

MANAGING COASTAL ACID SULFATE SOILS: THE BARKER INLET EXAMPLE

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INTRODUCTION

Intertidal wetlands surrounding Barker Inlet, near Adelaide, South Australia, have been progressively drained by bunding over the last 150 years. Consequently, these areas have dried, exposing pyrite in the organic-rich mangrove and intertidal samphire soils with sulfidic materials—potential acid sulfate soils (PASS)—to the air. Oxidisation of pyrite has produced sulfuric acid causing sulfuric horizons—actual acid sulfate soils (ASS)—to form (Fitzpatrick *et al.* 1996). The bunded area now contains approximately 12 km² of PASS and 1.6 km² of actual ASS that predominately occur in the Gillman area. The acidification of these soils and interstitial water bodies has led to various degrees of degradation of the immediate and receiving environments, namely Barker Inlet.

The production, export and fate of leachate associated with ASS has been poorly understood in the Gillman area, and strategies have not existed to appropriately manage these complex soils, acidic water and oxidation products. 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. Future development at Gillman, that will disturb the soils or change the local hydrology, could cause further environmental damage by increasing the oxidation of pyrite and off-site transportation of acidity and other metal contaminants. These soils need to be appropriately managed to protect the Gillman and Barker Inlet environments.

Management strategies should to be based on adequate characterisation and mapping of the sulfidic materials, sulfuric horizons and other regolith layers. Understanding the distribution, evolution, nature and inter-relationships of the coastal sediments is vital for effective planning of ASS management and selection of appropriate remediation options. However, the development plans for land influenced by ASS will also dictate the remediation options available to achieve a desired environmental outcome. Through the National Coastal Acid Sulfate Soils Program (CASSP) we have: (i) defined the ASS problem at Gillman through characterisation and risk mapping; (ii) developed remediation strategies outlined in an ASS management plan; and, (iii) trialed a number of field-scale remediation experiments (Thomas *et al.* 2003).

In this paper we summarise the methods used to characterise and map ASS, which underpin the strategies we have developed to manage ASS in the Barker Inlet.

PHYSICAL SETTING

The Gillman study site is located 15 km north of Adelaide and covers an area of about 4 km² (Figure 1). The natural elevation of the area ranges from -1.0 m AHD in creek channels, to 1.5 m AHD on undulating mounds between tidal creeks that drain to the north (< 1% slope) toward North Arm Creek. The climate of the area is Mediterranean, which is characterised by cool-to-mild, wet winters and extended hot, dry summers. The mean annual rainfall for the area is 470 mm mainly falls between May and September. The high potential evaporation demand (1,760 mm per year) exceeds rainfall by almost four to one and, accordingly, groundwater movement is predominately vertical, with very low lateral seepage rates of 0.3 to 0.6 m/yr (Pavelic & Dillon 1993).

ASS CHARACTERISATION AND MAPPING

A comprehensive review detailing existing information relating to physiography, soil types, geology, geomorphology, vegetation, elevation, geotechnical and hydrological data, ecology, contamination history and land use of the Gillman and Barker Inlet area was conducted by Thomas *et al.* (2001).

Characterisation

A conceptual model has been created to illustrate the biogeochemical and physical processes occurring in the actual ASS at Gillman (Figure 2). The model helps to summarise the chemical and physical changes that occur when tidal influences are excluded from mangrove sediments. It shows how and where acidity and contaminants

(e.g., heavy metals, arsenic and oxyhydroxysulfates) are produced in the soil profile, their movement and spatial distribution in this environment. This information provided the basis for development of ASS map classes and treatment categories for the ASS risk map, and in developing the trial remediation experiments listed at the end of this paper.



Figure 1: (1a) The study area is located 15 km north of Adelaide and surrounded on three sides by industrial development and North Arm Creek (Barker Inlet) to the north. (1b) Aerial photo of the study site shows a series of linear bund walls separating the paired study sites. The tidally-inundated mangrove and samphire study area to the north (1c) is separated from the drained study site to the south (1d) which contains actual ASS and the remediation trial experiments, by a bund wall that was constructed in the 1960s.

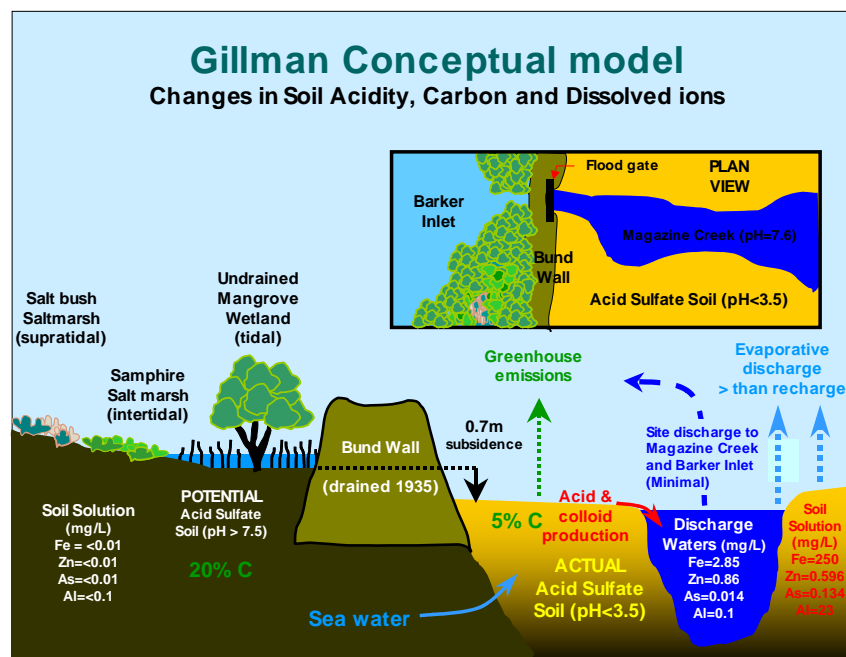


Figure 2: Conceptual model illustrating chemical and physical changes that occur when tidal influences are excluded from sulfidic materials in mangrove sediments.

Risk mapping

Landform and vegetation mapping, based on 1:40,000 scale aerial photography, provided an ideal base for the development of the regional Barker Inlet ASS risk map (Merry *et al.* 2003). This map base is viewable as intertidal/marine maps of the SA Atlas at the following URL: <http://www.atlas.sa.gov.au/>. This information, together with a detailed field investigation (soil profile descriptions of push drill rig holes, 32 backhoe pits and hand auger holes; soil mapping along open drains and creeks; and chemical analysis of over 100 soil samples) was used to produce a detailed ASS risk map for the Gillman area (scale 1:7,500). This enabled the identification of problem areas (ASS risk classes), which were assigned to treatment categories.

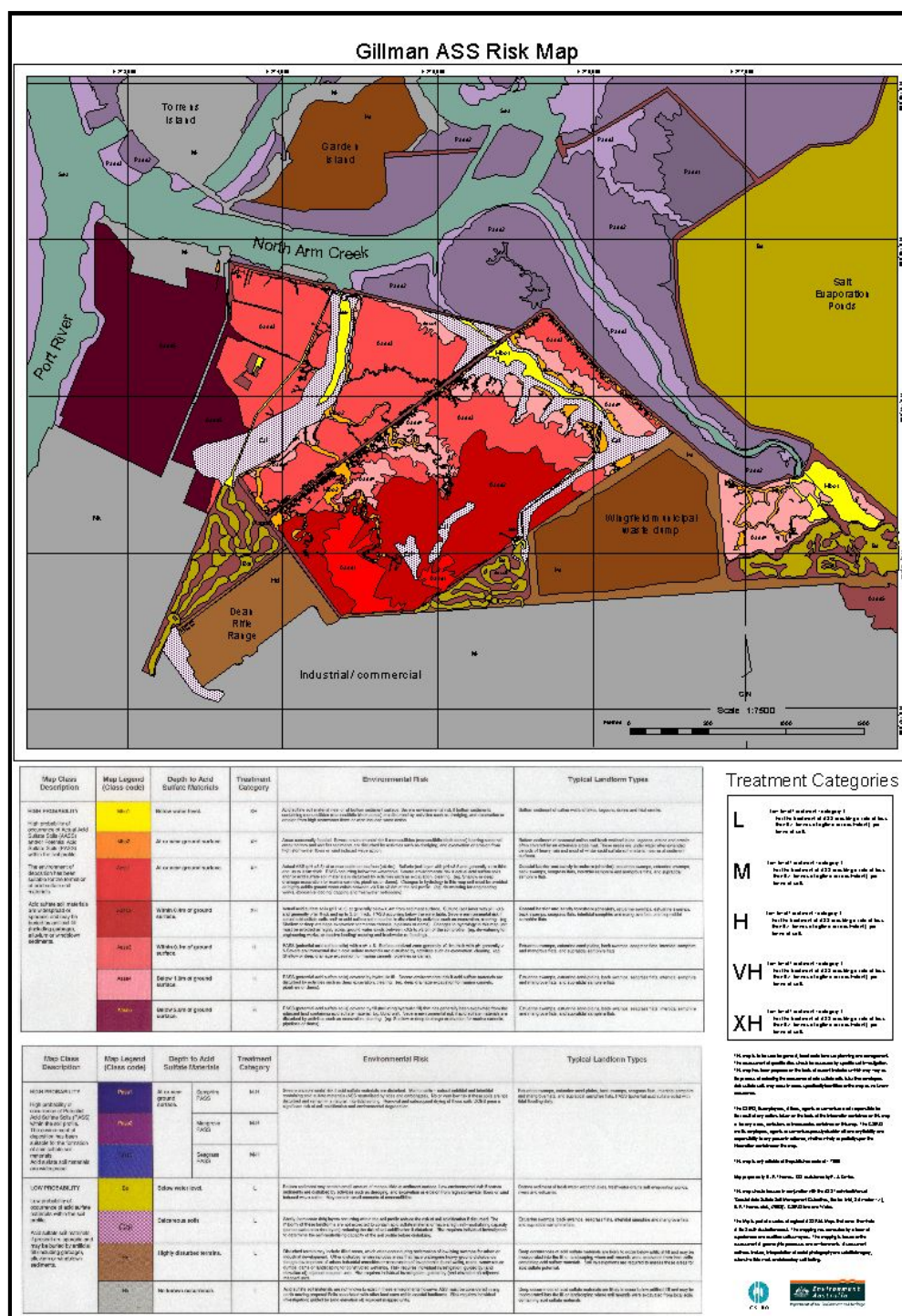


Figure 3: A detailed 1:7,500 scale ASS risk map shows the range and distribution of soil types found in the Gillman area. Red colours are various actual ASS with sulfuric horizons with underlying sulfidic material. Purple colours are various soils containing sulfidic materials with no sulfuric horizons (PASS). Not to scale.

The map legend in Figure 3 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 (e.g., Belperio & Rice 1989). The 14 mapping units (outlined in the legend) are allocated an ASS risk class (likelihood/ease of ASS disturbance) and corresponding treatment category (equivalent to tonnes (t) of pure, fine agricultural lime, CaCO_3 , required to fully treat the total weight/volume of disturbed ASS). Finally, management and remediation strategies have also been assigned to each mapping unit, based on experimental data from remediation trials.

MANAGEMENT STRATEGIES FOR ASS IN BARKER INLET

Before development in coastal areas can take place, the developer must first: (i) assess the risk associated with ASS disturbance through a thorough ASS investigation; (ii) prepare a long-term ASS management plan; (iii) conduct a field trials of remediation techniques at the site; and, (iv) develop contingency plans in case of complications (Ahern *et al.* 1998, 2000). Successful management of ASS depends on the results of the ASS investigation. Results from the investigation determine the most appropriate management strategies for a site. Such an investigation would need to provide information on: the environmental setting; location of and depth to ASS; existing and potential acidity present in the soil; and, soil characteristics. Consequently, we have developed the following staged approach, based on Dear *et al.* (2002), to assist developers make ASS risk assessments:

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)

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 'XH', 'H' or 'M-H' treatment category (Extremely High, High and Medium to High treatment category) or within 500 m of 'M' treatment category, i.e., in treatment category 'L' (Low treatment category), it can be assumed that coastal ASS are not present. However, if the works are located within classes 'Mbo' (mono-sulfidic black ooze), 'Aass' (actual acid sulfate soil) or 'Pass', or within 500 m of these classes, 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

The investigation should include a field inspection to consider soil and surface and subsurface water characteristics, and if necessary, a limited ground water analysis. Many of the indicators for actual and potential ASS are quite different, so the field inspection should investigate for the presence of both soil materials.

Remediation options

Basic principles of ASS remediation are to:

- avoid or minimise disturbing sulfidic materials;
- contain acidic leachate within soil profile using barriers;
- neutralise acidity and at the same time manage the movement/discharge of toxic oxidation products; and,
- 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), (Thomas *et al* 2003):

1. Re-flooding:
 - a. Seawater re-flooding (neutralisation);
 - b. Water table management (containment and neutralisation); and,
 - c. Freshwater wetlands (neutralisation and dilution).
2. Bioremediation (neutralisation and containment);
3. Lime slotting (chemical neutralisation); and,
4. Leaching/aging (requires chemical neutralisation).

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 Gillman and Barker Inlet area.

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