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CHAPTER 2

ATLAS OF AUSTRALIAN ACID SULFATE SOILS

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SUMMARY

The Atlas of Australian Acid Sulfate Soils (ASS) is a new web-based hazard assessment tool with a nationally consistent legend, which provides information about the distribution and properties of ASS across Australia. This tool is available on ASRIS (Australian Soil Resource Information System: www.asris.gov.au) and every polygon or mapping unit is attributed with information pertaining to: (i) 4 classes of "probability of occurrence", (ii) 4 levels of confidence relating to the quality of data source, and (iii) 10 additional descriptors such as desiccation cracks. The Atlas is a constantly evolving national map of available ASS information, which also includes priority case studies at a range of localities across Australia. (e.g. http://www.clw.csiro.au/acidsulfatesoils/index.html).

In Australia, ASS occupy an estimated 215,000 km^2 of which 58,000 km^2 is coastal ASS and 157,000 km^2 is inland ASS. In the coastal zone 41,000 km^2 are exposed at some point during the tidal cycle with the remaining 17,000 km^2 being permanently subaqueous. Finally, 126 km^2 of ASS with sulfuric material has been mapped.

The Atlas of Australian ASS has been utilised as a basis to:

- Assist in the development a robust national framework to estimate and predict occurrence of inland and coastal ASS in Australia
- Support and enhance implementation of the National ASS Management Strategy (www.deh.gov.au/coasts/cass/index.html, which aims to avoid disturbance of all types of ASS
- Assist the successful adoption of land and water management options
- Assist the development of a nationally consistent ASS policy framework across Australia

HOW THE ATLAS OF AUSTRALIAN ASS WAS PUT TOGETHER

The Atlas of Australian ASS project was developed under the auspices of the National Committee for Acid Sulfate Soils (NatCASS) and completed by CSIRO Land and Water with assistance from staff in all states throughout Australia. The ASS qualification was inferred from surrogate datasets. The ASS Atlas was put together in two parts using two different methodologies and classification paths. First the Atlas of "Coastal" ASS was compiled using existing state ASS mapping and other datasets that mapped landscape indicators of ASS environments, e.g. coastal vegetation mapping. At a later stage, the interior of the Australian continent was back-filled with "Inland" ASS mapping, inferred from broader and coarser scale national soil and hydrography mapping. The result of these two exercises were combined to form the current Australian ASS Atlas.

The "Coastal" ASS component

Existing Coastal Acid Sulfate Soil mapping from states were received and processed to varying degrees to conform to the Atlas of Australian ASS classification system (see Appendix A). Classification of state mapping polygons to the NatCASS classification system was as follows: In the case of SA, NSW, Qld and WA the original state ASS classifications were directly translated to the Atlas of Australian ASS classification. These translations were undertaken by the creators of the state data and other experts within the respective states.

Due to the more broad classifications of the original Victoria and Tasmania ASS mapping, polygons for these two states were initially translated to a broad Atlas of Australian ASS classification group (e.g. Tidal, Non-tidal) by the data custodians then subsequently differentiated further through intersecting with other layers. These included the 3 second SRTM DEM and North Coast Mangrove mapping GIS datasets. The former being used to differentiate within the Non-Tidal zones (i.e. classes Ae-j and Be-j) and the latter used to differentiate the Tidal zones (i.e. Ab-d, Bb-d).

Mapping of the Tidal-Zone classes was augmented for all states except SA and NSW with 1:100K Coastal Waterways Geomorphic Habitat Mapping (Geoscience Australia). This dataset was used to infer additional areas of subaqueous material in subtidal wetland (class Aa & Ba) and Intertidal Flats (class Ab & Bb).

The "Inland" ASS component

Provisional inland ASS classifications were derived from National and (in the case of Tasmania) state soil classification coverages combined with 1:250K series 3 Hydrography and Multiresolution Valley Bottom Floor Index (MrVBF). A matrix devised to translate combinations of Soil Order (Isbell 1996) and landscape "wetness" to NatCASS inland ASS codes. The foundation for the inland component is very coarse, being underpinned by the Atlas of Australian Soils (1:2M scale) with "wetness" inferred from 1:250K topographic hydrography (see Appendix 2).

With ongoing field investigations and acquisition of more detailed local spatial data sets, the resolution and accuracy of the inland ASS component is being continually improved from its current, first cut "broad brush" depiction.

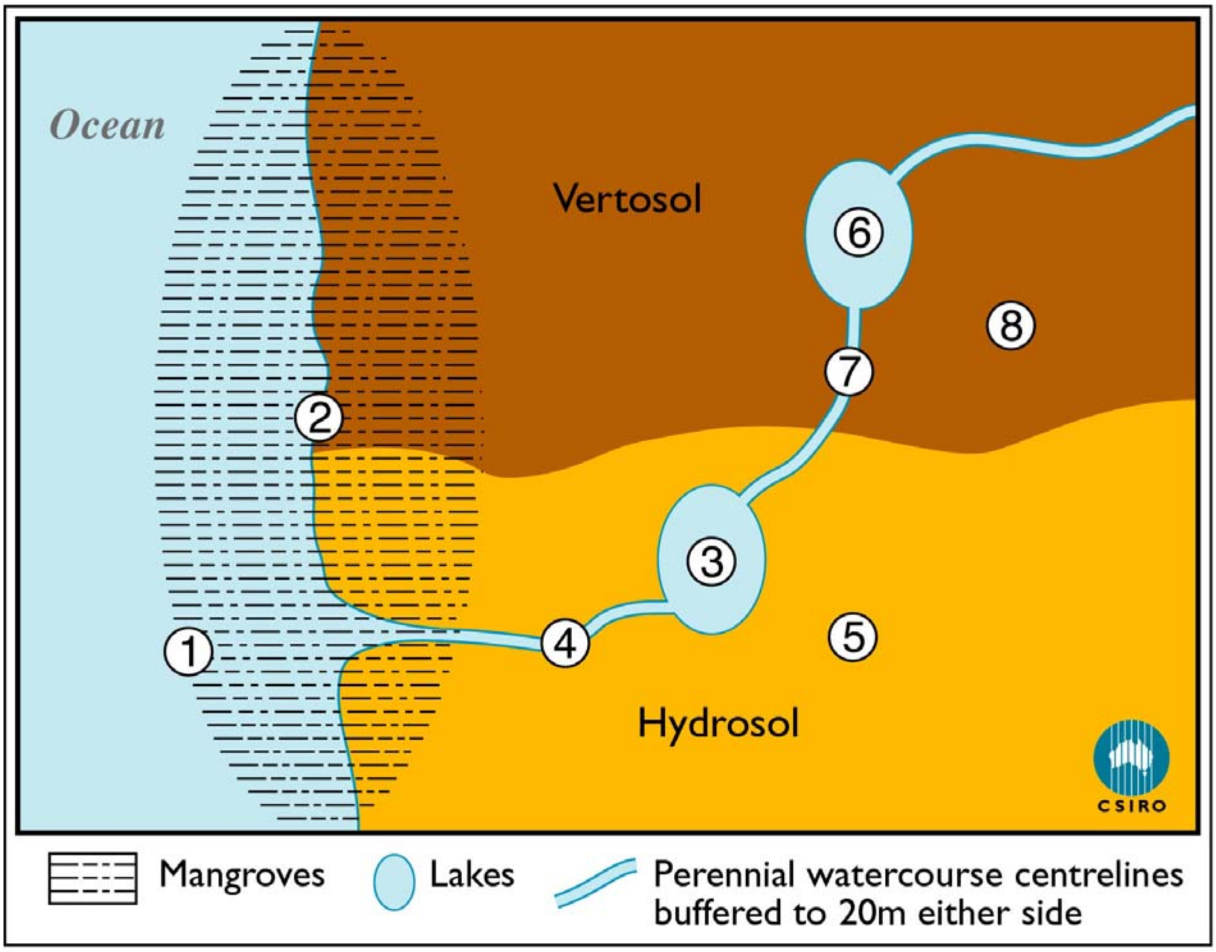

Figure 1. Examples of occurrences of different ASS. See Table 1 for explanations for map.

Table 1. Explanation of example ASS settings (from Fig 1) and how they relate to legend and areal calculations

Setting	Chance of ASS occurrence in map unit	Legend probability class	Typical extent within setting if ASS present	Map unit polygon area scaling factor
1 Subaqueous marine soils	>70%	A	100%	1.0
2 Intertidal flats	>70%	A	100%	1.0
3 Hydrosols under lakes	>70%	A	80%	0.8
4 Riparian zone hydrosols	>70%	A	10%	0.1
5 Hydrosols	>70%	A	5%	0.05
6 Vertosols under lakes	>70%	A	50%	0.5
7 Riparian zone Vertosols	5 - 70%	B	5%	0.05
8 Vertosols	<5%	C	5%	0.05

FEATURES OF THE ATLAS OF AUSTRALIAN ASS

The Australian ASS mapping project seeks to make accessible, all currently available ASS mapping and information across the whole continent presented in a uniform, highly descriptive and systematic classification system (the “Legend” - See Appendix 1). Consequently the component ASS mapping in descriptions are from disparate sources and of varying quality, accuracy and mapping scales. A principle feature of the ASS Atlas is that every polygon is attributed with information pertaining the quality of its source, confidence in the ASS classification code and scale of the mapping (Appendix 1). The Atlas has enabled estimates of the area of ASS extent to be calculated across Australia (Table 1).

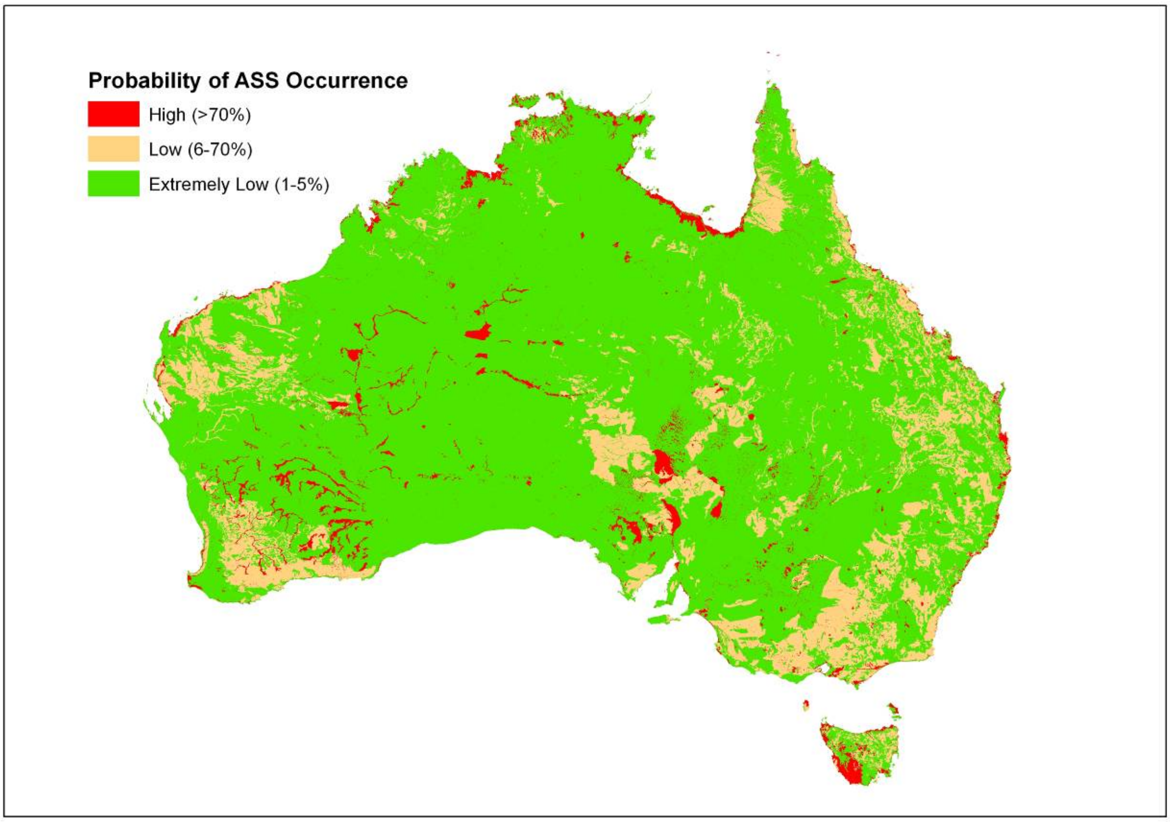

Figure 2. Map of Australian ASS. The latest mapping is disseminated live via Web served GIS facility at www.asris.csiro.au.

Of the 7,693,111 km^2 of the Australian land and offshore assessed ASS 300,528 km^2 is deemed to have a high probability of ASS occurrence and 1,106,786 km^2 deemed to have a low probability of occurrence. The remaining 6,285,797 km^2 of land and near offshore soils is rated as extremely low probability of occurrence. Scaling factors are applied to these total areas to estimate the actual extent of ASS within these landscapes. With the area scaling factors applied, there is estimated to be 154,269 km^2 of High Probability ASS and 65,771 km^2 of Low Probability ASS (Figure 2). The landscape settings where ASS is found within these High and Low Probability extents are broken down in Table 2 below.

Table 2. Area (km^2) of ASS classes in Australian landscapes with high or low probability of ASS occurrence

ASS setting	Area (km^2)
Subaqueous ASS (Marine setting)	16,930
Tidal zones	23,972
Floodplain in coastal settings	6,667
Sandplains & dunes in coastal settings	9,681
Other coastal settings	206
ASS in inland settings	157,031
Disturbed ASS	853
Within the above categories:	
Observed ASS with sulfuric material (pH <4)	126
Observed MBO (Monosulfidic black ooze)	81

APPLICATION OF ATLAS FOR AUSTRALIAN ASS LEGEND TO THE MAPPING OF ASS IN THE LOWER LAKES OF THE RIVER MURRAY

The lower lakes (Lakes Alexandrina and Albert) are two lakes totalling approximately 81,000ha in area located at the terminus of the Murray River. Once estuarine systems, they are now freshwater lakes due to the installation of seawater exclusion barrages in the 1930's. (Figure 3).

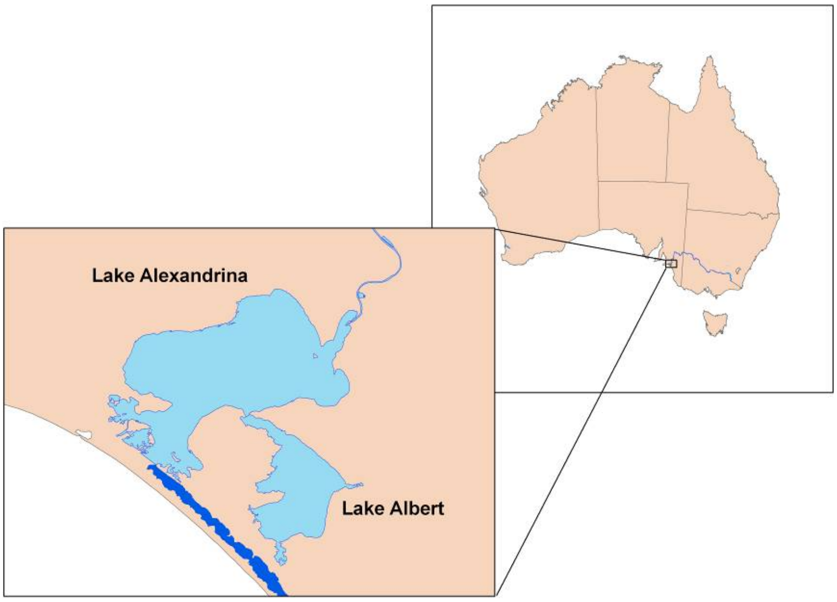

Figure 3. Lower Lakes location map

Sulfidic material containing iron pyrite forms naturally in freshwater and marine settings as a result of the depositing of large amounts of organic matter, such as decaying vegetation, in saturated and anaerobic wetland areas. With sufficient sources of iron and sulfate such anaerobic environments are ideal for the build-up of iron sulfide minerals. In the Lower Murray region's waterways iron sulfides have been accumulating in submerged and waterlogged soils since the construction of locks, weirs and barrages over 50 years ago, and have led to the retention of water in the river system.

The current drought conditions (worst on record), however, has dropped water levels in the River Murray, particularly between Lock 1 (at Blanchetown) and the Lower Lakes (Alexandrina and Albert). These low water levels have exposed submerged or subaqueous soils, wetlands, areas of riverbank and parts of the lower lakes that contain high levels of pyrite. This has resulted in the artificially thick layers of accumulated sulfide minerals being exposed to air for the first time leading to the development of sulfuric material with pH levels dropping below 4 because of the formation of sulfuric acid. Dredging operations have also exposed sulfides to oxygen, resulting in the formation sulfuric material.

We have identified four sequential phases (Classes of ASS) that occur when these soils dewater as water levels drop. The four broad Classes of acid sulfate soils form depending on drainage conditions, which range from submerged or subaqueous soils to saturated and unsaturated drained soils (Figure 4).

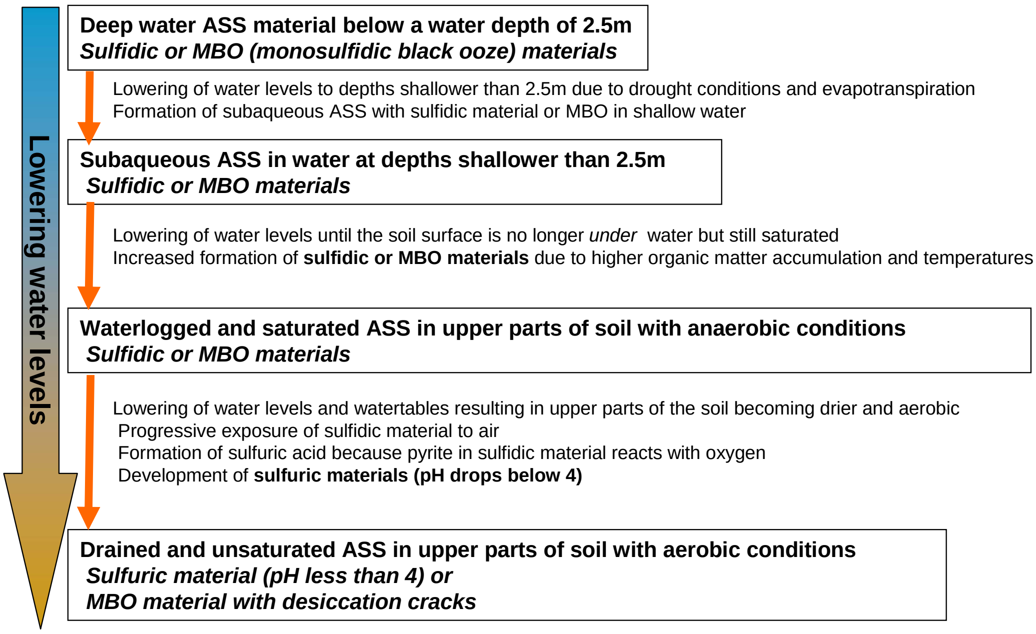

Figure 4. Generalised conceptual model showing the sequential transformation of four Classes of ASS due to lowering of water levels from "Deep water ASS" → "Subaqueous ASS" → "Waterlogged and saturated ASS" (all containing sulfidic material with high sulfide concentrations and pH>4) to → "Drained and unsaturated ASS" containing sulfuric material (pH<4) in the upper soil layers. A wide range of ASS Subtypes containing organic materials/peat, clays and sands have been identified in the ASS classes (definitions in detailed map Legend in Table 2) and in ASS maps (see accompanying ASS maps). (From Fitzpatrick *et al*. 2008a,b,c,d).

Some areas also contain substantial 'monosulfidic black ooze' (MBO) material, which causes rapid oxygen depletion of lake and drainage waters when the ooze is mixed with oxygenated waters during disturbance. Unpleasant odours have been experienced in some areas of exposed soils with desiccation cracks when water levels are extremely low or allowed to evaporate to dryness due to rotting vegetable matter and release of sulfidic gases (e.g. 'rotten egg smell').

Field observations and chemical analysis confirm the generalised conceptual model in Figure 4, which illustrates the four sequential phases (broad classes of ASS) that occur when the soil classes progressively dewater as water levels drop from pre-drought water levels (approximately plus 0.5 mAHD) to current levels (close to minus 0.5m AHD). The conceptual model, the detailed field survey and laboratory data (e.g. chemistry and texture), and the subtypes of ASS were used to construct the final map legend for the ASS maps of the River Murray below Blanchetown (Lock 1) and Lakes Alexandrina and Albert when water levels were at pre- drought and current drought conditions (Fitzpatrick *et al* 2008 a,c,d). To easily identify types and subtypes of ASS (Table 3) a "Soil Identification Key", was developed for ASS in the River Murray and Lower Lakes systems to easily identify and classify the fourteen Subtypes of ASS and non-ASS (Fitzpatrick *et al* 2008 a,c,d). The key uses a collection of plain language names for ASS types and subtypes in accordance with the legend for the Atlas of Australian ASS (Appendix 1), which is designed for people who are not experts in soil classification systems such as the Australian Soil Classification (Isbell 1996). Attributes include water inundation (subaqueous soils), organic material, cracks or structure, texture, colour, features indicating waterlogging (hydric conditions) and 'acid' status – already acidified, i.e. sulfuric material, or with the potential to acidify, i.e. sulfidic material (Isbell 1996).

DEVELOPMENT OF PRIORITY (HOTSPOT) REGIONS/AREAS AND SITES ACROSS AUSTRALIA

Part of the Atlas of Australian ASS website establishes a national database for storage and display of ASS data was established for several key priority regions across Australia. A national protocol for showcasing priority/hotspot areas via the Atlas of Australian ASS on the ASRIS website was developed. This involved the development of a standard presentation format document for each region, area or site across Australia, which has been hotlinked to a national map of Priority areas in ASRIS. More specifically, the database of representative priority case studies around Australia (with images appropriate to each case) has detailed information on the following:

- Soil data (e.g. morphological, chemical, physical, soil classification)
- Coastal (estuary) hydrology, geology and geomorphology
- Climate, land use, vegetation, etc
- Environmental hazard assessment such as pollution hazard rating, infrastructure impact rating (e.g. subsidence, corrosion), environmental sensitivity rating (e.g. proximity to Ramsar designated wetlands).
- Major cause of oxidation or increased anaerobic conditions of ASS.
- Off-site impacts.
- Available options for amelioration and management.
- Estimates of the increase (or decrease) in area of acidified ASS or increased anaerobic condition of ASS.

As further information on hotspot areas is uploaded progressively across the country, web browsers will be able to view a map of Priority regions/areas/sites on the web and access information about them via a hyperlink by clicking on the map. South Australian examples of priority (hotspot) regions/areas and sites have been developed and published as a series of CSIRO Land and Water Science Reports (in PDF format with ASS data that reside on the CSIRO Land and Water ASS website and are hotlinked from ASRIS). Several similar examples have been developed for all the other States as PDF documents, which reside on the respective State-based websites.

An example of a case study is the Gulf of St Vincent (GSV) and Barker Inlet “Priority Region.” This is a priority or hotspot region site linked to the “Atlas of Australian Acid Sulfate Soils” website via the Australian Soil Resources Information System - ASRIS) report (CSIRO Land and Water Science Report No. 35/08: Fitzpatrick *et al* 2008b). The website summarises factors associated with formation of pyrite and sulfuric acid across the wide range of ASS types that occur and the key impacts this has on coastal, estuarine and mangrove swamp environments that fringe the shoreline of the GSV. This report also provides the following critical database information on coastal ASS:

- Properties (descriptions of 6 major types of ASS materials that commonly occur as layers in soil profiles)
- Conceptual process models (schematic soil-landscape cross sections)
- Australian and international soil classification systems (Types of ASS based on the legend used in the Atlas of Australian Acid Sulfate Soils, Australian Soil Classification, Soil Taxonomy and World Reference Base)
- Distribution (ASS map and aerial extent in hectares for GSV and Barker Inlet)
- Impacts (Land and water degradation; noxious odours; climate change and greenhouse gas emissions)
- Management and remediation options (brief overview of general principles)

Similar priority or hotspot case studies across Australia have been developed and are either published or in the process of being published, with a view to being accessible via the National ASS Atlas website.

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Table 3: Explanation of ASS Map Legend for Lower Lakes and River Murray below Lock 1

Lowering water levels →

Deep water ASS material below a water depth of 2.5m	**Subaqueous ASS in shallow water (<2.5m depth)**		**Waterlogged and saturated ASS in upper part of soil with anaerobic conditions**		**Drained and unsaturated ASS in upper part of soil with aerobic conditions**	
	Subtype of ASS	[1]Map code	Subtype of ASS	[1]Map code	Subtype of ASS	[1]Map code
	Sulfidic subaqueous organic soils	Ak(p2)o	Sulfidic organic soils	Al(p2)	Sulfuric organic soils	Al(a1)
	Sulfidic subaqueous clayey soils	Ak(p2)c	Sulfidic vertosols (clayey)	Bo(p2)	Sulfuric vertosols (clayey)	Ao(a1)d
	Sulfidic subaqueous sandy soils	Ak(p2)s	Sulfidic hydrosols (sandy)	Am(p2)	Sulfuric hydrosols (sandy)	Am(a1)
	Sulfidic subaqueous soils	Ak(p2)	Sulfidic hydrosols (sandy)	Bm(p2)		
	[2]MBO subaqueous soils	Ak(m2)	[2]MBO Sulfidic hydrosols	Am(m2)	[2]MBO hydrosols (Desiccation cracks)	Am(m2)d

[1] **Map code: Map Legend codes (see below); [2]MBO: Monosulfidic Black Ooze subaqueous soils**

Symbols in map code: A, B, C or D; k, l, m, o (a, p, m 1,2 or 3) o, c, s, d

Probability of Occurrence of Acid Sulfate Soils:

A - High probability of occurrence (> 70% of mapping unit)
B - Low probability of occurrence (6-70% of mapping unit)
C - Extreme low probability of occurrence (1-5% of mapping unit) with occurrences in small localised areas.
D - No probability of occurrence <1% of mapping unit (e.g. outcrops of hard calcrete).

Codes:

k - Subaqueous soils (in shallow water <2.5 m depth)
l - Organosols (organic or peaty soils)m - Hydrosols (Saturated in upper part to develop anaerobic conditions)
o - Vertosols (cracking clay soils with slickensides)

Subscripts to codes:

(a) - Sulfuric material (pH < 4)
(m) - Monosulfidic Black Ooze (MBO) material
(p) - Sulfidic material (pH > 4 but on aging pH drops below 4)

Confidence levels: Map polygon contains ASS, and:

(1) - All necessary analytical and morphological data are available
(2) - Analytical data are incomplete but are sufficient to classify the soil with a reasonable degree of confidence.
(3) - No necessary analytical data are available but confidence is fair, based on a knowledge of similar soils in similar environments.
(4) No necessary analytical data are available and classifier has little knowledge or experience with ASS, hence classification is provisional.

Descriptors: used where more information is available

o - Organic material (sapric and hemic material)
c - Clayey material (> 35 % clay; light, medium and heavy clay)
s - Sandy materials (= sand, loamy sand, clayey sand texture groups)
d - Desiccation cracks.

AHD = Australian Height Datum, which approximates mean sea level

APPENDIX 1

LEGEND for Australian Atlas of Acid Sulfate Soils[1] (ASS) map. Developed by Rob Fitzpatrick (CSIRO/ NatCASS), Steve Marvanek (CSIRO) and Bernie Powell (QNRW/ NatCASS) with input from several workers across Australia and overseas (2nd June, 2008)

Code and Map Unit	Distinguishing soil/sediment properties, vegetation, landforms, or other characteristics
PROBABILITY OF OCCURRENCE OF ASS[1]	
A High Probability of occurrence	>70% chance of occurrence in mapping unit
B Low Probability of occurrence	6-70% chance of occurrence in mapping unit
C Extremely low probability of occurrence	1-5% chance of occurrence in mapping unit with any occurrences in small localised areas
D No probability of occurrence	<1% chance of occurrence in mapping unit (e.g. thick outcrops of hard rock, ferricrete, calcrete, silcrete)
MAP UNIT (area scaling factor)	
PROFOUNDLY DISTURBED	
x Disturbed ASS[1] terrain (1.0)	ASS[1] material present below urban development, or present in former tidal zones inside bund walls (e.g. dredge spoil, ponds, major excavations) or as anthropic[5] ASS or fill material > 0.3 m thick.
SUBTIDAL ZONE[7] SUBAQUEOUS MATERIALS[6]	
a Subaqueous material in subtidal wetland[7] (1.0)	PASS[2] material and/or MBO[4]. Often seagrasses.
TIDAL ZONES[8]	
b Intertidal[9] flats (1.0)	PASS[2] generally within upper 1 m. Often with mangroves.
c Supratidal[10] flats (1.0)	ASS[1] generally within upper 1 m. Halophytes (mainly samphire), salt marsh, salt pans.
d Extratidal[11] flats (0.8)	ASS[1] generally within upper 1 m.
NON-TIDAL ZONES Floodplains	
e Floodplains < 2 m AHD[12] (0.8)	ASS[1], generally within upper 1 m. Grasslands, reedlands and wetland forests (e.g. Melaleuca, Casuarina). Includes backplains, backswamps and interbarrier swamps.
f Floodplains 2 - 4 m AHD[12] (0.7)	ASS[1], generally below 1 m from the surface. Generally wetland forests (e.g. Melaleuca, Casuarina). Includes plains and levees.
g Floodplains > 4 m AHD[12] (0.7)	ASS[6], generally below 3 m from the surface. Generally forests. Includes plains and levees.
NON-TIDAL ZONES Sandplains and dunes in coastal[15] landscapes	
h Sandplains and dunes <2 m AHD[12]	ASS[1], generally within 1 m of the surface. Often wet heath. Holocene or Pleistocene.

(0.7)	
i Sandplains and dunes, 2 - 10 m AHD[12] (0.7)	ASS[1], generally below 1 m from the surface. Heath, forests. Holocene or Pleistocene.
j Sandplains and dunes, > 10 m AHD[12] (0.7)	ASS[1], generally below 1 m from the surface. Heath, forests. Mainly Pleistocene.
Inland (i.e. not coastal[15]) landscapes (> 10 m AHD[12]) in wet / riparian areas[13] associated with:	
k Subaqueous material in lakes[14] (1.0)	ASS[1] material and/or MBO[4]
l Organosols (0.8/0.05)	ASS[1] generally within upper 1 m in wet / riparian areas with Organosols (Isbell 1996)
m Hydrosols (0.8/0.1/0.05)	ASS[1] generally within upper 1 m in wet / riparian areas with Hydrosols (Isbell 1996)
n Sodosols, Chromosols and Dermosols (0.5/0.05)	ASS[1] generally within upper 1 m in wet / riparian areas with Sodosols, Chromosols and Dermosols (Isbell 1996)
o Vertosols (0.5/0.05)	ASS[1] generally within upper 1 m in wet / riparian areas with Vertosols (Isbell 1996)
p Calcarosols (0.5/0.05)	ASS[1] generally within upper 1 m in wet / riparian areas with Calcarosols (Isbell 1996)
q Kandosols, Ferrosols, Tenosols, Rudosols, Podosols and Kurosols (0.5/0.05)	ASS[1] generally within upper 1 m in wet / riparian areas with Kandosols, Ferrosols, Tenosols, Rudosols and Podosols (Isbell 1996)
SUBSCRIPTS TO CODES	
(a) Actual ASS (AASS)[3]	Actual acid sulfate soil (AASS) = sulfuric material (Isbell 1996, p.122.)
(p) Potential ASS (PASS[2])	Potential acid sulfate soil (PASS) = sulfidic material (Isbell 1996, pp. 121-122)
(m) MBO[4], significant occurrence	Monosulfidic Black Ooze (MBO) is organic ooze enriched by iron monosulfides (Bush *et al*. 2004).
CONFIDENCE LEVELS (after Isbell 1996) Map polygon contains ASS, and:	
(1) All necessary analytical and morphological data are available	
(2) Analytical data are incomplete but are sufficient to classify the soil with a reasonable degree of confidence	
(3) No necessary analytical data are available but confidence is fair, based on a knowledge of similar soils in similar environments	
(4) No necessary analytical data are available and classifier has little knowledge or experience with ASS, hence classification is provisional	
OPTIONAL DESCRIPTORS	
<u>f</u> Fill materials	Undifferentiated fill material between 0.5m and 3 m thick, overlays ASS materials
<u>h</u> Hypersaline or gypseous horizons generally within 10 cm of the surface	Hypersaline is equivalent to hypersalic as defined by Isbell (1996, p 47). Saltpans are common, average annual rainfall is generally < 400 mm, and the vegetation is dominated by halophytes (samphire, salt bush, blue bush) Gypseous is equivalent to gypsic as defined by Isbell (1996, p 114).
<u>o</u> Organic material	Organic, as for organic materials defined by Isbell (1996, p 116; including sapric, and hemic material). Average annual rainfall is generally > 400 mm, and the vegetation is mainly grassland (e.g. saltwater couch, Phragmites)
<u>n</u> Self neutralising sulfidic material	Self neutralising sulfidic material (PASS material) confirmed by field observation, sampling and laboratory analyses (commonly carbonate rich).
<u>D</u> Deep variant ASS	ASS generally deeper than the depth specified in the legend
<u>P</u> Pleistocene	Based on dating or stratigraphic evidence
<u>e</u> Excavation feature	Excavated drains, canals, lakes, dams and other water accumulating structures within which modern ASS forms.
<u>d</u> Desiccation cracks	Desiccation cracks usually expressed as irreversible trans-horizon polygonal cracks, often with coarse columnar ped structures,

	which usually forms as a result of desiccation and dewatering of clayey or peaty subaqueous soils and sediments during drying and wetting cycles.
c Clayey material	Clayey material (>35% clay; light, medium and heavy clay)
s Sandy material	Sandy materials (sand, loamy, sand, clayey sand texture groups)

Examples (i): Ae (p1) h Polygon with high probability of ASS occurrence in a floodplain < 2 m AHD, with potential ASS confirmed by analytical and morphological data, that also contains a hypersaline and gypsic horizons.
(ii): Bx (a2) f - Polygon with low probability of ASS occurrence in a disturbed environment with actual ASS. Analytical data are incomplete but are sufficient to classify the soil with a reasonable degree of confidence. The actual ASS is now covered by 0.5 to 3 m of undifferentiated fill material.

[1]Acid Sulfate Soils (ASS) are all those soils in which sulfuric acid may be produced, is being produced, or has been produced in amounts that have a lasting effect on main soil characteristics (Pons 1973). This general definition includes: (i) potential, (ii) actual (or active), and (iii) post-active ASS, three broad genetic soil types that continue to be recognized (e.g. Fanning 2002). ASS form in coastal, estuarine, mangrove swamp and marsh environments because these waterlogged or highly reducing environments are ideal for the formation of sulfide minerals, predominantly iron pyrite (FeS_2). Soil horizons that contain sulfides are called sulfidic materials (Isbell 1996; Soil Survey Staff 2003) and can be environmentally damaging if exposed to air by disturbance. Exposure results in the oxidation of pyrite, with each mole of pyrite yielding 4 moles of acidity (i.e. 2 moles of sulfuric acid). This process transforms sulfidic material to sulfuric material when, on oxidation, the material develops a pH of 4 or less (Isbell 1996); note that a sulfuric horizon has a pH of 3.5 or less according to Soil Survey Staff (2003).

1. Acid sulfate soil (ASS) may include PASS or AASS + PASS.

2. Potential acid sulfate soil (PASS) = sulfidic material (Isbell 1996, pp. 121-122)

3 Actual acid sulfate soil (AASS) = sulfuric material (Isbell 1996, p.122.)

4. Monosulfidic Black Ooze (MBO) is organic ooze enriched by iron monosulfides (Sullivan *et al*. 2002).

5. Anthropic material is profoundly modified soil material, the term being derived from the soil order Anthroposol as defined by Isbell (1996, p 18).

6. Subaqueous materials: Soil materials that form in sediment found in shallow permanently flooded environments. Excluded from the definition of these soils are any areas “permanently covered by water too deep (typically greater than 2.5m) for the growth of rooted plants (Stolt 2006).

7. Subtidal wetlands: Permanently inundated areas within estuaries dominated by subaqueous soils and submerged aquatic vegetation. Subtidal: (adjective) continuous submergence of substrate in an estuarine or marine ecosystem; these areas are below the mean low tide (Stolt 2006).

8. Tidal zone or flat: An extensive, nearly horizontal, barren or sparsely vegetated tract of land that is alternately covered and uncovered by the tide, and consists of unconsolidated sediment (mostly clays, silts and/or sand, and organic materials) (Stolt 2006).

9. Intertidal zone is that between mean lower low water (MLLW) and mean higher high water (MHHW) (see MHL).

10. Supratidal zone is that above mean higher high water (MHHW), but below the extratidal zone. Spring tides will reach the lower part of the supratidal zone, the average spring tidal level being that known as mean high water springs (MHWS). See Isbell (1996, p 47) and MHL

11. Extratidal zone and the supratidal zone boundary is defined by vegetation community, i.e. grassland v saltmarsh (see Isbell 1996, p 47).

12. Australian Height Datum (AHD) approximates mean sea level. AHD is a surface based on mean sea level adopted in 1971, and described in Special Publication 10 -Australian Geodetic Datum Technical Manual, Division of National Mapping, for the National Mapping Council.

13. Riparian/wet zones: integration of topographic wetness index (TWI), which defines the "riparian/wet" zones and the "deposition/sedimentary" zones through Multiresolution Valley Bottom Floor Index (MrVBF) (Gallant and Dowling, 2003). MrVBF data from Dr John Gallant (CSIRO) for national MrVBF and TWI coverage (250 m cell size).

14. Lakes: Waterbodies from GEODATA TOPO 250K Series 2 Topographic Data, Hydrography Theme, Geoscience Australia http://www.ga.gov.au/meta/ANZCW0703005458.html.

15. Coastal zone: Includes coastal waters and those areas landwards of the coastal waters where there are processes or activities that affect the coast and its values. Natural Resource Management Ministerial Council (2006) – Glossary of terms Page 50. Commonwealth of Australia Department of the Environment and Heritage, Canberra, ACT. . National Cooperative Approach to Integrated Coastal Zone Management: Framework Implementation Plan. ISBN 0642550514.

APPENDIX 2

Legend classification matrix used for inland Acid Sulfate Soils

ASC Soil Order Isbell (1996)	Legend Probability and Map Unit (polygon area scaling factor) Under Lake	Adjacent to watercourse	Away from lakes & water courses
Anthroposols	A (0.5)	A (0.05)	B (0.05)
Calcarosols	A p (0.5)	A p (0.05)	C p (0.05)
Chromosols	A n (0.5)	B n (0.05)	C n (0.05)
Dermosols	A n (0.5)	B n (0.05)	B n (0.05)
Ferrosols	A q (0.5)	B q (0.05)	C q (0.05)
Hydrosols	A m (0.8)	A m (0.1)	A m (0.05)
Kandosols	A q (0.5)	B q (0.05)	C q (0.05)
Kurosols	A q (0.5)	B q (0.05)	C q (0.05)
Organosols	A l (0.8)	A l (0.05)	A l (0.05)
Podosols	A q (0.5)	B q (0.05)	C q (0.05)
Rudosols	A q (0.5)	B q (0.05)	C q (0.05)
Sodosols	A n (0.5)	A n (0.05)	B n (0.05)
Tenosols	A q (0.5)	B q (0.05)	C q (0.05)
Vertosols	A o (0.5)	B o (0.05)	C o (0.05)
Lakes	A k (1.0)	N/A	N/A