treatment Priorities

ASM Procedure No.7 – Acid Sulfate Soil Treatment Priorities

Management / Treatment Strategy	Brief description	Limitations
1. Avoidance strategies		
Plan 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.
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.
1. 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.
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.
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.
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.
2. Neutralisation of Acid Sulfate Soils		
Neutralisation of ASS	• Incorporation of alkaline materials (e.g., ag lime) 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).
3. 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).

Management / Treatment Strategy	Brief description	Limitations
4. Strategic reburial		
Strategic reburial	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).
5. 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.
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).
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 (e.g., shallow infrastructure trenching).
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. 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.
6. Considered unacceptable management strategies		
Above ground capping	Placing untreated ASS above ground and encapsulating under a non-porous cap.	
Accelerated oxidation	Accelerated 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.

Appendix H: ESTIMATING SOIL TREATMENT LEVELS

ASM Procedure No. 8 – Estimating soil treatment levels

Estimating treatment levels and ag-lime required to treat the total weight of disturbed Acid Sulfate Soil – based on soil analysis (Dear *et al*, 2014).

The tonnes (t) of pure fine ag-lime, CaC03 required to fully treat the total weight/volume of 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 (t) = m^3 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**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**4.0**	**5.0**
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
1,000	1.4	2.8	4.7	9.4	19	28	37	47	70	94	117	140	187	234
2,000	2.8	5.6	9.4	19	37	56	75	94	140	187	234	281	374	468
5,000	7.0	14	23	47	94	140	187	234	351	468	585	702	936	1.170
10,000	14	28	47	94	187	281	374	468	702	936	1,170	1,404	1,872	2,340

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

+ An approximate soil weight in tonnes can be obtained from the calculated volume by multiplying volume (m^3) 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 100 m^3 of such soil may weigh up to 170 tonnes. 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, Peroxide Oxidisable Sulfur and Total Oxidisable Sulfur. For samples with pH <5.5, the existing acidity must also be determined by appropriate laboratory analysis e.g., Titratable Actual Acidity. Soils with retained acidy e.g., 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.