INSTRUCTIONS FOR THE

TREATMENT AND MANAGEMENT

OF ACID SULFATE SOILS, 2001

Queensland
Government

Produced by the Queensland Environmental Protection Agency in consultation with the Department of Natural Resources and Mines and the Department of Primary Industries.

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Introduction

These instructions have been developed to give direction in undertaking activities that may drain or disturb acid sulfate soils (ASS). The instructions are modular, and depending on the scale of the project and the type of management proposed for a particular activity one or all modules may apply. The modules have been provided to address general ASS management issues and four specific treatment or management techniques in current use. The instructions are structured as follows:

- Module A - General Management Requirements that Apply to All Acid Sulfate Soil Treatment and Management
- Module B - For the Management of Undisturbed Acid Sulfate Soils
- Module C - For the Management of Potential Acid Sulfate Soils Using Strategic Reburial Techniques
- Module D - For the Treatment of Acid Sulfate Soils Using Neutralisation Techniques
- Module E - For the Treatment and Management of Acid Sulfate Soils Using Separation Techniques

Compliance with these instructions may be required as a condition of a statutory approval (for example an environmental authority or development permit) when sufficient understanding of the site has been demonstrated and sound management proposal has been put forward. Module A applies to all sites and activities. Module B applies when undisturbed ASS are present at the site. Modules C, D and E apply as relevant to the treatment or management techniques that have been chosen, or permitted to use. Reference or cross-reference to any module within these instructions also includes the site specific or activity specific conditions relevant to that module that are included in the statutory authority for a given site or project.

Site or activity specific requirements will also appear as conditions in the statutory approval if such requirements are necessary or desirable. Such conditions may over-ride some of the requirements of this document.

Each module of these instructions is presented in two parts. **Part One** states performance requirements that *must be complied with* for activities covered by the subject of that module. **Part Two** provides examples *of measures that should be taken* to demonstrate the general environmental duty and to assist in complying with the requirements of Part One. Implementation of measures in Part Two of each module should reduce the risk of environmental harm associated with the activity that is being undertaken.

It is important to note that **avoidance** of disturbance of (or other impacts on) ASS **is the preferred means of management**. However, these instructions apply in cases where:

- some ASS disturbance is considered ecologically sustainable from an environmental risk perspective because practicable best practice environmental management strategies have been developed for the site; and
- the critical areas for avoidance have either been prescribed (in a statutory approval) or have been identified accurately in the application/ proposal for the activity or development and avoided in the design.

This document focuses on soil treatment and management. Water quality management is also required in association with ASS management (example management of metals mobilised at low pH, etc). This document does not authorise any contamination of any waters associated with ASS drainage disturbance or excavation. Management strategies outlined in this document are based on a principle of containing and managing all impacts within appropriate areas of the site being developed.

Implementation of these instructions will only be effective if accompanied with a sufficient understanding of the distribution and severity of ASS on a site and adjacent areas. Therefore these instructions should be implemented with reference to results from a sound pre-development ASS investigation undertaken using best-practise sampling and analysis techniques.

Note that where there is failure to comply with these instructions, appropriate proceedings may be instigated. These may include but not be limited to the issuance of Penalty Infringement Notices, Environmental Protection Orders, Restoration Notices and court action that covers the impacts of inappropriate activities/works, whether these impacts are on-site or are occurring off-site as a result of on-site activities/works.

Module A: General Management Requirements that Apply to All Acid Sulfate Soil Treatment and Management

Some requirements and principles that apply to ASS management and treatment are relevant to all sites at which ASS may be drained, disturbed or excavated. This module contains requirements relating to general management of ASS to minimise risk to the environment.

Part One: The operator must comply with the following.

WHAT MUST BE TREATED OR MANAGED

1.1 Total potential acidity (TPA) must be treated or managed in accordance with this instruction for any ASS that exceeds the action criteria listed in Table 1:

Table 1: Action criteria for soils (based on their texture and the amount disturbed) that will require an ASS management plan.

Texture (type of material)	Approx clay content (%)	1–1000 tonnes disturbed soil		>1000 tonnes disturbed soil	
		Sulfur trail (% S)	Acid trail (mol H^+/ tonne)	Sulfur trail (% S)	Acid trail (mol H^+/tonne)
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, silty clays)	=40	0.10	62	0.03	18

(Table 1 is reproduced from Ahern and Watling 2000, with permission)

(a) <u>If the soil pH is <5.5</u> then the Total Actual Acidity (TAA) of the soil must be added to the Total Sulfidic Acid (TSA) and the total of TSA + TAA assessed against the action criteria below at b or c; and

(b) <u>If 1 to 1000 tonnes of ASS are to be disturbed</u>:

i. Texture range sands to loamy sands (less than 5 % clay) samples have equal or greater than 0.03 %S oxidisable sulfur or 18 mole H^+/tonne oven dry basis; or

ii. texture range sandy loams to light clays (5% to 40% clay) samples have equal or greater than 0.06 %S oxidisable sulfur or 36 mole H^+/tonne oven dry basis; or

iii. texture range light-medium to heavy clays and silty clays (greater than 40 % clay) samples have equal or greater than 0.1 %S oxidisable sulfur or 62 mole H^+/tonne oven dry basis.

(c) Or i<u>f greater than 1000 tonnes of ASS are to be disturbed</u>:

i. For all texture categories samples have equal or greater than 0.03 %S oxidisable sulfur or 18 mole H^+/tonne oven dry basis.

MINIMUM SPECIFICATION TO BE MET ON PROCESS CONTROLS

1.2 ASS that have been drained, disturbed or excavated must only be stored in areas that are designed to contain and collect all contaminants and prevent the contamination of waters. Treatment or management of ASS in accordance with Modules C, D and/or E of this instruction and site/activity specific conditions on any relevant statutory approval must be carried as out soon as practicable.

FOR ASS TO BE REMOVED FROM THE SITE OR RELOCATED FROM STORAGE/TREATMENT AREAS SPECIFIED UNDER CONDITION 1.2

1.3 Only material confirmed to be below the action criteria specified in condition 1.1 or verified to meet specifications for the relevant treatment process (eg. condition 4.2 or 5.5) may be removed from the site or treated as no longer being ASS material for the purposes of this document.

Part Two: Should environmental harm be caused or threatened, the operator must be able to demonstrate that all reasonable and practicable measures have been taken to comply with the requirements in Part One.

THE FOLLOWING ARE SOME MEASURES THAT ARE EXPECTED TO BE IMPLEMENTED. THE OPERATOR IS NOT LIMITED TO ONLY THESE MEASURES.

1.i. Ensure a good prior understanding of the site through sampling and analysis of the soils (in accordance with Ahern *et al*., 1998a) and groundwater conditions prior to final design or construction/activity. See also State Planning Policy 1/00, Annex 2 (currently being updated as the ASS State Planning Policy Guidelines).

1.ii. Any area of disturbed ASS or area that receives ASS must be treated as potentially contaminated until such a time as the soil is shown to comply with condition 1.3. Bunding, diversion drains, contaminated water treatment impoundment's may be used to contain surface run-off from ASS storage and treatment areas. ASS must not be used in the construction of bunds and other diversion devices.

1.iii. Minimise the surface area of ASS exposed to oxidising conditions and minimise the time exposed. An exception is during treatment when it may be deliberately spread out thinly on a lime pad for drying prior to immediate and complete treatment with neutralising agents (e.g. lime).

1.iv. For the purpose of risk assessment and management planning, any on-site or adjacent surface and groundwaters should be assessed to gain a good understanding of the environmental values to be protected. Any proposed, or likely, discharges or releases to these waters must be consistent with protecting these environmental values.

1.v. Dilution is not an acceptable solution. Contaminants resulting from oxidation of ASS should be collected, treated, and/or managed on-site. Neutralisation of ASS sourced acid using seawater as a buffering agent is not an acceptable primary means of neutralising acidity. Discharges to waters must not have a significant impact on pH, buffering capacity, colour or ionic composition of the water.

1.vi. To minimise risk of contamination of surface and groundwaters, the pH of any standing water collected within containment areas and drainage systems must be monitored and treated to maintain a pH of 6.5 to 8.5 on-site (or other pH range consistent with site specific conditions if relevant). In areas with naturally low-pH receiving waters, the upper end of this range should be adjusted to avoid introducing pH elevating influences if discharges occur. In areas discharging to sea/estuarine water, the lower end of this range should be adjusted to avoid impacts on the buffering capacity or ionic composition of the receiving waters.

1.vii. Do not place ASS on top of marine plants or other native vegetation (unless the destruction of those plants has been permitted under the relevant legislation such as a permit from DPI Fisheries, NR&M Vegetation Management, Local Authority etc).

Advisory Note 1: DPI does not support the placement of any spoil on intertidal lands, or marine plants as a matter of policy. It is a DPI requirement to place spoil materials above Highest Astronomical Tide (HAT).

ON THE USE OF NEUTRALISING AGENTS

1.viii. Infiltration of surface water (rain and drainage) passing through ASS to groundwater should be prevented. If this is not possible, surface applications of neutralising agent should be applied to the treatment area/s at a rate capable of neutralising all acid waters that might infiltrate through ASS, prior to placing ASS in the treatment areas. The minimum application rate should be equivalent to no less than 50t of fine agricultural lime/ha (or 5kg fine agricultural lime/m^2). This application may need to be increased depending on stockpile height and actual and potential acidity of the ASS.

Advisory Note 2: Due to clumping and crusting of neutralising agents exposed to damp, surface liming will need to be applied to treatment areas prior to each layer of ASS that is placed there. Note that this neutralising agent is in addition to, and not part of, the quantity of neutralising agent calculated as necessary to mix with the soil to treat the soil under Module D.

1.ix. Neutralising agents to be stored under conditions that will prevent the deterioration of their effectiveness.

1.x. Neutralising agents used on the site (for example along drainage lines and at the base of treatment areas) must be replenished and or replaced regularly to remain effective against loss by wind or water erosion.

Advisory Note 3: Most neutralising agents used to treat soils are in particulate form, and these particles clump and form surface crust when exposed to wet or humid conditions. This can make them ineffective at raising pH.

1.xi. If use of other than tried and proven neutralising agents is proposed, then (a) investigation into the risk associated with the use of the neutralising agent

should be undertaken; for example, some neutralising agents such as cement kiln dust contain other elements or compounds that may pose environmental risk in some situations; and (b) validation or proof of effectiveness by a small scale trial should be provided. More detail on neutralising agents can be found in Ahern *et al*., 1998c.

Advisory Note 4: Due care should be demonstrated in the selection and appropriate containment and storage of neutralising agents and in calculating the required amount of the specific neutralising agent selected for treatment of ASS or affected waters. There is a need to consider the neutralising value, effective neutralising value; solubility; pH; chemical constituents; moisture content; impurities; and grades, fineness or particle size. This is especially relevant to the more soluble forms of neutralising agents such as hydrated lime that may result in very high pH waters if they are stored carelessly or misused.

1.xii. Receipts, dockets or other records showing all acquisitions of neutralising agents must be kept along with records of how and where this neutralising agent was used on site.

Advisory Note 5: Accurate GPS readings are considered essential for these records as site characteristics can change dramatically during construction.

VISUAL MONITORING

1.xiii. Regular visual monitoring should be undertaken to identify signs of ASS oxidation. This monitoring should include detecting:

- Unexplained scalding, degradation or death of vegetation;
- Unexplained death or disease in aquatic organisms;
- Formation of the mineral jarosite and other acidic salts in exposed or excavated soils;
- Areas of green-blue water or extremely clear water indicating high concentrations of aluminium;
- A transition to, or establishment of, a community dominated by acid tolerant species;
- Invasion of a community or area by acid tolerant species;
- Rust coloured deposits on plants and on the banks of drains, water bodies and watercourses indicating iron precipitates;
- Corrosion of concrete and/or steel structures in contact with soil or water.
- Black to very coloured waters indicating de-oxygenation

Advisory Note 6: Also note any sulfurous smells; eg. hydrogen sulfide or rotten egg gas.

PROCEDURES AND DOCUMENTATION

1.xiv. These procedures (and those applied under Modules B to E) should be documented as they apply to the activity. All responsible persons should be made aware of their obligations (preferably in writing) and it should be ensured that those persons are suitably trained and supervised in the management of ASS. This documentation may form part of a site management plan or a management system required as a condition of a statutory approval relating to this activity.

Advisory Note 7: Other references that may be useful in implementing reasonable and practicable measures for the treatment and management of ASS are listed at the back of this document.

Module B: For the Management of Undisturbed Acid Sulfate Soils

Undisturbed ASS means ASS that is naturally occurring at, or adjacent to a site (see Module C). This module applies to its management when that ASS is either:

- not going to be excavated or extracted and treated in accordance with Modules C, D or E of this instruction; or
- will not be extracted until a certain stage of the activity/development, and until that time must be managed under this module to prevent oxidation.

Management techniques for undisturbed ASS must also be applied to potential ASS (PASS) or PASS fines that have been reintered at a site (see Module C).

This management technique is designed for the management of PASS, although undisturbed soils sometimes contain low levels of actual ASS (AASS) due to natural processes that lower the water table (example such as tidal fluctuations or drought). If levels of AASS exceeding the action criteria are detected at a site, remediation or restoration may be required; this is not dealt with under this instruction. Furthermore care will need to be taken where considerable levels of AASS are present in the soil profile. Changes to the hydrology (e.g. raising the water table) may reduce the rate of oxidation of PASS, yet contribute to an increased the rate of export of existing soil acidity from the soil profile. In such a case, the administering authority must be advised of the site condition and consulted in determining appropriate action.

Activities that must be carefully managed to comply with this module include those that may lower the water table at the site or in surrounding areas (examples dewatering, drainage, excessive hardening of soils or surfaces, interruption of groundwater flows, use of groundwater, or excavation of voids). Impact assessment should be used to determine if proposed activities are incompatible with this module. If incompatible, the activity should be avoided, or subjected to site specific conditioning if a practicable environmental management strategy for the site supports the ecological sustainability of the development.

Part One: If* in situ *ASS are present at, or adjacent to, the site of the activity/development, then the operator must comply with the following.

UNDISTURBED PASS MANAGEMENT

2.1 Prevent any lowering of the permanent groundwater table height that might be caused by the activity.

Advisory Note 8: If some degree of lowering of the permanent groundwater table height is acceptable on a site-specific basis, this will be specifically permitted (detailing area and to what depth) under the statutory approval requiring compliance with this instruction. In such a case the site specific condition will over-ride the requirement in condition 2.1.

2.2 If the permanent groundwater table height might reasonably be expected to be lowered by activities that are undertaken (dewatering, drainage, dry excavation), or

structures that are installed (drains, hardening, extraction bores), and should management strategies fail, then implement sufficient groundwater monitoring to demonstrate that the permanent groundwater table height has not been lowered during the duration of these works. Such monitoring must, at a minimum, provide groundwater levels, pH, EC, and the chloride and sulfate concentration for each aquifer in each area that may be subject to impact, and must be monitored regularly throughout the duration of the period of potential impact, with additional monitoring during periods that may represent higher risk of impact.

Advisory Note 9: Based on the level of risk of lowering of the permanent groundwater table height and the potential for environmental harm, site-specific groundwater monitoring conditions may apply to any statutory authority and provide greater detail on the nature of groundwater monitoring required to satisfy this condition.

2.3 Activities that result in the release, or accumulation and potential future release, of acid from the oxidation of undisturbed PASS must not be undertaken.

Part Two: Should environmental harm be caused or threatened, the operator must be able to demonstrate that all reasonable and practicable measures have been taken to comply with the requirements in Part One.

THE FOLLOWING ARE SOME MEASURES THAT ARE EXPECTED TO BE IMPLEMENTED. THE OPERATOR IS NOT LIMITED TO ONLY THESE MEASURES.

2.i. Ensure a good prior understanding of groundwater at the site and surrounds (identify all aquifers and aquacludes/aquatards and their normal seasonal levels, water quality, and the direction and rate of flow). Install monitoring bores to be maintained prior to, during and post-construction.

2.ii. Implement groundwater monitoring for the minimum parameters of water table height, pH, EC, sulfate and chloride concentration, for each affected aquifer. Calculate the $Cl:SO_4$ ratio. This data should regularly be graphed against time to allow a quick visual check to pick up any trends or events in a timely manner.

2.iii. Maximise the use of wet construction techniques such as traditional dredging rather than dry/dewatered construction techniques. Avoid material that cannot be extracted by wet techniques (clayey peats).

2.iv. Ensure your risk assessment is accurate and thorough. For example: Using soil and groundwater information that has been collected, calculate the quantity of PASS that may be exposed to oxidising conditions (cone of depression). Using site specific data, and considering vertical and horizontal oxygen diffusion, calculate the predicted quantity of PASS that might reasonably be expected to oxidise during or post-exposure to oxidising conditions . Assess the potential impact of any acid generated and metals mobilised. Assess potential for management and remediation to successfully contain acid and metals and rehabilitate soils. Consider this in the context of short- and long-term loads to the subcatchment and catchment in which the

site lies. Consider the potential for environmental harm to be caused by events of both relatively short- and long-duration.

2.v. Stage works to minimise the period of dewatering and the size of the cone of depression. This may involve constructing large voids stagewise using smaller cells that are bunded off from one another so that each cell is dewatered for a relatively short period. The use of sheet piling to isolate groundwater in work areas from external areas should be used in areas where there is high soil permeability for example sandy soils.

2.vi. If possible, use acid resistant precast structures for engineering solutions that will ultimately be submerged (example revetments, weirs, etc) to minimise the period of dewatering required for their installation.

2.vii. Minimise the depth of any essential drainage structures. Manage drainage to maintain the watertable surrounding drainage structures above the sulfidic layer in the soil.

2.viii. To prevent drawdown, implement groundwater recharge strategies in areas where activities might be expected to cause drawdown (with monitoring to demonstrate effectiveness).

Advisory Note 10: Care will need to be taken where considerable levels of AASS are present in the soil profile. Changes to the hydrology (e.g. raising the water table) may reduce the rate of oxidation of PASS, yet contribute to an increased the rate of export of existing soil acidity from the soil profile.

Advisory Note 11: Care must also be taken to ensure that any irrigation water being used to manage water tables is not acidic.

Module C: For the Management of Potential Acid Sulfate Soils Using Strategic Reburial Techniques

Strategic reburial or reinterment techniques are used to manage Potential Acid Sulfate Soils (PASS) and also PASS fines (resulting from the use of separation techniques - see Module E) by preventing their oxidation through long-term/permanent storage in an anoxic environment. These techniques are often chosen to minimise costs associated with other treatment methods where reinterment areas are available, or can be created by over excavation of non-acid sulfate soils. Where over excavation of non-ASS may include some excavation of PASS, then relevant modules (A, B, D) should be complied with in treating the excavated PASS.

Environmental controls are required to prevent onset of oxidation of sulfidic material in the PASS or PASS fines prior to, or during, its extraction and final placement below a permanent water table. This includes managing PASS to prevent oxidation in the periods:

a. between the identification of the PASS through the ASS Investigation of the site and the extraction of the PASS; and
b. during excavation and relocation to the reinterment site; and
c. during separation processing (such as sluicing or cycloning) prior to reinterment of PASS fines; and
d. at the reinterment location.

Prior to over-excavation at a site to create reinterment areas for PASS, the soils at the site must also be well characterised so that the locations for over-excavations can be determined and calculations of available space for placement of PASS performed. Excavation of PASS and creation of reinterment voids must be carefully staged to ensure adequate space below a permanent water table is available as required and that PASS will not be subject to interim storage in oxidising conditions that may result in the formation of actual ASS (AASS). If reinterment is to be to the bed of a water, then it is important to ensure that sufficient depth above the material to prevent oxidation can be achieved, and that the bed of the water will not be subject to future foreseeable disturbance (example dredging, silt removal, dewatering, disturbance by power boats, scouring etc). Long water bodies may be subject to significant wind generated wave action that can result in oxygenation and mixing of the deeper water. Design of such water bodies must prevent such occurrences.

WARNINGS:

1. *Once oxidation of ASS has commenced, further acid generation can continue to occur; depending on the pH, type of sulfidic compounds, availability of oxidising agents (oxygen can be transported in water as well as in air) and microflora; even if the soil is returned to anoxic conditions.*
2. *If material containing AASS is buried below the water table, a hydrogen sulfide gas producing process may take place which is very toxic. Hydrogen sulfide gas is dangerous and has caused many deaths.*
3. *Metal mobilising acid already in AASS is a potential source of leachate. Therefore it is not acceptable to use strategic reburial techniques to manage AASS.*

Part One: If it is intended to use strategic reburial or reinterment techniques to manage PASS, then the operator must comply with the following.

WHAT CAN BE MANAGED BY STRATEGIC REBURIAL/REINTERMENT BELOW THE PERMANENT WATER TABLE

3.1 Only PASS and PASS fines may be managed by strategic reburial or reinterment techniques. No AASS may be reburied or reintered without other prior treatment to achieve verified compliance with condition 1.3.

REINTERMENT OF PASS OR PASS FINES

3.2 PASS or PASS fines that are to be managed by reinterment may only be placed in an anoxic environment, that is covered by water at all times following placement.

Advisory Note 12: More specific requirements directing where and to what minimum depth this material can be placed may appear as a site specific condition if the works are being conducted under a statutory approval.

3.3 Surveyed maps showing the location, depth and volume of any strategically reburied or reintered PASS fines or reintered PASS in accordance with condition 3.2 or any relevant statutory approval requiring compliance with this instruction must be produced and retained as permanent records. Locations must be documented accurately using GPS equipment measuring to 2 to 3 metres accuracy.

3.4 As soon as practicable, copies of maps and associated documents produced in accordance with condition 3.3 must be sent to the chief executive officer of the local government authority with written notification of the type of material and its storage requirements, and the reason for this notification in accordance with this document, so that the local authority may be equipped to make informed land use decisions.

Part Two: Should environmental harm be caused or threatened, the operator must be able to demonstrate that all reasonable and practicable measures have been taken to comply with the requirements in Part One.

THE FOLLOWING ARE SOME MEASURES THAT ARE EXPECTED TO BE IMPLEMENTED. THE OPERATOR IS NOT LIMITED TO ONLY THESE MEASURES.

3.i. Prior to construction, demonstrate a sufficient understanding of soils at the site to make accurate calculations of space that can be made available by over-excavation of non-ASS, and the volume of PASS that will be extracted.

3.ii. Plan staged construction of voids and extraction of PASS to ensure that PASS can be placed in its **final** reinterment location without any delay. This planning should be well documented.

3.iii. Ensure decision makers and land holders are in agreement with the reinterment activity and that they understand future, long-term requirements for management. *It is recommended that evidence of this understanding is obtained in writing prior to any reinterment.*

3.iv. Temporary storage of PASS or PASS fines should be avoided. If temporary storage cannot be completely avoided it should be minimised. The reason for any temporary storage, and the material handling strategy should be clearly documented so that the location of PASS and PASS fines being relocated for strategic reburial is known by relevant authorities at all times. Time frames for relocation of PASS and PASS fines from temporary to permanent reinterment locations should be minimised and documented.

3.v. If temporary storage is absolutely necessary and approved, then a neutralising agent must be added as part of the temporary storage conditions to provide additional acid neutralising capacity to compensate to increased risk brought about by double handling. This amount must be negotiated with the local authorised officers. Some general advice may be available from the QASSIT team. The quantity and type of neutralising agent will be based on actual soil characteristics and a risk assessment considering site specific factors and method of handling proposed. Temporary storage of PASS or PASS fines is subject to all of the management requirements that are applied to final reinterment locations. Full clean-up of the temporary storage area must be undertaken on relocation of the PASS or PASS fines.

3.vi. When creating the voids to provide for strategic reburial of PASS, this void construction should not have adverse impacts on undisturbed PASS (see Module B).

3.vii. Implement additional soil sampling and analysis and spatial tracking of soils if this is warranted to ensure that only PASS (not AASS) is reintered.

3.viii. Ensure that any location that will be used for strategic reburial or reinterment (including surface water bodies) will not be subject of future works that may cause the disturbance and oxidation of PASS or PASS fines.

3.ix. Cap any PASS or PASS fines that are reintered in locations where capping may make a significant difference in preventing their potential future exposure to oxidising conditions (example; if placed on the bed of a water body where they may be disturbed by boats, or currents, or destratification). Capping materials must not contain any acid or acid sulfate soils and should be placed to a thickness of at least 0.5m (to take into account the difficulties of subsurface capping).

3.x. If it is impracticable to cap PASS or PASS fines that are reintered below surface waters; for example due to their consistency being unable to support a capping layer; then prior to commencement of the project limnological modelling must be provided to demonstrate that anoxic conditions can be maintained at the depth to which the PASS or PASS fines will be placed. This modelling must take into account all factors that may result in stratification and/or turnover of the waters, and must also consider foreseeable disturbances

to the waters; eg wind and wave action, use by boats, disturbance by inflows or outlets etc.

3.xi. If designing a water body that will include in its purpose a strategic reburial site, then ensure design prevents or minimises wind and wave action.

3.xii. Ensure that a stable water level of sufficient height to provide anoxic conditions, can be maintained for the foreseeable future in any location proposed to be used for strategic reburial or reinterment. As a minimum, monitor the surface or groundwater table height, pH, EC, sulfate and chloride concentrations until it is clear that the reinterment process has been successful.

Module D: For the Treatment of Acid Sulfate Soils Using Neutralisation Techniques

Neutralisation techniques are commonly used to treat ASS, rendering minimal the risk to the environment from acid produced from the soil. Laboratory analysis is used to determine existing or actual acidity and the maximum potential acidity. Neutralising agents must be applied at a rate to neutralise all actual plus potential acidity (plus a safety factor of 1.5 to 2 depending on circumstances).

Environmental controls are required during the neutralisation process to ensure any acid generated during this process is collected and neutralised, and that any metals mobilised by the acid are also contained. The soils must also be well characterised so that the amount of neutralising agent required can be accurately calculated. Spatial tracking of soils is also necessary for large projects to provide for verification testing and reapplication of neutralising agent if necessary. Consideration should also be given to other forms of acid soils (if soil pH is less than or equal to 5.5), or soils high in aluminium on a site if their disturbance is likely to increase normal levels of release of acid and metals causing similar impacts to oxidising acid sulfate soils.

Part One: If is is intended to use neutralising techniques to treat ASS, the operator must comply with the following:

SPECIFICATION TO BE MET ON NEUTRALISATION

4.1 If neutralising treatment is being applied to ASS, then a sufficient quantity of a finely ground neutralising agent must be applied to:

(a) treat total sulfidic acidity (TSA) and total actual acidity (TAA); eg. oxidisable sulfur % S + TAA in equivalent units of % S; contained in the soil; and

(b) additional neutralising agent must be added to provide a safety factor to compensate for impurities in the neutralising agent, non homogenous mixing and its solubility (or lack thereof). A minimum safety factor providing the equivalent neutralising capacity to the use of 1.5 times fine agricultural lime is required.

4.2 In addition to condition 4.1, it must be demonstrable via validated analytical techniques (e.g. POCAS) that sufficient neutralising agent has been applied to prevent any acidification or leaching of metals; eg. the soil must have a TPA less than stated in condition 1.1 for its texture class and a soil pH >5.5.

Advisory Note 13: If >1000t of soil is being disturbed, then the TPA action criteria is 18 moles H^+/tonne for all texture classes (see Table 1).

Advisory Note 14: If other verification methodology is prescribed in a statutory approval, then that over-rides these requirements based on the TPA methodology.

Advisory Note 15: If full POCAS is undertaken as a verification test, then calcium, magnesium and sodium results from both the KCl and the peroxide-KCL extract can be used to indicate the effectiveness of neutralising agents such as $CaCO_3$.

VERIFICATION TESTING

Conditions under this heading only apply if:

- more than 1000 tonnes of soil is to be disturbed; and/or
- to comply with condition 4.1, a quantity of neutralising agent equivalent to 5 or more tonnes of lime must be applied. (Table 2 in Appendix 1).

Advisory Note 16: Table 2 in Appendix 1 (reproduced from Dear *et al*., 2000), provides guidance regarding the sampling rates which are performance based. More or less frequent sampling may be appropriate depending on site specific soil conditions and the quality of the ASS Investigation of the site. If this is the case, and a grading of the site assessment (in accordance with Dear *et al*., 2000) and a recommended sampling rate for verification testing has been obtained in writing from the NR&M or EPA, then a site specific condition may appear in the relevant statutory approval indicating an alternative sampling rate, and that sampling rate will be used rather than the one stated at 4.3 in this instruction.

4.3 Samples must be taken to test compliance with condition 4.2 and must be analysed to determine the TPA of soil samples (or criteria for another authorised method) taken at a frequency of not less than 1 sample per 250m^3 of soil treated.

REQUIREMENT FOR FURTHER TREATMENT

4.4 Further neutralising treatment (including a further round of verification testing) must be applied to any ASS required to be tested under condition 4.3 and that does not comply with characteristics stated in condition 4.2.

Part Two: Should environmental harm be caused or threatened, the operator must be able to demonstrate that all reasonable and practicable measures have been taken to comply with the requirements in Part One.

THE FOLLOWING ARE SOME MEASURES THAT ARE EXPECTED TO BE IMPLEMENTED. THE OPERATOR IS NOT LIMITED TO ONLY THESE MEASURES.

4.i. The neutralising agent must be fine in consistency and must be mixed thoroughly throughout all of the soil at a rate including *at least* a 1.5 times safety factor. This is necessary to achieve effective neutralisation of the soil as most neutralising agents suitable to be used to treat soil are low in solubility, have slow reaction rates or are subject to coatings reducing their effectiveness. Greater safety factors should be applied if risk-elevating factors exist at the site.

4.ii. The soil must be managed to achieve a consistency that will allow for thorough mixing. This may entail drying (with associated management of any acid and other contaminants resulting) and mechanical turning and breaking up of the soil. This can be labour intensive. Drying should not be undertaken during foreseeable wet weather due to the increased risk of flushing acid out of AASS and into waters. A lime pad must always be pre-positioned prior to spreading soils for drying.

4.iii. If there is a likelihood that neutralisation treatment will not be effective for the soil type/s at the site (for example heavy clays or muds that are difficult to

mix), a small scale trial to demonstrate that the proposal is practicable must be performed prior to large scale neutralising treatment of the ASS being allowed.

4.iv. An example of how to determine appropriate neutralising agent application rates is provided for pure, fine $CaCO_3$ in the table reproduced with permission in Appendix 1 from Dear *et al*. (2000). The calculation of the amount of neutralising agent required will vary depending on which neutralising agent is chosen. Refer also to Ahern *et al*. (1998c) for further guidance on calculation of neutralising rates.

4.v. Following from 4.ii, ASS may only be spread (on a lime pad) in treatment or storage areas to a depth that can be properly treated by thoroughly mixing neutralising agent through the soil (usually 20 to 30 cm). This will, to some degree, be dependent on the soil type and the equipment being used for mixing. Additional layers of soil must not be applied until verification testing has shown that further treatment of the soil is not required. The basal surface or 'treatment pad' should be limed before receiving any untreated material.

4.vi. Excavation should be staged to ensure sufficient drying and mixing time can be achieved with the treatment areas available (estimate rate of throughput in cubic metres/unit time). Staging should also ensure that adequate time is available to obtain the results of verification testing before placing further layers of soil in treatment areas. The location and total area required for treatment &/or storage of excavated material should be defined prior to commencement of excavation works. This is of particular importance for a development that will use treated spoil as fill for another part of the development.

4.vii. To demonstrate that verification testing has been performed as required in Part One, a spatial tracking system for soil lots will need to be implemented. This will entail as a minimum being able to identify where each lot of soil tested has been located so that it can be correlated with laboratory analysis results to allow further treatment to be applied if necessary. This system must be documented, and the documents retained.

4.viii. Module A Part 2, especially "On the use of neutralising agents", is also relevant. Some neutralising agents have a higher risk associated with them compared to finely ground agricultural lime ($CaCO_3$). Pilot studies may be necessary for some reagents.

Module E: For the Treatment and Management of Acid Sulfate Soils Using Separation Techniques

Separation techniques are increasingly being used to treat ASS to remove all fine particles of pyrite and monosulfides from potential acid sulfate soils (PASS). These fine particles will be referred to as PASS fines. PASS fines are removed from ASS by suspending these fine particles in a slurry and separating them from the larger soil particles (eg. by sluicing or cycloning). This may be as an add on process specifically designed to manage ASS (example sluicing as part of a dredging/filling operation). Alternatively, it may be an integral part of an activity such as screening where soils are cycloned to separate various size particles of sand and aggregate product. When separation of PASS fines is effective, the soil need no longer be treated as an ASS as it will not contain the chemical composition that meets the action criteria set in Ahern *et al*. (1998a) and condition 1.1. To confirm that the separation process has been effective, verification testing is performed as described in Part One. Spatial tracking of soils is also necessary to provide a management system for verification testing and further treatment if necessary.

Environmental controls are required during the separation process to ensure that PASS fines are not oxidised either during processing or in the longer-term at the location where it is proposed that they are to be submerged or reintered. Soil managed by separation techniques must be stored where any acid that may be generated (if separation has not been effective) can be contained, collected and neutralised. The soils must be well characterised to determine whether they are an appropriate soil type to apply separation techniques to. For example, separation techniques lend themselves to sandy soils, but may be ineffective for clayey peat soils that are difficult to break up to achieve a suspension of fine particles.

Part One: If it is intended to use separation techniques to manage ASS, the operator must comply with the following:

MINIMUM SPECIFICATION TO BE MET ON PROCESS CONTROLS

5.1 When undertaking separation techniques the process must be continuously monitored and managed so as to prevent any oxidation of any PASS fines.

5.2 ASS that has been processed by separation techniques must only be placed in areas that are designed to contain and collect all contaminants and prevent the contamination of waters. Verification of effective removal of PASS fines from this ASS must be carried as out soon as practicable.

MANAGEMENT OF PASS FINES CONCENTRATED BY THE PROCESS

5.3 Any PASS fines that are exposed to oxidising conditions must be collected and treated by neutralisation in accordance with Module D of this instruction.

5.4 Only PASS and PASS fines that have not been exposed to oxidising conditions may be managed by strategic reburial or reinterment below the permanent water table. Any PASS fines that are to be managed by this method must be managed in accordance with Module C of this instruction.

SPECIFICATION TO BE MET AFTER SEPARATION PROCESS

5.5 ASS that has been treated or processed by separation techniques must comply with the following characteristics:

a. No sample shall exceed 0.04% by oven dry weight of oxidisable sulphur content.
b. If any single sample exceeds 0.03% by oven dry weight oxidisable sulphur, then the average of any six (6) consecutive samples (including the exceeding sample) shall have an average oxidisable sulphur content not exceeding 0.03% by oven dry weight.
c. If more than one sample, in any six (6) consecutive samples, exceeds 0.03% by oven dry weight oxidisable sulphur, then the average of any six (6) consecutive samples (including the exceeding samples) shall have an average oxidisable sulphur content not exceeding 0.025% by oven dry weight.

Advisory Note 17: the intent of these specification limits is to achieve localised average sulfur content in placed soils that is lower than action limits for treatment in condition 1.1. Where approved by NR&M or EPA, TPA values may be substituted for oxidisable S% eg 0.04%S (TPA 24 mol H^+/t); 0.03 %S (TPA 18mol H^+/t); 0.025%S (15mol H^+/t).

VERIFICATION TESTING

5.6 Samples must be taken to test compliance with condition 5.5 and must be analysed to determine the % oxidisable sulphur content of soil samples taken at a frequency of not less than one (1) sample per 250m^3 lot of soil that has been processed by separation techniques. Accepted methods for determining oxidisable sulfur are outlined in Ahern *et al*., 1998a and/or "Laboratory Methods" in Ahern *et al*., 1998b or their update.

Advisory Note 18: Less frequent sampling conditions can be negotiated with relevant authorities where demonstrated understanding of the site and performance of management strategies has been documented. If this is the case, such conditions will appear in the relevant statutory authority.

Advisory Note 19: Approval may be given for acid trail analysis; eg. TPA; in some circumstances and would, in such cases, override the methodology indicated by this instruction. See relevant statutory authority.

REQUIREMENT FOR REPROCESSING OR FURTHER TREATMENT

5.7 Any ASS that is treated or processed by separation techniques that does not comply with characteristics stated in Condition 5.5 above must be:
i. reprocessed in accordance with this module to further remove PASS fines (this is only allowed if fines have not already oxidised); or
ii. treated by neutralisation techniques in accordance with Module D of this instruction.

Part Two: Should environmental harm be caused or threatened, the operator must be able to demonstrate that all reasonable and practicable measures have been taken to comply with the requirements in Part One.

THE FOLLOWING ARE SOME MEASURES THAT ARE EXPECTED TO BE IMPLEMENTED. THE OPERATOR IS NOT LIMITED TO ONLY THESE MEASURES.

5.i. Areas selected for the placement of soils that have been processed by separation techniques must be treated as potentially contaminated until such a time as verification testing confirms successful treatment of the soil. See Module A regarding potentially contaminated areas.

The treatment area selected for the placement of the processed material (see 5.ii.) should be limed and/or layered with a thin layer of washed sand incorporated with lime. This basal liming will act as a precautionary barrier to intercept acidity from oxidation of any pyritic sediments not separated during the sluicing process. The liming rate should be determined based on the proposed thickness of the material to be placed on the treatment area, and the likely pyrite content of the material (based on testing during the trial stage of the operations). A safety factor should be incorporated in the liming calculations based on the texture (clay/peat etc.) of the materials that will be placed on the area.

5.ii. If there is a likelihood that processing for separation will not be effective for the soil type/s at the site (for example clayey or peaty sediments), a small scale trial to demonstrate that the proposal is practicable must be performed prior to large scale use of separation techniques .

5.iii. Soils that have been processed by separation techniques may only be spread in treatment areas to a depth that will allow further treatment under condition 5.7; such as thoroughly mixing neutralising agent through the soil (usually 20 to 30 cm). Additional layers of soil should not be applied until verification testing has shown that further treatment of the soil is not required.

5.iv. The pH of the slurry in the sluicing channels or other separation device should be monitored several times a day. If the pH drops below 6.5, a source of acidity should be identified. If the pH continues to drop, sluicing, etc should be stopped until the cause of oxidation or other source of acid is found. Neutralising material may need to be added to the slurry.

5.v. The profile of sluicing channels should be regularly inspected and maintained to prevent the accumulation of PASS fines in the channel.

5.vi. When the separation process is to cease (for the day, weekend etc), sluicing channels (or the equivalent for other methods) should be flushed with water to prevent the settling and oxidation of PASS fines in the sluicing channels.

5.vii. To demonstrate that verification testing has been performed as required in Part One, a spatial tracking system for soil lots will need to be implemented. This will entail as a minimum being able to identify where each lot of soil tested has been located so that it can be correlated with laboratory analysis results to allow further treatment to be applied if necessary. This system must be documented, and the documents retained.

Definitions

Acid Sulfate Soil (ASS) means a soil or soil horizon that contains sulfides; or an acid soil horizon affected by oxidation of sulfides (the meaning under the *Environmental Protection (Water) Policy 1997*).

Actual Acid Sulfate Soils (AASS) means soils or sediments containing highly acidic soil horizons or layers resulting from the oxidation of soil materials that are rich in iron sulfides such as pyrite (FeS_2). This oxidation produces acid in excess of the soil's capacity to neutralise the acidity, resulting in a pH of 4 or less. The presence of pale yellow acidic mottles and coatings of jarosite or related products confirms an actual acid sulfate soil, but jarosite need not be present. Soils or sediments with pH 4.1 to 5.5 may also contain acid or remnants of iron and aluminium ions from previous oxidation and hence require treatment.

anoxic means in the absence of oxygen.

authorised officers means appropriate officers of the signatory departments to the Memorandum of Understanding (ie. Environmental Protection Agency, Department of Natural Resources and Mines and the Department of Primary Industries).

bed of water means is the ground under a body of water and the pervious and impervious materials (such as mud, sand, coral, ballast, shingle, gravel, clay, earth) that are within waters **and contiguous with** the ground under a body of water.

cone of depression means the depression in the groundwater table or surface

dewatering means the deliberate pumping siphoning, draining or other diversion of waters to render a site or area dry.

excessive hardening means hardening of soils or the application of hard surfaces over soils that prevents groundwater recharge, or results in a barrier to groundwater flows that may lead to a reduction in the groundwater table level exposing PASS.

Marine plant (1) includes the following (a) a plant (a **"tidal plant"**) that usually grows on, or adjacent to, tidal land, whether it is living, dead, standing or fallen;(b) material of a tidal plant, or other plant material on tidal land; (c) a plant, or material of a plant, prescribed under a regulation or management plan to be a marine plant. **(2) "Marine plant"** does not include a declared plant under the *Rural Lands Protection Act 1985*.

PASS fines means fine particles from PASS soils containing pyrite and/or monosulfides.

Potential Acid Sulfate Soils (PASS) means soils or sediments containing iron sulfides or sulfidic material which have not been exposed to air and oxidised. The field pH of these soils or sediments in their undisturbed state is usually >4, and may be neutral or slightly alkaline. These soils or sediments are saturated with water in their natural state.

permanent ground water table height means the normal seasonal groundwater table height prior to influence by human activities as evidenced by groundwater monitoring and soil data.

the operator means the person(s) and/or company who is undertaking or planning to undertake works that may involve the disturbance of ASS.

oxidisable sulfur is determined by methods as outlined in Ahern *et al*., 1998a and/or "Laboratory Methods" in Ahern *et al*., 1998b.

reburial and reinterment for the purposes of this document includes burial 1. below the ground and the permanent groundwater table and 2. by submerging below surface waters.

sheet piling means an assemblage of sheeting (eg. metal or plastic) laid or lying one upon another in a more or less orderly fashion and driven vertically into the ground to support a structure or form part of a wall.

Total Actual Acidity (TAA) and Total Potential Acidity (TPA) are laboratory analyses determined as outlined in Ahern *et al*., 1998a or more recent additions or supplements to that document as such become available.

Total sulfidic acidity (TSA) is a measure of the acidity after oxidation of sulfidic material minus the soil's actual acidity. (ie. TSA = TPA - TAA).

verified for the purpose of this document means soil that has been tested in accordance with Verification Testing conditions of the appropriate module of this document (example conditions 4.3 and 5.6).

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

References

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Appendix One: Table Reproduced from Dear *et al*., 2000 by permission.

TABLE 2 Treatment categories and lime required to treat a weight of disturbed acid sulfate soil – based on soil analysis

The tonnes (t) of pure fine lime 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 soil sulfur analysis (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 (or calculate values exactly).

Disturbed	**Soil Analysis - Oxidisable Sulfur (S %) + TAA** (in equivalent units of %S)													
(tonnes) *	***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	0.05	0.05	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	0.05	0.05	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.2	1.4	1.9	2.3
15	0	0.05	0.1	0.1	0.3	0.4	0.6	0.7	1.1	1.4	1.8	2.1	2.8	3.5
20	0.05	0.1	0.1	0.2	0.4	0.6	0.7	0.9	1.4	1.9	2.3	2.8	3.7	4.7
25	0.05	0.1	0.1	0.2	0.5	0.7	0.9	1.2	1.8	2.3	2.9	3.5	4.7	5.9
35	0.05	0.1	0.2	0.3	0.7	1.0	1.3	1.6	2.5	3.3	4.1	4.9	6.6	8.2
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
75	0.1	0.2	0.4	0.7	1.4	2.1	2.8	3.5	5.3	7.0	8.8	11	14	18
100	0.1	0.3	0.5	0.9	1.9	2.8	3.7	4.7	7.0	9.4	12	14	19	24
200	0.3	0.6	0.9	1.9	3.7	5.6	7.5	9.4	14	19	24	28	38	47
500	0.7	1.4	2.3	4.7	9.4	14	19	24	35	47	59	70	94	117
750	1.1	2.1	3.5	7.0	14	21	28	35	53	70	88	105	141	176
1,000	1.4	2.8	4.7	9.4	19	28	38	47	70	94	117	141	187	234
2,000	2.8	5.6	9.4	19	38	56	75	94	141	187	234	281	375	468
5,000	7.0	14	23	47	94	141	187	234	351	468	585	702	936	1171
10,000	14	28	47	94	187	281	375	468	702	936	1171	1405	1873	2341

L	**Low treatment**: (<0.1 t lime). *Submit disturbance dimensions & Lab Analysis proof to Local Government (L.G.).* Apply 0.05 t (1 bag) or 0.1 t (2 bags) of lime.
M	**Medium treatment:** (≤0.1 to 1 t lime). *Submit disturbance dimensions & Lab Analysis proof to L.G.* Thoroughly mix lime (0.1-1 t) & bund the site.
H	**High treatment**:(>1 to 5 t lime). *Submit* E*arthworks Application, Management Plan & Lab Analysis proof to L.G* . Management, bunding & monitoring required.
VH	**Very High treatment:** (>5 tonne lime). Earthworks *Application or Impact Assessment required for L.G. (& State agencies*). Detailed management, monitoring & bundi

A detailed ASS site investigation & management plan is required if disturbing > 1,000 tonnes of ASS (oxidisable S ³ 0.03 %S or equivalent TPA or TAA.)

Lime rates are for pure fine $CaCO_3$ using a safety factor of 1.5. A factor that accounts for Effective Neutralising Value is needed for commercial grade lime (see, Ahern *et al* 1998c).

An approximate weight can be obtained from volume by multiplying volume (cubic m) by bulk density (t/m^3). (use 1.7 if B.D. is not known)

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