ENVIRONMENTAL
EARTH SCIENCES
THE KNOW AND THE HOW

REPORT NO. 710291

DRAFT ACID SULFATE SOIL MANAGEMENT PLAN

ENVIRONMENTAL EARTH SCIENCES QLD
PREPARED FOR AGL UPSTREAM INFRASTRUCTURE INVESTMENTS PTY LTD
8 SEPTEMBER 2010
VERSION 1

EXECUTIVE SUMMARY

The Gloucester Gas Project (the Project) includes works for the extraction of coal seam gas (CSG) from the Gloucester Basin within the PEL 285 area. The Project involves the development of gas wells and associated infrastructure, the development of a Central Processing Facility (CPF), and the construction and operation of a high pressure gas transmission pipeline from Stratford to a delivery station at Hexham, NSW.

The 100 m wide pipeline corridor and 30m right-of-way (ROW) traverses approximately 95 km extending from near Stratford in the north to Hexham in the outer suburbs of Newcastle in the south.

Mapping by DLWC in 1998 indicates that the highest probability of encountering ASS during earthworks will be in the southern section (coastal zone) of the proposed project alignment from KP76 to KP96. There is a low probability of encountering ASS in the central and northern sections. This early assumption will be confirmed during a preliminary field investigation.

This acid sulfate soil management plan (ASSMP) has been constructed for the purposes of managing the disturbance of acid sulfate that may be encountered during the construction of the Gloucester Gas Pipeline. No acid sulfate soil investigation has been undertaken for the pipeline corridor. The probable occurrence of acid sulfate soil has been determined based on published ASS Risk mapping undertaken by DLWC and NSW DPI. This ASSMP is conceptual and preliminary and is subject to upgrade when acid sulfate soil data specific to proposed disturbance within the pipeline corridor are available.

This ASSMP provides advice on field and laboratory testing for acid sulfate soils; risk assessment of environmental impacts that may manifest when ASS are disturbed; and management procedures for handling and treating soils, managing dewatering discharge and a monitoring plan for soils and water.

Project Manager
Timothy Rohde
Senior Environmental Scientist

Project Director / Internal Reviewer
Peter Scott
Senior Principal Scientist

Technical Reviewer
Peter Scott
Senior Principal Scientist

Edited By
Peter Scott
Senior Principal Scientist

TABLE OF CONTENTS

APPENDICES

FIGURES

LIST OF ACRONYMS

A	Active management
AASS	Actual Acid Sulfate Soil
AHD	Australian Height Datum
ANC	Acid Neutralising Capacity
ASL	Above Sea Level
ASS	Acid Sulfate Soil
ASSMP	Acid Sulfate Soil Management Plan
BP	Before present
bgl	Below ground level
CRS, S_{CR}	Chromium Reducible Sulfur
DECCW	Department of Environment, Climate Change and Water
DEWHA	Department of Environment, Water, Heritage and the Arts
MBO	Monosulfidic black oozes
N	Major concern
NA	Net acidity
NAG_{pH}	Net Acid Generating Potential
NASS	Not acid sulfate soil
P	Periodic monitoring
PASS	Potential Acid Sulfate Soil
PH_{F}	Field pH water test
PH_{FOX}	Field pH peroxide test
QC	Quality Control
R	Regular monitoring
RAM	Risk Assessment Matrix
S	Sulfur
S_{POS}	Peroxide oxidisable Sulfur
TAA	Titratible Actual Acidity
TOS	Total Oxidisable Sulfur

1 INTRODUCTION

1.1 Purpose

AGL Upstream Infrastructure Investments Pty Ltd (AGL) is proposing to construct a 95km long high pressure gas transmission pipeline from Stratford to a delivery station at Hexham, NSW. The proposed pipeline construction earthworks involves clearing a 25-30m right-of-way (ROW) along the length of the pipeline corridor, removing and stockpiling the topsoil and excavating a trench up to 1-2.5m deep for placement of the pipeline.

The proposed gas pipeline corridor will pass through coastal lowland <5 m Australian Height Datum (AHD) between KP76 to KP96 within the Hunter River coastal floodplain and estuary, including Ramsar wetlands (Hexham Swamp Lower Hunter). To date no acid sulfate soil assessment has been undertaken by AGL or their consultants, an assessment required before commencement of construction activity to determine the risk of ASS disturbance. Mapping of acid sulfate soils (ASS) by the NSW Department of Land and Water Conservation (DLWC), now part of NSW Dept of Environment and Climate Change (DECC), identifies that there are areas of high acid sulfate soil risk present between KP76 and KP96 of the pipeline corridor that are likely to be disturbed by clearing and construction activity requiring the development of an Acid Sulfate Soils Management Plan.

This ASSMP has been prepared as part of environmental management commitments detailed in the Environmental Assessment (EA) prepared by AECOM Australia Pty Ltd for the Gloucester Gas Project (AECOM 2009).

This ASSMP has been prepared by Environmental Earth Sciences (EES) to assist AGL with the ASS assessment, treatment and management, and mitigation of identified environmental risks relating to disturbance of ASS within the pipeline corridor, principally in coastal lowlands from KP76 to KP96. All excavated materials will be reused onsite as trench backfill for the pipeline construction. This ASSMP addresses performance requirements, performance criteria, environmental obligations which may influence the management, treatment, verification and disposal / reuse of acid sulfate soils; and leachate/trench dewatering water treatment and disposal for the pipeline project.

This ASSMP is intended to fulfil AGL's objectives:

- no discharge from the pipeline construction site or soil or water designated treatment sites of acid sulfate material;
- no acidic drainage from the pipeline site or designated soil or water treatment sites caused by the filling and construction activities of the Project; and
- no visual indicators of the release of acidic material and/or acidic waters from the pipeline construction site.

1.2 Aims

The aims of this ASSMP are to:

- undertake an ASS assessment of the areas of ASS risk
- guide the excavation, treatment and placement(trench backfilling) of ASS;
- comply with the statutory environmental requirements;
- protect the environmental values of the Hunter Estuary Wetlands
- manage disturbance of acid sulfate soils which have the potential to change the physio-chemical status of the Hunter Estuary Wetlands, to minimise the risk of change

1.3 Overview of Proposed Pipeline Construction

1.3.1 Location and description

The Gloucester Gas Project (the Project) includes works for the extraction of coal seam gas (CSG) from the Gloucester Basin within the PEL 285 area. The Project involves the development of gas wells and associated infrastructure, the development of a Central Processing Facility (CPF), and the construction and operation of a high pressure gas transmission pipeline from Stratford to a delivery station at Hexham, NSW. The pipeline corridor avoids traversing towns for a majority of its length, until it reaches Duckenfield and Woodberry north of Hexham.

The 100 m wide pipeline corridor that contains a 30m right-of-way (ROW) traverses approximately 95 km extending from near Stratford in the north to Hexham in the outer suburbs of Newcastle in the south. The landscape traversed by the pipeline is predominantly rural, agricultural and pastoral with visual and landscape characteristics similar to the Stage 1 Gas Field Development Area (GFDA).

1.3.2 Acid sulfate soils description

Acid sulfate soil (ASS) formed on coastal lowlands are generally found <2.5-3 m Above Sea Level (ASL) the highest point of sea level rise following ice shelf melt during the mid Holocene (~6000y BP). The sea level has been dropping ever since due to isostatic adjustment of the lithosphere. For the purposes of discussion herein ASL is equivalent to AHD.

NSW regulatory requirement assumes that all coastal soils <5 m AHD likely to be disturbed by excavation or water table draw-down be assessed for their acid ASS properties. Where their presence is identified a management plan for minimising impacts must be developed.

In coastal lowlands ASS may be present as actual acid sulfate soils (AASS) or potential acid sulfate soil (PASS). PASS are sulfidic soils formed in coastal lowlands subject to tidal inundation or saline groundwater where conditions are conducive for accumulation of iron sulfides in soils (e.g. source of sulfate, source of iron, reducing conditions (organic rich), and stable low energy environment. AASS occur where natural (e.g. draught impacts on groundwater levels, or regular rise and fall of groundwater) or anthropogenic (e.g. land development, drainage works, etc) activity has disturbed and subjected ASS (PASS) to oxidation releasing acidity and reaction products (iron, sulfate, calcium, magnesium, aluminium etc).

Mapping of ASS by the DLWC, depicted in Figure 1, shows the location and distribution of coastal lowland that may contain ASS. The Gloucester to Hexham gas pipeline will pass through coastal lowland <5 m Australian Height Datum (AHD) between KP76 to KP96 within the Hunter River coastal floodplain and estuary, including Ramsar wetlands (Hexham Swamp Lower Hunter).

A referral was lodged with the Department of Environment, Water, Heritage and the Arts (DEWHA) to ensure that due consideration was given to the potential impacts upon matters of NES and that the requirements of the EPBC Act were adequately met. A response from the DEWHA on 30th September 2008 deemed that the proposed project was a ‘controlled action’ as it was considered likely to have a significant impact on:

- Wetlands of international importance; and
- Listed threatened species and communities.

More specifically, the DEWHA determined that, based upon the information submitted with the referral that the Project:

- Involved disturbance of acid sulfate soils which have the potential to change the physio-chemical status of the Hunter Estuary Wetlands;
- Involved the potential disturbance of breeding populations of nationally threatened frog species including the Booroolong frog (*Litoria booroolongensis*) and the Giant Barred frog (*Mixophyes iteratus*).

1.3.3 Pipeline construction limitations

The pipeline can be divided into 3 sections:

- Northern;
- Central; and
- Southern.

It is believed that the highest probability of encountering ASS during earthworks will be in the southern section (coastal zone) of the proposed project alignment. There is a low negligible probability of encountering ASS in the central and northern sections. This assumption should be confirmed during a preliminary field investigation (Phase 1 Section 3 of this Plan). The Phase 1 investigation will be used to determine the requirement for a detailed investigation (Phase 2, section 4 of this Plan). Once the spatial distribution of ASS can be adequately defined a risk assessment should be undertaken (Phase 3, section 6 of this Plan) and management/monitoring options defined (Phase 4, section 7.1 and 7.6 of this Plan). Given the knowledge of the occurrence of ASS in the coastal zone, Phase 1 and Phase 2 could be combined.

Southern Section

The southern section contains coastal lowlands. The Department of Land and Water Conservation (DLWC) ASS Risk Mapping (Naylor et al, 1998) has defined the coastal lowland near Hexham that the pipeline corridor traverses, between KP 76 and KP96, as containing acid sulfate is located within 1-4m AHD.

Some ASS potential also exists between 0-1 m AHD in the pipeline route adjacent to the Hunter River.

The highest probability of encountering ASS is believed to be in the lowland areas of the alignment between pipeline KP 79 and KP 96. Limited field investigations would need to be undertaken during the preliminary phase (Phase 1, Section 3.2) of the project to confirm this early assumption. However more detailed investigation is likely to be warranted to define and implement effective management/treatment procedures to limit impacts from disturbing ASS.

1.3.4 Soil Excavation

ASS occur between KP76 and KP96 of the pipeline route. There is a high risk of ASS between KP 79 and KP96, and low risk of ASS occurrence between KP76 and KP79 (refer to Section 3.1).

The construction and installation of the pipeline would require significant excavation along the 95 km length to CPF Site 7 (or approximately 100 km length to CPF Site 1) prior to operation. This would involve the clearing and grading of a 25-30 m ROW along the length of the pipeline. The clearing of the ROW would remove the top 100-150 mm of soil and stockpile the material for reuse in the rehabilitation of the area. The impact width of approximately 25-30 m would enable construction activities, including trenching, access roads, stockpiling of removed soil and vegetation and storage. In environmentally sensitive areas along the pipeline, the ROW may be reduced to minimise impacts to vegetation or habitat along the pipe.

The pipeline will be 10”-16” high tensile steel with protective coating. The pipeline installation would involve trenching to allow for a minimum depth of cover to 750 mm depth for installation of the high pressure steel pipe which would be anodised for protection. The assumed trench depth ranges up to 2-3m. The pipe would be lowered into the trench using cranes and machinery, before cleaning and testing. The installation would be undertaken in sections of up to 20 km to maintain access for agricultural and farming practices and to minimise quantities of soil

Earthworks associated with the construction of the pipeline will include:

- Land clearing of the pipeline corridor for access
- Roads
- Trenching for pipeline burial
- Disturbance of water courses for pipeline installation

Stockpiled PASS or AASS will readily oxidise in the presence of atmospheric conditions. Adequate stockpile management, treatment and reuse/disposal will be required as part of this ASSMP.

1.3.5 Dewatering and Drainage

Dewatering and drainage may be required wherever the pipeline intercepts or traverses creek crossings. KP 85 to KP 96 is generally at 1-2 m AHD elevation. The existing water table may be close to the natural ground surface along this section of the pipeline alignment. Dewatering and drainage maybe required in the installation trench to allow burial of the pipeline.

Lowering of the natural groundwater level will allow oxidation of any PASS or AASS that may be present in the face of the excavated trench. Permanent and temporary surface water and groundwater storage will require monitoring prior to earthworks, during and post earthworks (including runoff). Frequency of monitoring will be tailored to the site but will range between daily and monthly.

A quantity of saline water maybe recovered as a result of dewatering. This will require temporary storage and treatment before discharge. Discharge will be subject to monitoring and compliance with water quality objectives described within this Plan.

1.3.6 Temporary Storage of Acid Sulfate Soil

The preferred management option of ASS is avoidance. The following management options are available for temporary soil stockpiles:

- reduction of stockpile size by minimising trench excavation, reducing the total volume of disturbed soil;
- strategic reburial of excavated soil both on and off-site to reduce stockpile size and reduce oxidation potential; and
- where oxidation potential cannot be reduced, that is, stockpiling exceeds approximately 1-5 days dependent on soil texture; neutralisation of acidity using finely crushed limestone will be required prior to reuse on-site or disposal off-site.

1.3.7 Reuse or Disposal of Acid Sulfate Soil

Re-use on-site and disposal off-site is dependent on adequate management and the potential risk of environmental harm from oxidation products from ASS being released to the environment. The likelihood of net acidity being released is dependent on the inherent properties of the soil, volume of disturbance, monitoring, treatment and management. Excavated soil will preferentially be reused as backfill once the pipeline is installed.

1.3.8 Resource database

This ASSMP was developed through extensive knowledge of acid sulfate soil assessment and management. The Bibliography provides key publications on assessment, management and regulations of acid sulfate soils in the coastal lowlands of Australia. Appendix A provides methodology guidelines for the assessment of acid sulfate soils.

2 SITE OVERVIEW

2.1 Geology and Hydrogeology

During the Quaternary period (1.8 million to present) sands and fluvial sediments were deposited, dependent on the varying sea levels. During periods of lower sea levels, up to 120m below present day levels, the estuary and coastline extended 25km further seaward. During periods of sea level rise, vast quantities of marine sand were transported landward across the inner continental shelf as landward moving (transgressing) sand sheets and barriers. This process has created the Hunter estuary as a barrier estuary (McManus et al, 2000; Chapman, et al, 1982). The estuary itself has two distinct barriers: the Outer and Inner Barriers.

The Outer Barrier consists of a belt of beach, dune, estuarine and lagoonal sediments from the Holocene age (i.e. sediments deposited within the last 10,000 years). The eastern edge of the Outer Barrier forms the present day coastline.

The Inner Barrier is a second belt of marine sediments, located landward of the Outer Barrier. In between the Inner and Outer Barriers the estuary has formed, Tilligerry Creek extends south west from Port Stephens, and Fullerton Cove forms a basin connected to the Hunter River.

2.1.1 Soils

The project area extends from Gloucester in the north to Hexham in the South. The area occupies two soil landscape sheets, being the Newcastle 1:100 000 Soil Landscape Sheet and the Dungog 1:100 000 Soil Landscape Sheet. A review of these landscape sheets has identified several soil landscapes that the Project is likely to encounter during construction and operation of the proposed project.

The soils of the project area can broadly be defined as predominantly alluvial. Potential soil landscapes limitations related to this broad soil category include:

- High erosion potential
- Dispersible soils;
- Seasonal water logging;
- Poor soil drainage; and
- Acid sulfate soils

Spatially some areas of the proposed alignment are more likely to encounter ASS (Table 1).

TABLE 1 SOILS OF THE PROPOSED PROJECT AREA

Zone	Landform Description	Kilometre Markers	Possible Issues
Southern Section	Dominated by extensive alluvial plains and terraces, with some tidal creeks and swamps / estuarine backplains.	Hexham Area KP76-KP96	High water table Water logging Flooding Acid sulfate soil.

The southern section of the proposed alignment is of greatest concern with the presence of high groundwater levels and estuarine landscape features (such as tidal creeks and swamps) along with the presence of ASS making the management of works in this area a primary issue to this ASSMP.

2.2 Environmental Receptors and Risks

The main environmental receptor of concern is the estuarine waterways, in particular the RAMSAR listed Hunter Estuary Wetlands, in the southern section of the alignment (Table 1). The oxidation of AASS and PASS releases sulfuric acid which dissolves heavy metals into solution making them available for transport off-site. The combination of sulfuric acid and heavy metals can have detrimental effects on land, water and biota. Such effects include:

- Acidification of water ways, wetlands and estuaries which leads to massive fish kills. In turn de-oxygenation of the water can lead to toxic algal blooms. Acid has also been linked to chronic effects on aquatic systems that include disease, reduced hatching and survival growth rates for a wide range of species.
- Degradation of the ecology of wetlands and shallow freshwater and brackish aquifer systems by loss of water quality, habitat and dependent ecosystems. Apart from the direct effect of acid production causing fish kills and declines in the number and diversity of invertebrate populations, acidification and heavy metal production can have a negative impact on macrophytes and other aquatic vegetation on which aquatic animals are dependent for food, shelter and reproduction. Loss of aquatic animal life can in turn, have serious consequences for higher food chain dependent species, such as birds.
- Acidification of waters can impact the built environment causing disruption of foundation through sulfate ‘heave’, corrosion of concrete and steel structures, and clogging of drains.

2.2.1 Surface Water

Environmental Management (with reference to release of potentially impacted water from areas containing ASS) will also need to be cognisant of major waterways within the project area and stakeholders that rely upon surface water abstraction.

The Hunter River flows in a south westerly direction from Glenbawn Dam in the north of the catchment to meet the Goulburn River near Denman. From Denman it flows in a south-easterly direction through Singleton and Maitland to meet the South Pacific Ocean at Newcastle. All creeks and rivers within the Hunter catchment are tributaries of the Hunter River.

Primary land use in the catchment reliant on the Hunter River includes power generation, coal mining, heavy industries, irrigated agriculture, infrastructure within Newcastle (the second largest urban area in NSW), and fisheries. A number of dams have been built in lower sections of the Hunter River to regulate flows, minimising the risk of flooding and promoting the abovementioned activities. Major water management issues include water quality, declining native fish population numbers, increased development (both urban and industrial), poor riparian vegetation cover, altered stream form, high stock and domestic use of groundwater, and riparian usage on unregulated streams.

The pipeline corridor crosses the lower Hunter River beyond KP 80. In addition a number of wetlands that form the Hunter Estuary Wetland System are within or close to the Pipeline corridor to the east, south and north.

Based on spatial distribution of disturbed ASS (Phase 1, Phase 2 and Phase 3 studies) water monitoring and management at several of the locations described will need to be incorporated into the ASSMP.

2.3 Groundwater Abstraction

The excavation and installation of the pipeline normally, by necessity, results in the disturbance of soils the potential requirement for dewatering of the superficial aquifer water table to facilitate site works. There is a need to undertake best practice ASS and dewatering management that achieves sound environmental outcomes.

To assess potential adverse environmental effects associated with the installation and the long-term operation of the proposed pipeline, the following analytical and interpretive evaluation may be required:

- assessment of the dewatering water discharge options; and
- review of potential for groundwater drawdown associated with trench dewatering.

These evaluations may require separate or supplementary studies to this ASSMP if deemed significant.

Of note dewatering and drainage will be required wherever the pipeline intercepts or traverses creek crossings. KP85 to KP96 is generally at 1-2 m AHD elevation. The existing water table is close to the natural ground surface along this section of the pipeline alignment. Dewatering and drainage will be required in the installation trench to allow burial of the pipeline.

Lowering of the natural groundwater level will allow oxidation of any PASS or AASS that maybe present in the face of the excavated trench. Permanent and temporary surface water and groundwater storage will require monitoring prior to earthworks, during and post earthworks (including runoff). Frequency of monitoring will be tailored to the site but will range between daily and monthly.

During trenching and installation of the proposed gas pipeline where dewatering measures are required to provide a dry work environment the dewatering rates will need to be determined based on:

- the estimation that the maximum drawdown depth at the trench will be nominally 2m below ground level;
- the trench length that is open per day; and
- a hydraulic permeability coefficient (m/d), consistent with documented geology to be used in the calculation of the dewatering rates.

Dewatering rates are calculated based on modified Dupuit Forcheimer equation (Freeze, 1979) according to Driscoll (1986). The Dupuit Forcheimer equation provides an evaluation of the discharge rates in a linear dewatering array. The modified Dupuit Forcheimer equation evaluates the trench end conditions, incorporating a radial dewatering array, (site specific).

2.4 Current and Historical Land use

Landuse within the project area is related to landform, geology, vegetation and soil type.

The landform of the study area is characterised by two regions; the Gloucester Basin Region to the north and the Hunter Valley Region to the south. The Hunter Valley Region and principally the Lower Hunter area is the focus of this Plan. The Gloucester Basin Region is elevated and does not have an acid sulfate soil issue and therefore will not be discussed in this section.

The Lower Hunter region forms a transition zone for many plant and animal species between the subtropical influences of the north and the cooler, less fertile conditions to the south.

The Hunter Valley Region has three physiographic regions of relevance; Clarencetown Hills (continuing from the Gloucester Basin Region described above), Medowie Lowlands and The Lower Hunter Plains (Table 2).

TABLE 2 HUNTER VALLEY PHYSIOGRAPHIC SUBREGIONS

Subregion	Description
Medowie Lowlands	Occurring to the south east of the Clarencetown Hills the lowlands are formed predominantly on Carboniferous sediments and volcanics.
The Lower Hunter Plains	Extending from Seaham to Newcastle Harbour, these low plains occupy the southern area of the pipeline.

The landscape of the Hunter Valley has great diversity with sub-alpine areas in the highlands to broad coastal heathlands near the ocean. The lower Hunter Valley is relatively flat, with a large flood plain, which narrows in width in the upper reaches. An important area of the Lower Hunter Plains is the Hunter estuary, an important site for migratory shorebirds, fish and crustaceans, many of which are commercial and recreational significant. The Lower Hunter Estuary contains wetland areas listed internationally under the Ramsar Convention due to their unique mix of wetland types, important for maintaining biological diversity and conservation of migratory shorebirds.

The catchment covers a diverse area with the dominant non-agricultural land uses including urban and rural residential development, coal mining, power generation, heavy industry, shipping, tourism, manufacturing and fisheries. The major agricultural industries include table and wine grapes, cereal cropping, grazing, dairying, and beef, pork and poultry production. As with the Gloucester Basin Region traditional and hobby farms are concentrated around townships.

Land use within the proposed project area relies heavily on abstraction of surface water (section 2.2.1). Protection of surface water from potentially impacted ASS runoff from the site of excavation is an important element of the ASSMP.

3 PHASE 1: PRELIMINARY SAMPLING AND ANALYTICAL PROGRAM

3.1 Preliminary Desktop Assessment

A preliminary desktop assessment based on ASS risk mapping by DLWC (Naylor et al, 1998) and NSW Department of Primary Industries (2008). *Acid Sulfate Soils Priority Investigations for the Lower Hunter River Estuary; Report to the Department of Environment, Water, Heritage and the Arts. Department of Primary Industries (Aquatic Habitat Rehabilitation), Port Stephens* has been completed and indicates that the highest likelihood of intercepting PASS and AASS along the proposed alignment is as follows:

- Low Probability of Occurrence
  - KP 76-78: between 2-4 m AHD
  - KP 78-79: between 1-2 m AHD
- High Probability of Occurrence
  - KP 79-85: between 2-4 m AHD
  - KP 85-96: between 1-2 m AHD

Some ASS potential also exists between 0-1 m AHD in the pipeline route adjacent to the Hunter River.

High Probability of Occurrence refers to landform elements in which the geomorphic processes have been suitable for the formation of ASS have been classed as having a High Probability of Occurrence. ASS in these environments are widespread or sporadic. They may also be very close to the surface or buried by many metres of alluvium or windblown sand. Bottom sediments of estuaries, rivers, creeks and lakes are also considered areas of High Probability of Occurrence. Environments associated with this risk map class are all closely related to Holocene deposits (12000y BP-Present).

Low Probability of Occurrence is where environments have not generally been suitable for ASS formation, or ASS are highly localised or sporadic, they have been classed as having a Low Probability of Occurrence. ASS may be close to the surface or buried by many metres of alluvium or windblown sand. The majority of these landforms are not expected to contain ASS. Soil materials are often Pleistocene in age (2.5My – 12000y BP).

An ASS is an environment and health risk and a preliminary field assessment will be required to delineate the spatial distribution of ASS along the proposed alignment.

3.2 Preliminary Field Assessment

The preliminary field assessment will be undertaken by an appropriately qualified soil scientist, and aim to confirm the findings of the desk-top assessment:

- soil characterisation; and
- a detailed description of the profiles for the major soil horizons present would be undertaken for each bore log in accordance with the *Australian Soil and Land Survey.*

Field testing to screen for the presence of acid sulfate soils will be completed for Field pH(pH_F) and Field pH Peroxide Test (pH_{FOX}).

- Samples will be collected every 0.25m interval down the borehole as per Acid Sulfate Soil Management Advisory Committee (ASSMAC) and Queensland Acid Sulfate Soil Investigation Team (QASSIT) Guidelines.
- Field tests for ASS screening will be conducted 0.25m samples collected from each borehole
- Borehole spacing along the proposed pipeline corridor between KP76 and KP96 will be 200m for Phase 1. It is noted that ASSMAC Guidelines recommend a spacing of 50-100m for linear projects likely to disturb acid sulfate soils. However for large projects, particularly where prior knowledge of the site exists (e.g. published ASS Risk Maps) this Guideline could be modified, subject to concurrence with relevant regulatory authority. Table 3 sets out the minimum sampling frequency for field testing.

TABLE 3 FIELD TEST SCHEDULE

Kilometre Marker (km)	Borehole Spacing (m)	Sample Number and Depth (m)
KP 76-86	200	8-12 samples (0.25m) per bore hole 2-3m (depth)
KP 86-96	200	8-12 samples (0.25m) per bore hole 2-3m (depth)

- Testing will follow QASSIT methodology (QASSIT Guidelines, Ahern et al 1998; Soil Management Guidelines v3.8 Dear et al 2002; and Acid Sulfate Soils Laboratory Methods Guidelines Ahern et al 2004). The methodology is set out in Appendix A.

A number of factors need to be considered in arriving at positive field sulfide identification:

- Conventionally a field pH_F <5.5 is indicative of actual acidity and pH_{FOX} <4.5 is indicative of potential acid sulfate soils.
- A pH_{FOX} value at least one unit below field pH_F may indicate acid generating material requiring further testing. The greater the difference between the two measures (ΔpH), the more indicative the value is of a potentially acidic soil material. The lower the final pH_{FOX} value is, the better the indication of a positive result.
- If the $pH_{FOX} < 3$, and the above condition applies, then it strongly indicates a PASS. The more the PH_{FOX} drops below 3, the more positive the presence of sulfides.
- A pH_{FOX} of 3-4 is less positive and laboratory analysis is needed to confirm if sulfides are present.
- For pH_{FOX} 4-5 the test is neither negative nor positive. However further testing is required. Sulfides may be present either in small quantities and be poorly reactive under the quick field test conditions or the sample may contain carbonate, which neutralises some or all of the acid produced by oxidation. Equally the pH_{FOX} may be produced by organic acids and there may be no sulfides present in this situation.
- For pH_{FOX} > 5 and little or no drop in pH from the field value, little net acidification ability is indicated.

The field pH (pH_F) and field pH peroxide (pH_{FOX}) tests have been developed for a rapid assessment in the field of the likelihood of acid sulfate soils. These tests are easy to conduct, quick, and have a minimum set-up cost. The field tests have been developed to give reasonable prediction for many soils (provided the tests are performed properly) whilst at the same time being relatively easy to perform with a minimal amount of equipment. Soil field pH tests provide a useful indication of the existing and potential acidity levels in the soil. Although these field tests may provide an indication of ASS presence, they are purely qualitative and do not give any quantitative measure of the amount of acid that has been or could be produced through the oxidation process.

pH_F is pH of ASS measured in the field on a mixture of soil and water.

pH_{FOX} is pH of ASS measured in the fields on a mixture of soil and 15% hydrogen peroxide.

Field staff will be provided with Table 4 that provides a summary of field test responses to assess whether further action is required.

TABLE 4 FIELD PEROXIDE TEST RESULT INTERPRETATION

$pH_{1:5}$	pH_{FOX}	∆pH	∆Temp (ºC)	Effervescence*	Action Required
≥5.0	≥4.5	≤2.0	<5ºC	None-Mild	None
<5.0	<4.5	>2.0	>5ºC	Mild-Strong	Preliminary lab assessment
<5.0	<2.5	>2.0	>10ºC	Strong-Extreme	Detailed assessment

Source: Victorian Government Department of Sustainability and Environment (2008)

Note(s): 1. levels of effervescence are: none; mild; strong; extreme
2. * also includes iron precipitation
3. see Attachment 1 for field peroxide test data sheet

Importantly it should be noted that the method is a field based method used for screening actual and potential acid sulfate soils that also captures acidity generated by non-sulfidic soils e.g. organosols etc.

If it is concluded by the appropriately qualified soil scientist that (based on application of the Phase 1 *Preliminary risk assessment guidelines*) the site does **NOT POSE** a potential for either the occurrence or oxidation of ASS, then a report will be prepared to this effect. The report will justify why further assessment is not warranted and include maps of the site showing features, any sample locations and areas of potential ASS occurrence (if these are present).

If it is concluded by the appropriately qualified soil scientist that (based on application of the Phase 1 *Preliminary risk assessment guidelines*) the site **DOES POSE** a potential for either the occurrence or oxidation of ASS, then at least 40 samples (if more than 40 are positive to field testing) or fewer (if less than ***40 samples*** are positive to field testing) will be subject to further laboratory testing.

The laboratory analytical program requires consideration of handling and storage. Due to the potentially volatile nature of the sulfur compounds being assessed and the act of removing them from an anoxic environment, collected samples will be sealed to minimise oxygen exchange, placed in the dark and kept cool to frozen (preferably <4ºC) until received at the laboratory.

If samples cannot be deliver to a NATA accredited laboratory within 24 hours the following options will be employed:

- Freezing the samples and/or transporting to the laboratory with dry ice; or
- Oven drying to 80-85ºC forced convection as quickly as possible and transporting/ storing in a low humidity environment.

Laboratory testing will involve the following:

- Titratable Actual Acidity (TAA),
- Chromium Reducible Sulfur (CRS) and
- Acid Neutralising Capacity (ANC).

Tests will be completed at NATA accredited laboratory from delivered sub-samples prepared by qualified field staff. Testing will follow QASSIT methodology (Ahern et al, 1998, 2004). QASSIT (1998) recommending sampling at 0.5 m intervals, with tests completed at the top and bottom of each distinct horizon.

The potential for samples to produce acid will be assessed against the screening criteria presented in Table 5.

TABLE 5 ACTION CRITERIA TO TRIGGER FURTHER TESTING

Type of Material		**≤1000 T (≤600 m^3) disturbed**			**>1000 T (>600 m^3) disturbed**		
Texture	**Clay**	**Sulfur Trail**	**Acid Trail**	**NAGP**	**Sulfur Trail**	**Acid Trail**	**NAGP**
Units	%	%S	mol H$^+$/T	kgH$_2$SO$_4$/T	%S	mol H$^+$/T	kgH$_2$SO$_4$/T
Coarse	≤5	0.03	18	1.0	0.03	18	1.0
Medium	5-40	0.06	36	2.0	0.04	25	1.4
Fine	≥40	0.1	62	3.0	0.05	31	1.8

Note(s): 1. ‘disturbed’ refers to excavation, dewatering, dredging, etc
2. refer to Table 6 below for conversion factors between laboratory units
3. Coarse = sands; Medium = sandy loams/silts to light clays/silts; Fine = medium to heavy clays, silty clays
4. NAGP net acid generation potential – requires %S and acid neutralizing capacity (ANC) to determine

4 PHASE 2: DETAILED SAMPLING AND ANALYTICAL PROGRAM

A phase 2 detailed sampling and analytical program will be undertake only if the preliminary assessment indicates a requirement for in-filling to improve sample density and delineation of ASS along the proposed alignment.

Borehole spacing will be 100m, and similar sampling frequency discussed Section 3.2 (Table 3) will be implemented.

The sampling pattern for a full ASS site assessment will consider the nature of the area being assessed and the proposed future development works. It will include maps showing pre-existing and proposed sampling locations, as well as site features and areas of potential ASS occurrence (based on desk-top and/or preliminary assessment). Phase 1 results will be used to refine the Phase 2 Sampling Analysis Plan.

The sampling plan will justify how the samples collected will be representative of the soil materials present in the area to be assessed. Sampling density requirements will be based on the size of the area being assessed and the nature of the proposed development.

Data quality is typically discussed in terms of precision, accuracy, representativeness, comparability and completeness. Based on the outcome of Phase 1, further infill sampling maybe required to develop a better understanding of the spatial distribution of ASS and its location along the proposed alignment.

5 INTERPRETATION AND REPORTING

Based on the results of assessment from Phase 1 and Phase 2 testing, interpretation is undertaken to determine the risk of oxidation of the identified ASS sediments in the event of excavation, dewatering, dredging or other forms of disturbance that potentially introduce oxygen to the soil.

Hazard classes are a management tool for defining material based on impact to the environment, and are based on soil sulfur (S) and net acid generation potential (NAGP) values. Classes normally used are no risk (no-sulfur or non-reactive), moderate risk and high risk. An explanation of these classes is presented in the following sections, and definitions are provided in Table 6.

TABLE 6 SOIL SULFIDE HAZARD CLASSES

Risk Class	No risk				Risk			
Hazard Class	**'No-sulfur'**		**'Non-reactive'**		**'Moderate Risk'**		**'High Risk'**	
Texture Group	**Sulfur**	**NA**	**Sulfur**	**NA**	**Sulfur**	**NA**	**Sulfur**	**NA**
1	1	N/A	>1 (<10)[4]	<3	>1	>3	>10	>5
2	2	N/A	>2 (<20)[4]	<6	>2	>6	>20	>10
3	3	N/A	>3 (<30)[4]	<9	>3	>9	>30	>15

Note(s): 1. all units in kg H2SO4 generated per tonne of soil
2. NA net acidity (sulfur + acid – buffering capacity)
3. Texture groups are: 1. Coarse: sands; 2. Medium: loams/silts-light clays; 3. Fine: medium to heavy clays, silty clays
4. 4 sulfur levels exceeding the values in brackets require confirmation through incubation tests or weathering trials

Soils classified as 'no sulfur' are not acid sulfate soils (NASS), while 'non-reactive' soils are completely self buffering and do not require management through neutralisation if oxidised (although they do require monitoring).

The 'no risk – no-sulfur' (NASS) classification is based solely on the presence of sulfides (S) measured by the TOS, S_{CR} or S_{POS} methods. No risk – no-sulfur is defined as soil below the S threshold values given in Table 6.

'Non-reactive' is based on net acidity (NA) and is defined as having S values greater than the no-sulfur threshold, but NA values below 3 times that of the no-sulfur values. Thus threshold values are as follows:

- for sand, NA <3 kg H_2SO_4/tonne;
- for sandy silts and silts, NA <6 kg H_2SO_4/tonne; and
- for sandy clays, silty clays and clays, NA <9 kg H_2SO_4/tonne.

Note that these levels are based on consideration of buffering agents in the soil, as per the equation:

- NA (kg H_2SO_4/tonne) = sulfur (S) + acidity (TAA) + retained acidity (S_{RAS} at $pH_{KCl}<4.5$) – buffering (ANC/Ca+Mg)

'Moderate risk' and 'high risk' sediment and soil are likely to cause a significant adverse risk to the environment. Essentially, moderate risk will generate a small amount of acid slowly while high risk will either generate acid quickly, in large volumes, or both. According to the definition in ASSMAC 1998, these are the only two classes that are considered to be ASS from a management point of view. High-risk material should not be disturbed or, if disturbance cannot be avoided, should be kept in an anoxic state (i.e. Phase 3 and Phase 4 will be triggered).

If the presence of ‘moderate risk’ or ‘high risk’ sediment and/ or soil is confirmed, an Environmental Risk Assessment (Phase 3) followed by implementation of the management procedures (Phase 4) will be prepared to determine an appropriate management response for the proposed development.

If it is concluded by the appropriately qualified scientist that (based on application of the Phase 2 *Full site assessment guidelines*) the site either does or does not pose a potential for either the occurrence or oxidation of ASS, then a report will be written to this effect. The primary aim of the Phase 2 *Full site assessment* is to identify the extent of ASS occurrence to enable the management procedures of this ASSMP to be implemented.

A simple report will be produced at the end of Phase 1 testing, with a comprehensive report delivered after the completion of Phase 2 testing.

6 PHASE 3: ENVIRONMENTAL RISK ASSESSMENT

The use of the risk assessment matrix (RAM) is intended as a tool for risk identification and to assist in the development of this ASSMP. Further assessment may be required to determine risk to the environment in greater detail (e.g. groundwater investigation) and determine the parameters that must be met in order to demonstrate acceptable risk to the environment.

The risk assessment matrix aims to address the following:

- the degree of environmental risk that may be associated with disturbance of ASS; and
- provide a number of management (including potential treatment) options to reduce the risk to an acceptable level.

The likelihood that Net Acidity (NA) will be generated depends on the inherent properties of the soil and the proposed amount of ASS disturbance. In this context risk is not considered as whether or not the generation of NA will occur, but whether the amount of NA generated by disturbing ASS will be of significant enough magnitude to cause concern.

The RAM uses the NA of soil determined during the full site assessment (Phase 2) and the proposed amount of ASS to be disturbed (excavated and/ or potentially dewatered) to assign a risk rating: active management (A); regular monitoring (R); periodic monitoring (P); and no major concern (N). The ascribed risk rating corresponds to a required management response (Table 7, Table 8 and Table 9).

TABLE 7 RISK ASSESSMENT MATRIX (RAM)

Disturbed ASS (T)	**Net Acidity (kg H_2SO_4/T)**				
	≤1.2	**1.2-9.8**	**≥9.8-19.6**	**≥19.6-30.6**	**≥30.6**
1	N	N	N	N	N
5	N	N	N	P	P
10	N	N	P	P	R
50	N	P	P	R	R
100	N	P	R	A	A
200	P	R	R	A	A
500	P	R	A	A	A
1000	R	A	A	A	A
2000	R	A	A	A	A
>2000	A	A	A	A	A

Note(s): 1. NA already considers soil buffering capacity (ANC/FF)
2. Management ratings: (N)o concern; (P)eriodic monitoring; (R)egular monitoring; and (A)ctive management

TABLE 8 MANAGEMENT RESPONSE REQUIRED

Rating	**Response required**	**Management options (Table 9)**
Active management (A)	• Update ASSMP required; • Further assessment may also be required; • Ongoing monitoring system needs to be established; and • The proposed development should be considered as a '**Do Not Proceed**' issue unless specific strategies are developed, through an update of the ASSMP, to reduce the level of risk.	1, 2a & 2b
Regular monitoring (R)	• Update of ASSMP where required; and • Review of ongoing monitoring system may be required.	1, 2a, 2b & 3
Periodic monitoring (P)	• Review and update the ASSMP.	1, 2a, 2b, 3 & 4
No major concern (N)	• Accept or manage as part of standard construction management	1, 2a, 2b, 3 & 4

TABLE 9 MANAGEMENT HIERARCHY

No.	**Management Option**	**Description**
1.	Avoidance of disturbance	Remove risk by avoiding disturbance
2a.	Prevention of oxidation (on-site)	Reduce risk by strategic reburial below water table on-site
2b.	Prevention of oxidation (off-site)[1, 2]	Reduce risk by strategic reburial below water table off-site[1, 2]
3.	Neutralisation	Reduce risk by buffering for potential acid production on-site
4.	Disposal off-site[2]	Reduce risk by disposing of ASS off-site for treatment

Note(s): 1. 1 for off-site reburial, materials tracking is an important and vital component
2. 2 off-site disposal as per IWMP (WASS) and EPA Victoria Publication 448.3

7 PHASE 4: ACID SULFATE SOIL MANAGEMENT

The management of ASS will follow a number of key principles, which have been adapted from the soil management guidelines described in the ASS Manual (ASSMAC 1998) and Soil Management Guidelines (Dear et al, 2002). These management principles are:

- wherever possible, ASS below the water table *will not be disturbed by excavation or dewatering* to ensure that PASS or AASS are not exposed to air and allowed to oxidise;
- where disturbance is unavoidable, *disturbance will be minimised or otherwise managed* (preferably through reburial) to prevent environmental impacts caused by the oxidation of ASS. Management strategies will be required; and
- where environmental impacts have occurred due to oxidation of ASS, the disturbance *will be remediated wherever possible*, or alternative risk-based management strategies will be implemented to prevent potential impacts to the receiving environment (surface water bodies described in section 2.2.1).

The proposed project will likely disturb ASS and will assess the risk associated with disturbance through the consideration of on-site and off-site impacts. A detailed ASS assessment (as outlined in Phase 1 (section 3) and Phase 2 (section 4) will be required to be undertaken to provide information on the environmental setting, location and depth of ASS, existing and potential acidity present in the soil and related soil characteristics.

The ultimate outcome of the preliminary risk assessment (Phase 1, section 3) and full site assessment (Phase 2, section 4) guidelines is to determine a hazard class (Table 6) for the soil. The net acidity results combined will be combined with the proposed amount of ASS to be disturbed to assign a risk rating from the RAM (Table 7). Table 7 has been developed to assist in evaluating the potential environmental risk associated with ASS disturbance by identifying the risk category (Phase 3, section 6). Four risk categories (Active management, Regular monitoring, Periodic monitoring and No concern) have been defined in Table 8. These categories relate to managing risk of ASS disturbance and potential oxidation so that adverse impacts on the receiving environment are mitigated.

This ASSMP is required as the project area (or parts) can be assigned (based on published ASS mapping data) a moderate, significant or high risk rating. As no field investigations have yet been undertaken the current ASSMP (this document) is necessarily conceptual. It is anticipated that based on Phase 1, Phase 2 and Phase 3 studies that the ASSMP will be updated to reflect actual site conditions. This will include the inclusion of detailed site plans showing the location and extent of ASS and treatment plans and locations. The ASSMP will also be updated to include details of validation testing of both excavated soil and surrounding water ways to ensure that adequate site management is being undertaken.

7.1 Management Strategies

The location and extent of ASS at site is not currently known, however, there are a number of management strategies that can be employed based on analysis using Phases 1, Phase 2 and Phase 3.

7.1.1 No major concern

Disturbance of ASS that is assigned a risk rating of No Major Concern does not require a site specific ASSMP; however project management will ensure:

- any site run-off and/or infiltration will be managed and monitored (at least for pH) according to the site environmental management plan (EMP); and
- aglime treatment of any soil excavated and allowed to oxidise will be undertaken with a neutralising agent according to the NA of the soil, with appropriate validation to confirm that no further oxidation can occur.

7.1.2 Periodic monitoring required

If the project area (or part thereof) is assigned a risk management rating requiring Periodic Monitoring the ASSMP would be updated to ensure:

- if excavation is unavoidable and ASS is allowed to oxidise, the soil will be treated according to NA of the soil;
- any surface water and site run-off will be managed and monitored (at least for pH), with appropriate bunding to prevent or limit any infiltration of acid leachate to groundwater during earth works; and
- if a neutralising agent is used it will be thoroughly mixed with the soil, and validation sampling and laboratory analysis will be undertaken to confirm that no further oxidation can occur.

7.1.3 Regular monitoring

Management options if the project is assigned a Regular Monitoring ranking the ASSMP will be updated to include detailed plans and instructions for the following actions:

- provision of bunding of the site to collect all site run-off during earthworks;
- monitoring of pH of any water contained within the bund (e.g. after rainfall) and treatment of water to maintain pH within the range 6.5-8.5 prior to discharge;
- construction of temporary barriers in stockpiling areas to prevent infiltration;
- management of stockpiled soil to ensure that the potential oxidation period is not exceeded (dependent on soil texture – refer to Table 10);
- documentation of spatial tracking of excavated soil; and
- establishment of on-going monitoring program(s) for surface water, groundwater and stockpiled soil. Water chemistry indicators will also be considered in the formulation of a monitoring program.

TABLE 10 UNCONTROLLED STOCKPILING DURATION BASED ON SOIL TEXTURE

Type of material		**Duration of stockpiling**	
Texture (McDonald *et al.* 1990)	**Clay (%)**	**Short-term**	**Medium-term**
***Coarse* (Sands to loamy sands)**	≤5	overnight	14 days
***Medium* (Sandy loams to light clays)**	5-40	2-3 days	21 days
***Fine* (Medium to heavy clays & silty clays)**	≥40	5 days	28 days

Note(s): 1. These timeframes do not apply to monosulfidic black oozes (MBOs), such material should not stockpiled
2. Medium-term stockpiles should have a temporary barrier installed to prevent infiltration of leachate
3. these periods can be exceeded if site-specific data (e.g. AWT) confirms a longer holding time has no adverse effect

7.1.4 Active management

If the project is assigned a risk rating requiring Active Management the ASSMP will be updated to include (but not be limited to):

- requirements for further assessment (e.g. environmental risk assessment and detailed hydrogeological assessment);
- provision of bunding of the site to collect all site run-off during earthworks;
- monitoring of pH of any water contained within the bund (e.g. after rainfall) and treatment of water to maintain pH within the range 6.5-8.5 prior to discharge;
- construction of temporary barriers in stockpiling areas to prevent infiltration;
- management of stockpiled soil to ensure that the potential oxidation period is not exceeded (dependent on soil texture - refer to Table 10). Note that under this risk category, ASS will not be excavated for reburial;
- documentation of spatial tracking of excavated soil; and
- establishment of an on-going monitoring program for surface water, groundwater and stockpiled soil. Water chemistry indicators listed will be considered in the formulation of a monitoring program.

For sites requiring Active Management, the ASSMP would be submitted to the relevant regulatory authority for comparison with the risk assessment matrix (RAM), as well as for consideration of other sensitive issues associated with the site, such as proximity to wetlands and marine parks, and height above sea-level. This process may result in a higher level of overall assessment including an Environmental Effects Statement or equivalent.

7.2 Treatment Strategies

7.2.1 Minimisation of disturbance

The amount of ASS requiring excavation and/or dewatering can be minimised through the design for the proposed development. This consideration will relate to an understanding of where exactly, in terms of lateral and depth occurrences, ASS is positioned on the site. Dewatering impacts can more easily be minimised through installation of hydraulic impediments to dewatering such as engineered ‘curtains’ (e.g. shoring), re-injection wells and galleries, infiltration basins, and wet excavations etc.

Ideally exposure of ASS should be minimised and the construction strategy needs to consider limiting stockpiling keeping trench moist and backfilling trench as soon as practicable.

The project will remove vegetation and topsoil prior to construction of the trench for installation of the pipeline. The ASS assessment is required to determine the impact of this initial clearing on near surface acid sulfate soils including local groundwater impacts. The ASS management strategy for the initial clearing of the ROW is dependent on the ASS assessment. This Plan will require updating when this information becomes available.

7.2.2 On-site strategic reburial

Essentially, there are two forms of strategic reburial: below the permanent water-table at the floor of a permanent open water body; and buried below the permanent water-table beneath a cap of NASS. A feature of the reburial strategy is that monitoring will be required to ensure that the ASS sediments remain saturated, and water-table levels remain elevated, following ASS placement.

This option may not be feasible given the limited (narrow) extent of the excavation.

7.2.3 Off-site strategic reburial

Off-site strategic reburial follows the same principles as on-site reburial (detailed above), with the additional compliance requirements of stringent stockpile tracking and timing, as well as updating the ASSMP to include both sites (source and receipt sites). Table 10 should be referred to for stockpiling duration, while soil should be transported in a moist to saturated state. All off-site movements of ASS need to be tracked, with information to include (but not be limited to): date; time left source site; soil pH at source site; truck registration number; volume/ tonnage; time at receipt site; soil pH at receipt site; and date/time soil is buried.

Should the pH of the tracked ASS be lowered by more than 1.5 units during transit, or be <6.0 at the receipt site, further chemical assessment of the soil will be required. In addition to the above, the chemical characteristics of surface water and/or groundwater at the burial location will be determined and monitored for a period of time following burial of ASS at the site. These requirements will be detailed in the updated ASSMP developed for the site if this option is chosen.

This may include disposal at licenced land fill.

This option may not be practicable and is likely to require Regulatory approval.

7.2.4 Neutralisation

The most common method of neutralising acidic sediments is the mixing of finely crushed limestone or agricultural lime ($CaCO_3$) with the targeted material. The neutralising requirements of ASS are based on the actual acid produced (total actual acidity or TAA), potential for further production of acid (net acid generation potential or NAGP), and the effective neutralising value (ENV) of the neutralising agent to be used.

According to ASSMAC (1998), liming rates are calculated based on a ‘safety factor’ of 1.5 (kg of lime per tonne of soil), which allows for inefficient mixing and the slow reaction rate of agricultural lime. The safety factor of 1.5 is determined through calculating the neutralising value (NV) and effective neutralizing value (ENV) of the liming material used.

Neutralisation will be undertaken on a designed pad. Pad construction will follow QASSIT guidelines. Validation testing and monitoring will be used to ensure that all acidity is neutralised prior to reuse or disposal.

7.2.5 Topsoil

The project proposes to clear the ROW corridor of vegetation and topsoil. The topsoil needs to be managed and placed and stored separate in low manageable stockpiles. It should not be mixed with sub-soil material removed from the trench. This material will contain seed and vegetation stock endemic to the site and will provide the basis for site remediation. It should not be limed.

7.2.6 Soil stockpile construction

Stockpile construction will adhere to the following principles:

- Prior to excavation an acid sulfate soil investigation will be completed and treatment options including limestone neutralisation will be defined, and liming rates determined.
- Where Lime treatment of excavated ASS is required it will take place within purpose-built lime treatment pads located either within the ROW adjacent to the trench or in dedicated lime treatment area.

- If treatment is required the soil will need to be dried prior to lime addition to enable the uniformly mixing lime with the ASS material by physical and/or mechanical means.
- Where practicable (i.e. – adequate space is available) soil types with different acid generating capacities will be stockpiled separately and managed according to their individual risk level.
- Soils will be stockpiled as far away from environmental receptors and drains as practicable to minimise potential for mobilisation of the soils, and impacts from the soils into these waterways.
- The amount of neutralising agent will be based on the ASS assessment and will include a safety factor of 1.5 as defined in Section 7.2.5.
- All ASS excavated will be stockpiled on a purpose built lime treatment pad that will include a constructed guard layer of crushed, compacted limestone or equivalent neutralising agent to a minimum thickness of 300 mm.
- The calculated thickness of the 'guard layer' is dependent on the height of material to be treated on the pad and will need to be assessed and should consist of a minimum 100 mm thickness of crushed limestone. The treatment pad will be bunded using low permeability fill material of sufficient height to enable to capture of potentially acidic waters/ run-off from the ASS and rainfall from a 1 in 10 year storm event.
- The stockpile containment will be constructed so that all leachate and run-off is collected and the ingress of surface water is prevented. This may necessitate the construction of containment bunds and diversion banks. The containment bunds/diversion banks will be constructed on non-acid-generating, low-permeability soils.
- The stockpile lime treatment pads will be constructed so that all leachate and run-off can infiltrate through the neutralising guard layer if deemed appropriate. Where infiltration to ground is impracticable, leachate and run-off will be diverted to a containment pond and tested for water quality and need for treatment prior to disposal to the environment.
- The surface area of the stockpile will be minimised to reduce the extent of material exposed to atmospheric oxygen. This may involve:
    - Shaping the stockpile and/or capping or lining it with a material that will minimise drying by wind and sun and prevent the ingress of rainfall. This management practice will apply to soils collected from above the water table;
    - Limiting the height of stockpiles should be limited to less than 1m wherever possible.
    - Spraying the surface of the stockpile to keep it moist using iron-free water or neutralising solution. The spray will need to be carefully managed to prevent overwetting of the stockpile material and should comprise a fine mist to prevent desegregation of the soil from the stockpile surface. This management practice will be suitable for soils collected from below the water table.
- The exposure of stockpiles and trench should be limited wherever possible; ideally excavated material should be returned to the trench within 24 hours; if this not possible keeping the stockpiles moist and neutralised as discussed above should be adopted; Table 10 outlines exposure options for stockpiles based on texture.

7.2.7 Method of neutralisation

The method of neutralisation will adhere to the following principles:

- ***Where untreated soils have been stockpiled*** on a containment pad, soil neutralisation will occur at the time of backfilling by backfilling the excavation with both the untreated soils and the neutralising agent present in the pad. Approximate mixing of the acid generating soils and the neutralising agent during backfilling will occur by vertically “cutting back” the stockpile and “raking in” the neutralising agent within the excavation.

- ***Where treated soils are to be stockpiled*** on a containment pad, the excavated material will be neutralised using a suitable neutralising agent. The amount of neutralising agent required will be based on the highest percent sulfur concentration for that soil type as determined by the ASS assessment.
- Neutralisation will be undertaken by mechanical application on the containment pad to achieve uniform blending of the neutralising material and the acid generating soils.
- Where excavation works are undertaken in areas of limited space, alternative neutralisation options, such as treatment of soil within a neutralisation unit, off-site neutralisation, in-situ injection of the neutralising agent prior to excavation, or injection of neutralising agent into stockpiles are options that may be considered.

The method of neutralisation will need to be considerate of the soil type to be neutralised. In particular:

- Uniform blending of sands and sandy silts can typically be accomplished using mechanical tilling or “bucket blending” methods;
- Uniform blending of peats, silts and clays is usually difficult to achieve using standard earthworking equipment. These materials are generally more suitable for off-site disposal. If treated on-site the treatment method will need to include crushing or fragmenting of the soil (whilst minimising oxygen exposure) prior to treatment.

7.3 Dewatering Management

Table 11 summarises the excavation management practices that should be followed for each of the management levels to minimise the risk of oxidation of acid sulfate soils due to construction activities associated with installation of the pipeline resulting in the requirements to dewater and impact on the groundwater. Non-linear infrastructure activities are also provided.

From the risk assessment management levels can be derived for acid sulfate soil handling and dewatering activities. The management levels adopt the following principles:

- Level 1 –- represents a low risk to the environment whereby measurable environmental impacts are unlikely. No active management practices will be adopted.
- Level 2 – represents a moderate risk to the environment in that impacts may occur but are not certain to occur. Management practices will focus on routine monitoring to identify change, and adopt active management strategies as a contingency.
- Level 3 – represents a high risk to the environment whereby impact to the environment is likely without management. Active management practices will be undertaken to ensure protection of environmental values.

A ***Level 1*** management ranking represents those earthworks scenarios where acid sulfate soils are absent or are present in low concentrations above the water table or where earthworks activities are sufficiently short term to minimise the opportunity for oxidation of acid sulfate soils. As a result, disturbance of these materials is unlikely to result in any environmental impacts that would not naturally occur in the environment. Due to the low level of risk, no active acid sulfate soil management will be undertaken for those sites with a Level 1 management ranking.

A ***Level 2*** management ranking represents those earthworks scenarios where acid sulfate soils are likely to be present in with a moderate acid generating potential or with a high acid generating potential but in low volumes. Management of these soils will adopt a *monitor-and-react* strategy if signs of oxidation occur.

A ***Level 3*** management ranking represents those earthwork scenarios where acid sulfate soils are likely to be present in abundance and have a high likelihood of generating acidity during the period of earthworks. Active management of these soils will be undertaken

TABLE 11 EXCAVATION MANAGEMENT REQUIREMENTS

Management Level	Linear Infrastructure	Non linear Infrastructure
Level 1	Standard construction management practices to be adopted. No specific acid sulfate soil considerations required.	Standard construction management practices to be adopted. No specific acid sulfate soil considerations required.
Level 2	Where possible, trench segments will be excavated in lengths that permit the opening and closing of the trench within 48 hours Where in-situ PASS is exposed for a period exceeding 5 days, neutralisation of the sides and base of the excavation will be undertaken prior to backfilling.	Where in-situ PASS is exposed for a period exceeding 5 days, neutralisation of the sides and base of the excavation will be undertaken prior to backfilling.
Level 3	Implementation of alternate construction methods (e.g. horizontal directional drilling (HDD)) will be considered. Where soils must be disturbed, trench segments will be excavated in the shortest practicable lengths. Where in-situ PASS is left exposed, neutralisation of the sides and base of the excavation (e.g. barriers of high grade aglime, spraying with liquid neutralising agents) will be undertaken routinely as appropriate throughout the duration of the exposure. Installing pipeline under wet conditions. This is common to tidal areas where dewatering may be very difficult or not possible.	Implementation of construction methods that exclude the availability of oxygen (e.g. sheet piling) will be considered. Where in-situ PASS is left exposed, neutralisation of the sides and base of the excavation (e.g. barriers of high grade aglime, spraying with liquid neutralising agents) will be undertaken routinely as appropriate throughout the duration of the exposure.

The aim of the preferred dewatering method should be to minimise the radius of influence of the cone of depression. Any dewatering activity should strive to minimise impacts to surrounding water bore users and sensitive surface water receptors. Common options for dewatering methods include:

- ***Sump Pumps***: Sump pumping is the simplest method of dewatering excavations. Sumps are usually sited at the lowest point of the excavation and made big enough to hold sufficient water for pumping and to keep the floor of the excavation dry. A pump is provided for each sump and connected to a discharge pipe. Sump pumps are generally suitable for low-flow, short-term dewatering with small dewatering volumes
- ***Well-Point Systems:*** Well-point systems comprise a series of closely spaced wells connected to a header-pipe and usually pumped by a collective suction lift pump. Dewatering using well-points is generally suitable for low to moderate flow, medium-term dewatering. Some continuity of the permeability is required for maximum effectiveness, although this can be mitigated by varying the spacing and vertical distribution of the wells.
- ***Positive Cut Off (e.g. Sheet piling):*** Sheet piling involves the installation of impermeable steel walls around the edge of the excavation to limit groundwater

influx. Sheet piling will generally be necessary for deep excavations with significant drawdown of the water table to limit the cone of depression of the dewatering activities. Sheet piling is often used in combination with well-point systems to stabilise pressures around the excavations.

Other water exclusion methods such as soil refrigeration and impervious soil barriers can be considered where standard methods are deemed unsuitable.

7.3.1 Dewatering discharge treatment

Dewatering discharge may require treatment to ensure that it does not have any adverse impact to receiving water bodies. Treatment may include but is not limited to sediment filtration or settlement, neutralisation, and/or contaminant removal. The need for dewatering discharge treatment is determined through monitoring of the dewatering discharge, groundwater and/or surface waters in the area in proximity to the pipeline corridor.

It is noted that treatment of groundwater in all environments to near neutral pH (6.5 to 8.5) is generally required by the Regulatory Authorities to ensure future mobilisation of metals in the soil profile is not promoted. Table 12 summarises some of the key treatment methods and the groundwater quality indicators that should trigger treatment methods. It is noted however in many coastal environments natural acid soils prevail and support often unique vegetation and faunal communities.

TABLE 12 WATER TREATMENT OPTIONS

Water Quality Trigger	Treatment Method
pH < 5.0	Neutralisation treatment using calcite pellets. Lime sands, or hydrated lime, as appropriate for the project.
pH of dewatering discharge more than 1 pH unit less than pH of receiving water body	pH adjustment (e.g. neutralisation)
Total Titratable Acidity > 40 mg/L	Neutralisation treatment and aeration and settlement to precipitate dissolved metals
Total Suspended Solids – visible	Sediment filtration through geofabric or equivalent if discharging to an open water body. No treatment required if reinfiltrating through an infiltration basin because the aquifer will work as a sediment filtration system. May require flocculation.
Metals/toxicants concentration in dewatering discharge could result in an increase of the seasonal background concentration of the receiving body by >10%	Suitable toxicant filtration/flocculation method to be employed.

7.3.2 Dewatering discharge disposal

Options of discharging excess water following treatment, where necessary, should be considered in the following order of priority:

- ***Dust Suppression***: Dewatering discharge should in the first instance be used for dust suppression during construction works. As dewatering discharge volumes will generally exceed dust suppression requirements, additional discharge disposal methods will typically need to be employed.

- ***Infiltration System***: This is the preferred option as it recharges the water into the environment from which it has been removed. Its effectiveness is limited by the hydraulic properties of the soil strata to which the water is discharged (hydraulic conductivity, depth to groundwater table). Infiltration systems must generally include installation of an infiltration basin to prevent flooding of the surrounding environment, although in some select environments discharge to ground may be considered acceptable. This option will require monitoring of the water quality to ensure reinfiltrated discharge does not degrade the water quality of the receiving environment.

- ***Drainage System***: This method may be considered where dewatering discharge volumes are high and space available for re-infiltration is limited. Employment of a drainage system is generally limited by the hydraulic capacity of the drainage system. This option will require monitoring of the water quality to ensure reinfiltrated discharge does not degrade the water quality of the receiving environment.

- ***Surface Water Bodies***: Discharge to surface water bodies must be undertaken in a manner that ensures no loss of amenity (odour or visual impacts), or change to the water quality in the receptors to ensure that the ecosystem of the receiving water body is sustained. Most surface water bodies have a high environmental significance and discharge to significant lakes and wetlands is controlled through regulatory licences.

Prior to discharges going into these environments relevant approvals should be sought from regulatory authorities. Appropriate standards will be determined on a case by case basis in accordance with regulatory environmental guidelines.

7.4 Performance Criteria

Performance of the ASSMP will be measured against the monitoring program described in section 7.5.

Performance will be recorded in site logs and reporting as outlined in section 5.

7.5 Monitoring Program

If ASS is rated as requiring active management (A), regular monitoring (R), or periodic monitoring (P) for water prior to, during, and subsequent to the development taking place will be undertaken. This will include, but not be limited to, monitoring of permanent and temporary surface water bodies, groundwater monitoring where practicable, dewatering ponds and run-off monitoring following rain or excavation events.

The frequency of monitoring will be updated in the finalised ASSMP subject to the outcome of the ASS assessment. The monitoring frequency will range between daily and monthly for the duration of the project.

7.5.1 Dewatering Discharge

Where dewatering occurs in the presence of acid sulfate soils or where discharge is to occur adjacent to an environmentally sensitive environment, monitoring of dewatering discharge will be undertaken to ensure that long-term environmental harm does not occur in the receiving environment.

Where treatment of dewatering discharge occurs, monitoring of the discharge water quality will occur both before and after any treatment process. Table 13 summarises the minimum monitoring to be undertaken and acceptable performance criteria for the dewatering discharge (pre-treatment). Where dewatering discharge exceeds the performance criteria (pre- or post-treatment), it is an indication that treatment of the discharge is necessary prior to discharge or an alternative disposal strategy to the environment.

TABLE 13 DISCHARGE MONITORING SCHEDULE

Analyte	Frequency	Acceptable Performance Criteria
Field pH, Electrical Conductivity (EC), Oxidation Reduction Potential(ORP), temperature, **Field Total Titratable Acidity (TAA)** **Standing Water Level (SWL) for groundwater**	Daily for the duration of dewatering.	Pre-treatment pH > 5.5 Post-treatment pH between 6.5 – 8.5 EC within 10% of receiving environment TTA < 40 mg/L
Field ferrous iron (Fe^{2+}) and ferric iron (Fe^{3+})	Weekly	Fe^{2+} < 10 x applicable guidelines for the receiving environment Fe^{3+} stable
Laboratory pH, EC, TAA, Sulfate(SO$_4$), Chloride(Cl)	Fortnightly	Laboratory results within 0.5 pH units and EC and TAA within 20% of field values
Visual water clarity (field measured turbidity) where discharge to a surface water body occurs **hydrocarbons**	Daily	Visual Water Clarity is "Clear" No visible hydrocarbons
Total Suspended Solids and Total Dissolved Salts where discharge to a surface water body occurs	Weekly	TSS and TDS < 10% greater than the seasonal background of the receiving environment

7.5.2 Surface Water and Groundwater

Monitoring of groundwater and permanent surface water bodies potentially affected by the development will be undertaken prior to the development commencing (in order to obtain 'background' data), and for a period of time following the completion of the development (to ensure equilibrium conditions have returned post-development). Parameters such as pH, EC, ORP, temperature and SWL will be measured regularly in the field.

In addition to dewatering discharge monitoring, monitoring of suitable groundwater and/or surface water sites (e.g. at and along the pathway to the receptor) will be undertaken for dewatering activities with a duration greater than 2 weeks or at sites where the cone of depression is predicted to extend to within 200 m of an environmentally sensitive area.

Table 14 summarises the minimum frequency of monitoring to be undertaken by a suitably qualified site supervisor or environmental scientist and acceptable performance criteria. These criteria may be modified in consideration of site-specific criteria, that would be determined based on baseline data collection, as considered appropriate.

The location of monitoring points for surface and (if applicable) installation of monitoring piezometers for groundwater is subject to an ASS assessment being undertaken as described in Sections 3, 4 and 5.

TABLE 14 SURFACE WATER AND GROUNDWATER MONITORING SCHEDULE

Analyte	Frequency	Acceptable Performance Criteria
Water Levels **(groundwater monitoring only)**	Twice-weekly during dewatering	Performance criteria to be established on a site-by-site basis to ensure drawdown does not adversely impact surrounding bore users or environmental receptors
Water Levels **(groundwater monitoring only)**	Weekly to fortnightly post dewatering	Monitoring to continue until water levels reach pre dewatering levels in consideration of seasonal water table fluctuations
Field pH, EC, Total Titratable Acidity (TAA), DO, redox **(Surface water)**	Twice-weekly during dewatering	ΔpH <0.5 pH units in one week EC and TAA within 15% of background water quality
Field Fe^{2+} , Fe^{3+} **(Surface water)**	Fortnightly during dewatering	Fe^{2+} < 10 x applicable guidelines for the receiving environment Fe^{3+} stable
Laboratory pH, EC, TAA **(Surface water)**	Fortnightly during dewatering	Laboratory results within 0.5 pH units and EC and TAA within 20% of field values
Laboratory analysis of pH, SO_4, Cl total alkalinity, total acidity, total Al and Fe, dissolved Al, As, Cr, Cd, Fe, Mn, Ni, Zn, and Se, Total-N, Total-P, NH_4-N, H_2S **(Surface water and groundwater)**	Start and End of Dewatering or construction program, when water table level recovers and 1 month after Groundwater level recovery. This can be extended to surface water bodies	Analytes below applicable water quality guidelines for the resource or within 20% of background water quality where background concentrations already exceed applicable guidelines.
Visual inspection of surface water bodies where discharge to a surface water body occurs **(Surface water)**	Daily during dewatering	Discharge causes no visible floating oil, foam, grease, scum, flocculent, or deposition of sediment or turbidity
TSS and TDS of surface water body where discharge occurs **(Surface water)**	Fortnightly during dewatering	TSS and TDS < 10% greater than the seasonal background of the receiving environment

7.5.3 Soil

The following validation and monitoring will be undertaken:

- Untreated soils will be checked daily for visual signs of acid generation (e.g. – formation of jarosite or iron oxides). Representative soil samples will be collected daily from the surface of the stockpile (minimum 2 samples per stockpile face) and tested for pH_F. (See section 3.2 for more detail on how to undertake and interpret these field tests)
- Treated soils will be sampled at a rate of 1 sample/50 m3 soil and tested for pHF and pH_{FOX} following treatment to validate the effectiveness of the neutralisation process.
- When pH_F and pH_{FOX} is found to be within the performance criteria (Section 3.2), soils will be considered suitable for backfill into the trench.

- Leachate and run-off from the stockpiles will be field tested for pH, EC, temperature and total acidity prior to release to the environment, to determine if neutralisation is necessary.
- Should evidence of potential oxidation of ASS be observed through pH changes in particular, laboratory testing will be carried out.

7.6 Contingency

An appropriate volume of neutralising agent will be kept on-site for the duration of the development to allow its use if localised acidification of stockpiled or dewatered soil is detected.

Contingency plans will be developed on a site-specific basis to address actions to be undertaken where performance criteria are not met. Contingency plans will consider, but not be limited to, implementation of the following:

- If due to unforeseen circumstances, the duration of the earthworks activities is extended, a reassessment of the management strategies will be undertaken and implementation of a higher level of soil management will be adopted if warranted.
- If any soils are encountered during excavation works that are not representative of the soils previously identified, these soils will be treated in accordance with the procedures adopted for the highest risk soil previously identified at the site.
- If pH_F results of the untreated soils are outside the acceptable thresholds, the soil stockpile will be covered with a guard layer of neutralising agent or irrigated with a liquid neutralising agent.
- If pH_F and pH_{FOX} results of treated soil validation samples are outside the acceptable thresholds, further lime treatment of soils will be undertaken prior use as backfill (linear infrastructure) or submission of samples to the laboratory (nonlinear infrastructure);
- If laboratory analysis of treated soils are outside of the criteria set out in Table 5 and Table 6, further lime treatment of soils will be undertaken prior to re-use on-site or soils will be disposed to an appropriate off-site facility; and
- If leachate and run-off exceed the performance criteria, neutralisation of the leachate and run-off to achieve the performance criteria will be undertaken prior to release to the environment.

8 LIMITATIONS

This report has been prepared by Environmental Earth Sciences QLD ABN 109 442 284 in response to and subject to the following limitations:

1. The specific instructions received from AECOM Australia;
2. There has been no acid sulfate soil investigation undertaken by AECOM or AGL
3. This Plan is limited and considered conceptual and preliminary as there has been no acid sulfate soil investigation of the land likely to be disturbed by the proposed pipeline construction activity;
4. May not be relied upon by any third party not named in this report for any purpose except with the prior written consent of Environmental Earth Sciences QLD (which consent may or may not be given at the discretion of Environmental Earth Sciences QLD);

5. This report comprises the formal draft report, documentation sections, tables, figures and appendices as referred to in the index to this report and must not be released to any third party or copied in part without all the material included in this report for any reason;
6. The report only relates to the site referred to in the scope of works being located at the proposed Gloucester to Hexham Pipeline ("the site");
7. The report relates to the site as at the date of the report as conditions may change thereafter due to natural processes and/or site activities;
8. No warranty or guarantee is made in regard to any other use than as specified in the scope of works and only applies to the depth tested and reported in this report;
9. Fill, soil, groundwater and rock to the depth tested on the site may be fit for the use specified in this report. Unless it is expressly stated in this report, the fill, soil and/or rock may not be suitable for classification as clean fill if deposited off site; and
10. Our General Limitations set out at the back of the body of this report.

9 BIBLIOGRAPHY

Acid Sulfate Soils Management Advisory Committee (ASSMAC) (1998) — *Acid sulfate soil manual*.

ASSMAC, 2000: National strategy for the management of coastal acid sulfate soils. Prepared by National Working Party on Acid Sulfate Soils, January 2000.

Ahern CR, Ahern, MR, and Powell B, 1998: Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils (ASS) in Queensland. Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland.

Ahern CR, McElnea AE and Sullivan LA, 2004. Acid Sulfate Soils Laboratory Manual. Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland.

Bush, R (Ed) (1993) — *Proceedings of the national conference on acid sulfate soils*. Coolangatta 24-25 June 1993Coast Protection Board (CPB) (2002) — *Acid Sulfate Soil Development Guidelines and Risk assessment Criteria* (accessed March 2007). http://www.environment.sa.gov.au/coasts/pdfs/cpb_policy_document_2002.pdf.

Dear SE, Moore NG, Dobos SK, Watling KM, and Ahern CR, 2002: Soil Management Guidelines, Qld Acid Sulfate Soil Technical Manual v3.8. Department of Natural Resources, Mines and Energy, Indooroopilly, Queensland.

Dear, S E, Moore, S K, Watling, K M, Fahl, D and N G, Dobos (2004) — *Legislation and policy guide*. In *Queensland acid sulfate soil technical manual*. Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia. Version 2.2, September 2004.

Department of Environment (DoE) (WA) (2006) — *Draft identification and investigation of acid sulfate soils*. Acid Sulfate Soils Guideline Series. Prepared by Land & Water Quality Branch. May 2006.

DoE (WA) (2004a) — *Guidance for groundwater management in urban areas on acid sulfate soils*. Acid Sulfate Soils Guideline Series. October 2004.

DoE (WA) (2004b) — *Treatment and management of disturbed acid sulfate soils*. Acid Sulfate Soils Guideline Series. October 2004.

DoE (WA) (2003a) — *Preparation of acid sulfate soil management plan (ASSMP)*. Acid Sulfate Soils Guideline Series. April 2003.

DoE (WA) (2003b) — *Proposed framework for managing acid sulfate soils*. Prepared by Environmental Management Division. June 2003.

EPA Victoria Publication 655 (1999) — *Acid sulfate soil and rock*. August 1999.

EPA Victoria Publication 448.3 (2007a) — *Classification of Wastes*. May 2007.

EPA Victoria DRAFT Publication 1121 (2007b) — Draft soils sampling guideline (off-site management and acceptance). April 2007.

Fitzpatrick, R W, Thomas, B P and Merry, R H (2007b) — *Acid Sulfate Soils*. Chapter 9. In: Bryars, S, Shepherd, S A, Kirkegaard, I R and Harbison, P (eds) Natural History of Gulf St Vincent. Royal Society of South Australia Inc. Adelaide, South Australia.

Hazelton, P A and Murphy, B W, Eds (2007) — *What do all the numbers mean?* A guide for the interpretation of soil test results. NSW Department of Natural Resources. CSIRO Publishing.

Isbell, R F (1996) — *The Australian soil classification*. CSIRO Publishing, Melbourne.

McDonald, R C, Isbell, R F, Speight, J G, Walker, J and Hopkins, M S (1998) — *Australian soil and land survey – field handbook*. Second Edition. CSIRO Land and Water.

Mulvey, P (1993) — *Pollution, prevention and management of sulfidic clays and sands*. In Bush, R (Ed.) Proceedings for the National Conference on Acid Sulfate Soils, Coolangatta, June 1993.

National Working Party on Acid Sulfate Soils (2000) — *National strategy for the management of coastal acid sulfate soils*. NSW Agriculture, Wollongbar. http://www.mincos.gov.au/pdf/natass.pdf.

Naylor, S.D., Chapman, G.A., Atkinson, G., Murphy, C.L., Tulau, M.J., Flewin, T.C., Milford, H.B., Morand, D.T. 1998, Guidelines for the Use of Acid Sulfate Soil Risk Maps, 2nd ed., Department of Land and Water Conservation, Sydney.

NSW Department of Primary Industries (2008). *Acid Sulfate Soils Priority Investigations for the Lower Hunter River Estuary; Report to the Department of Environment, Water, Heritage and the Arts. Department of Primary Industries (Aquatic Habitat Rehabilitation),*

Pons, L J (1973) — *Outline of the genesis, characteristics, classification and improvement of acid sulfate soils*. In 'Proceedings of the 1972 (Wageningen, Netherlands) International Acid Sulfate Soils Symposium, Volume 1.' (Ed. H. Dost) pp 3-27. International Land Reclamation Institute Publication 18, Wageningen, Netherlands.

Smith, R J and Smith, H J (Eds) (1996) — *Proceedings of the second national conference on acid sulfate soils*. Coffs Harbour 5-6 September 1996.

Soil Survey Staff (2003) — *Keys to Soil Taxonomy 9th Ed*. United States Department of Agriculture, Soil Conservation Service: Blacksburg. http://soils.usda.gov/technical/classification/tax_keys/ (accessed March 2007)

Sullivan, L A, Bush, R T and Fyfe, D (2002) — *Acid sulfate soil drain ooze: Distribution, behaviour and implications for acidification and deoxygenation of waterways*. In C. Lin, M.D.

Thomas, B P, Fitzpatrick, R W, Merry, R H and Hicks, W S (2003) — *Coastal acid sulfate soil management guidelines, Barker Inlet, SA*. Acid Sulfate Soil Technical Manual (version 1.2). CSIRO Land and Water, February 2003.

Victorian Department of Primary Industries (DPI) (2003) — *Acid sulfate soil hazard maps – guidelines for coastal Victoria*. CLPR Research Report No. 12, March 2003.

Victoria Government Department of Sustainability and Environment, 2008: Draft Strategy for Coastal acid sulfate soil. Victoria Government Department of Sustainability and Environment, East Melbourne, Victoria.

Victorian Government Gazette (1999) — *Industrial Waste Management Policy (Waste Acid Sulfate Soils)*. No. S 125 Wednesday 18 August 1999.

Western Australian Planning Commission (2003) — *Planning guidelines for acid sulfate soils*. Planning Bulletin Number 64, November 2003.

10 GLOSSARY OF TERMS

The following descriptions are of terms used in the text of this report. A list of the references used in providing this glossary is presented in Section 9 of this report.

Acid neutralising capacity (ANC) the soils natural resistance to acid generation. It is the number of moles of protons per unit mass of soil required to raise the pH of the soil by one pH unit. ANC is measured as percentage $CaCO_3$.

Acid Sulfate Soil (ASS) soil containing iron sulfides deposited during either the Pleistocene or Holocene geological epochs (Quaternary aged) as sea levels rose and fell.

Acidify addition of acid to lower pH.

Actual Acid Sulfate Soil (AASS) soil in which soil sulfides are undergoing oxidation and producing more acid than the soils ANC, leading to a net acid generation.

Alluvial describes material deposited by, or in transit in, flowing water.

Anaerobic reducing or without oxygen.

Anoxic sediments, soil and waters in which the dissolved oxygen concentration approaches zero.

Aquifer rock or sediment in a formation, group of formations, or part of a formation which is saturated and sufficiently permeable to transmit economic quantities of water to wells and springs.

Aquifer, confined aquifer that is overlain by a confining bed with significantly lower hydraulic conductivity than the aquifer.

Aquifer, perched region in the unsaturated zone where the soil is locally saturated because it overlies soil or rock of low permeability.

Background natural level of a property.

Baseline initial value of a measure.

Borehole an uncased well drill hole.

Buffer ionic compound, usually a salt of a weak acid or base~~,~~ added to a solution to resist changes in its acidity or alkalinity and thus stabilise its pH.

Colluvial unconsolidated soil and rock material moved down-slope by gravity.

Contaminant generally, any chemical species introduced into the soil or water. More particularly relates to those species that render soil or water unfit for beneficial use.

Contamination is considered to have occurred when the concentration of a specific element or compound is established as being greater than the normally expected (or actually quantified) background concentration.

Dilution the mixing of a small volume of contaminated leachate with a large volume of uncontaminated water. The concentration of contaminants is reduced by the volume of the lower concentrated water. However the physical process of dilution often causes chemical disequilibria resulting in the destruction of ligand bonds, the alteration of solubility products and the alteration of water pH. This usually causes precipitation by different chemical means of various species.

Discrete sample samples collected from different locations and depths that will not be composited but analysed individually.

Drawdown lowering of a water table by pumping from one or more wells.

Ephemeral stream a stream that flows only during periods of precipitation and briefly thereafter, or during periods of elevated water-table levels when the stream is in direct hydraulic connection with the underlying unconfined aquifer (i.e. receives base-flow).

Groundwater water held in the pores of an aquifer.

Hydraulic Head. The sum of the head's (potentials) at a point in an aquifer.

Leachate water that flows through waste material (or other material) will liberate soluble molecules to form leachate.

Net acid generation potential (NAGP) difference between the TOS and ANC reported on a kilogram H_2SO_4 production per tonne of soil.

Oxidation originally referred only to the addition of oxygen to elements. However oxidation now encompasses the broader concept of the loss of electrons by electron transfer to other ions.

Parameters population value of a particular characteristic, which is descriptive of the distribution of a random variable.

pH logarithmic index for the concentration of hydrogen ions in an aqueous solution, which is used as a measure of acidity.

Potential Acid Sulfate Soil (PASS) a soil that has the potential to become acidic if it is exposed to the atmosphere.

QA/QC Quality Assurance / Quality Control.

Remediation restoration of land or groundwater contaminated by pollutants, to a state suitable for other, beneficial uses.

Sodic term given to soil with a level of exchangeable sodium cations greater than 10-15% of the soils cation exchange capacity (CEC), or soluble sodium cations greater than 10-15 times the square root of soluble calcium and magnesium cations. These terms are known as exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) respectively.

Total Acidity (TA) difference between the soil CEC and ANC.

Total Actual Acidity (TAA) moles of titratable protons per unit mass of soil displaced by an un-buffered KCl solution, otherwise known as the salt-replaceable acidity.

Total Organic Carbon (TOC) measure of the total organic carbon within a water sample. It is complementary to the oxygen demand analyses and theoretically independent of the form in the carbon exists.

Total Oxidisable Sulfur (TOS) maximum oxidisable sulfur present and represents the maximum production of acid possible from sulfide oxidation.

Water table interface between the saturated zone and unsaturated zones. The surface in an aquifer at which pore water pressure is equal to atmospheric pressure.

ENVIRONMENTAL EARTH SCIENCES GENERAL LIMITATIONS

Scope of services

The work presented in this report is Environmental Earth Sciences response to the specific scope of works requested by, planned with and approved by the client. It cannot be relied on by any other third party for any purpose except with our prior written consent. Client may distribute this report to other parties and in doing so warrants that the report is suitable for the purpose it was intended for. However, any party wishing to rely on this report should contact us to determine the suitability of this report for their specific purpose.

Data should not be separated from the report

A report is provided inclusive of all documentation sections, limitations, tables, figures and appendices and should not be provided or copied in part without all supporting documentation for any reason, because misinterpretation may occur.

Subsurface conditions change

Understanding an environmental study will reduce exposure to the risk of the presence of contaminated soil and or groundwater. However, contaminants may be present in areas that were not investigated, or may migrate to other areas. Analysis cannot cover every type of contaminant that could possibly be present. When combined with field observations, field measurements and professional judgement, this approach increases the probability of identifying contaminated soil and or groundwater. Under no circumstances can it be considered that these findings represent the actual condition of the site at all points.

Environmental studies identify actual sub-surface conditions only at those points where samples are taken, when they are taken. Actual conditions between sampling locations differ from those inferred because no professional, no matter how qualified, and no sub-surface exploration program, no matter how comprehensive, can reveal what is hidden below the ground surface. The actual interface between materials may be far more gradual or abrupt than an assessment indicates. Actual conditions in areas not sampled may differ from that predicted. Nothing can be done to prevent the unanticipated. However, steps can be taken to help minimize the impact. For this reason, site owners should retain our services.

Problems with interpretation by others

Advice and interpretation is provided on the basis that subsequent work will be undertaken by Environmental Earth Sciences QLD. This will identify variances, maintain consistency in how data is interpreted, conduct additional tests that may be necessary and recommend solutions to problems encountered on site. Other parties may misinterpret our work and we cannot be responsible for how the information in this report is used. If further data is collected or comes to light we reserve the right to alter their conclusions.

Obtain regulatory approval

The investigation and remediation of contaminated sites is a field in which legislation and interpretation of legislation is changing rapidly. Our interpretation of the investigation findings should not be taken to be that of any other party. When approval from a statutory authority is required for a project, that approval should be directly sought by the client.

Limit of liability

This study has been carried out to a particular scope of works at a specified site and should not be used for any other purpose. This report is provided on the condition that Environmental Earth Sciences QLD disclaims all liability to any person or entity other than the client in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by any such person in reliance, whether in whole or in part, on the contents of this report. Furthermore, Environmental Earth Sciences QLD disclaims all liability in respect of anything done or omitted to be done and of the consequence of anything done or omitted to be done by the client, or any such person in reliance, whether in whole or any part of the contents of this report of all matters not stated in the brief outlined in Environmental Earth Sciences QLD’s proposal number and according to Environmental Earth Sciences general terms and conditions and special terms and conditions for contaminated sites.

To the maximum extent permitted by law, we exclude all liability of whatever nature, whether in contract, tort or otherwise, for the acts, omissions or default, whether negligent or otherwise for any loss or damage whatsoever that may arise in any way in connection with the supply of services. Under circumstances where liability cannot be excluded, such liability is limited to the value of the purchased service.

APPENDIX A

Soil morphology as an indicator of Coastal ASS occurrence

Field description and soil morphology

Sampling of ASS in sub-aqueous and wetland environments can be achieved by various means, depending on the nature of the materials encountered. This could include hand dug pits and augering for wet soils. In all soil profiles, distinct layers or soil horizons must be demarcated, described and summarized. Soil profiles must be sampled by horizon. Morphological descriptors and physical properties such as colour, consistency, structure and texture should be described according to McDonald *et al*. (1990). A general flowchart for soil sample collection and analysis is shown in Chart 1. Air must be excluded as far as possible from the samples. On return to the laboratory samples must be kept at <4ºC until analysed. Moisture contents must be recorded and bulk densities estimated.

Soil colour, structure, texture and consistency along with field pH are the most useful properties for soil identification and appraisal (see Section 11 Glossary of Terms). Soil colour, structure and consistency provide practical indicators of soil redox status and existing acidity. This relates directly to soil aeration and organic matter content in the soils of Victoria. Consequently, these field indicators should be used to help develop a user-friendly soil identification key to categorize the various ASS and other soil horizons encountered in the field.

Incubation of soil material and Accelerated Weathering Trials (AWTs)

The formal Australian Soil Classification (Isbell 1996) and Soil Taxonomy (Soil Survey Staff 2003) tests for identification of sulfidic material is to incubate samples for eight weeks to determine whether pH drops to <4.0 and/or jarosite mottles have formed (which implies that the pH has dropped below 3.5). Collection and storage of moist samples in chip trays and artificially maintaining moisture and heat produces similar conditions and can similarly be used as a diagnostic test for the presence of sulfidic material. This is referred to as an accelerated weathering trial (AWT).

Note that while not yet formally recognized as a standard diagnostic tool in CASS assessment, incubation tests and AWTs will in the future become a requirement for all CASS assessments.

Table 1 (below) has been presented as a guide to the use of water chemistry results in the identification of the potential for soil sulfide occurrence.

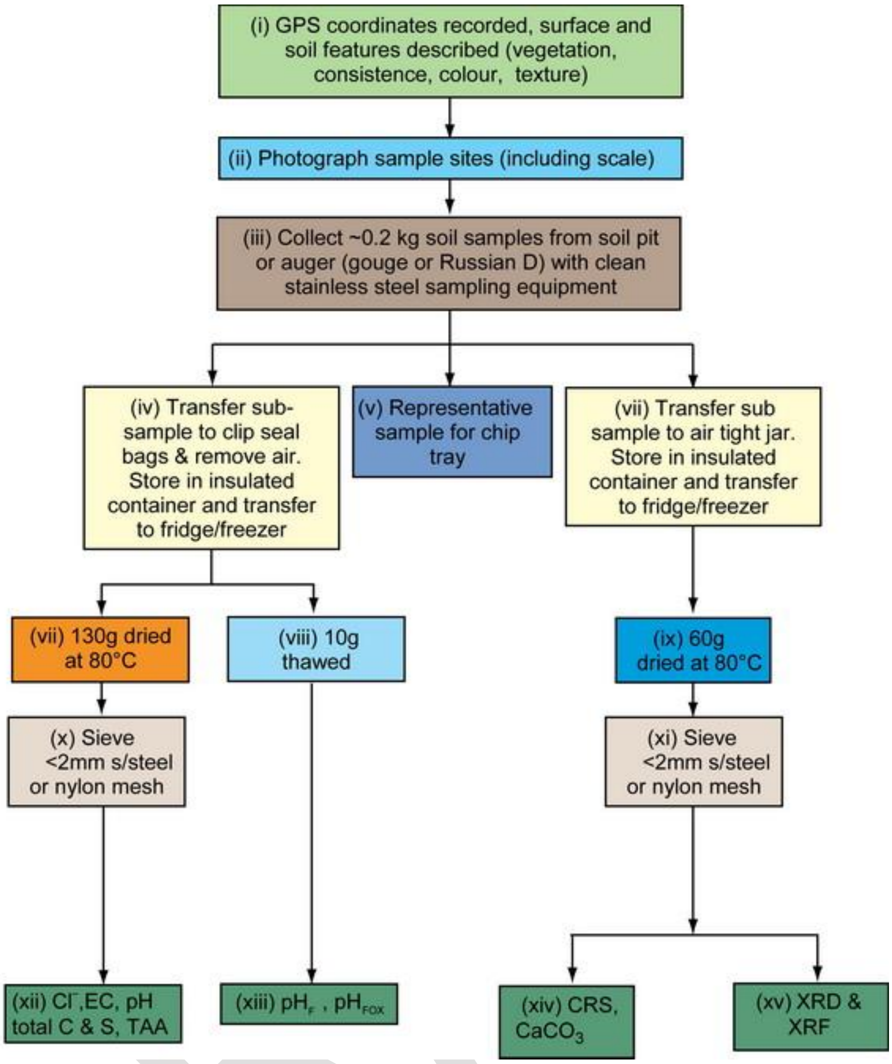

Chart 1: General flow chart for soil sampling and subsequent laboratory analyses (after Fitzpatrick 2007a).

Water chemistry as an indicator of CASS occurrence

Low pH and elevated sulfate (SO_4) in groundwater, streams and drain waters is an indication of pyrite oxidation. However other environmental factors also cause acid water and elevated SO_4, but by considering such indicators in combination the validity of such observations is improved.

Considering individual ions in isolation is problematic for interpretation of water chemistry. Hence it is recommended that all water samples analysed as part of a CASS assessment include a complete balance of cations (Na^+, Ca^{2+}, Mg^{2+}, K^+, NH_4^+, Fe^{2+}) and anions (Cl^-, SO_4^{2-}, HCO_3^-, NO_3^-, NO_2^-, PO_4^{3-}, F^-) as well as pH and TDS/EC. It is also highly preferable that pH, EC and redox (as well as potentially DO and temperature) be measured in the field and pH and TDS in the laboratory to provide assurance that the chemistry of collected waters has not altered in transit.

As SO_4 is naturally elevated in seawater (connate seawater is often present in the pores of CASS profiles) at close to 2,700 mg/L, it is best to look at it in combination with other less reactive anions such as chloride (Cl^-). The influence of natural neutralizing agents in the soil profile as buffers to acid generation can also be assessed by referring to bicarbonate (HCO_3) concentrations in water as compared to Cl.

The Cl/SO_4 ratio in seawater is 7.0-7.2, and the Cl/HCO_3 ratio in seawater is 135-140. Hence, in an estuarine or previously estuarine environment, when these ratios are reduced below the natural seawater relationship, an additional source of SO_4 or HCO_3 is present. This additional source may be SO_4 from oxidized pyrite, or HCO_3 from dissolution of carbonaceous material in the soil profile. Further, if the Cl/SO_4 ratio is low and the pH is neutral, both pyrite and a buffering agent such as shell grit must be present (Mulvey 1993). This can be confirmed through determining the Cl/HCO_3 ratio.

Redox (Eh) values are useful in that negative redox (reducing or oxygen depleted conditions) is an indicator of an environment suitable to the occurrence (and formation) of pyrite, while positive redox is an indication of conditions favourable to the oxidation of pyrite (if in the presence of moisture and oxygen).

Table 1 has been presented as a guide to the use of water chemistry results in the identification of potential soil sulfides. It is noted that the ratios used are only relevant for soil profiles containing connate seawater, and hence where the TDS is <1000-1500 mg/L (<1500-2500 µS/cm EC), the ratios either do not apply or should be used with extreme caution. Hence, care must be taken if using Table 2 for waters influenced by run-off or other sources of fresh water.

Table 1: Water Chemistry Indicators for Assessing the Presence of Soil Sulfides

Class	pH	Cl/SO_4	Cl/HCO_3	Eh (mV)	Sulfide Behaviour	Action Required
1	6-8	5-9	130-150	-ve	Absent or never oxidised	None
2	7-9	>9	<130	-ve	SO_4 converted to S (incl $H_2S_{(g)}$)*	Preliminary study
3	<5	>5	>150^	-ve	Acidity due to other causes	Explain other source
4	5-8	<4	<130	+ve	S oxidized but buffered by carbonate	Preliminary study
5	4-8	<2	<100	+ve	Abundant S oxidized, but neutralised	Detailed assessment
6	2-4	<2	>150^	+ve	Some S, low buffering capacity	Detailed assessment
7	<2	<2	>150^	+ve	Abundant S with no buffering capacity	Highly detailed study

Note(s): 1. the Cl/SO_4 ratio is only relevant when TDS >1000 mg/L
2. this table is produced after Mulvey 1993
3. * noted as 'rotten egg gas'
4. ^ HCO_3 converted to $CO_{2(g)}$ and lost to atmosphere

Field peroxide tests as an indicator of CASS occurrence

The peroxide field test is based on artificially accelerating oxidation of sulfidic material to release potential acidity. The pH of a sample after reaction with hydrogen peroxide (H_2O_2) is a qualitative indication of the likelihood that a soil material or sediment has the potential to form sulfuric material or an acid sulfate soil when exposed to the atmosphere (e.g. when excavated). The H_2O_2 reacts with sulfides to produce sulfuric acid (H_2SO_4). Sulfuric acid in turn reacts with neutralizing agents in the sample, such as carbonates and clay minerals. The final pH and reaction vigor can then be interpreted to qualitatively assess soil or sediment materials (Table 2).

The reaction that is produced during peroxide tests is:
Sulfidic material + hydrogen peroxide → sulfuric acid + iron sulfate minerals + heat.

It is important to note with field peroxide tests that:

11. peroxide is an extremely dangerous chemical that must be handled, diluted, stored and applied to soil with extreme care;
12. field peroxide results are prone to false positives due to the oxidation of organic matter; and
13. a further indication to the oxidation of sulfides in this reaction is the formation of red (iron) precipitate.

For a complete description of the field pH test methods, Watling, Ahern and Hey (2004) — *Acid sulfate soil field pH tests* in Ahern *et al*. (2004) is recommended as a source. Table 2 is provided as a field guide to soil pH and peroxide tests.

Table 2: Field Peroxide Test Results Interpretation

$pH_{1:5}$	pH_{FOX}	ΔpH	ΔTemp (ºC)	Effervescence*	Action Required
≥5.0	≥4.5	≤2.0	<5ºC	None-Mild	None
<5.0	<4.5	>2.0	>5ºC	Mild-Strong	Preliminary lab assessment
<5.0	<2.5	>2.0	>10ºC	Strong-Extreme	Detailed assessment

Note(s): 1. levels of effervescence are: none; mild; strong; extreme
2. * also includes iron precipitation
3. see Attachment 1 for field peroxide test data sheet

FIGURES

Figure 1: Acid Sulfate Risk Map (southern section)