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Demonstrating Amelioration of Acid Sulfate Soils, Barker Inlet/ Gillman Area, SA

Final Report

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CSIRO Land and Water
Final Report, February 2003

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Important Disclaimer

Cover Photograph

From CSIRO Land and Water

File: LSD Adding lime .jpg from Stage 4 Report to EA

Description: Adding "Penrice Grits" liming product to the newly constructed Lime Slot at the ASS remediation site near Gillman, SA. The Lime slot is 1.5meters deep and extends 130 meters along-slide the "lime slot drain", visibly and full of water to the left of the lime slot.

Contents

FINAL REPORT

Coastal Acid Sulfate Soils Program (CASSP)

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3. Plain English Summary

Mudflats, adjoining seagrass meadows, intertidal saltmarsh, grey mangrove forests, and supratidal samphire wetlands characterize the Barker Inlet of the Port Adelaide River estuary. Bund walls were built along the estuary early last century and the land drained in an attempt to reclaim it for industrial and agricultural purposes. Consequently, these areas have dried, exposing to the air pyrite in the organic rich mangrove and intertidal samphire soils, or potential acid sulfate soils (PASS). Oxidising pyrite has produced sulfuric acid causing actual acid sulfate soils (ASS) to form. The acidification of these soils and interstitial water bodies has lead to various degrees of degradation of the immediate and receiving environments in the Barker Inlet.

The production, export and fate of leachate associated with ASS were poorly understood in the Gillman area of the Barker Inlet, and strategies have not existed to appropriately manage these soils, acidic water and oxidation products. Disturbing PASS through excavation or draining can lead to the formation of ASS resulting in soil acidification and environmental degradation. Disturbing or changing local hydrology of actual ASS can also cause environmental damage though further oxidation of pyrite and increasing the off-site transportation of acidity and other metal contaminants. No specific guidelines for the management of PASS, which are generally benign in their natural state, or for managing actual ASS currently exist in South Australia.

The Coastal Acid Sulfate Soils Program (CASSP) was established to define the ASS problem at Gillman, to prevent it from increasing and investigate remedial actions to reduce the impact these soils are having on the environment.

The ASS-affected land at Gillman is largely vacant, but controlled by many different private and public organisations and housing amenities such as: a major municipal waste dump, salt evaporation ponds, warehousing, a small arms firing range, storm water retention basins with open drains and constructed freshwater and saline (tidal) wetlands. Segments of the land are constantly changing hands along with development plans. Work has begun on drains and bridge foundations for a major road, the Mawson Connector, that will cross and disturb PASS and ASS at Gillman. A new underground gas pipeline is planned to run beside the new road with work beginning in the middle of 2003.

A detailed ASS risk map was produced for the Gillman area (scale 1:5000). This information, together with the detailed landform and vegetation mapping of 65 saltmarsh habitats carried out by the South Australian Coast and Marine Branch (viewable as part of the web-based South Australia Atlas: http://www.atlas.sa.gov.au/), was used to produce a regional ASS risk map of the Barker Inlet. This has allowed for potential problems to be prioritised (ASS Risk classes), and assigned to treatment categories. These treatment categories relate to managing risk so there is no adverse impact on the receiving environment.

The following Acid sulfate soil remediation trials were developed and tested on the most degraded ASS areas in Barker Inlet:

- **Re-flooding** trials utilizing existing freshwater, tidal and saline ponds in constructed wetlands and brackish water in a storm-water ponding basin.
- **Bioremediation** trial to re-establish reducing conditions to stop pyrite oxidation by the addition of sulfate-reducing bacteria and various organic wastes, in effect re-establishing the sulfide formation processes that operate in the mangrove soils outside the bund wall.
- **Leaching/ aging** trial to establish the reactivity chemistry of leachate drained from various types of ASS and PASS "stockpiles" was conducted.
- **Slotting trial** using soda lime by-products to treat acidic meteoric water and groundwater leachate discharging to streams and wetlands.
- **Tidal flushing/drainage** trial in highly reducing, eutrophic potential ASS where mangrove dieback is occurring at St Kilda.

The manual "Coastal Acid Sulfate Soil Management Guidelines, Barker Inlet SA" (Version 1.1), provides management guidelines that will assist land managers in making appropriate decision on utilisation of a variety of ASS affected lands in the Barker Inlet/Gillman and South Australia.

This project has advanced new concepts (properties of CASS in a Temperate/ Mediterranean climate) and practical information (ASS Risk, checklists, treatment categories) about coastal ASS in the Barker Inlet area. This information has already been provided to local stakeholders (councils and land holders) and policy makers via websites (ASS maps), field workshops and conference presentations, and as popular articles (e.g. Coastline bulletin) and popular fact sheets (held at the St. Kilda Mangrove walk interpretive centre). This information will aid in avoiding excavation of Potential ASS and the tackling of solutions for remediation of Actual ASS in the Barker Inlet, particularly in areas at St. Kilda and Gillman.

The project has also improved the understanding of the extent of the problem, improved the soil and water quality in the remediation trials site, and will help reduce or avoid future remediation costs by implementing "best practice" remedial and preventive measures/ guidelines into local government development policy. This has been achieved using an approach that also takes into account the wider aspects of social, ecological, commercial and government requirements for the future use of the lands.

These guidelines will be developed as a set of ASS planning policies to be implemented at local government level (for Port Adelaide Enfield Council, Salisbury Council, Torrens Catchment Water Management Board and Northern Adelaide & Barossa Catchment Water Management SA.).

During the project, we were able to communicate many aspects of the remediation methods being trailed and the environmental risks associated with ASS and PASS to local state government agencies and consultants through field day workshops, educational pamphlets and brochures.

We have also reported our work and presented findings to scientific peers at the 5th International CASS Conference in August/September 2002 at Tweed Heads NSW.

Outcomes from this project provide a solid understanding of temperate ASS needed to manage similar soils elsewhere in southern Australia, in particular those identified as risk areas by the South Australian Inventory of Acid Sulfate Soil Risk (Atlas) project.

A file containing images of ASS and associated landscapes, with captions, has been produced.

Mr Brett Thomas a PhD student was specifically appointed as part of the 2 year CASSP project (Phase 1) in order to maintain the project after CASSP funding had ceased. Research for his PhD has formed an integral part of the CASSP project to develop suitable remediation methods for ASS in the Barker Inlet/Gillman area. The three year project is jointly funded by Environment Australia's Coastal Acid Sulfate Soils Program (CASSP) with project consortium (Port Adelaide/Enfield Council, Land Management Corporation, CSIRO Land & Water, Penrice Soda Products, Department of Environment and Heritage, Salisbury Council, Torrens Catchment Water Management Board, Northern Adelaide, Barossa Catchment Water Management Board and the St Kilda Mangrove Trail & Interpretative Centre). The consortium provided additional funding to finance the third year or Phase 2 of the project. In Phase 2, Brett Thomas will continue to monitor the rehabilitation experiments for another year (two seasons) and undertake more detailed analyses of soils and waters to develop process models. This information will be used to progressively update the manual “Coastal Acid Sulfate Soil Management Guidelines, Barker Inlet SA” (i.e. version 1.2: to be presented to BIPEC by July 2003; and version 1.3: to presented to BIPEC by June 2004). Several journal publications will be completed from data obtained from both Phase 1 (CASSP project) and Phase 2 (PhD theses completion date, June 2004).

4. Project Performance

The project objectives, described in Milestone Report 1, are summarised from the original proposal.

Project objectives:

1. Quantify the biogeochemical and physical processes in various acid sulfate soils and construct a series of conceptual models, which will point to options to better manage ASS in the Barker Inlet/Gillman area.
2. Develop and trial a series of innovative remediation techniques such as bioremediation, liming using waste by-products and sea water flushing.
3. Publish recommended remediation techniques and applicability to potential landuses.
4. Participate in holding field days.
5. Produce educational materials (St Kilda Mangrove Trail & Interpretative Centre).
6. Present findings at national scientific meetings, and report work in peer-reviewed literature.
7. Develop a set of ASS planning policies at local government level (for Port Adelaide Enfield Council, Salisbury Council, Torrens Catchment Water Management Board and Northern Adelaide & Barossa Catchment Water Management SA.).

Project Objective 1.

Quantify the biogeochemical and physical processes in various acid sulfate soils and construct a series of conceptual models, which will point to options to better manage ASS in the Barker Inlet/ Gillman area.

A series of conceptual models have been created which illustrate the biogeochemical and physical processes in both the actual ASS problem at Gillman and the PASS problems at St Kilda (figures 1 and 2). The models help describe the chemical and physical changes that occur when tidal influences are excluded from mangrove sediments, which then oxidise. They also show how and where acidity and contaminants (e.g. heavy metals, arsenic and oxyhydroxysulfates) are produced in the soil profile, and have helped us to understand better their movement and spatial distribution in the environment. This information provided the basis for developing ASS risk maps (map classes and treatment categories) and in developing the trial remediation experiments and management options outlined in the ASS Technical Manual "Acid Sulfate Soil Management Guidelines, Barker Inlet, SA (Appendix 1).

Gillman Area

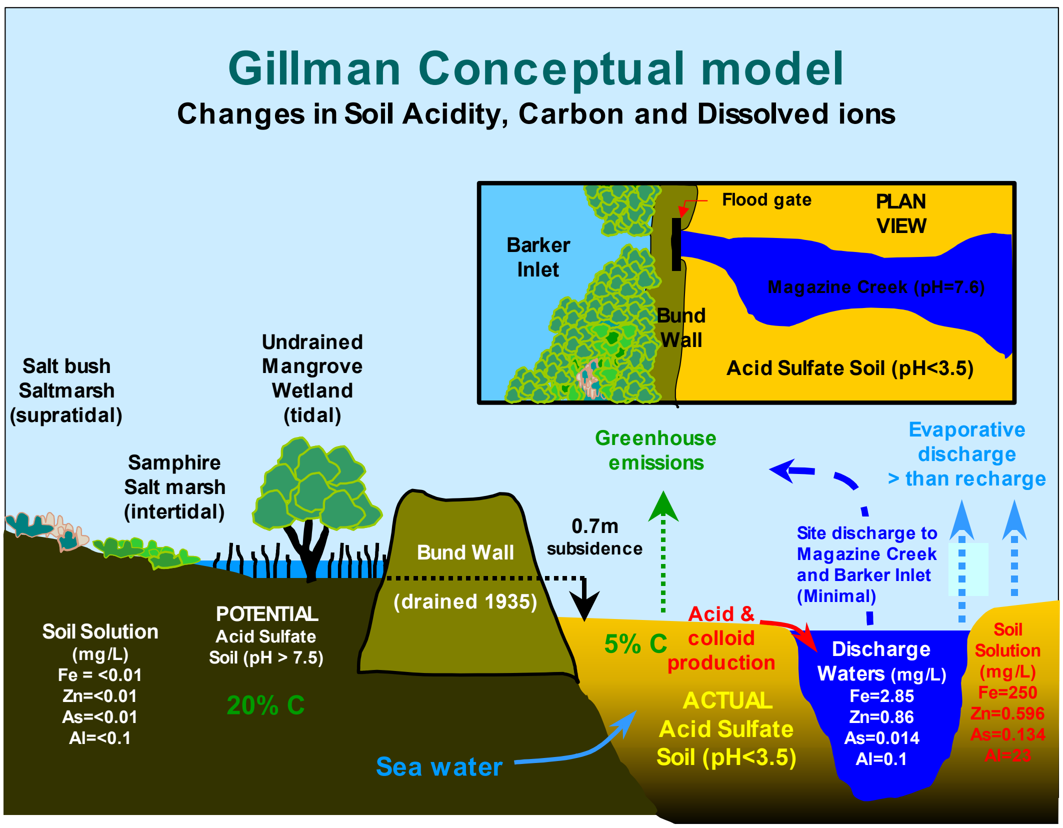


Figure 1. *This conceptual model illustrates the chemical and physical changes that occur when tidal influences are excluded from mangrove sediments that then oxidise to form actual ASS. Knowing how and where acidity and contaminants are produced in the soil profile has helped us to better understand their movement and spatial distribution in the Gillman environment, and develop ASS risk management and remediation guidelines.*

St Kilda Area

In response to environmental concerns surrounding eutrophication, mangrove deaths and samphire habitat loss in the mangrove woodlands at St Kilda, we developed an extensive monitoring program to help us understand the chemical and physical processes that are occurring in the soil and water, and develop remediation options to help evaluate them. A schematic diagram has been produced to help illustrate the processes that are occurring at St Kilda (Figure 2).

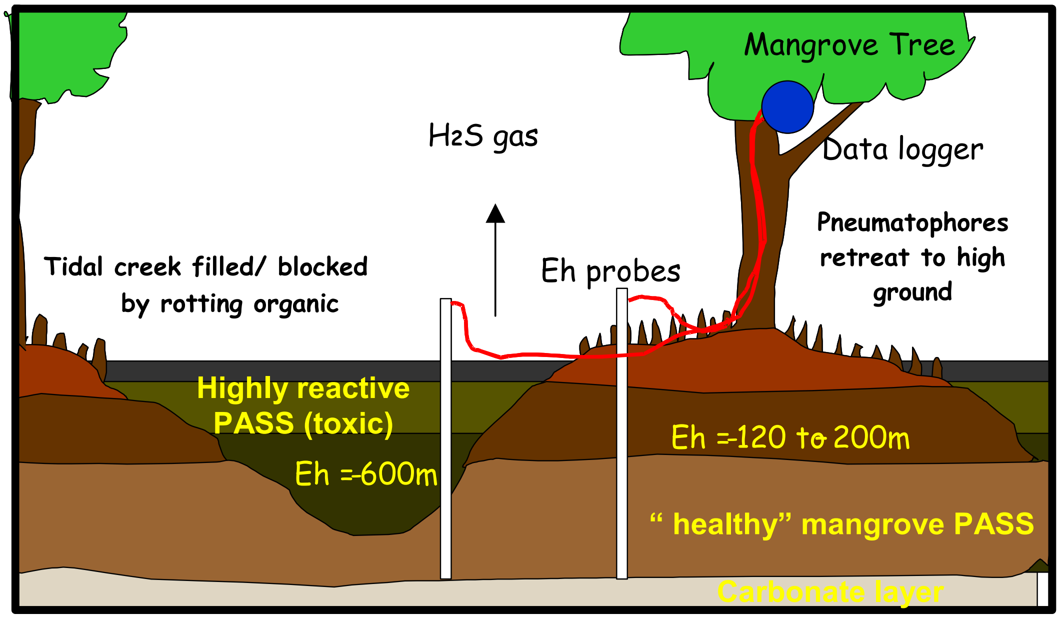


Figure 2. *This diagram shows the installation of redox monitoring equipment and contrasting soil profiles at St Kilda. The brown soil layers represent "healthy" mangrove soils that are slowly being eroded away by water flowing (slowly) through the tidal creeks. The creeks are filled with rotting organic matter such as sea-grass and ulva (sapric material) that has become extremely reducing (Eh's down to –600mV) as bacteria break it down. These soil conditions are "toxic" to the mangrove phneumatophores (breather roots), which have to retreat to "higher ground". This leaves the creek banks very susceptible to erosion, further restricting the area that pneumotophores can survive. When areas of high ground become too small, mangrove trees are unstable and easily knocked down during storms, killing them.*

The constrution of a seawall and marina at St Kilda have changed the tidal regime of the mangrove forests. Although the bund wall doesn't exclude the tide from inundating these mangroves, it blocks a number of tidal creeks that allow the tidal water to flow back out into the Inlet. Seawater and organic debris carried in by the tide is therefore pooling and blocking the tidal creeks causing eutrophic, stagnant conditions that are killing the mangroves.

Enhancing the tides' ability to "flush" nutrients from the stagnant reaches of the mangrove woodland would be the first step to remediation, although ultimately reducing nutrient inputs to St Vincent Gulf and Barker Inlet would be the preferred solution.

Management and remediation guidelines developments that have potential to alter the natural tidal flushing of mangrove forests are outlined in the ASS Technical Manual "Acid Sulfate Soil Management Guidelines, Barker Inlet, SA (Appendix 1).

Project Objective 2)

Develop and trial a series of innovative remediation techniques such as bioremediation, liming using waste by-products and sea water flushing.

Management strategies can only be successful if based on adequate mapping of the sulfide contents, soil reactivity and depths to which sulfuric and sulfidic horizons occur. Understanding the distribution, evolution, nature and inter-relationships of the coastal sediments is also vital for effective planning of ASS management and selecting appropriate remediation strategies. However, the development plans for land affected by ASS also dictates remediation options available to achieve a desired environmental outcome.

ASS-affected land at Gillman is largely vacant, but controlled by many different private and public organisations, and housing amenities such as: a major municipal waste dump, salt evaporation ponds, storm water retention basins with open drains and constructed freshwater and saline (tidal) wetlands. Segments of the land are constantly changing hands along with development plans. The area will soon host a major arterial freeway, and is under pressure for industrial subdivisions and other industrial developments.

A soil map (Figure 3) and schematic cross sections (Figure 1 and 2) were created to characterize the soils and locate suitable sites for monitoring and conducting remediation trials. An integrated program of quantitative pedological work, including good interpretative descriptions, chemical and physical investigations (e.g., redox measurement using Pt Eh electrodes and site hydrology) and environmental assessment has been carried out to better understand the spatial distribution of soils and contaminants (e.g. heavy metals, arsenic and oxyhydroxysulfates). This information provided the basis for devising trial experiments and management options. The ASS in the bunded areas have been compared with PASS in adjacent, relatively undisturbed mangrove, samphire and sea grass flats.

The following remediation trials appropriate to the use of land and soil type were conducted on the most degraded ASS in the area (figures 4 and 5 show the design of the experiments).

- Re-flooding trials utilizing existing freshwater, tidal and saline ponds in constructed wetlands and brackish water in a storm-water ponding basin.
- Bioremediation trial to re-establish reducing conditions to stop pyrite oxidation by the addition of sulfate-reducing bacteria and various organic wastes, in effect re-establishing the sulfide formation processes that operate in the mangrove soils outside the bund wall.
- Slotting trial using soda lime by-product to treat acidic, discharging, meteoric water or groundwater leachate.
- Tidal flushing/drainage trial in highly reducing, eutrophic potential ASS where mangrove dieback is occurring at St Kilda.
- Leaching/ aging trial to establish the reactivity chemistry of leachate drained from various types of ASS and PASS “stockpiles”.

The results obtained from these remediation trial experiments were used to develop guidelines included in ASS Technical Manual "Acid Sulfate Soil Management Guidelines, Barker Inlet, SA (Appendix 1) to assist land managers in making the most appropriate decision on utilisation and remediation of a variety of ASS affected lands in Gillman/ Barker Inlet areas.

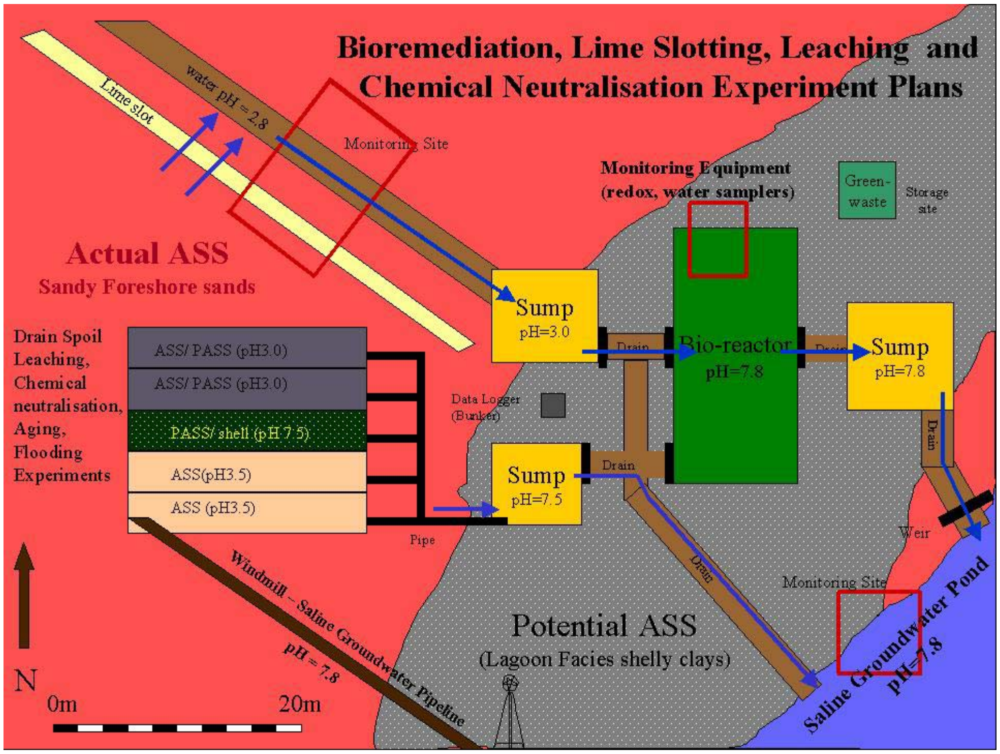


Figure 4. *Remediation trials appropriate to the use of land and soil type were conducted on the most degraded ASS in the Gillman area. This figure shows the layout of the experiments conducted at Gillman.*

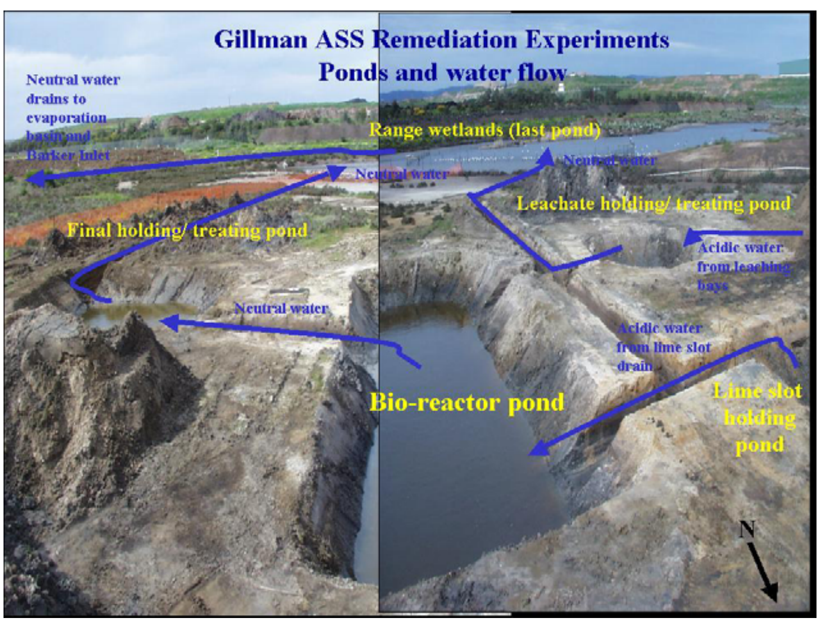


Figure 5. *This figure shows the layout of the bio-remediation experiment and the movement, treatment and improvement of water through the system.*

A selected pictures of the from the Gillman remediation trials are presented below.

Profile BG 14. Actual Acid Sulfate Soil (grey sand & brown mangrove peat covered by light gray clay and soil) containing yellow jarosite mottles (pH <2.5)

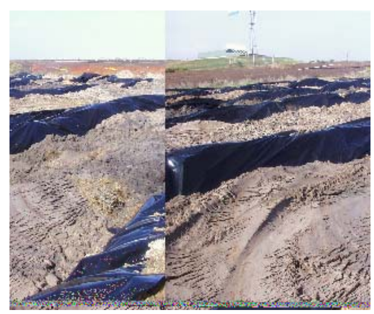
Seawater re-flooding experiment in the lower Barker Inlet Wetlands. This flooded area was formally a salt evaporation pan.

Secondary sulfate salts (tamarugite, sideronatrite, jarosite and gypsum identified by XRD analysis) formed on sandy ASS in profile BG 14. These salts are a store of acid that does not require oxygen to generate acid.

Bio-remediation experiment pond. Actual ASS was placed in the bottom of the plastic lined pond and covered with organic matter before being filled with acidic ground water (pH 2.8) from the drain pictured above.

Three months after construction, iron oxides are precipitating from the water that now has a pH of 5.4.

Lime (Penrice Grits) being added to the Lime Slot. The drain to the left contains water with a pH < 2.8



Leaching/ aging experiment soil heaps containing sulfidic material that formed actual Acid Sulfate Soil after exposure to the air.

Project Objective 3)

Publish recommended remediation techniques and applicability to potential land uses.

There has been no previous work on recommended remediation techniques and applicability to potential land uses in Barker Inlet. The project has provided and published information and guidance through the preparation of a very detailed coastal ASS map of the Gillman area (Figure 6) and an ASS Technical Manual "Acid Sulfate Soil Management Guidelines, Barker Inlet, SA" (Appendix 1).

The ASS Technical Manual contains a checklist that relates to the ASS risk map and map legend to give guidance and management procedures for disturbance of ASS during the process of development and details recommended remediation options/ techniques for the various (mapped) ASS categories and degraded lands at Gillman. The ASS Technical Manual checklist is summarised below. The Gillman ASS risk map (Figure 6) and a summarised version of the map legend (Table 1) follow. A soil description and soil analysis data-base (appending the Manual), contains detailed soil descriptions and analytical data on soil profiles (examples) represented in the mapped soil units (Table 2. contains a description of soil profile BG14 and is typical of the soils found in the map unit Aass1).

ASS Risk Project

Projects involving the possible disturbance of ASS must first assess the risk associated with disturbance through the consideration of both on- and off-site impacts. A thorough ASS investigation is an essential component of risk assessment. Such an investigation is needed to provide information on the environmental setting, location of and depth to ASS, existing and potential acidity present in the soil, and soil characteristics.

Successful management of ASS depends on the results of the investigation—and results from the investigation determine the most appropriate management strategy for a site. The following staged approaches to assessment of large disturbances/developments is suggested:

Establish whether acid sulfate soils are present on the site

A 'desk top' study is the first step in any preliminary assessment. A desktop study should be followed by field assessments, including preliminary field tests such as field pH, the field peroxide test and the field sulfate test. Detailed soil and water sampling and laboratory analysis may be required at the detailed assessment stage to validate the likely environmental risks of undertaking the proposal.

Step 1: Check AHD and size of excavation

Check whether the proposed site development is located <5 m AHD, where the natural groundcover is <20 AHD, and involve excavation of >100 m3 or fill >500 m3 over 0.5 m average depth. However, if yes proceed to Step 2. If no it can be assumed that coastal ASS are not present.

Step 2: Check ASS risk maps (Gillman or Barker Inlet maps)

Step 2: Check whether the site is located in the ***Gillman or Barker Inlet ASS maps*** as having either a high or low risk of ASS on the ASS risk maps. Reference to these coastal ASS maps should be the first step in any investigation. For example, if the works are not located within Classes 1a-3 (high risk category) or within 500 m of Classes 4-6 (medium risk category), it can be assumed that costal

ASS are not present. However, if the works are located within Classes 1-7, or within 500 m of Classes 1-7 further investigation is then required to determine if ASS are actually present and whether they are present in such concentrations as to pose a risk to the environment.

Action following Step 2

If the works are in an area identified on maps as suggesting a risk to the environment, and if the works are likely to disturb these soils proceed to Step 3. If the works are not in or will not affect a mapped area, proceed without further consideration of acid sulfate soils.

Step 3: Examine field soil and water indicators

Step 3: Examine whether any of the soil or field indicators listed in the glossary are present. The investigation should include a field inspection to consider soil and surface and subsurface water characteristics and if necessary, limited ground water analysis. Because many of the indicators for actual and potential ASS are quite different, field inspection should investigate for the presence of both soil materials (see glossary – for indicators).

Figure 6. Gillman ASS Risk Map.

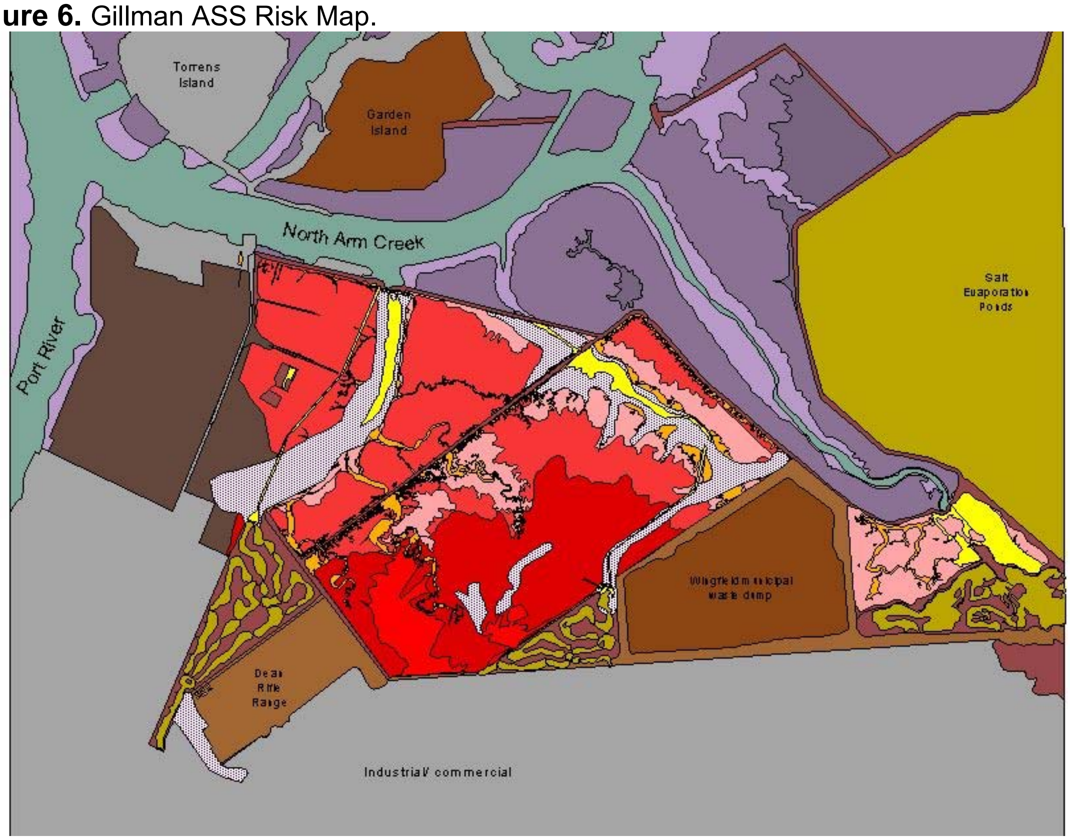


Figure 6. *Gillman ASS Risk Map. It is important to increase awareness of the presence and spatial distribution of both ASS and PASS and their varying degrees of reactivity in order to manage these soils effectively. The mapping units (outlined in the legend below) indicate the various soil types found in at Gillman. The soil types have been allocated ASS risk classes and correspond to treatment categories. Management and remediation strategies developed by the project have also been assigned to the mapped soil types. These options are obtainable from the map legend.*

Table 1. Summarised Gillman ASS Risk Map Legend.

Map Class Description	Map Legend (Class code)	Depth to Acid Sulfate Materials	Treatment Category
High Probability High probability of occurrence of Actual Acid Sulfate Soils (AASS) and/or Potential Acid Sulfate Soils (PASS) within the soil profile. The environment of deposition has been suitable for the formation of acid sulfate soil materials. Acid sulfate soil materials are widespread or sporadic and may be buried by artificial fill (including garbage), alluvium or windblown sediments.	Mbo1	**Below water level.** Acid sulfate soil material near or at sediment surface.	XH
	Mbo2	**At or near ground surface.** Areas seasonally flooded.	XH
	Aass1	**At or near ground surface.** Actual ASS (pH >3.5) at or near sediment surface (<0.4m). Sulfuric (soil layer with pH >3.5 and generally >1m thick and up to 3.5m thick. PASS occurring below the watertable.	VH
	Pass1	**At or near ground surface.** Samphire PASS (<1m thick)	M-H
	Pass2	**At or near ground surface.** Mangrove PASS (<1m thick)	M-H
	Pass3	**At or near ground surface.** Seagrass PASS (< 1m thick)	M-H
	Aass2	**Within 0.4m of ground surface.** Actual acid sulfate soils (pH >3.5) at generally below 0.4m from sediment surface. Sulfuric (soil layer with pH >3.5 and generally >1m thick and up to 3.5m thick. PASS occurring below the watertable.	VH
	Pass4	**Within 0.1m of ground surface.** PASS (potential acid sulfate soils) with a pH > 5. Surface oxidized zone generally <0.1m thick with pH generally < 5.	H
	Pass5	**Below 1.0m of ground surface.** PASS (potential acid sulfate soils) covered by hydraulic fill.	H
	Pass6	**Below 2.0m of ground surface.** PASS (potential acid sulfate soils) covered by fill that has generally been excavated from the adjacent land containing acid sulfate material. Eg. Bund wall.	H
Low Probability Low probability of occurrence of acid sulfate materials within the soil profile. The environment of deposition has **generally not** been suitable for the formation of acid sulfate soil materials. Soil materials are generally Pleistocene in age. Acid sulfate soil materials, if present are sporadic and may be buried by artificial fill (including garbage), alluvium or windblown sediments.	Bs	**Below water level.** Bottom sediment may contain small amount of monosulfide at sediment surface.	L
	Ca	**Calcareous soils** Shelly (carbonate rich) layers occurring within the soil profile reduce the risk of soil acidification if disturbed.	L
	Hd	**Highly disturbed terrains.** Risk requires individual investigation; guided by (and elevation of) adjacent mapped units.	L
	Nk	**No known occurrence.** Acid sulfate soil materials are not known to exist or expected to exist in these environments	

Table 2.

Description Sheet for Site (BG14)

Site No: CA78 [Mfp96/Site 1]	**Locality**: Gillman, Barker Inlet area, Adelaide			
Datum: WGS84 UTM(m)	**Zone:** 54	**Easting**: 275465	**Northing**: 6143180	
ASS Risk Class	H-VH			**Photo file**:
C&M Mapping Unit [1]	Land Outside Saltmarsh; outside C&M Branch mapped area; reclaimed drained land			BG14 (B Thomas)
Soil Classification	[2] Sulfuric Redoxic Hydrosols	[3] Hydraquentic Sulfaquept	[4] Orthithionic Fluvisols	
Vegetation	Annual grasses			
Site observations made and sampled by: CSIRO L&W			**Date**: 1996/2002	
Site description: Eastern end of MFP transect and close to site BG11, east of Gillman rifle butts: flat, relict dune; shallow water table.				

Depth (cm)	**Brief soil description**:	%S_{cr}	**Lime rate Kg/m³**	**Total C %**	**Org C %**	**pH** 0.01M $CaCl_2$	**EC DS/m 1:5**	**Bulk Density**[4]	**Treatment category**
0 - 20	A1: dark grey-brown; sandy clay loam; mottled; sub angular blocky, firm; many fine roots	0.005	3.6	1.32	1.32	3.84	2.87	0.8	L
20 - 38	E: pale brown; loamy sand; mottled; massive; few roots; very weak; sharp wavy boundary	0.008	0.88	0.39	0.39	3.53	0.77	1.0	L
38 - 58	Btg1: dark grey; light clay; mottled; massive; very weak; sharp boundary	0.016	4.6	3.15	3.15	3.33	4.33	0.6	M
58 - 90	Bgj2: greyish brown;; clayey sand; yellow jarosite mottles; massive; very weak; sharp/ smooth boundary	0.009	0.5	0.25	0.25	3.9	2.4	1.3	L
90 - 130	Bgj3: greyish brown; sand; yellow jarosite mottles; massive; very weak; diffuse boundary	0.517	24.3	0.27	0.27	3.6	3.9	1.5	H
130 - 160	Bg4: greyish brown; sand; yellow jarosite mottles; massive, very weak; diffuse boundary	0.249	19.5	1.07	1.07	3.6	5.8	1.5	M-H
160 - 200	Bg5: olive grey; sand; massive	0.83	39.0	0.31	0.31	3.7	8.22	1.6	XH

Comments:

This profile is an actual ASS that has significantly acidified the soil materials. Liming rate listed includes a safety factor of 1.5.

[1] SA Department of Environment and Heritage, Coast and Marine Branch [2] Australian Soil Classification, Isbell (1996) [3] US Soil Taxonomy (1999) [4] World Reference Base for Soil resources, FAO (2000) [5] Estimated for saturated soils from % dry weight [6] Composition of coarse material

The full map legend also explains the environmental risks associated with disturbing the mapping units (soil types) and the geomorphology (land form) that the soils/ sediments were deposited in. This information allows correlation with previous geological and hydrological studies (eg. Belperio and Rice 1989; and others[1]).

The legend also contains the following treatment categories:

Low level treatment = L, Medium level treatment = M, High level treatment = H, Very high level treatment = VH, and Extra High level treatment - XH) From: Dear SE, Moore NG, Dobos SK, Watling KM, and Ahern CR (2002) Soil Management Guidelines: In *Queensland Acid Sulfate Soil Technical Manual*: (version 3.8) Department of Natural Resources and Mines, Indooroopilly, Queensland, Australia.

Treatment categories are based on the weight of soil to be disturbed and the existing plus potential acidity present in the soil. Consequently they relate to managing risk by neutralisation of ASS so that there is no adverse impact on the receiving environment.

Basic principles of ASS remediation are to:

- **Contain** acidic leachate using barriers or within soil profile.
- **Neutralise** acidity and at the same time manage the movement/discharge of toxic oxidation products.
- **Dilute** acidic leachate before discharging into the receiving waters.

The following approaches to remediation of ASS are considered for the Barker Inlet and Gillman Physiography, the details of which are contained in the manual "Coastal Acid Sulfate Soil Management Guidelines, Barker Inlet SA" (Version 1.1), (Appendix 1.):

1. Re-flooding
    a. Seawater re-flooding - (neutralization)
    b. Water Table Management - (containment and neutralization)
    c. Freshwater wetlands - (neutralization and dilution)
2. Bioremediation - (neutralization and containment)
3. Lime slotting – (chemical neutralization)
4. Leaching/ aging – (requires chemical neutralisation)
5. Tidal Flushing (neutralisation and dilution)

It is expected that the guidelines produced during this project, along with increased awareness, will have a large impact on future management of land use and infrastructure development in the Barker Inlet area.

[1] Belperio A.P. and Rice R.L., 1989. Stratigraphic investigation of the Gillman investigation site, Port Adelaide estuary. Geological Survey, Department of Mines and Energy South Australia.

Project Objective 4)

Participate in holding field days.

A number of field trips were held during the development of the project at both Gillman and St Kilda.

A Demonstration Workshop was conducted at the Gillman remediation trials site on the 15th of October 2002, was attended by 22 people, representing industry (Transport SA and environmental/ geotechnical consultancy companies), BIPEC members (Steering Committee) and the Project committee. A field-trip brochure for the Gillman ASS remediation experiments was produced and disseminated at the Worksop Demonstration day.

Project Objective 5)

Produce educational materials (St Kilda Mangrove Trail & Interpretative Centre).

An educational pamphlet titled “Mangrove Muds” was completed to explain the environmental problems associated with nutrient loading in the marine ecosystem. This pamphlet is being distributed through the Mangrove Interpretive Centre at St Kilda and is aimed at late primary schools and high school students. We have also disseminated information though the media; Channel Ten’s “Totally Wild” children’s science education program.

Two “user-friendly” educational publications have been produced to disperse information on CASS issues and risks to other demographics:

1. A brochure has been published that outlines the various characteristics of coastal ASS in the Barker Inlet to inform landholders, developers, the local community and students about potential problems associated with the coastal ASS.

2. The development brochure “Coastline” bulletin (No 33) titled “A strategy for implementing CPB policies on coastal acid sulfate soils in South Australia” was produced. This bulletin outlines the CASS issues and proposed implementation polices in SA with a specific case study from Barker Inlet. At least 1500 colour copies will be printed.

These pamphlets are contained in Appendix 2 of this report.

We have transferred the knowledge gained in this project to the public community, school students and scientific community through a number of publications at conferences and in journals (in press). This process will continue as the papers make their way through the scientific refereeing and publishing process. As there has been no previous extensive work on the distribution and properties of coastal ASS in South Australia, this project has resulted in a rapid increase in local awareness that will be reinforced by the adoption of planning procedures.

Incorporation of information and maps a new Manual developed by Transport South Australia entitled “Protecting Waterways”. The manual is designed to give staff, consultants and the community guidance in procedures and measures to address water quality and protect aquatic ecosystems, and infrastructures. Rob Fitzpatrick gave a 45-minute presentation at the launch of the manual (including a training session) on 12th December 2002. Information about CASS in SA and digital photographs are included in the manual.

Project Objective 6)

Present findings at national scientific meetings, and report work in peer-reviewed literature.

We have been able to transfer information and findings to an extensive and diverse audience through media, conferences presentation, and seminars, publications of abstracts, posters, and brochures throughout the project. Mr Brett Thomas and Dr Rob Fitzpartick gave oral presentations and a poster presentation to an international scientific audience at the 5th International ASS Conference in September 2002. Abstracts outlining the project and presentations were published in the Conference transactions. The references for these documents are listed below.

- **Abstract: Approaches to remediation of acid sulfate soils in Barker Inlet**, South Australia. Published in the 5th International CASS Conference transactions. A presentation detailing this abstract was also presented at the conference in August/September 2002 at Tweed Heads.
  Reference:

  Thomas B.P., R.W. Fitzpatrick, R.H. Merry, W.S. Hicks and P.G. Davies (2002) Approaches to remediation of acid sulfate soils in Barker Inlet, South Australia. 5th International Acid Sulfate Soils Conference, Tweed Heads, NSW, 25th to 30th August 2002. Book of extended abstracts p 67-68.

- **Oral Presentation: Approaches to remediation of acid sulfate soils in Barker Inlet, South Australia.** This paper was presented by Brett at the 5Th International CASS Conference at Tweed Heads on the 30th August 2002.

- **Abstract: Properties and distribution of South Australian coastal sulfate soils and their environmental hazards.** Published in the 5th International CASS Conference transactions. A poster detailing this abstract was presented at the conference in August/September 2002 at Tweed Heads.

  Reference:

  Fitzpatrick R. W., P .G. Davies, B. P. Thomas, R. H. Merry, D. G. Fotheringham and W. S. Hicks (2002). Properties and distribution of South Australian coastal acid sulfate soils and their environmental hazards. 5th International Acid Sulfate Soils Conference, Tweed Heads, NSW, 25th to 30th August 2002. Book of extended abstracts. p. 40 –41.

- **Poster presentation:** Properties and distribution of South Australian coastal acid sulfate soils and their environmental hazards. This abstract was presented as a poster at the 5th International CASS Conference transactions. August/September 2002 at Tweed Heads.

Findings and maps have also been incorporated into a new Manual developed by Transport South Australia entitled “Protecting Waterways”. The manual is designed to give staff, consultants and the community guidance in procedures and measures to address water quality and protect aquatic ecosystems, and infrastructures. Rob Fitzpatrick gave a 45-minute presentation at the launch of the manual (including a training session) on 12th December 2002. Information about CASS in SA and digital photographs are included in the manual.

Two journal papers are currently being prepared for publication in the Australian Journal of Soil Research, Special 5th International ASS Conference Proceedings Edition.

A website is has been developed where all previous milestone reports will be made publicly available at URL: http://www.clw.csiro.au/staff/FitzpatrickR/publications.html
CSIRO Land and Water are in the process of re-developing websites but we expect that this location will be available in the near future.

Project Objective 7.

Develop a set of ASS planning policies at local government level (for Port Adelaide Enfield Council, Salisbury Council, Torrens Catchment Water Management Board and Northern Adelaide & Barossa Catchment Water Management SA.).

At the time the project was initiated, the SA Government had not addressed the need for planning and engineering guidelines in relation to the management of coastal acid sulfate soils. Port Adelaide Enfield Council in collaboration with CSIRO implemented the project with the clear objective to lever the development of these policies in the metropolitan area, and raise the urgent risks of unmanaged development in areas that were significant for likelihood of CASS. The Council has, as a key part of the project, incorporated the development of local planning policy in relation to the development of PASS in coastal land in the City into its programme of Development Plan Amendments (PARs) for the coming year. The project has driven the State Government to begin its investigations into the issues, and Council will continue to work with Planning SA and the Coast Protection Board to finalise and promote planning policies that can be used by all local and State authorities as a model.

In 2003 / 2004 the Council is also developing a corporate Environmental Management System to ensure its operations are environmentally sustainable - the issue of CASS is being incorporated into new engineering policies and procedures accordingly, following the implementation and outcomes of this project. The project has served to significantly raise the profile of ASS in policy and planning agencies in South Australia.

In 2000 Port Adelaide Enfield Council developed a 'State of the Environment Report' for the City, including data management processes, indicator development, and monitoring/evaluation regimes, as per the OECD State-Pressure-Response model, and identified ASS as a major issue to be addressed urgently. This project has assisted in the development of appropriate bio- or other indicators for ASS in the region, and support Council's environmental reporting and natural resource accounting processes.
The Council's new Environment Strategic Plan (to be endorsed in March 2003) has (as a result of the project's successful implementation) put into place a 3-year program of strategic activities and partnerships to continue to collaborate on the further policy development required.

Prior to this project, no legislative mechanism existed within South Australia to assess proposed developments in coastal acid sulfate soil (CASS) risk areas. As a result of the project, the Coast Projection Board (CPB), which has jurisdiction over most coastal areas, has now included development and hazard policies within its draft Policy Document relating specifically to coastal acid sulfate soils.

Additional Achievements and Data

Indicate important achievements you have made in addition to your project objectives. Again, please use the Performance Indicators as listed in Item K to support your statements.

Please include any other data that may have been collected during the life of the project that are consistent with the Performance Indicators as listed in Item K. For example, demonstration activities may not be a project objective but performance indicator data for demonstration may have been collected.

1. Implementing Regional, Catchment and Local Area and Land Management Planning

In what way has your project contributed to the development or implementation of a regional strategy or management plan?

This project has made considerable progress in identifying the distribution of ASS and their associated risks in the Barker Inlet area but in particular the Gillman area, which contains actual ASS. This task is a key action of the National Strategy for the Management of Coastal Acid Sulfate Soils. The development and endorsement of planning policy at council and state levels will for the first time provide a basis for land management planning in SA.

The Gillman site has been mapped in detail and areas of high risk have been identified, thereby ensuring proactive management and essential complementary planning measures can be implemented. This has allowed for potential problems to be prioritised (ASS Risk classes), minimised and mitigated in advance wherever possible.

This project has advanced new concepts (properties of CASS in a Temperate/ Mediterranean climate) and practical information (ASS Risk, checklists, treatment categories) about coastal ASS in the Barker Inlet area. This information has already been provided to local stakeholders (councils and land holders) and policy makers via websites (ASS maps), field workshops and conference presentations, and as popular articles (e.g. Coastline bulletin) and popular fact sheets (held at the St. Kilda Mangrove walk interpretive centre). This information will aid in avoiding excavation of Potential ASS and the tackling of solutions for remediation of Actual ASS in the Barker Inlet, particularly in areas at St. Kilda and Gillman.

2. Use of Project Results

Has your project had any benefits for any other groups? If so, by whom and in what way?

Results and data (e.g. CASS Maps of Gillman and Barker inlet) derived from this project have been used as follows:

- Popular material has been provided to Mangrove Walk Interpretative centre (see appendix 2).
- Incorporation of information and maps a new Manual developed by Transport South Australia entitled "Protecting Waterways". The

manual is designed to give staff, consultants and the community guidance in procedures and measures to address water quality and protect aquatic ecosystems, and infrastructures. Rob Fitzpatrick gave a 45 minute presentation at the launch of the manual (including a training session) on 12^{th} December 2002. Information about CASS in SA and digital photographs are included in the manual.

- Uptake of results and conceptual biogeochemical models in scientific papers presented at the 5th International Acid Sulfate Soil Conference. Some of this information was also presented as part of an Invited key note address "Inland acid sulfate soils - a big growth area" presented at the 5th International Acid Sulfate Soils Conference, Tweed Heads, NSW, 25th to 30th August, 2002. Invited to publish a paper in the Australian Journal of Soil Science.
- Landholder and Council meetings: several one-on-one discussions between the research team and local landholders have taken place and these prove to be a most effective communication mechanism. Researchers have learnt from Landholders and council staff, and local observation has been important to the design of our approach and verification of results.
- The project has provided context for Mr Brett Thomas's PhD research project involving mapping and remediation of ASS in Barker Inlet.

3. Program Administration

Please provide comments on CASSP project administration. This information may be able to assist future funding programs.

We believe that this project benefited from having access to a good project steering committee, The Barker Inlet and Port Estuary Committee (BIPEC). Mr Harry Pitrans is secretary of BIPEC and attended most project meetings and field workshops.

Close interaction with an effective technical committee of advisers from the Project Consortium: Port Adelaide Enfield Council, CSIRO Land & Water, Land Management Corporation, Penrice Soda Products, Department of Environment and Heritage, Salisbury Council, Torrens Catchment Water Management Board, Northern Adelaide & Barossa Catchment Water Management Board and the St Kilda Mangrove Trail & Interpretative Centre.

Establishment of the project also benefited from a very constructive strategic planning meeting (Stage 1 and 2 milestone reports) with field trip held in the early days of the project.

Have appreciated interaction with EA management their helpful feedback, especially from Trevor Costa during the establishment phase of the project.

4. Future Action

How is your group planning to maintain the project after funding has ceased?

Mr Brett Thomas a PhD student (with three year stipend – Appendix 3) was specifically appointed as part of the 2 year CASSP project **(Phase 1)** in order to maintain the project after CASSP funding had ceased. Brett Thomas has been based at the Waite Campus, CSIRO Land & Water, Adelaide and used all the CASSP field sites in the Barker Inlet/Gillman area. Research for his PhD has formed an integral part of the CASSP project to develop suitable remediation methods for ASS in the Barker Inlet/Gillman area. At the second milestone meeting Brett Thomas was appointed Project Officer. The **three year** project is jointly funded by Environment Australia's Coastal Acid Sulfate Soils Program (CASSP) with Port Adelaide/Enfield Council, Land Management Corporation, CSIRO Land & Water, Penrice Soda Products, Department of Environment and Heritage, Salisbury Council, Torrens Catchment Water Management Board, Northern Adelaide, Barossa Catchment Water Management Board and the St Kilda Mangrove Trail & Interpretative Centre. The consortium provided additional funding to finance the third year or **Phase 2** of the project (Brett Thomas PhD project – operating and stipend).

In Phase 2, Brett Thomas will continue to monitor the rehabilitation experiments for another year (two seasons), undertake more detailed analyses of soils and waters (powder X-ray diffraction, scanning electron microscopy, transmission electron microscopy, geochemistry, stable isotopes of S, more detailed soils and geomorphology mapping, redox monitoring, thin section analyses). This information will be used to progressively update the ASS Technical Manual "Acid Sulfate Soil Management Guidelines, Barker Inlet, SA" (Appendix 1), (i.e. version 1.2: to be presented to BIPEC by July 2003; and version 1.3: to presented to BIPEC by June 2004). Several journal publications will completed over the next year – based on data obtained from both Phase 1 (CASSP project) and Phase 2 (PhD thesis publication – due in June 2004).

The current CASSP project (Phase 1) will produce, in addition to web and other outputs already described, at least one scientific journal publication (Australian Journal of Soil Science).

In addition to this, we will prepare information sheets, which will be supplied to developers that have the potential to be affected by development in ASS prone areas in both Council districts. This information will be made available at the St Kilda Mangrove Trail and Interpretative Centre, and Council offices.

We recommend that a South Australian Technical Committee for ASS be formed to have oversight and to interact with local government and development zones. This committee should also be charged with identifying suitably qualified consultants and analytical laboratories to ensure that the guidelines, and soil and water analysis procedures, are followed.

CSIRO Land and Water staff involved in this project also share a national perspective and mandate to conduct research that assists in the management of Australia's land and water resources. CSIRO Land & Water has committed itself to continuing involvement in ASS research in the Barker Inlet area. It has recently held meetings involving key federal and state stakeholders in the management of Australian Coastal ASS to develop a National Project. The meeting aimed to strengthen the alliances between these stakeholders to facilitate more effective research into Australian ASS. CSIRO Land & Water ASS research activity involves coastal and inland ASS as well as links to mineral exploration and dryland salinity research at a national level. The synergies developed by integrating knowledge in these areas will continue to bring significant added value to the work. For example, sulfur isotope techniques developed from inland ASS and mineral exploration research look like being a significant part of our toolkit to be used in Brett Thomas's PhD project involving coastal ASS remediation studies at Gillman and St Kilda.

Glossary of Terms related to Acid Sulfate Soils

acid sulfate soil materials (ASS) saline soils or sediments containing pyrites, which once drained (as part of remedial land management measures, or as part of coastal development), become acidic releasing large amounts of acidity into the ecosystem with consequent adverse effects on plant growth, animal life, etc. These soils are widespread around coastal Australia (especially when associated with mangrove swamps) and occur to an unknown extent in inland areas.

potential acid sulfate soil materials (PASS) – in their pristine state PASS materials occur in saline wetland seeps or are buried beneath alluvium and:

(i) contain black sulfidic material (see below), are waterlogged and anaerobic;

(ii) contain pyrite (typically framboidal);

(iii) have high organic matter content;

(iv) have pH 6-8.

Other indicators: Waterlogged greyish or black sediments. Bottom sediments of estuaries or tidal lakes. Soils that react to the Peroxide Test.

actual acid sulfate soil materials (AASS) - when PASS are disturbed:

(i) contain a sulfuric horizon (see below) because pyrite is oxidised to sulfuric acid (pH <3.5-4);

(ii) iron sulfate-rich minerals form, commonly as pale and bright yellow or straw-coloured mottles containing jarosite, natrojarosite or sideronatrite. May occur in any material excavated and left exposed

Other indicators: Water characteristics: Water of pH < 4 in adjacent streams, drains, ground water, etc.; Unusually clear or milky blue-green drain water flowing from or within the area (due to aluminium released by the ASS); Iron stains on drain or pond surfaces, or iron-stained water Landscape and other characteristics; Sulfurous (H2S) smell after rain following a dry spell or when the soils are oxidised or disturbed; scalded or bare low lying areas. Corrosion of concrete and/or steel structures.

sulfidic material: waterlogged material or organic material that has a pH >3.5 and contains sulfide-sulfur. If incubated as a layer 1 cm thick under moist conditions (field capacity) while maintaining contact with the air at room temperature shows a drop in pH of more than 0.5 or more units to a pH value of 4 or less (i.e. 1:1 by weight in water, or in a minimum of water to permit measurement) within 8 weeks (Soil Survey Staff 1999).

sulfuric horizon: a horizon composed either of mineral or organic soil material that has both pH <3.5 (1:1 by weight in water, or in a minimum of water to permit measurement) and bright yellow jarosite mottles. A sulfuric horizon is defined as being 15 cm or more thick (Soil Survey Staff ,1999)

classification soil the systematic arrangement of soils into groups or categories on the basis of their characteristics. Broad groupings are made on the basis of general characteristics and subdivisions on the basis of more detailed differences in specific properties. For complete definitions of taxa see Soil Survey Staff (1999).

Further Information:

Soil Science Society of America. 1997. Internet Glossary of Soil Science Terms [Online]. Available at http://www.soils.org/sssagloss/ (verified 3 May 2001).

Soil Survey Staff (1999). Soil Survey Staff 1999. Soil Taxonomy - a basic system of soil classification for making and interpreting soil surveys, Second Edition. United States Department of Agriculture, Natural Resources Conservation Service, USA Agriculture Handbook No. 436 pp 869.

Acknowledgements

During the conduct of this project, assistance and support was received from the following people. Their help is greatly appreciated.

Ms Peri Coleman

Ms Rebecca Dunn

Mr Sean Forrester

Mr Henry South

Dr Freeman Cooke

Mr Andrew Cowley

5. **Total Project Funding Details**

   Details of project funding are provided separately.

6. **Proponent declaration:**
   Authorised representatives of the recipient organisation must sign this report.
   In order to maximise the benefits of the Natural Heritage Trust to others, information relating to all CASSP projects is regarded as in the public domain and is publicly available on request. Nevertheless, under Commonwealth privacy legislation, personal information cannot be divulged without the consent of those involved.

Do you consent to the inclusion of contact name and telephone details in response to public information requests concerning this project?	**Yes**		**No**	

Signature			
Contact name (Please print)		Ms Verity Sanders	
Organisation		Port Adelaide Enfield Council	
Position in organisation		Environmental officer	
Date:	17/03/2003	Tel:	(08) 8405-6727

I declare that the information given on this form including data on project performance, is complete and correct, and expenditure of moneys paid under the financial agreement has been solely upon the project and in accordance with the terms of the Agreement and its conditions.

Signature			
Printed name		Ms Verity Sanders	
Organisation		Port Adelaide Enfield Council	
Position in organisation		Environmental officer	
Date:	17/03/03	Tel:	(08) 8405-6727

Signature			
Printed name			
Organisation			
Position in organisation			
Date:		Tel:	

Appendix 3

Advertisement used for PhD STUDENTSHIP - Applications closed 22 February 2001

PhD STUDENTSHIP

Remediation of coastal acid sulfate soils in the Barker Inlet / Gillman area, South Australia

A PhD candidate is sought to join a research group and consortium working on altered landscapes in the Barker Inlet/Gillman area that have given rise to Acid Sulfate Soils (ASS) as a result of bunding and the exclusion of seawater. This area of metropolitan Adelaide remains undeveloped and the project aims to demonstrate and assess appropriate remediation techniques to assist future management and amelioration of ASS. The production, export and fate of acidic leachate associated with ASS are poorly understood in the project area and in South Australia. Consequently, strategies do not exist to appropriately manage these ASS and curtail pyrite oxidation and neutralise or leach existing acidity, and at the same time manage the release of acidic water and oxidation products. The project will develop and trial a series of innovative remediation techniques such as bioremediation, liming using waste bi-products and sea water flushing. A key outcome of this work will be the development of methods to readily identify the wide range of complex ASS problems and options to better manage ASS in the Barker Inlet/Gillman area. The person will be required to participate in holding field days, publish recommended remediation techniques and applicability to potential landuses.

The student will be based at the Waite Campus, CSIRO Land & Water, Adelaide with field sites in the Barker Inlet/Gillman area. Research for this PhD will form part of a larger project to develop suitable remediation methods for ASS in the Barker Inlet/Gillman area. The project is jointly funded by Environment Australia's Coastal Acid Sulfate Soils Program (CASSP) with Port Adelaide/Enfield Council, Land Management Corporation, CSIRO Land & Water, Penrice Soda Products, Department of Environment and Heritage, Salisbury Council, Torrens Catchment Water Management Board, Northern Adelaide, Barossa Catchment Water Management Board and the St Kilda Mangrove Trail & Interpretative Centre.

The student will be supervised by Dr. Rob Fitzpatrick (CSIRO Land and Water/University of Adelaide), Mr Richard Merry (CSIRO Land and Water) and Mr Warren Hicks (CSIRO Land and Water). The position is available after February 2001 and is offered for a term of three years subject to satisfactory progress. Stipend to be paid is AUS$21,000 pa. Selection Criteria:

- Meet requirements for admission to a PhD program at The University of Adelaide.
- BSc Honours (level H2A or above) in soil science, earth science, or a related environmental science degree.
- Genuine interest in development of methods to rehabilitate and manage ASS that aim to achieve increased economic, environmental and ecological sustainability.
- Australian Resident status.

Further details are available from Dr. Rob Fitzpatrick (CSIRO Land & Water/University of Adelaide) phone 08 8303 8511, fax 08 8303 8550 or e-mail: rob.fitzpatrick@adl.clw.csiro.au. Applicants should provide full personal details, Australian residential status, Curriculum vitae and the names and addresses of three referees. Applications should be forwarded to The Recruitment Officer, CSIRO Land & Water, Private Bag No.2, Glen Osmond SA 5064. Applications close 22nd February 2001.