3.2 Hazard Identification - Acid sulfate soils

The following sections provide insight into the identification of acid sulfate soils (ASS). They describe the origins of ASS, distribution throughout Australia, Victoria and known examples within the Corangamite Catchment Management Authority (CCMA) region.

Information has been assembled from a number of various sources from around Australia. These sources of information are duly recognised and acknowledged at the start of each section.

3.2.1 What are Acid Sulfate Soils?


Introduction

Acid sulfate soils are the common name given to soils containing iron sulfides. In Australia, the acid sulfate soils of most concern are those which formed within the past 10,000 years, after the last major sea level rise.

Iron sulfide formation and oxidation

During the last major sea level rise new coastal landscapes formed through rapid sedimentation. Bacteria in these organically rich, waterlogged sediments converted sulfate from tidal waters, and iron from the sediments, to iron disulfide (iron pyrite). When exposed to air, iron sulfides oxidise and produce sulfuric acid, hence the name acid sulfate soils.

Potential acid sulfate soils

The iron sulfides are contained in a layer of waterlogged soil. This layer can be clay, loam or sand, and is usually dark grey and soft. The water prevents oxygen in the air reacting with the iron sulfides. This layer is commonly known as potential acid sulfate soil (PASS) because it has the potential to oxidise to sulfuric acid.

Actual acid sulfate soils

When the iron sulfides are exposed to air and produce sulfuric acid, they are known as actual acid sulfate soils. The soil itself can neutralise some of the sulfuric acid. The remaining acid moves through the soil, acidifying soil water, groundwater and, eventually, surface waters.

Fig. 3.1: This soil pit shows both potential and actual acid sulfate soils together. The wet grey mud at the bottom of the pit is the iron sulfide layer. The mottled yellow layer above the wet mud is actual acid sulfate soil. The yellow colour is jarosite, a sulphur mineral. Its presence shows that the iron sulfides are oxidising and forming sulfuric acid. The oxidation has occurred because the watertable has dropped and exposed the top section of the iron sulfide layer to air.

Fig. 3.2: Actual acid sulfate soils showing yellow streaks and mottling patterns containing jarosite (pH <4) in the grey subsoil.

Fig. 3.3: Potential acid sulfate soils showing dark sulfidic material (pH 7).
3.2.2 Location of Coastal Acid Sulfate Soils in Australia


Iron sulfide layers were formed under tidal conditions, so they are found mostly, but not exclusively, in low-lying areas near the coast. They are still being formed today in mangrove forests and salt marshes, estuaries and tidal lakes. In general, we expect to find iron sulfide layers where the surface elevation is less than five metres above mean sea level.

In Australia, iron sulfide layers are found along the coastlines of the Northern Territory, Queensland and New South Wales. They are also found along the northern coastline of Western Australia, and around Perth, Adelaide and Westernport Bay near Melbourne. Scientists have estimated that there are more than two million hectares of acid sulfate soils in Australia containing about one billion tonnes of iron sulfides. One tonne of iron sulfides can produce about 1.5 tonnes of sulfuric acid when oxidised.

Under natural conditions, iron sulfide layers are covered by water and colonised by native vegetation, as shown above. Any acid produced is usually neutralised by the tidal flows of alkaline sea water. The rest of the acid remains in the soil. In severe droughts, plant roots can take up so much of the water in the soil that the water table drops and exposes the iron sulfide layer to air. When this occurs, acid is generated and, in floods following dry periods, some acid can be released into streams. 

Areas where iron sulfide layers occur are waterlogged and often drained for agriculture. Drainage and excavation of these areas expose the iron sulfide layers to air. Drainage greatly accelerates the natural rate of oxidation, so that large slugs of acid groundwater are released rapidly into estuarine streams. The concentrated acid can overwhelm the stream’s capacity to neutralise it. The acid can then affect the health of fish and other organisms.

When drains are dug in the iron sulfide layer, excavated heaps of iron sulfide muds are often left beside the drain as shown above. This drain spoil oxidises it produces acid, a process which can continue for many years. The acid makes it difficult for plants to grow on the spoil; when it rains, the acid leaches into the drain water. The problems associated with drainage of acid sulfate soils mean that drainage works need to be undertaken with extreme caution and in consultation with relevant authorities.

In some areas of Australia, acid sulfate soils drained 100 years ago are still releasing acid. In clay soils, the oxidation process is very slow, possibly taking centuries, because it is difficult for air to circulate in the clay. Oxidation of sandy materials can be quite rapid, sometimes taking less than a year, and in some situations, only weeks or months because of good air circulation within the soil.
### 3.2.3 Extent of Acid Sulfate Soils in Victoria


ASS in Victoria is observed to occur in a range of soil textures, from loamy sands to light clays and heavier.

The study by Rampant et al (2003) focused on the occurrence of ASS in close proximity to the Victorian coast (Figure 3.8), with some exclusions (mangroves). The area of ASS above the high water line was estimated to be approximately 55,000 ha. In comparison with New South Wales and Queensland, this is a relatively small area of land.

**Distribution of acid sulfate soils in Victoria**

The estimated coastal areas with ASS for each catchment management authority (CMA) region and shire are shown in Tables 3.1 and 3.2 respectively. The West Gippsland CMA region has the highest area, followed by Corangamite CMA and then Port Phillip CMA regions (Table 3.1). About one-quarter of this area is on public land. Shires with the highest areas of ASS are Wellington and Greater Geelong City, each with 3-4 times the area of ASS of the shires of South Gippsland, Moyne, Wyndham, East Gippsland and Glenelg (Table 3.2).

<table>
<thead>
<tr>
<th>CMA region area</th>
<th>Private land (ha)</th>
<th>Public land (ha)</th>
<th>Total land (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corangamite</td>
<td>9,614</td>
<td>4,231</td>
<td>13,845</td>
</tr>
<tr>
<td>East Gippsland</td>
<td>1,723</td>
<td>928</td>
<td>2,651</td>
</tr>
<tr>
<td>Glenelg</td>
<td>5,850</td>
<td>1,256</td>
<td>7,106</td>
</tr>
<tr>
<td>West Gippsland</td>
<td>14,305</td>
<td>5,361</td>
<td>19,666</td>
</tr>
</tbody>
</table>

**Table 3.1: Extent of Acid sulfate soils within each CMA region**

<table>
<thead>
<tr>
<th>Shire</th>
<th>Private land (ha)</th>
<th>Public land (ha)</th>
<th>Total land (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bass Coast</td>
<td>1,335</td>
<td>599</td>
<td>1,934</td>
</tr>
<tr>
<td>Bayside City</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cardinia City</td>
<td>975</td>
<td>58</td>
<td>1,033</td>
</tr>
<tr>
<td>Casey City</td>
<td>1,685</td>
<td>214</td>
<td>1,899</td>
</tr>
<tr>
<td>Colac Otway</td>
<td>815</td>
<td>516</td>
<td>1,331</td>
</tr>
<tr>
<td>Corangamite</td>
<td>858</td>
<td>523</td>
<td>1,381</td>
</tr>
<tr>
<td>East Gippsland</td>
<td>1,505</td>
<td>1,110</td>
<td>2,615</td>
</tr>
<tr>
<td>Frankston City</td>
<td>324</td>
<td>-</td>
<td>324</td>
</tr>
<tr>
<td>Glenelg</td>
<td>1,938</td>
<td>602</td>
<td>2,540</td>
</tr>
<tr>
<td>Greater Dandenong City</td>
<td>119</td>
<td>-119</td>
<td>-</td>
</tr>
<tr>
<td>Greater Geelong City</td>
<td>8,305</td>
<td>3,440</td>
<td>11,745</td>
</tr>
<tr>
<td>Hobson Bay City</td>
<td>764</td>
<td>260</td>
<td>1,024</td>
</tr>
<tr>
<td>Kingston City</td>
<td>1,726</td>
<td>-</td>
<td>1,726</td>
</tr>
<tr>
<td>Mornington Peninsula</td>
<td>22</td>
<td>25</td>
<td>47</td>
</tr>
<tr>
<td>Moyne</td>
<td>3,889</td>
<td>572</td>
<td>4,461</td>
</tr>
<tr>
<td>Queenscliffe Borough</td>
<td>109</td>
<td>36</td>
<td>145</td>
</tr>
<tr>
<td>South Gippsland</td>
<td>3,946</td>
<td>636</td>
<td>4,582</td>
</tr>
<tr>
<td>Surf Coast</td>
<td>426</td>
<td>56</td>
<td>482</td>
</tr>
<tr>
<td>Warrnambool City</td>
<td>391</td>
<td>199</td>
<td>590</td>
</tr>
<tr>
<td>Wellington</td>
<td>9,698</td>
<td>4,257</td>
<td>13,954</td>
</tr>
<tr>
<td>Wyndham City</td>
<td>2,937</td>
<td>24</td>
<td>2,961</td>
</tr>
</tbody>
</table>

**Table 3.2: Extent of Acid sulfate soils within local government areas (shires)**

![Fig. 3.8: Indicative coastal Acid sulfate soils distribution in Victoria](image)
Coastal Acid Sulfate Soil Hazard

Fig. 3.9: Areas where coastal potential acid sulfate soils may be found in Victoria

Acid Sulfate Soil

- No acid sulfate soils
- Shallow: Low acid sulfate soils
- Shallow: Moderate acid sulfate soils
- Shallow: High acid sulfate soils
- Deep: Low acid sulfate soils
- Deep: Moderate acid sulfate soils
- Deep: High acid sulfate soils

Estimated extent of probable acid sulfate soils

Legend

- Freeway
- Major roads
- Watercourses
- Contours
- Waterbodies
- Public land
- 1:100,000 map title
- Catchment management authority boundaries

Local government areas

- Bayside
- Golden Plains
- Greater Geelong
- Kingston
- Mornington Peninsula
- Queenscliff
- Surf Coast
- Wyndham

Fig. 3.10: Potential acid sulfate soils found in City of Greater Geelong by CSIRO in 2005
ACID SULFATE SOILS - HAZARD IDENTIFICATION

Acid Sulfate Soil

- No acid sulfate soils
- Shallower than 1m
  - Low acid sulfate soils
  - Moderate acid sulfate soils
  - High acid sulfate soils
- Deeper than 1m
  - Low acid sulfate soils
  - Moderate acid sulfate soils
  - High acid sulfate soils
- Estimated extent of probable acid sulfate soils

Legend

- Freeway
- Major roads
- Watercourses
- Contours
- Waterbodies
- Public land
- 1:100,000 map title
- Catchment management authority boundaries

Local government areas

- Colac Otway
- Corangamite
- Glenelg
- Moyne
- Golden Plains
- Surf Coast
- Warrnambool

Fig. 3.11: Potential acid sulfate soils identification across south west Victoria
3.2.4 Known Extents in the Corangamite CMA Region

Source: CSIRO (Cox et al 2007) Scoping study of coastal and inland acid sulfate soils in the Corangamite CMA

CSIRO Land and Water undertook a reconnaissance study of coastal and inland acid sulfate soils within the Corangamite Catchment Management Authority region. The subsequent report presented information on the nature, distribution, impacts, management and remediation of acid sulfate soils in this region.

It summarised factors generally associated with formation of pyrite and sulfuric acid in these reactive soils and the key impacts this has on a wide range of environments. The specific objectives of the study were:

- to assess the extent and severity of coastal acid sulfate soils to determine if the current zoning along the coast within the Corangamite Catchment Management Authority region is sufficient to prevent problems from acid sulfate soils and potential acid sulfate soils (from development); and
- to assess the extent and severity of inland acid sulfate soils to determine if the current zoning within the Corangamite Catchment Management Authority region is sufficient to prevent problems from acid sulfate soils and potential acid sulfate soils (from development).

Soils from 29 sites were inspected and 109 soil samples collected and characterised using morphological descriptors and physical properties such as colour, consistency, structure and texture. Eighty-five samples were selected for basic laboratory analyses such as soil pH, electrical conductivity (1:5 soil:water) and peroxide pH, and fifty-nine samples selected for detailed analyses including:

- chromium reducible sulfur, carbonate content and acid-base accounting;
- mineralogical analyses i.e. powder X-ray diffraction and scanning electron microscopy; and
- geochemical analyses using X-ray fluorescence spectroscopy.

A wide range of acid sulphate soil types containing sulfidic materials (pH > 4 with pyrites) are currently developing in a wide range of landscapes in the Corangamite Catchment Management Authority region, often in association with areas undergoing salinisation. No actual acid sulfate soil was identified. However, the Princetown area has concentrations of reduced inorganic sulfur that are some of the highest recorded in Australia and these represent an extreme acid sulfate soil risk. Additionally, levels of trace metals and metalloids were found and their ecotoxicity needs to be assessed. Oxidation of sulfidic materials and monosulfidic black ooze following the lowering of water tables or soil disturbance is contributing to degraded saline seepages and poor stream water quality. The methodology used helped verify the acid sulfate soil risk classes, develop treatment categories and recommend management options.

Conclusions-Key findings

1. No actual acid sulfate soils were identified at either inland or coastal sites. All soil samples tested had a pH > 4 throughout the profile.

2. Potential ASS were identified at 10 sites and these present an ASS hazard ranging from moderate to severe:
   - Peroxide pH indicated that, although many of the soil samples contain sulfidic material, most samples have a high acid neutralising capacity. We sampled 17 areas and examined 29 profiles and tested eighty soil samples. The pHFOX of 32 samples in 9 areas fell below 5.0, displaying a tendency to form actual acid sulfate soil if excavated.
   - Chromium Reducible Sulfur analysis (SCr) indicated that all samples from all areas exceeded the acid sulfate soil action criteria proposed by Dear et al., (2002).
   - Carbonate content of most soil samples was very high. The highest values (> 20%) were in shelly soil horizons in the intertidal areas around Corio Bay.
   - Acid Base Accounting identified 25 soil samples with a positive Net Acid Generating Potential (i.e. they do not contain sufficient neutralising material to buffer the acid that they could potentially produce). Apart from Merrigig Creek, these samples were from coastal areas influenced by (Holocene) marine conditions.

3. Compared with ANZECC interim sediment quality standards, elevated trace metal(loid) concentrations were identified at all sites (Cr, Ni and As). In these circumstances the ANZECC Guidelines recommend further investigation to determine background levels and availability of the metals.

4. The Princetown area has concentrations of RIS that are some of the highest recorded in Australia and these represent and extreme ASS risk. Table 3.2 lists sites against ASS type, provides the soil classification, assess ASS risk against the infrastructure and environmental elements at risk and provides management recommendations.

![Fig. 3.12: Sampling site locations of potential acid sulfate soils taken across the Corangamite region by CSIRO study carried out in 2006](image-url)
<table>
<thead>
<tr>
<th>Acid sulfate soils type</th>
<th>SLU</th>
<th>Location</th>
<th>Site No’s</th>
<th>Soil Classification</th>
<th>Impacted Element</th>
<th>Risk Class</th>
<th>Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfidic material in inland streams, swamps and depressions</td>
<td>156</td>
<td>Derrinallum</td>
<td>COR1</td>
<td>Aquic Epipedal Sulfidic or Episodic Vertosol</td>
<td>L-M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>190</td>
<td>Meringig Creek</td>
<td>COR9</td>
<td>Melanic Sulfidic Hypersalic Rudosol</td>
<td>H</td>
<td>H</td>
<td>M</td>
</tr>
<tr>
<td>Sulfidic material in inland saline lakes</td>
<td>153, 146</td>
<td>Lake Gnpurt</td>
<td>COR2, 2</td>
<td>Hypersalic Sulfidic Gypsic Hydrosoil</td>
<td>M</td>
<td>L</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>153</td>
<td>Lake Corangamite, Cundare Barrage channel</td>
<td>COR4, 5, 6, 7</td>
<td>Hypersalic Sulfidic Gypsic Hydrosoil</td>
<td>H</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Sulfidic material in coastal swamps and depressions</td>
<td>200</td>
<td>Reedy Lake, Lake Connewarre</td>
<td>COR10, 11</td>
<td>Melanic Sulfidic Redoxic Hydrosoil</td>
<td>M</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td></td>
<td>200</td>
<td>Hospital Swamp, Lake Connewarre</td>
<td>COR12, 13, 14</td>
<td>Sulfidic Redoxic Hydrosoil</td>
<td>H</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>Sulfidic material in upper 1m in supratidal flats often with samphires</td>
<td>205</td>
<td>Point Henry Salt Marsh (Samphire)</td>
<td>COR15, 17</td>
<td>Natric or Sulfidic Calcarosolic Supratidal Hydrosoil</td>
<td>L-M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>205</td>
<td>Avalon</td>
<td>COR23, 24</td>
<td>Basic Sulfidic or Stratric Rudosol</td>
<td>L-M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Sulfidic material in upper 1m in intertidal flats</td>
<td>194</td>
<td>Beach</td>
<td>COR19, 20</td>
<td>Natric Sulfidic Intertidal Hydrosoil</td>
<td>M-H?</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Sulfidic material in upper 1m in estuarine channels and intertidal salt marsh</td>
<td>200</td>
<td>Breamlea</td>
<td>COR8</td>
<td>Hemic Sulfidic Supratidal Hydrosoil</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td>Sulfidic material in constructed wetlands</td>
<td>205</td>
<td>Point Henry Constructed wetland</td>
<td>COR16</td>
<td>Natric or Sulfidic Calcarosolic Extratidal Hydrosoil</td>
<td>L</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>Sulfidic material buried below fill materials</td>
<td>194</td>
<td>Drysdale (“Marina” embankment)</td>
<td>COR18</td>
<td>Natric Sulfidic Intertidal Hydrosoil</td>
<td>H</td>
<td>H</td>
<td>?</td>
</tr>
<tr>
<td>Sulfidic material in sandplains and dunes</td>
<td>199</td>
<td>Point Lonsdale</td>
<td>COR21</td>
<td>Shelly Salic Hydrosoil</td>
<td>M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>199</td>
<td>Point Lonsdale</td>
<td>COR22</td>
<td>Shelly or Sulfidic Salic Hydrosoil</td>
<td>M</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td></td>
<td>96</td>
<td>Aire River</td>
<td>COR26, 27</td>
<td>Histic-Sulfidic Extratidal Hydrosoil</td>
<td>H</td>
<td>H</td>
<td>H</td>
</tr>
<tr>
<td></td>
<td>96</td>
<td>Princetown Swamp, Gelibrand River</td>
<td>COR28, 29</td>
<td>Histic-Sulfidic Intertidal Hydrosoil</td>
<td>VH</td>
<td>VH</td>
<td>VH</td>
</tr>
</tbody>
</table>

Table 3.3: Acid sulfate soils type, location, classification, risk class and management
Case Study of Acid sulfate soils in the City of Greater Geelong

Source: CSIRO (Cox et al 2005) Investigations into the potential risk of Acid Sulfate soils on proposed development in the City of Greater Geelong.

Based on previous work, including a very good review by the Centre for Land Protection Research of Victorian Department of Primary Industries, a total of 11,745 ha of acid sulfate soils were reported within Greater Geelong City, ranking it as the second greatest for extent of acid sulfate soils of all shires in Victoria.

This study was commenced to identify the potential for acid sulfate soils to have an impact on future development in the City of Greater Geelong and to determine if a major study of acid sulfate soils was warranted. Thus a desktop study was commenced to develop a series of overlays of the spatial distribution of specific parameters that the literature said were needed for potential acid sulfate soil development (e.g. low lying areas). From this an overlay was developed which predicted possible acid sulfate soil distribution within the City of Greater Geelong. This information was overlain by the planning zones. Twelve sites were then chosen for investigation where it was thought that acid sulfate soils may have an impact on future development in the City of Greater Geelong.

Soil samples to analyse for acid sulfate soils within the laboratory were only collected at three of the sites. The others were discounted as either there was no visible evidence of acid sulfate soils or acid sulfate sites within the area were confined to areas that were obvious wetland and zoned “Public Conservation and Resource”. The only exception to this were sites at Avalon (AV02) and Point Henry (PH02). Prior to any development, these areas must be sampled for potential acid sulfate soils as their disturbance could lead to the development of sulfuric acid.

Conclusions

Although ASS are found throughout the City of Greater Geelong, they are mostly confined to Public Conservation and Resource areas. Exceptions to this were the sites of a disused salt evaporation pond at Avalon (AV02) and tidal flat adjacent to the smelting plant at Point Henry (PH02).

The site at Avalon has potential to produce foul odours, if it were ever redeveloped, due to the high SCR of the soil. However, the large ANC of the soil should guard against issues of acidification, should the site be disturbed through excavation.

The site at Point Henry was the only one tested which had any acid sulfate soil potential and this was considered marginal at most. A total element analysis of sediments from this site (found in Appendix 3 of the report), supports previous findings of soil pollution from the nearby smelting operation.
3.2.5 Desk Top Recognition

It is unlikely that on-ground staff will have any great opportunity to carry out significant scoping studies prior to works commencing. However, the following section briefly describes a two step process that has been developed in NSW for assessment of the potential presence of ASS prior to field work.


A two step process as follows, can be employed prior to any field work if the presence of acid sulfate soils is suspected

**Step 1:** Check the acid sulfate soils maps.
- each state has a series of published acid sulfate soil hazard maps. For Victoria, consult the DPI maps produced by Rampant et al in 2003.

**Step 2:** Check to see if the area meets the geomorphic or site criteria.

The following geomorphic or site criteria should be used to determine if acid sulfate soils are likely to be present:
- sediments of recent geological age (Holocene i.e. last 10,000 years)
- soil horizons less than 5 m AHD
- marine or estuarine sediments and tidal lakes
- in coastal wetlands or back swamp areas: waterlogged or scalded areas: interdunes swales or coastal sand dunes (if deep excavation or drainage proposed)
- in areas where the dominant vegetation is mangroves, reeds, rushes, and other swamp tolerant or marine vegetation such as swamp mahogany (Eucalyptus robusta), paperbark (Melaleuca quinquenervia) and swamp oak (Casuarina glauca)
- in areas identified in geological descriptions or in maps as bearing sulfides minerals, coal deposits, or former marine shales/sediments (geological maps and accompanying descriptions may need to be checked)
- deep older estuarine sediments >10 metres below ground surface, Holocene or Pleistocene age (only an issue if deep excavation is proposed).

3.2.6 Field Recognition

Recognition of both actual and potential ASS in the field is seen as the most important function for on-ground staff engaged in works programs in areas containing ASS. The following section provides assistance in visually identifying ASS as well as providing advice on other key indicators which can be used to identify ASS in the field such as pH, water characteristics, vegetation distress and infrastructure damage.

**Visual Recognition**


**Recognition**

It is useful to know what the iron sulfide layer looks like so that if it is uncovered accidentally it can be re-covered with water immediately. The photograph below shows excavated iron sulfide soil – dark grey and wet. It is also important to be able to recognise indicators of actual acid sulfate soils to prevent further acidification of land and waterways. These indicators include the cloudy green-blue water, excessively clear water, iron stains, poor pasture, scalded soil, and yellow jarosite.

**Identifying and characterising Acid sulfate soils**

Although a plethora of complex terminology and standards has evolved in the literature in relation to acid sulfate soils, in this report these have been simplified to the following two concepts:
- Actual acid sulfate material (i.e. sulfuric horizon) is a coastal sedimentary material that once contained iron pyrites, and may still contain some, but which has been exposed to the atmosphere by drainage or disturbance so that the pyrite has oxidised to form sulfuric acid, thereby decreasing the pH of the soil to less than 3.5. This material is also characterised by bright yellow or straw-coloured mottles of the mineral jarosite and often contain dark reddish-coloured streaks of iron oxide
- Potential acid sulfate material (i.e. sulfidic material) is a coastal sedimentary material that contains iron pyrites that have not been oxidised. Consequently, the pH is usually near neutral (approximately 7).

A key to recognising these materials is presented in Figure 3.16, and the conditions used by Soil Taxonomy (Soil Survey Staff 1999) to identify them are presented in Box 1. The chemical and biochemical processes that occur in soils, leading to the formation of acid and various characteristic minerals, are not simple. Outlines of these are given in Table 3.4.
The following key can be used to help identify and classify “actual acid sulfate” and “potential acid sulfate” materials:

**Is pH 3.5 or less?**
(1:1 by weight of soil in water, or in a minimum of water to permit measurement)

**OR**
are bright yellow jarosite mottles present?

**Is pH between 4 and 6 on ageing soil for 8 weeks?**
(Ie. pH shows a drop of more than 0.5 pH unit to pH of 4 or less in 1:1 by weight of soil in water, or in a minimum of water to permit measurement)

**AND**

is n-value >1?

is total S > 2%?

---

**Actual Acid Sulfate Soil material (sulfuric horizon)**

**Potential Acid Sulfate Soil material (highly reactive) (sulfidic material)**

**Potential Acid Sulfate Soil material (slightly reactive)**

No acid sulfate or potential acid sulfate material present, or sufficient neutralising material (usually shell or calcium carbonate) is present to maintain a high pH.

*Fig. 3.16: A key for identification of acid sulfate soil materials*
Soil Survey Staff (1999) requires the following conditions for identifying a sulfuric horizon or acid sulfate material

- 15cm or more thick
- samples are identified as having sulfuric horizons (or acid sulfate properties) if the pH is **3.5 or less** (1:1 by weight in water, or in a minimum of water to permit measurement) and shows evidence that the low pH is caused by sulfuric acid. The evidence is one or more of the following:
  - jarosite concentrations, or
  - directly underlying sulfidic materials (defined below), or
  - 0.05% or more water-soluble sulfate.

Soil Survey Staff (1999) requires the following conditions for identifying sulfidic material or potential acid sulfate material (pH decrease after ageing in laboratory)

- sample to be kept moist (field capacity) as a layer 1cm thick, while maintaining contact with the air at room temperature
- after two weeks, a 4g sub-sample is extracted with 4mL water and the pH determined (i.e. 1:1 by weight of soil in water, or in a minimum of water to permit measurement)
- samples are identified as having sulfidic materials (or potentially acid sulfate properties) if the pH on ageing for 8 weeks shows a drop more than **0.5 pH unit or more, to a pH value of 4.0 or less**.

Box 1: Soil Taxonomy conditions for identifying sulfuric horizons and sulfidic material
### Soil Type

#### Potential Acid Sulfate Soil (PASS)

**Soil characteristics**
- waterlogged soils - unripe muds (soft, sticky and can be squeezed between fingers, blue grey or dark greenish grey mud with a high water content), silty sands or sands (mid to dark grey) or bottom sediments (dark grey to black eg. iron monosulfides “black oozes”) possibly exposed at sides and bottom of drains or cuttings, or in boreholes
- peat or peaty soils
- coffee rock horizons
- a sulfurous smell e.g. hydrogen sulfide or ‘rotten egg’ gas.

**Water characteristics**
- waterlogged soils
- water pH usually neutral but may be acidic
- oily-looking iron bacterial surface scum (the similar appearances of iron bacterial scum and a hydrocarbon slick can be differentiated by disturbing the surface with a stick: bacterial scum will separate if agitated whereas a hydrocarbon slick will adhere to the stick upon removal.)

**Vegetation characteristics**
- dominant vegetation is tolerant of salt, acid and/or waterlogging conditions e.g. mangroves, saltcouch, *Phragmites* (a tall acid tolerant grass species), swamp-tolerant reeds, rushes, paperbarks (*Melaleuca* spp.) and swamp oak (*Casuarina* spp.).

**Soil characteristics**
- presence of corroded shell
- sulfurous smell e.g. hydrogen sulfide or ‘rotten egg’ gas
- any jarositic horizons or substantial iron oxide mottling in surface encrustations or in any material dredged or excavated and left exposed.

**Water characteristics**
- water of pH <5.5 (and particularly below 4.5) in surface water bodies, drains or groundwater (this is not a definitive indicator as organic acids may contribute to low pH in some environments such as *Melaleuca* swamps)
- unusually clear or milky blue-green water flowing from or within the area (aluminium released by ASS acts as a flocculating agent)
- extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits
- oily looking bacterial surface scum (differentiated from a hydrocarbon slick of similar appearance as described for PASS).

**Vegetation characteristics**
- dead, dying, stunted vegetation*
- scalded or bare low-lying areas*
- poor vegetation regrowth in previously disturbed areas

**Vegetation characteristics**
- corrosion of concrete and/or steel structures* (including foundations, fences, masonry/brick walls, pipes).

* May also be due to excessive salinity or to salinity in combination with AASS.

#### Actual Acid Sulfate Soil (AASS)

**Soil characteristics**
- presence of corroded shell
- sulfurous smell e.g. hydrogen sulfide or ‘rotten egg’ gas
- any jarositic horizons or substantial iron oxide mottling in surface encrustations or in any material dredged or excavated and left exposed.

**Water characteristics**
- water of pH <5.5 (and particularly below 4.5) in surface water bodies, drains or groundwater (this is not a definitive indicator as organic acids may contribute to low pH in some environments such as *Melaleuca* swamps)
- unusually clear or milky blue-green water flowing from or within the area (aluminium released by ASS acts as a flocculating agent)
- extensive iron stains on any drain or pond surfaces, or iron-stained water and ochre deposits
- oily looking bacterial surface scum (differentiated from a hydrocarbon slick of similar appearance as described for PASS).

**Vegetation characteristics**
- dead, dying, stunted vegetation*
- scalded or bare low-lying areas*
- poor vegetation regrowth in previously disturbed areas

**Vegetation characteristics**
- corrosion of concrete and/or steel structures* (including foundations, fences, masonry/brick walls, pipes).

* May also be due to excessive salinity or to salinity in combination with AASS.

> Often AASS will directly overlay PASS, with the fluctuating watertable level marking the boundary between the two units.