

Assessment of Acid Sulfate Soil Materials in the Edward and Wakool Rivers Region of the Murray-Darling Basin

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The contents of this publication do not purport to represent the position of the Murray-Darling Basin Authority. They are presented to inform discussion for improved management of the Basin's natural resources.

Cover Photograph

View of the creek channel at site 20246_2. The soil consisted of a cover of possibly schwertmannite, followed by MBO and a soft grey clay below.

Photographer: Rob Muller.

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EXECUTIVE SUMMARY

The Edward and Wakool River system is a complex network of inter-connecting rivers, creeks, flood-runners and artificial channels located north of the River Murray and west of Deniliquin (Baldwin 2009). The topography is generally flat. The region has been extensively cleared, and has vegetation varying from river red gum forest through to riverine grasslands to mallee scrub. Acid sulfate soils have been observed in the main channel of the Wakool River, Niemur River and a number of associated creek systems (e.g. Baldwin 2008, 2009; Tulau 2009; Ward et al. 2010). However, at many sites within the Edward and Wakool River system, sulfidic sediments have largely been identified based on visual indicators.

The Murray-Darling Basin Authority (MDBA), in partnership with its Partner Governments and scientists, instigated the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project (MDB ASSRAP), which aims to assess the spatial extent of, and risks posed by acid sulfate soil materials in the Murray-Darling Basin. The MDB ASSRAP project also aims to identify and assess broad management options.

The MDBA Acid Sulfate Soil Risk Assessment Advisory Panel prioritised 96 wetlands throughout the Murray-Darling Basin for detailed acid sulfate soil assessment. This report provides the results of Phase 1 of a two-phased detailed acid sulfate soil assessment procedure for priority wetlands in the Edward and Wakool Rivers region. This Phase 1 report is aimed solely at determining whether or not acid sulfate soil materials are present in the Edward and Wakool Rivers region priority wetlands.

This study identified the presence of acid sulfate soil materials at 18 of the 39 sites examined in the Edward and Wakool Rivers region. The type and prevalence of acid sulfate soil materials observed in each wetland is summarised in the table below. The presence of acid sulfate soils was identified in six of the 12 wetlands examined.

Type and prevalence of acid sulfate soil materials in each wetland.

Type of actual or potential acid sulfate soil material	Wetland ID (No. of sites)											
	20035	20111	20177	28200	20229	20230	20246	20264	20580	20832	20833	21761
Sulfuric	0	1	1	3	2	0	1	0	0	0	0	0
Hypersulfidic	0	1	4	2	0	0	3	0	0	1	0	0
Hyposulfidic ($S_{CR} \geq 0.10\%$)	0	0	0	0	0	0	1	0	0	2	0	0
Monosulfidic (observed)	0	1	3	2	0	0	2	0	0	2	0	0
Monosulfidic (potential)	1	1	4	4	4	2	4	2	1	2	2	3
Hyposulfidic ($S_{CR} < 0.10\%$)	0	0	0	0	0	0	0	0	0	1	0	0
Other acidic (pH_w &/or $pH_{INCUBATION}$) 4 – 5.5	2	2	0	0	2	2	0	2	1	0	2	0
Other soil materials	0	0	0	0	0	0	0	0	0	0	4	4

Sulfuric materials were observed at eight sampling sites. The reduced inorganic sulfur content of the samples was high in some areas (i.e. S_{CR} was up to 0.83% S). Hypersulfidic soil materials were present in 11 soil profiles (two of these profiles also contained hyposulfidic materials), and another soil profile contained hyposulfidic materials (with $S_{CR} \geq 0.10\%$ and $< 0.10\%$). Monosulfidic soil materials were observed at 26% (i.e. 10) of the

sampling sites. These results indicate that acidity would be produced upon oxidation of sulfides in some of these materials.

A total of 30 surficial soil materials contained soluble sulfate equal to or in excess of the 100 mg/kg trigger value for monosulfidic black ooze (MBO) formation potential. The potential formation of MBO was identified in all of the wetlands examined. Other acidic soil materials often with a pH < 5 were also observed at an additional 13 sites.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there were eight high priority sites based on the presence of sulfuric material, 11 high priority sites based on hypersulfidic material, three high priority sites based on hyposulfidic ($S_{CR} \geq 0.10\%$) material and 10 high priority sites based on monosulfidic material. There was one moderate priority site based on the presence of a hyposulfidic material with $S_{CR} < 0.10\%$. In addition, 30 of the 39 sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard. All wetlands in the Edward and Wakool Rivers region receive a high priority ranking on at least one of the criteria.

The potential hazards at the wetland-scale posed by acid sulfate soil materials in priority wetlands in the Edward and Wakool Rivers region are as below:

- **Acidification:** The data indicate that in eight of the wetlands examined the degree of acidification hazard is low. However, three of the wetlands assessed (i.e. Wetland 20177, 28200 and 20246) contained acid sulfate soil materials with high net acidities that represent a high acidification hazard. In addition, one wetland (i.e. Wetland 20229) contained sulfuric materials with moderate net acidities that represent a moderate acidification hazard.
- **Deoxygenation:** High monosulfide concentrations ($S_{AV} \leq 0.40\% S$) in surface soils in four wetlands (i.e. Wetland 20177, 28200, 20246 and 20832) represent a high deoxygenation hazard. In addition, the soluble sulfate contents of 30 surface soil materials were equal to or greater than the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- **Metal mobilisation:** The low acidification hazard in all except four wetlands indicates that soil acidification is not likely to increase the solubility of metals. At the four wetlands with a moderate to high acidification hazard, soil acidification may increase the solubility of metals. The presence of monosulfidic materials in some surface soils at four wetlands, and the potential for MBO formation identified in all wetlands, may also result in an appreciable metal release hazard. This would depend on factors such as the potential for MBO formation and the metal loading in the wetland.

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1. INTRODUCTION

1.1. Region overview

The Edward and Wakool River system is a complex network of inter-connecting rivers, creeks, flood-runners and artificial channels located north of the River Murray and west of Deniliquin (Baldwin 2009). A series of control structures located throughout the area regulate the flow in the Edward and Wakool River system which flows into the River Murray near Swan Hill (Baldwin 2009). The topography is generally flat. The region has been extensively cleared, and has vegetation varying from river red gum forest through to riverine grasslands to mallee scrub. The soils in the region are predominantly Grey and Aquic Vertosols and Hydrosols. Some dispersive soils are evident.

Sulfidic sediments have been observed in the main channel of the Wakool River, Niemur River (also known as Mallan Mallan Creek) and a number of associated creek systems (including Tuppal, Jimaringle, Cochran, Wyam and Merran Creeks) (e.g. Baldwin 2008, 2009; Tulau 2009; Ward et al. 2010). Sulfuric (i.e. pH < 4) and sulfidic sediments have also been observed in incised channels that are associated with deep layers of monosulfidic black ooze (MBO) overlain with a halite crust (Tulau 2009). Extensive death and dieback of river red gums and black box have also often been observed. However, at many sites within the Edward-Wakool River system, sulfidic sediments have largely been identified based on visual indicators.

Many of the channel systems in the Edward and Wakool River system are highly saline, particularly in the western part of the system (Baldwin 2009). Baldwin (2008) reported electrical conductivities ranging from 6,000 $\mu\text{S cm}^{-1}$ in a partially filled reach of the Wakool River to over 100,000 $\mu\text{S cm}^{-1}$ in a waterhole in Wyam Creek. The high salinities provide a source of sulfate essential for sulfide accumulation. Acidification of waterholes has also been reported in the Wakool River main channel, with pH levels as low as 2.9 (Baldwin 2009).

Wetlands in this region were identified for acid sulfate soil assessment based on their environmental significance or the risk they may pose to surrounding waters. Approximately 70 rapid acid sulfate soil assessments were completed throughout the Edward and Wakool River system as part of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project (MDB ASSRAP). A total of 12 wetlands were identified and selected for further detailed assessment based on being identified as having a high priority as a result of soil and water parameters exceeding screening trigger values (see Appendix 2), and having a risk profile. The parameters exceeding the ASSRAP trigger values at the 12 sites selected for further assessment and their score priority level are shown in Table 1-1.

Table 1-1: Summary of parameters exceeding the ASSRAP trigger values and score priority level at the Edward and Wakool Rivers assessment sites.

Wetland ID	pH Soil	pH Water	EC Soil	EC Water	Sulfate Soil	Sulfate Water	Priority
20035	Moderate	Moderate	-	-	High	Moderate	High
20111	-	-	High	High	-	High	High
20177	Moderate	-	-	High	-	High	High
28200	Extreme	Moderate	High	High	High	High	Extreme
20229	Moderate	Moderate	High	-	High	High	High
20230	Moderate	-	-	-	-	-	Moderate
20246	Moderate	Moderate	High	High	High	High	High
20264	Extreme	-	-	-	-	-	Extreme
20580	-	-	-	-	-	-	Low
20832	-	-	High	High	High	High	High
20833	Moderate	-	High	-	High	-	High
21761	-	-	High	-	High	-	High

1.2. Acid sulfate soils in the Murray-Darling Basin

Acid sulfate soil is the term commonly given to soil and sediment that contain iron sulfides, or the products of sulfide oxidation. Pyrite (FeS_2) is the dominant sulfide in acid sulfate soil, although other sulfides including the iron disulfide marcasite (Sullivan and Bush 1997; Bush 2000) and iron monosulfides (Bush and Sullivan 1997; Bush *et al.* 2000) can also be found.

Sulfidic sediments accumulate under waterlogged conditions where there is a supply of sulfate, the presence of metabolisable organic matter and iron-containing minerals (Dent 1986). Under reducing conditions sulfate is bacterially reduced to sulfide, which reacts with reduced iron to form iron sulfide minerals. These sulfide minerals are generally stable under reducing conditions, however, on exposure to the atmosphere the acidity produced from sulfide oxidation can impact on water quality, crop production, and corrode concrete and steel structures (Dent 1986). In addition to the acidification of both ground and surface waters, a reduction in water quality may result from low dissolved oxygen levels (Sammut *et al.* 1993; Sullivan *et al.* 2002a; Burton *et al.* 2006), high concentrations of aluminium and iron (Ferguson and Eyre 1999; Ward *et al.* 2002), and the release of other potentially toxic metals (Preda and Cox 2001; Sundström *et al.* 2002; Burton *et al.* 2008a; Sullivan *et al.* 2008a).

Acid sulfate soils form naturally when sulfate in the water is converted to sulfide by bacteria. Changes to the hydrology in regulated sections of the Murray-Darling Basin (MDB) system (due to higher weir pool levels), and the chemistry of rivers and wetlands have caused significant accumulation of sulfidic material in subaqueous and wetland margin soils. If left undisturbed and covered with water, sulfidic material poses little or no threat of acidification. However, when sulfidic material is exposed to the air, the sulfides react with oxygen to form sulfuric acid (i.e. sulfuric materials with $\text{pH} < 4$). When these sulfuric materials are subsequently covered with water, significant amounts of sulfuric acid can be released into the water.

Other hazards associated with acid sulfate soil include: (i) mobilisation of metals, metalloids and non-metals, (ii) decrease in oxygen in the water column when monosulfidic materials are mobilised into the water column, and (iii) production of noxious gases. In severe cases, these risks can potentially lead to damage to the environment, and have impacts on water supplies, and human and livestock health.

Record low inflows and river levels in recent years have led to the drying of many wetlands in the MDB, resulting in the exposure of sulfidic material in acid sulfate soil, and soil acidification in many wetlands. The extent and potential threat posed by acid sulfate soil requires urgent assessment.

Despite decades of scientific investigation of the ecological (e.g. Living Murray Icon Site Environmental Management Plan: MDBC 2006a,b,c), hydrological, water quality (salinity) and geological features of wetlands in the MDB, we have only recently advanced far enough to appreciate the wide spectrum of acid sulfate soil subtypes and processes that are operating in these contemporary environmental settings - especially from continued lowering of water levels (e.g. Lamontagne *et al.* 2004; Fitzpatrick *et al.* 2008a,b; Shand *et al.* 2008a,b; Simpson *et al.* 2008; Sullivan *et al.* 2008a). Hence, the MDB Ministerial Council at its meeting in March 2008 directed the then Murray-Darling Basin Commission (MDBC) to undertake an assessment of acid sulfate soil risk at key wetlands in the MDB.

The MDBC (now the Murray-Darling Basin Authority – MDBA), in partnership with its Partner Governments and scientists, designed the MDB ASS Risk Assessment Project, which aims to assess the spatial extent of, and risks posed by acid sulfate soil in the Murray-Darling Basin. The project also aims to identify and assess broad management options.

Wetlands were identified for assessment based on their environmental significance as well as those that may pose a risk to surrounding waters. Through consultation with jurisdictions more than 19,000 wetlands within the MDB were identified. Due to their ecological significance, the decision was made to prioritise Ramsar-listed wetland complexes of the Murray-Darling Basin for immediate detailed acid sulfate soil assessment. In addition, due to the risk profile, wetlands along the Murray River between Blanchetown (Lock 1) and Wellington were also selected for immediate detailed acid sulfate soil assessment. For all other wetlands, a three tiered assessment process was developed, commencing with a desktop assessment, followed by on-ground rapid assessment and then detailed on-ground assessment at sites identified as high priority or having a risk profile. A total of 96 wetlands were identified and selected for further detailed assessment (Figure 1-1). These wetlands were divided for logistical reasons into the following seven regions:

- Murray River, Lock 1 to Lock 3, SA (21 wetlands),
- Murray River, Lock 3 to Lock 5, SA (31 wetlands),
- Mildura region, NSW and Vic (8 wetlands),
- Edward and Wakool Rivers, NSW (12 wetlands),
- Murray River, Hume to Yarrowonga, NSW and Vic (6 wetlands),
- Talwood-Mungindi region, Queensland (1 wetland), and
- Victorian Northern Flowing Rivers (17 wetlands).

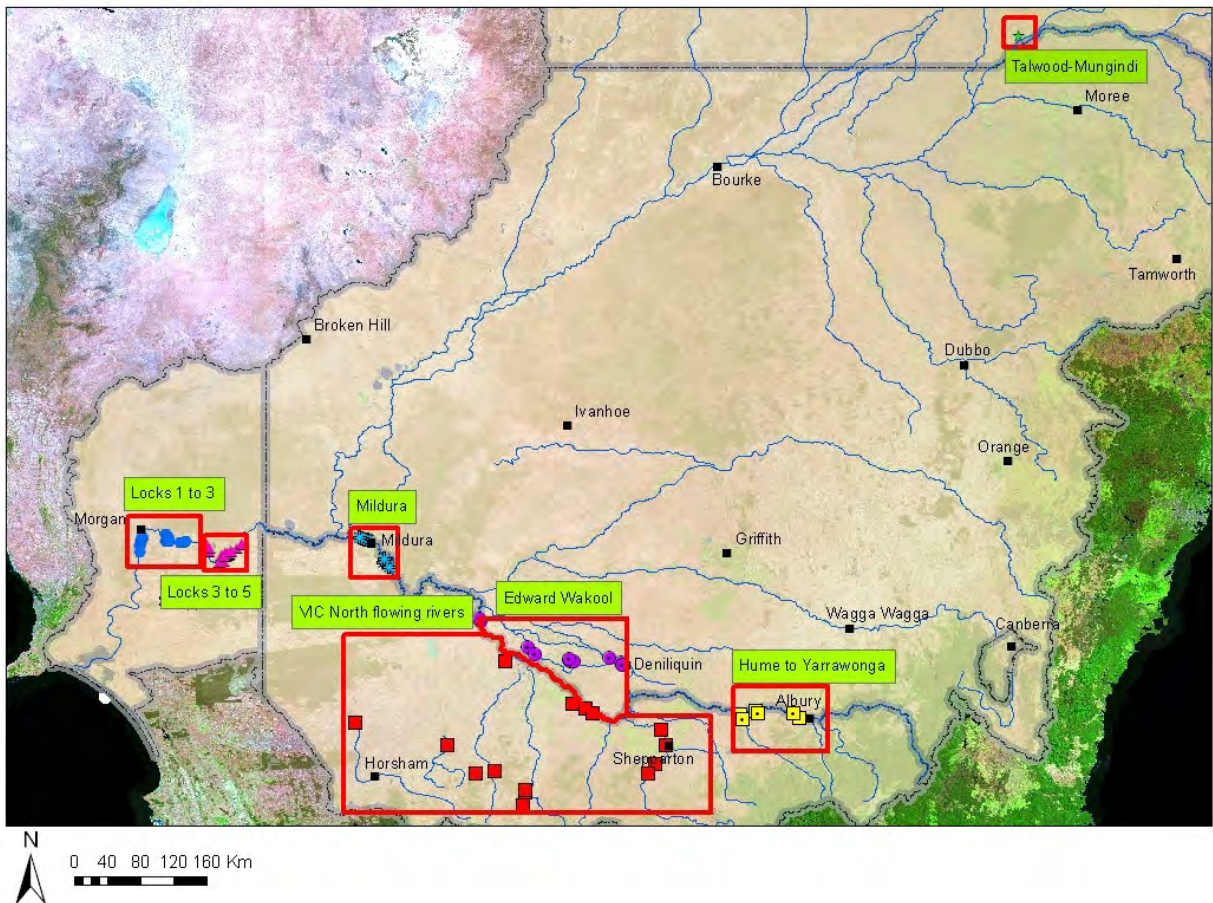


Figure 1-1. Map showing priority wetlands surveyed in the Murray-Darling Basin (source: MDBA).

The New South Wales Department of Environment, Climate Change and Water (NSW DECCW) carried out a detailed assessment at 39 representative sites within 12 wetlands in the Edward and Wakool Rivers region in March-April 2010 to determine whether acid sulfate

soils were present, or if there was a potential for acid sulfate soils to form within these wetlands (Figures 1-2 and 1-3). This assessment included the determination of sulfide content within the soil profile at each site. Water-soluble sulfate was used as an indicator of the potential of monosulfide black ooze (MBO) formation in these wetland sites.

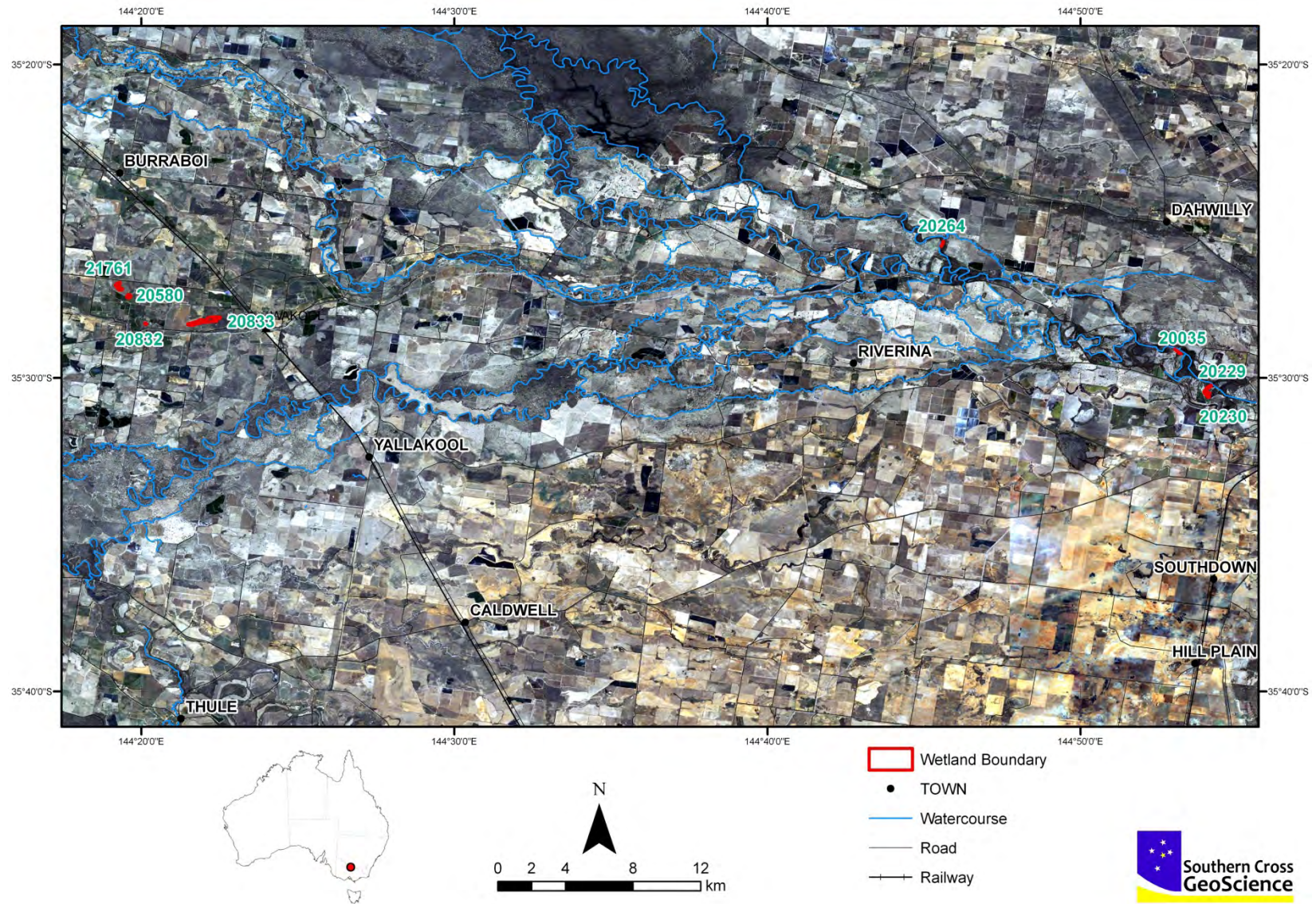


Figure 1-2. Map showing the areas assessed in the Edward and Wakool Rivers region (eastern section).

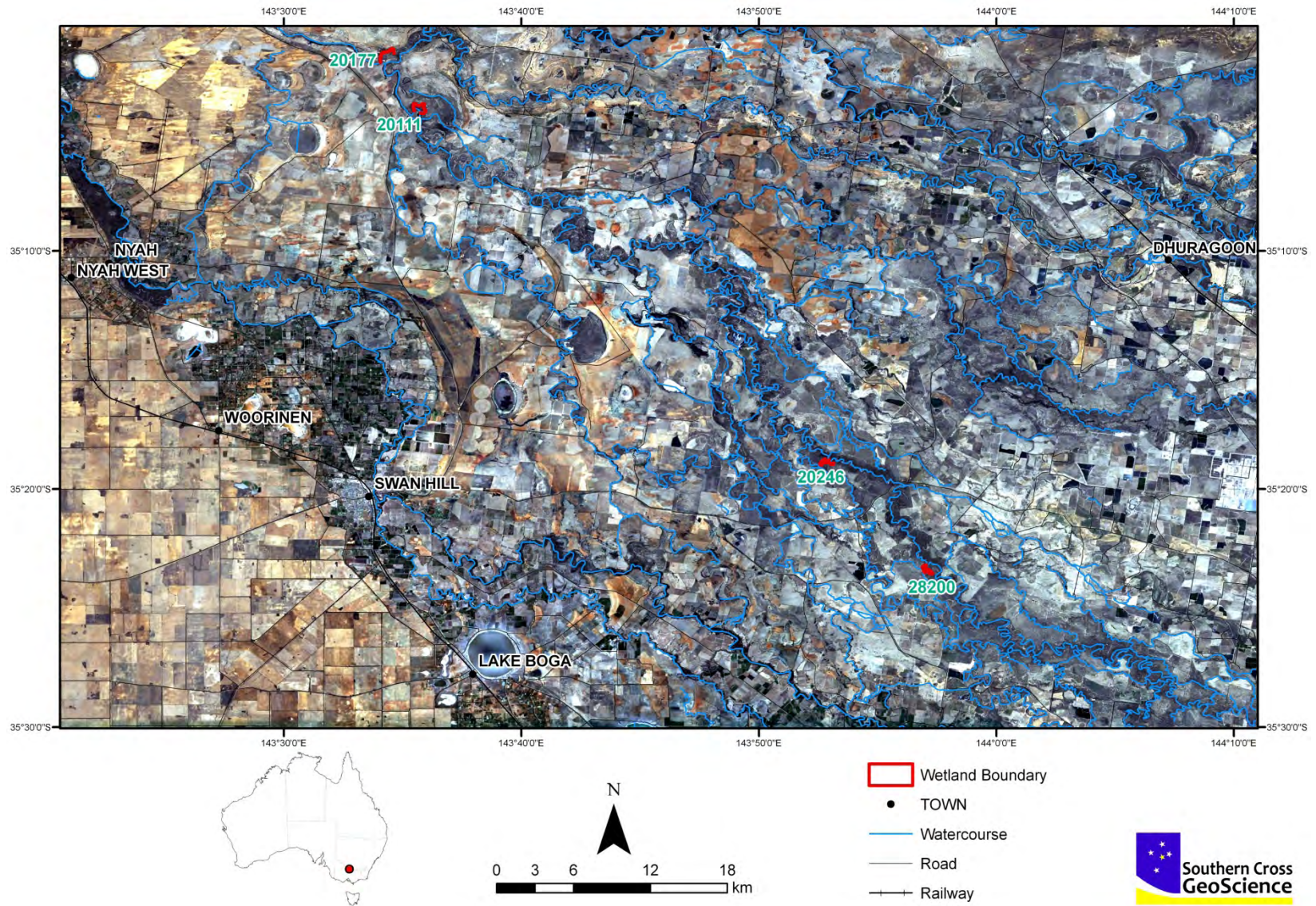


Figure 1-3. Map showing the areas assessed in the Edward and Wakool Rivers region (western section).

1.3. Detailed Acid Sulfate Soil assessments using two phases

The detailed assessment stage of the MDB ASS Risk Assessment Project involves comprehensive analysis using a set of established and tested field and laboratory methods to determine the presence and extent of acid sulfate soil and associated hazards, including potential for acidification, metal mobilisation and deoxygenation.

In summary the protocol developed by the MDB ASS Risk Assessment Project Scientific Reference Panel requires a two-phase procedure (MDBA 2010).

Phase 1 investigations determine whether or not acid sulfate soil materials are present (or absent) for the study area, and provide characterisation of the properties and types of acid sulfate soil materials.

Phase 1 activities include:

- site selection
- site and profile description
- sample collection and storage
- laboratory analysis (of soil and water)
- identification of acid sulfate soil materials
- prioritisation and selection of Phase 2 samples
- interpretation and reporting

Phase 2 investigations will only be conducted if the acid sulfate soil materials from Phase 1 are determined to be a priority concern for the study area and, based on Phase 1 recommendations, samples will undergo further investigations to determine their nature and severity and the specific risks associated with the acid sulfate soil materials.

Phase 2 activities include:

- laboratory analysis (of soil)
- risk assessment
- interpretation and reporting, including discussion on broad acid sulfate soil management options

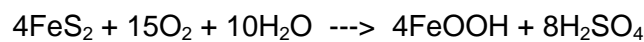
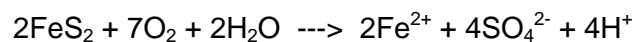
The soil samples to be analysed for Phase 2 will have been collected as part of the Phase 1 field assessment and then put into storage. Based on the Phase 1 report recommendations the client will identify samples and the analyses to be conducted on each of the samples for Phase 2.

Following a request from the Murray-Darling Basin Authority (MDBA), Southern Cross GeoScience were engaged to conduct a Phase 1 detailed assessment of acid sulfate soils at the priority wetlands in the Edward and Wakool Rivers region.

1.4. Methodologies used to assess acid generation potential

As detailed previously, sulfide minerals are generally stable under reducing conditions, however, on exposure to the atmosphere the acidity produced from sulfide oxidation can impact on water quality, crop production, and corrode concrete and steel structures (Dent 1986). In addition to the acidification of both ground and surface waters, a reduction in water quality may result from low dissolved oxygen levels (Sammut *et al.* 1993; Sullivan *et al.* 2002a; Burton *et al.* 2006), high concentrations of aluminium and iron (Ferguson and Eyre 1999; Ward *et al.* 2002), and the release of other potentially toxic metals (Preda and Cox 2001; Sundström *et al.* 2002; Burton *et al.* 2008a; Sullivan *et al.* 2008a).

In nature, a number of oxidation reactions of sulfide minerals (principally pyrite: FeS₂) may occur which produce acidity, including:



A range of secondary minerals, such as jarosite, sideronatrite and schwertmannite may also form, which act as stores of acidity i.e. they may produce acidity upon dissolution (re-wetting).

Acid-base accounting (ABA)

Acid-base accounting (ABA) is used to assess both the potential of a soil material to produce acidity from sulfide oxidation and also its ability to neutralise any acid formed (e.g. Sullivan *et al.* 2001, Sullivan *et al.* 2002b).

The standard acid-based accounting applicable to acid sulfate soils is described in Ahern *et al.* (2004) and summarised here. The equation below shows the calculation of Net Acidity (NA).

Net Acidity (NA) = Potential Sulfidic Acidity (PSA) + Titratable Actual Acidity (TAA) + Retained Acidity (RA) – Acid Neutralising Capacity (ANC)/Fineness Factor (FF)

The components in this ABA are further discussed below and by Ahern *et al.* (2004).

- Potential Sulfidic Acidity (PSA) also known as the 'acid generation potential' (AGP) is most easily and accurately determined by assessing the Chromium reducible sulfur (S_{CR} or CRS) and then converting this to PSA (AGP) as described in Ahern *et al.* (2004).
- Titratable Actual Acidity (TAA) is a measure of the actual acidity in acid sulfate soil materials that have already oxidised. It measures the sum of both soluble and exchangeable acidity.
- Retained Acidity (RA) is the acidity 'stored' in minerals such as jarosite, schwertmannite and other hydroxy sulfate minerals. Although these minerals may be stable under acidic conditions, they can release acidity to the environment when these conditions change.
- Acid Neutralising Capacity (ANC) is measured in soils with pH_{KCl} values > 6.5. These soils may potentially have ANC in the form of (usually) carbonate minerals, principally of calcium, magnesium and sodium. The carbonate minerals present are estimated by titration and alkalinity present expressed in CaCO₃ equivalents. By accepted definition (Ahern *et al.* 2004), any acid sulfate soil material with a pH_{KCl} < 6.5 has a zero ANC.

- Fineness Factor (FF) is defined by Ahern *et al.* (2004) as 'A factor applied to the acid neutralising capacity result in the acid-base account to allow for the poor reactivity of coarser carbonate or other acid neutralising material. The minimum factor is 1.5 for finely divided pure agricultural lime, but may be as high as 3.0 for coarser shell material'. Fine grinding of soil materials may lead to an over-estimate of ANC when carbonates are present in the form of hard nodules or shells. In the soil environment, they may provide little effective ANC as exposure to acid may result in the formation of surface crusts (iron oxides or gypsum), preventing or slowing further neutralisation reactions. For reasons including those above, the use of the Fineness Factor also applies to those naturally occurring alkalinity sources in soil materials as measured by the ANC methods.

1.5. Classification of soil materials

Recently, the Acid Sulfate Soils Working Group of the International Union of Soil Sciences agreed to adopt in principle the following five descriptive terminology and classification definitions of acid sulfate soil materials proposed by Professor Leigh Sullivan and co-authors in a plenary lecture and Acid Sulfate Soils Working Group meeting at the 6th International Acid Sulfate Soil and Acid Rock Drainage Conference in September 2008 in Guangzhou, China (Sullivan *et al.* 2008b). This new classification system for acid sulfate soil materials (Sullivan *et al.* 2009) has also been recently (October 2008) adopted by the Scientific Reference Panel of the Murray–Darling Basin Acid Sulfate Soil Risk Assessment Project for use in the detailed assessment of acid sulfate soils in the Murray–Darling Basin.

The criteria to define the soil materials are as follows:

1. **Sulfuric materials** – soil materials currently defined as sulfuric by the Australian Soil Classification (Isbell 1996). Essentially, these are soil materials with a $pH_W < 4$ as a result of sulfide oxidation.
2. **Sulfidic materials*** – soil materials containing detectable sulfide minerals (defined as containing greater than or equal to 0.01% sulfidic S). The intent is for this term to be used in a descriptive context (e.g. sulfidic soil material or sulfidic sediment) and to align with general definitions applied by other scientific disciplines such as geology and ecology (e.g. sulfidic sediment). The method with the lowest detection limit is the Cr-reducible sulfide method, which currently has a detection limit of 0.01%; other methods (e.g. X-ray diffraction, visual identification, Raman spectroscopy or infra red spectroscopy) can also be used to identify sulfidic materials.
**This term differs from previously published definitions in various soil classifications (e.g. Isbell, 1996).*
3. **Hypersulfidic material** – Hypersulfidic material is a sulfidic material that (i) has a field pH of 4 or more and (ii) is identified by experiencing a substantial* drop in pH to 4 or less (1:1 by weight in water, or in a minimum of water to permit measurement) when a 2–10 mm thick layer is incubated aerobically at field capacity. The duration of the incubation is either:
 - a. until the soil pH changes by at least 0.5 pH unit to below 4; or
 - b. until a stable** pH is reached after at least 8 weeks of incubation.**A substantial drop in pH arising from incubation is regarded as an overall decrease of at least 0.5 pH unit.*
***A stable pH is assumed to have been reached after at least 8 weeks of incubation when either the decrease in pH is < 0.1 pH unit over at least a 14 day period, or the pH begins to increase.*
4. **Hyposulfidic material** – Hyposulfidic material is a sulfidic material that (i) has a field pH of 4 or more and (ii) does not experience a substantial* drop in pH to 4 or less (1:1 by weight in water, or in a minimum of water to permit measurement) when a 2–10 mm thick layer is incubated aerobically at field capacity. The duration of the incubation is until a stable** pH is reached after at least 8 weeks of incubation.
**A substantial drop in pH arising from incubation is regarded as an overall decrease of at least 0.5 pH unit.*
***A stable pH is assumed to have been reached after at least 8 weeks of incubation when either the decrease in pH is < 0.1 pH unit over at least a 14 day period, or the pH begins to increase.*
5. **Monosulfidic materials** – soil materials with an acid volatile sulfide content of 0.01% S or more.

Non-Acid Sulfate Soil materials

In addition the Scientific Reference Panel of the Murray–Darling Basin Acid Sulfate Soil Risk Assessment Project agreed to identify the other acidic soil materials arising from the detailed assessment of wetland soils in the Murray–Darling Basin, even though these materials may not be the result of acid sulfate soil processes (e.g. the acidity developed during ageing may be the result of Fe^{2+} hydrolysis, which may or may not be associated with acid sulfate soil processes). The acidity present in field soils may also be due to the accumulation of acidic organic matter and/or the leaching of bases. Of course, these acidic soil materials may also pose a risk to the environment and would be identified during the present course of the Phase 1 detailed assessment. The definition of these other acidic soil materials for the detailed assessment of acid sulfate soils in the Murray–Darling Basin is as follows:

- 1. Other acidic soil materials** – either:
 - a. non-sulfidic soil materials that acidify by at least a 0.5 pH_w unit to a pH_w of < 5.5 during moist aerobic incubation
 - b. soil materials with a $\text{pH}_w \geq 4$ but < 5.5 in the field.
- 2. Other soil materials** – soils that do not have acid sulfate soil (or other acidic) characteristics.

2. METHODS AND MATERIALS

2.1. Field sampling of soils and waters

Field sampling of the 12 Edward and Wakool Rivers region priority wetlands was undertaken between 23rd March and 16th April 2010. A total of 194 soil layers were collected and analysed from 39 representative soil profiles within the Edward and Wakool Rivers region to assess the current and potential environmental hazard due to the presence of acid sulfate soils (Figure 1-2).

The number of sites sampled within each wetland was dependant on the size of the wetland (Table 2-1). A summary of the number of sites sampled in each of the Edward and Wakool Rivers priority wetlands is presented in Table 2-2. Sites were selected to ensure that the samples obtained were representative of each wetland for acid sulfate soil assessment. The rationale for site selection within each wetland is presented in Section 2.4.1.

Table 2-1. Study area size and suggested number of sites (MDBA 2010).

Study area size (ha)	Number of sample sites
<5	2
5 – 20	4
20 – 100	8
100 – 500	12
>500	20

Table 2-2: Summary of sites sampled in the Edward and Wakool Rivers.

Wetland ID	State	Main Name	Location	Area (m ²)	Area (ha)	No. of sites
20035	NSW	un-named wetland	Edward River Billabongs	11,008	1	2
20111	NSW	un-named wetland	Wakool River Billabongs	81,299	8	4
20177	NSW	Boiling Downs Creek	Wakool River Billabongs	86,182	9	4
28200	NSW	Glen Esk - Rusty Waterhole		49,025	5	4
20229	NSW	un-named wetland	Edward River Billabongs	58,099	6	4
20230	NSW	un-named wetland		10,568	1	2
20246	NSW	un-named wetland	Wakool River Billabongs	63,802	6	4
20264	NSW	un-named wetland	Edward River Billabongs	8,504	1	2
20580	NSW	Wakool-Tullakool Evaporation Basins	West Wakool saline depressions	31,584	3	1*
20832	NSW	Wakool-Tullakool Evaporation Basins	West Wakool saline depressions	4,889	<1	2
20833	NSW	Wakool-Tullakool Evaporation Basins	West Wakool saline depressions	268,613	27	6*
21761	NSW	Wakool-Tullakool Evaporation Basins	West Wakool saline depressions	73,112	7	4

* NSW DECCW only collected samples from 1 location at site 20580 as the site was small. In addition, only 6 locations were sampled at site 20833 due to limited access to the wetland.

At the majority of sites the soil profiles were sampled along a toposequence and where possible the profiles were chosen to represent: (i) the lowest point in the landscape, (ii) a moderately elevated site just above the observed or interpreted normal flow level, and (iii) an elevated site above the normal flow level.

Soil samples were collected from at least five sampling depths (to a maximum depth of 90 cm) using a range of implements (i.e. spades, and augers). At dry site locations soil pits were dug using a spade to approximately 0.6 m, and then a gouge auger was used to obtain soil samples below the base of the pit down to 90 cm or auger refusal. Soil samples were collected in two separate plastic jars (70 mL) with a screw top lid. Additional soil samples (500 g) were packed into plastic bags in which retained air was minimised for potential future Phase 2 laboratory analysis. Where soils were below the water, soil samples were obtained by using a shovel to grab the upper 20 cm and then a gouge auger was used to approximately 90 cm depth or to auger refusal. Where monosulfides were present the sample was collected into two glass jars (250 mL) with a screw top lid. All soil samples were maintained at $\leq 4^{\circ}\text{C}$ prior to analysis.

Soil samples from each depth at all sites were placed into two separate chip-trays. One tray was used in the determination of the pH following incubation ($\text{pH}_{\text{INCUBATION}}$) and the other was for long term archive storage.

Site and profile descriptions including global positioning system (GPS) coordinates are presented for each wetland in Appendix 1. Digital photographs were also taken to document each site and soil profile characteristics (see Appendix 1).

Surface water and groundwater quality data was collected from 13 sites in the Edward-Wakool Rivers region and are presented in Appendix 1. Water temperature, pH, specific electrical conductivity (SEC), dissolved oxygen (DO) and redox potential (ORP) were determined in the field using calibrated electrodes linked to a Hach HQ40d multi-parameter meter. Turbidity was measured using a calibrated Hach 2100P Turbidity meter. Alkalinity was also determined in the field by acid titration (Method 2320B) (APHA 2005).

Where water was present, filtered (0.45 μm) water samples were collected in 125 mL polyethylene bottles. Samples analysed for metals were acidified with a couple of drops of 0.5 % v/v high grade hydrochloric acid (HCl). Samples were stored at $\leq 4^{\circ}\text{C}$ and sent to the Environmental Analysis Laboratory, Southern Cross University for laboratory analysis.

Further details on the procedures followed in collection and storage of soil and water samples are presented in MDBA (2010).

2.2. Laboratory soil analysis methods

All soil samples were oven-dried at 80°C prior to analysis. Any coarse material (> 2 mm) present was removed by sieving, and then samples were ring mill ground.

The moisture content of each soil sample was determined following oven-drying at 80°C (Ahern *et al.* 2004). Several parameters were examined to determine whether acid sulfate soil materials were likely to be present, or if there was a potential for acid sulfate soil materials to form. The parameters measured in this study included pH (pH_W , pH_{FOX} , pH_{KCl} and $pH_{INCUBATION}$), titratable actual acidity (TAA), water soluble sulfate, chromium reducible sulfur (S_{CR}), retained acidity (RA), acid neutralising capacity (ANC), and acid volatile sulfide (S_{AV}).

The existing acidity of each soil layer (pH_W) was assessed by measuring the pH in a saturated paste (1:1 soil:water mixture) (Rayment and Higginson, 1992). The pH_{FOX} was determined following oxidation with 30 % hydrogen peroxide (H_2O_2) (Method 4E1) (Rayment and Higginson, 1992). The KCl extractable pH (pH_{KCl}) was measured in a 1:40 1.0 M KCl extract (Method Code 23A), and the titratable actual acidity (TAA) was determined by titration of the KCl extract to pH 6.5 (Method Code 23F) (Ahern *et al.* 2004). TAA is a measure of the actual acidity in soil materials, and the sum of soluble and exchangeable acidity. The pH following incubation ($pH_{INCUBATION}$) was determined on duplicate moistened soil materials placed in chip trays (Fitzpatrick *et al.* 2008c; Sullivan *et al.* 2009). The duration of the incubation was until a stable pH was reached after at least 8 weeks of incubation.

Water soluble sulfate (1:5 soil:water extract) was conducted on surface soil samples and was prepared following the procedures described in Rayment and Higginson (1992). Water soluble sulfate was analysed by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). The pyritic sulfur content was quantified using the chromium reduction analysis method of Burton *et al.* (2008b). The acid volatile sulfide fraction was extracted using a cold diffusion procedure (Hsieh *et al.* 2002).

Retained acidity (RA) was determined from the difference between 4M HCl extractable sulfur (S_{HCl}) and 1M KCl extractable sulfur (S_{KCl}) when the sample pH_{KCl} was < 4.5 (Method Code 20J) (Ahern *et al.* 2004). The retained acidity identifies stored soil acidity in the form of jarosite and similar relatively insoluble iron and aluminium hydroxy sulfate compounds (Ahern *et al.* 2004). Acid Neutralising Capacity, measured by the ANC_{BT} method (Method Code 19A2) (Ahern *et al.* 2004), was determined for sulfidic samples with a $pH_{KCl} \geq 6.5$. The Net Acidity was estimated by the Acid-Base Account method of Ahern *et al.* (2004). The objective of each method is discussed further in MDBA (2010).

2.3. Laboratory water analysis methods

The analysis of all water samples in this study was carried out by the Environmental Analysis Laboratory (EAL) at Southern Cross University. The water quality parameters measured on filter samples (0.45 µm) in this study included:

- major cations (Na, K, Ca, Mg) and Si (APHA 3120 ICPOES) (APHA 2005),
- dissolved bromide (APHA 4500 Br⁻) and chloride (APHA 4500 Cl⁻) (APHA 2005),
- dissolved nitrate (NO₃⁻) (APHA 4500 NO₃⁻) (APHA 2005),
- dissolved ammonia (NH₄) (APHA 4500 NH₃-H) (APHA 2005),
- dissolved phosphate (PO₄) (APHA 4500 P-E) (APHA 2005),
- dissolved sulfate (SO₄²⁻) (APHA 3120 ICPOES) (APHA 2005),
- trace metals (Ag, Al, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, Zn) (APHA 2005), and
- dissolved organic carbon (APHA 2005).

2.4. Quality assurance and quality control

2.4.1. Site selection and sample collection

The Senior Soil Surveyors for all the sampling undertaken in the Edward and Wakool Rivers priority wetlands were Mitch Tulau, Belinda Allman, David Morand and Rob Muller. Sampling was undertaken between 23rd March and 16th April 2010 by Mitch Tulau, Belinda Allman, David Morand, Rob Muller, Brian Jenkins, Greg Chapman, Michael Eddie and Jonathan Gray. A summary of what was done to select the site locations and layers that were sampled is presented below in Table 2-3. The sampling team were unable to access certain wetland areas due to steep banks, unnavigable waters or unstable substrate.

Table 2-3. Summary of site and layer selection for the Edward and Wakool Rivers priority wetlands.

Wetland ID	Main Name	Date Sampled	Comments on site/layer selection
20035	un-named wetland	23/03/10	Two site transect, sampled according to protocol.
20111	un-named wetland	06/04/10	Two site transect within wetland, and two site transect in flood chute outside mapped wetland, otherwise sampled according to protocol.
20177	Boiling Downs Creek	14/04/10	Three site transect adjacent to deep water body, and one outside transect – sampled according to protocol.
28200	Glen Esk - Rusty Waterhole	31/03/10	Sulfuric conditions, two sites at lowest point and two either end of system on higher elevation, sampled according to protocol.
20229	un-named wetland	19/03/10	Four site transect, sampled according to protocol.
20230	un-named wetland	25/03/10	Two site transect, sampled according to protocol.
20246	un-named wetland	30/03/10	Sulfuric conditions, two sites at lowest point and two spaced through the channel, sampled according to protocol.
20264	un-named wetland	12/04/10	Two site transect in typical area, sampled according to protocol.
20580	Wakool-Tullakool Evaporation Basins	07/04/10	One very small site, sampled according to protocol.
20832	Wakool-Tullakool Evaporation Basins	07/04/10	Two site transect sampled according to protocol.
20833	Wakool-Tullakool Evaporation Basins	15/04/10	No access to half of wetland as unable to obtain permission to the property adjoining the Crown Land reserve. Six site transect across widest section of wetland, sampled according to protocol.
21761	Wakool-Tullakool Evaporation Basins	08/04/10	Four site transect sampled according to protocol.

2.4.2. Laboratory analysis

For all tests and analyses, the Quality Assurance and Quality Control procedures were equivalent to those endorsed by NATA (National Association of Testing Authorities). The standard procedures followed included the monitoring of blanks, duplicate analysis of at least 1 in 10 samples, and the inclusion of standards in each batch.

Reagent blanks and method blanks were prepared and analysed for each method. All blanks examined here were either at, or very close to, the limits of detection. On average, the frequencies of quality control samples processed were: 5% blanks, $\geq 10\%$ laboratory duplicates, and 5% laboratory controls. The analytical precision was $\pm 5\%$ for all analyses.

2.5. Criteria for ranking soil materials for inclusion in Phase 2 of the detailed assessment process

The Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project agreed to recommend that soil materials be assigned the following priorities to undertake the Phase 2 detailed assessment:

High Priority

- 1) All sulfuric materials.
- 2) All hypersulfidic materials (as recognised by either 1) incubation of sulfidic materials or 2) a positive net acidity result with a Fineness Factor of 1.5 being used).
- 3) All hyposulfidic materials with S_{CR} contents $\geq 0.10\%$ S.
- 4) All surface soil materials (i.e. within 0-20 cm) with water soluble sulfate (1:5 soil:water) contents ≥ 100 mg SO_4 /kg.
- 5) All monosulfidic materials.

Moderate Priority

All hyposulfidic materials with S_{CR} contents $< 0.10\%$ S.

No Further Assessment

- 1) Other acidic soil materials.
- 2) All other soil materials.

It is important to note, while the criteria identifying samples for Phase 2 analysis is clearly defined, samples only go through to Phase 2 when consideration is given to the wetland as a whole.

3. RESULTS

3.1. Summary of field and laboratory results

3.1.1. Soil pH (pH_W , pH_{FOX} , pH_{KCl} and $pH_{INCUBATION}$)

The pH_W , pH_{FOX} , pH_{KCl} and $pH_{INCUBATION}$ data for the wetland sites examined in Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. The pH_W values ranged between 3.28 and 8.44, with the majority of the samples having a $pH_W > 4.5$. A total of eight sites from five wetlands within the Edward and Wakool Rivers region were classified sulfuric (i.e. $pH_W < 4$) including sites 20111_2 (5-20 cm), 20177_3 (20-90 cm), 28200_1 (0-5 cm), 28200_3 (5-10 cm, 40-90 cm), 28200_4 (40-90 cm), 20229_3 (40-90 cm), 20229_4 (40-90 cm) and 20246_4 (0-5 cm). None of the other soils in the Edward and Wakool Rivers region priority wetlands are classified as sulfuric materials as they all had a $pH_W > 4$.

The pH_{FOX} values ranged between 1.52 and 8.58. The majority of the soils showed a pH drop after treatment with peroxide, with a maximum decrease of 4.9 pH units (e.g. Figure 3-1). The pH_{FOX} results also indicate that many of the surface soils in the Edward and Wakool Rivers region may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. Four of the wetlands (i.e. Wetland ID 20580, 20832, 20833, and 21761) had $pH_{FOX} > 4$ in all layers. Half of the wetlands examined in the Edward and Wakool Rivers region had layers with $pH_{FOX} < 2.5$ (i.e. Wetland ID 20111, 20177, 28200, 20229, 20246 and 20264). However, the S_{CR} data shows that many of the layers which showed a substantial pH drop after treatment with peroxide contained no detectable sulfide (i.e. $S_{CR} < 0.01\% S$). While decreases in pH after treatment with peroxide are often used to indicate the presence of sulfide minerals in coastal acid sulfate soil materials, the S_{CR} data from these studies suggest that pH decreases in inland acid sulfate soil materials after peroxide has been added are often due to non-acid sulfate soil factors such as the oxidation of organic matter.

The $pH_{INCUBATION}$ values ranged between 1.94 and 7.48. Sixteen of the 39 sulfidic soil materials (i.e. $S_{CR} \geq 0.01\% S$) acidified to $pH < 4$ after at least 8 weeks of incubation (i.e. sites 20177_1 (0-5 cm and 40-90 cm), 20177_2 (40-90 cm), 20177_4 (40-90 cm), 28200_1 (5-10 cm and 40-90 cm), 28200_2 (10-90 cm), 20246_1 (40-90 cm), 20246_2 (0-90 cm) and 20246_3 (40-90 cm)). Two sulfidic soil layers with negative net acidities acidified to $pH < 4$ after at least 8 weeks of incubation (i.e. site 20246_2 (20-40 cm and 40-90 cm)). In addition, several non-sulfidic soils (i.e. other acidic) acidified to $pH < 4$ over the 8 week incubation period (Appendix 1). Several sulfidic soil materials that did not acidify to $pH < 4$ after at least 8 weeks of incubation were classified as hypersulfidic as they had positive net acidities (see Section 2.5).

Table 3-1. Summary soil data for pH testing and sulfur suite.

Parameter	Units	Minimum	Median	Maximum	n ¹
pH _W ²		3.28	5.77	8.44	194
pH _{FOX} ³		1.52	3.23	8.58	194
pH _{KCl} ⁴		4.07	5.40	9.13	194
pH _{INCUBATION} ⁵		1.94	4.27	7.48	194
TAA ⁶	mole H ⁺ /t	0.00	15.72	122.50	194
Soluble SO ₄ ⁷	mg SO ₄ /kg	36	215	26,100	39
S _{CR} ⁸	Wt. %S	<0.01	<0.01	0.83	194
S _{AV} ⁹	Wt. %S	<0.01	<0.01	0.40	194
RA ¹⁰	mole H ⁺ /t	0.00	0.00	228	194
ANC ¹¹	%CaCO ₃	0.00	0.00	10.15	194
NA ¹²	mole H ⁺ /t	-1345.06	22.70	388.99	194

¹ n: number of samples. ² pH_W: pH in saturated paste with water. ³ pH_{FOX}: pH after treatment with 30% H₂O₂. ⁴ pH_{KCl}: pH of 1:40 1 M KCl extract. ⁵ pH_{INCUBATION}: pH after least 8 weeks of incubation. ⁶ TAA: Titratable Actual Acidity. ⁷ Soluble sulfate: in 1:5 soil:water extract. ⁸ S_{CR}: Chromium Reducible Sulfur. ⁹ S_{AV}: Acid Volatile Sulfide. ¹⁰ RA: Retained Acidity. ¹¹ ANC: Acid Neutralising Capacity: by definition, where pH_{KCl} < 6.5 ANC = 0. ¹² NA: Net Acidity.

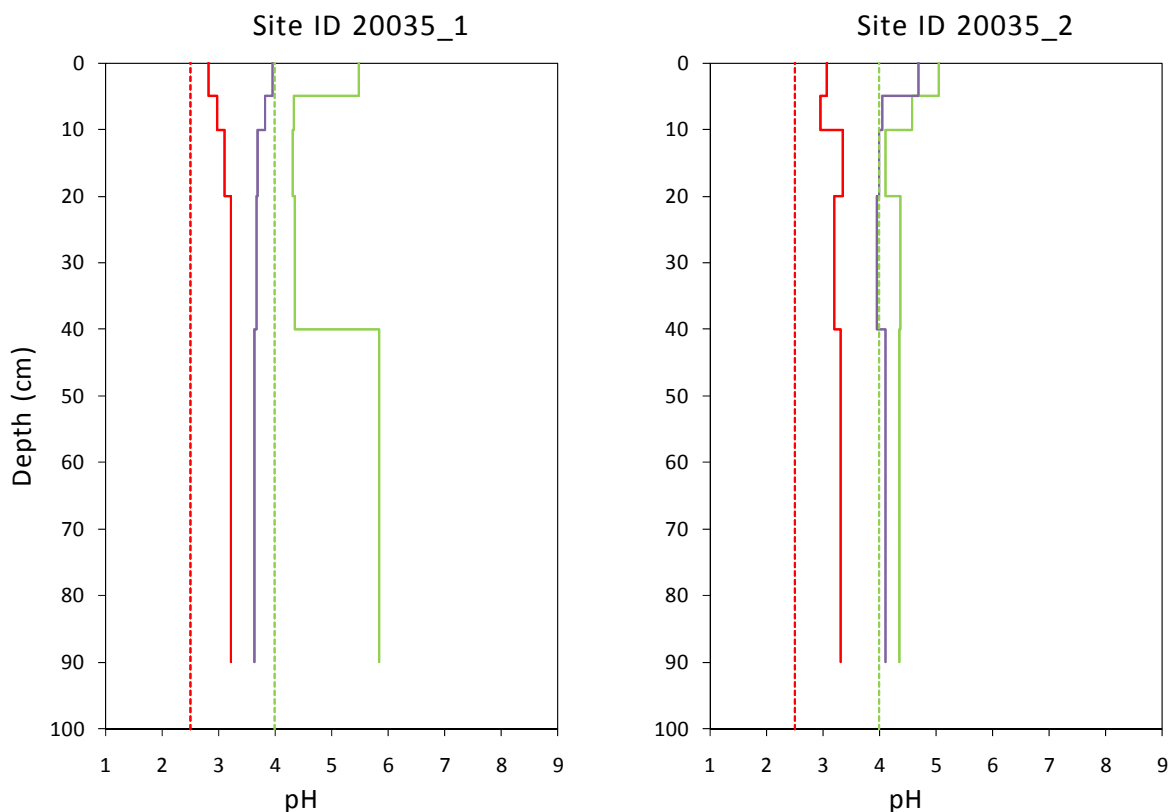


Figure 3-1. Depth profiles of soil pH for (200352_1 – 20035_2), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH (pH_{incubation} after at least 8 weeks as purple line). Critical pH_W and pH_{incubation} value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

3.1.2. Chromium Reducible Sulfur (S_{CR})

The chromium reducible sulfur (S_{CR}) data for the wetland sites examined in the Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. The S_{CR} values ranged between < 0.01 and 0.83% S. Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were present in five of the 12 wetlands examined (i.e. Wetland ID 20111, 20177, 28200, 20246 and 20832), with 39 materials of the 194 samples collected equal to or greater than the sulfidic criterion. A total of 12 sites of the 39 sites examined contained sulfidic materials.

A summary of the S_{CR} content and number of sulfidic soil materials observed in each wetland is given in Table 3-2. Wetlands 20177 and 20832 had the highest percentage of sites containing sulfidic soil materials (i.e. 100%). Wetland 20832 also had the highest percentage of layers examined containing sulfidic soil materials (i.e. 89%). Further information on the distribution of sulfidic sediments within each wetland is given in Appendix 1.

Table 3-2. Summary of the S_{CR} content and number of sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) observed within each wetland in the Edward and Wakool Rivers priority wetlands.

Wetland ID	Main Name	S_{CR} Range (%S)	No. of sulfidic sites	No. of sulfidic layers	Site No.
20035	un-named wetland	< 0.01	0 (0%)	0 (0%)	-
20111	un-named wetland	$< 0.01 - 0.03$	1 (25%)	1 (5%)	1
20177	Boiling Downs Creek	$< 0.01 - 0.58$	4 (100%)	12 (60%)	1 - 4
28200	Glen Esk - Rusty Waterhole	$< 0.01 - 0.33$	2 (50%)	7 (35%)	1, 2
20229	un-named wetland	< 0.01	0 (0%)	0 (0%)	-
20230	un-named wetland	< 0.01	0 (0%)	0 (0%)	-
20246	un-named wetland	$< 0.01 - 0.83$	3 (75%)	11 (55%)	1, 2, 3
20264	un-named wetland	< 0.01	0 (0%)	0 (0%)	
20580	Wakool-Tullakool Evaporation Basins	< 0.01	0 (0%)	0 (0%)	-
20832	Wakool-Tullakool Evaporation Basins	$< 0.01 - 0.28$	2 (100%)	8 (89%)	1, 2
20833	Wakool-Tullakool Evaporation Basins	< 0.01	0 (0%)	0 (0%)	-
21761	Wakool-Tullakool Evaporation Basins	< 0.01	0 (0%)	0 (0%)	-

3.1.3. Acid volatile sulfide (S_{AV})

The acid volatile sulfide (S_{AV}) data for the wetland sites examined in the Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. The S_{AV} values ranged between < 0.01 and 0.40% S. Monosulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were present in five of the 12 wetlands examined (i.e. Wetland ID 20111, 20177, 28200, 20246 and 20832), with only 29 materials of the 194 samples collected equal to or greater than the monosulfidic criterion. A total of 10 sites of the 39 sites examined contained monosulfidic soil materials. Further information on the distribution of monosulfidic sediments within each wetland is given in Appendix 1.

3.1.4. Acid Neutralising Capacity (ANC)

The acid neutralising capacity (ANC) data for the wetland sites examined in the Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. The ANC ranged between zero and 10.1 %CaCO₃ (see Table 3-1). Seven of the wetlands had no ANC in the soil profile (i.e. Wetland ID 20035, 20111, 20177, 28200, 20229, 20230 and 20264).

3.1.5. Net Acidity (NA)

The net acidity data for the wetland sites examined in the Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. Acid-base accounting calculations showed the net acidity ranged between -1,345 and 389 mole H⁺/tonne, with a median net acidity of 23 mole H⁺/tonne. The net acidity thresholds used to characterise the acid sulfate soil materials in this assessment include low net acidity (< 19 mole H⁺/tonne), moderate net acidity (19 - 100 mole H⁺/tonne) and high net acidity (> 100 mole H⁺/tonne). A summary of the net acidity data for each wetland is given in Table 3-3, and shows the presence of soil materials with moderate to high net acidities in all wetlands except the Wakool-Tullakool Evaporation Basin sites. Three hypersulfidic soil materials in both Boiling Downs Creek and Glen Esk - Rusty Waterhole had high net acidities. In addition, five hypersulfidic soil materials in Wetland ID 20246, and two sulfuric materials (and one other acid soil material) at Glen Esk - Rusty Waterhole, also had high net acidities.

The acidification hazard from acid sulfate soil disturbance posed by the five wetlands containing sulfuric soil materials (i.e. Wetland ID 20111, 20177, 28200, 20229 and 20246) is generally low to moderate, with only two sulfuric soil materials having a high net acidity (i.e. site 28200_3). The acidification hazard from acid sulfate soil disturbance posed by five wetlands containing hypersulfidic soil materials (i.e. Wetland ID 20111, 20177, 28200, 20246 and 20832) ranged from low to high, with net acidities ranging between -19 and 389 mole H⁺/tonne. As mentioned previously, a total of 11 hypersulfidic soil materials had high net acidities.

The positive net acidities in the non-sulfidic samples were due to the presence of some TAA and the lack of any ANC, although a few layers also contained some retained acidity (Appendix 1).

3.1.6. Water soluble SO₄

The water soluble SO₄ data for the wetland sites examined in the Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. The water soluble SO₄ in the surface soils (i.e. 0-5 cm) in the Edward and Wakool Rivers region ranged between 36 and 26,100 mg/kg. The surface soil layer in 30 of the 39 sites examined had a soluble SO₄ content exceeding the trigger value of 100 mg/kg indicating the potential formation of monosulfidic materials. At least one site in each of the 12 wetlands examined had a soluble SO₄ content exceeding the trigger value. The nine wetland sites with a soluble SO₄ content less than the trigger value included sites 20035_2, 20111_1, 20111_3, 20111_4, 20833_3 – 20833_6, and 21761_2.

Table 3-3. Summary of the net acidity data for all soil materials in each wetland in the Edward and Wakool Rivers priority wetlands.

Wetland ID	Main Name	Net Acidity (mole H ⁺ /tonne)		
		Minimum	Median	Maximum
20035	un-named wetland	11	68	85
20111	un-named wetland	2	31	58
20177	Boiling Downs Creek	18	44	389
28200	Glen Esk - Rusty Waterhole	18	62	297
20229	un-named wetland	10	36	82
20230	un-named wetland	9	23	67
20246	un-named wetland	-37	57	326
20264	un-named wetland	30	49	65
20580	Wakool-Tullakool Evaporation Basins	-116	-73	6
20832	Wakool-Tullakool Evaporation Basins	-1,345	-724	2
20833	Wakool-Tullakool Evaporation Basins	-1006	-107	10
21761	Wakool-Tullakool Evaporation Basins	-876	-563	-5

3.1.7. Titratable actual acidity (TAA)

The titratable actual acidity (TAA) data for the wetland sites examined in the Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. The TAA ranged between zero and 123 mole H⁺/tonne, with a median TAA of 16 mole H⁺/tonne. An increase in the TAA with depth was observed at some of the wetland sites examined (e.g. Figure 3-2).

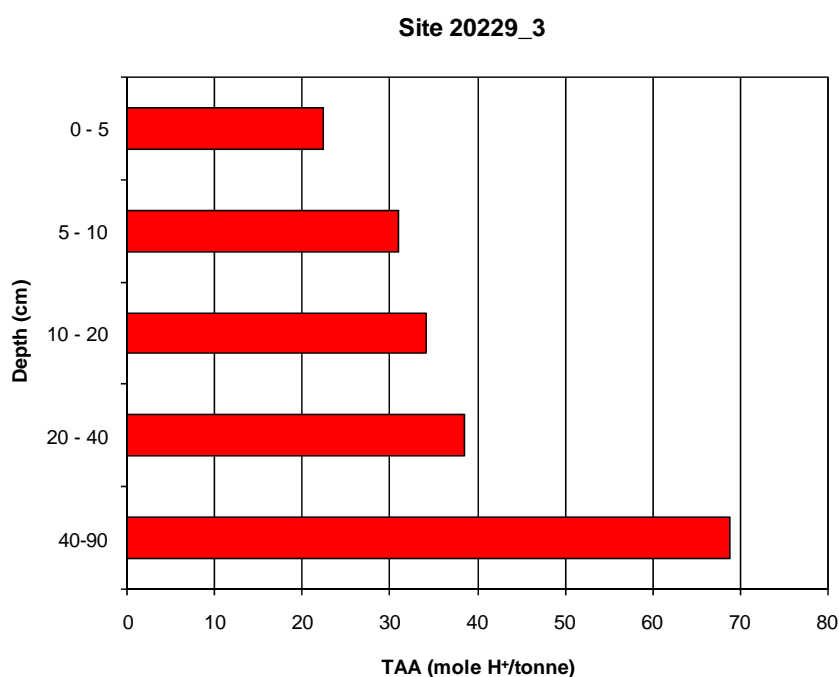


Figure 3-2. Variation in TAA (mole H⁺/tonne) with depth at site 20229_3.

3.1.8. Retained acidity (RA)

The retained acidity data for the wetland sites examined in the Edward and Wakool Rivers region are presented in Appendix 1 and summarised in Table 3-1. The retained acidity ranged between zero and 228 mole H⁺/tonne, with the majority of soil layers having no retained acidity (i.e. 184 materials of the 194 samples collected). Retained acidity was only detected in samples collected from four of the wetlands (i.e. Wetland ID 20035, 20177, 28200 and 20264). Site 28200_3 at Glen Esk - Rusty Waterhole contained retained acidity throughout the soil profile.

3.2. Hydrochemistry

The hydrochemical characteristics of the surface water and groundwater in the Edward and Wakool Rivers region were measured to provide an indication of the baseline water chemistry. Some of the chemical parameters measured may show temporal variations, and therefore the data collected only represents a snapshot of the water quality in the Edward and Wakool River region.

Surface water quality data was collected from 10 sites in the Edward and Wakool River region priority wetlands (including sites 20035_1, 20111_1, 20111_2, 20177_1, 20229_1, 20246_1, 20246_2, 20246_3, 20832_1 and 28200_1) (Appendix 1). At site 20111_2, field measurements were not recorded at the time of sampling. Groundwater data was collected from three locations in the Edward and Wakool River region priority wetlands (including sites 20177_2, 20177_4 and 28200_2) (Appendix 1).

A summary of the surface water and groundwater characteristics measured in the field are presented below in Tables 3-4 and 3-5. The results of the laboratory analyses are presented in Appendix 1. The field pH of the surface waters ranged between 2.52 and 8.63 (Table 3-4), with all (except site 20111_1) outside the most relevant ANZECC/ARMCANZ (2000) trigger values for aquatic ecosystems of 6.5 and 8.0. The water data indicates that the surface water at two sites has been affected by acidification (sites 20246_3 and 28200_1 had pH values of 2.87 and 2.52, respectively). The surface waters were often highly saline with a median SEC of 4,390 $\mu\text{S}/\text{cm}$. The surface water sulfate concentrations ranged between 38 and 3,914 mg/L (Appendix 1). Some nutrient (i.e. NO_3 , NH_4 , PO_4), metal (i.e. Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn), dissolved oxygen, SEC and turbidity values were found to be outside the most relevant ANZECC/ARMCANZ (2000) guideline value at some sites (see Appendix 1).

Table 3-4. Summary of surface water hydrochemical characteristics (field).

	pH	SEC $\mu\text{S}/\text{cm}$	DO mg/L	ORP mV	Turbidity NTU	Alkalinity (mg/L as HCO_3)
Minimum	2.52	137	0.42	-27.00	13	0
Median	6.09	4,390	8.02	246.00	61	34
Maximum	8.63	163,200	16.73	469.80	490	140
n ¹	9	9	9	7	9	9

¹ n: number of samples

The field pH of the groundwater ranged between 5.05 and 6.08, indicating that the groundwater at one location may have been affected by acidification (Table 3-5). The highly saline groundwater had sulfate concentrations of 650 and 652 mg/L.

Table 3-5. Summary of groundwater hydrochemical characteristics (field).

	pH	SEC $\mu\text{S cm}^{-1}$	DO mg/L	ORP mV	Turbidity NTU	Alkalinity (mg/L as HCO_3)
Minimum	5.50	18,970	0.41	-67.00	177	136
Median	5.94	21,540	0.62	9.50	648	150
Maximum	6.08	26,900	0.79	95.00	711	164
n ¹	3	3	3	3	3	2

¹ n: number of samples

4. DISCUSSION

A detailed assessment was undertaken in the Edward and Wakool Rivers region in March-April 2010 to determine whether acid sulfate soils were present, or if there was a potential for acid sulfate soils to form within these wetlands. This study identified the presence of acid sulfate soil materials in 18 of the 39 sites examined in the Edward and Wakool Rivers region. The soluble sulfate contents of 30 surficial soil materials sampled were equal to or exceeded the trigger value of 100 mg/kg indicating the potential formation of monosulfidic materials.

The type and prevalence of acid sulfate soil materials observed in each wetland is summarised below in Table 4-1. The presence of acid sulfate soils was identified in six of the 12 wetlands examined. Sulfuric materials were observed at eight sites in five of the wetlands. All sulfuric soil materials had low to moderate net acidities, with the exception of two soil materials with high net acidities at site 28200_3. A total of 11 hypersulfidic soil materials from three of the wetlands (i.e. Boiling Downs Creek (20177), Glen Esk - Rusty Waterhole (28200) and Wetland ID 20246) had high net acidities (i.e. > 100 mole H⁺/tonne). All other hypersulfidic soil materials had low to moderate net acidities. Hyposulfidic soil materials were only observed in two of the wetlands examined.

Many of the hypersulfidic and hyposulfidic soil materials were classified as hypermonosulfidic and hypomonosulfidic, respectively (Sullivan *et al.* 2010) (see Appendix 1). A total of 10 sites in five of the wetlands examined contained monosulfidic soil materials. High monosulfide concentrations in surface soils (i.e. 0-10 cm) in four of these wetlands (i.e. Wetlands 20177, 28200, 20246 and 20832) represent a high deoxygenation hazard. The potential formation of monosulfidic materials was identified in the surface soils at all of the wetlands examined. Other acidic soil materials often with a pH < 5 were observed at an additional 13 sites, and soil acidity may be sufficient for mobilisation of aluminium at some sites.

Table 4-1 Type and prevalence of acid sulfate soil materials in each wetland.

Type of actual or potential acid sulfate soil material	Wetland ID (No. of sites)											
	20035	20111	20177	28200	20229	20230	20246	20264	20580	20832	20833	21761
Sulfuric	0	1	1	3	2	0	1	0	0	0	0	0
Hypersulfidic	0	1	4	2	0	0	3	0	0	1	0	0
Hyposulfidic (S _{CR} ≥ 0.10%)	0	0	0	0	0	0	1	0	0	2	0	0
Monosulfidic (observed)	0	1	3	2	0	0	2	0	0	2	0	0
Monosulfidic (potential)	1	1	4	4	4	2	4	2	1	2	2	3
Hyposulfidic (S _{CR} < 0.10%)	0	0	0	0	0	0	0	0	0	1	0	0
Other acidic (pH _w &/or pH _{INCUBATION}) 4 – 5.5	2	2	0	0	2	2	0	2	1	0	2	0
Other soil materials	0	0	0	0	0	0	0	0	0	0	4	4

The findings of a detailed acid sulfate soil assessment recently completed by Southern Cross GeoScience and NSW DECWW within the in-stream and channel environments of the Edward-Wakool River system will provide a further understanding of the distribution and hazard of acid sulfate soils in this region.

5. HAZARD ASSESSMENT

5.1. Interpretation of soil and water data

Sulfuric soil materials were observed at eight of the sampling sites (Table 5-1).

Hypersulfidic materials occurred in the soil profile at 11 of the 39 sampling locations (Table 5-1). Sites where hypersulfidic materials occurred were usually in the lowest elevation drainage depressions where water-logged and reducing conditions, suitable for the formation of sulfides, occur.

The data indicate that in eight of the wetlands examined the degree of acidification hazard is low (see Appendix 1). However, three of the wetlands assessed (i.e. Wetland 20177, 28200 and 20246) contained acid sulfate soil materials with high net acidities that represent a high acidification hazard. In addition, one wetland (i.e. Wetland 20229) contained sulfuric materials with moderate net acidities that represent a moderate acidification hazard.

Hyposulfidic soil materials with $S_{CR} \geq 0.10\%$ and $S_{CR} < 0.10\%$ were present at three and one sampling sites, respectively (Table 5-1). In addition, other acidic soil materials often with a $pH < 5$ were observed at an additional 13 sites, and soil acidity may be sufficient for mobilisation of aluminium at some sites.

Monosulfidic soil materials ($S_{AV} \geq 0.01\%$) occurred in the soil profile at 10 sampling locations (Table 5-1). High monosulfide concentrations ($S_{AV} \leq 0.40\%$ S) in surface soils in four wetlands (i.e. Wetland 20177, 28200, 20246 and 20832) represent a high deoxygenation hazard. The soluble sulfate contents of 30 surficial soil materials sampled were equal to or exceeded the trigger value of 100 mg/kg indicating the potential formation of monosulfidic materials (Table 5-1). The potential formation of MBO was identified in all of the wetlands examined.

The water data indicates that the surface water at the majority of sites has not been affected by acidification. However, low pH values ($pH \leq 2.9$) at two of the sites containing sulfidic soil materials (i.e. sites 20246_3 and 28200_1) suggest acidification as a result of sulfide oxidation may have occurred (Appendix 1).

Table 5-1 Type and prevalence of acid sulfate soil materials.

Type of actual or potential acid sulfate soil material	Number of sampling sites containing sulfuric or sulfidic materials (Total sites = 39)	Proportion of total sampling sites (%)
Sulfuric	8	21%
Hypersulfidic	11	28%
Hyposulfidic ($S_{CR} \geq 0.10\%$)	3	8%
Monosulfidic (observed)	10	26%
Monosulfidic (potential)	30	77%
Hyposulfidic ($S_{CR} < 0.10\%$)	1	3%
Other acidic (pH_w &/or $pH_{INCUBATION}$) 4 – 5.5	13	33%
Other soil materials	8	21%

6. CONCLUSIONS AND RECOMMENDATIONS

This report provides the results of Phase 1 of a two-phased detailed assessment procedure to determine the hazards posed by acid sulfate soil materials in priority wetlands in the Edward and Wakool Rivers region. This Phase 1 report is aimed solely at determining whether or not acid sulfate soil materials are present in the Edward and Wakool Rivers region priority wetlands.

Sulfuric materials were observed at eight sampling sites. The reduced inorganic sulfur content of the samples was high in some areas (i.e. S_{CR} was up to 0.83% S). Hypersulfidic soil materials were present in 11 soil profiles (two profiles also contained hyposulfidic materials), and another soil profile contained hyposulfidic materials (with $S_{CR} \geq 0.10\%$ and $< 0.10\%$). Monosulfidic soil materials were observed in 26% (i.e. 10) of the sampling sites. These results indicate that acidity would be produced upon oxidation of sulfides in some of these materials.

A total of 30 surficial soil materials contained soluble sulfate equal to or in excess of the 100 mg/kg trigger value for MBO formation potential. The potential formation of MBO was identified in all of the wetlands examined. Other acidic soil materials often with a $pH < 5$ were also observed at an additional 13 sites.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there were eight high priority sites based on the presence of sulfuric material, 11 high priority sites based on hypersulfidic material, three high priority sites based on hyposulfidic ($S_{CR} \geq 0.10\%$) material and 10 high priority sites based on monosulfidic material. There was one moderate priority site based on the presence of a hyposulfidic material with $S_{CR} < 0.10\%$. In addition, 30 sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard. All wetlands in the Edward and Wakool Rivers region receive a high priority ranking on at least one of the criteria.

The potential hazards at the wetland-scale posed by acid sulfate soil materials in priority wetlands in the Edward and Wakool Rivers region are as below:

- **Acidification:** The data indicate that in eight of the wetlands examined the degree of acidification hazard is low. However, three of the wetlands assessed (i.e. Wetland 20177, 28200 and 20246) contained acid sulfate soil materials with high net acidities that represent a high acidification hazard. In addition, one wetland (i.e. Wetland 20229) contained sulfuric materials with moderate net acidities that represent a moderate acidification hazard.
- **Deoxygenation:** High monosulfide concentrations ($S_{AV} \leq 0.40\%$ S) in surface soils in four wetlands (i.e. Wetland 20177, 28200, 20246 and 20832) represent a high deoxygenation hazard. In addition, the soluble sulfate contents of 30 surface soil materials were equal to or greater than the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- **Metal mobilisation:** The low acidification hazard in all except four wetlands indicates that soil acidification is not likely to increase the solubility of metals. At the four wetlands with a moderate to high acidification hazard, soil acidification may increase the solubility of metals. The presence of monosulfidic materials in some surface soils at four wetlands, and the potential for MBO formation identified in all wetlands, may also result in an appreciable metal release hazard. This would depend on factors such as the potential for MBO formation and the metal loading in the wetland.

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8. APPENDICES

APPENDIX 1. Wetland reports

8.1. Wetland ID 20035

8.1.1. Location and setting description

This is a short, very narrow wetland running parallel to the south side of the Edward River. It is part of a chute system. The wetland is about 500 m long, 50 m wide and 1 ha. At the time of the soil survey in April 2010 it was densely choked with red gum suckers. Water was present, with prominent iron flocs, but not connected to the Edward. The remnants of a cracked surface with prismatic structure were evident underfoot within the waterbody. Sediment from the wetland banks was accumulating on the channel margins.

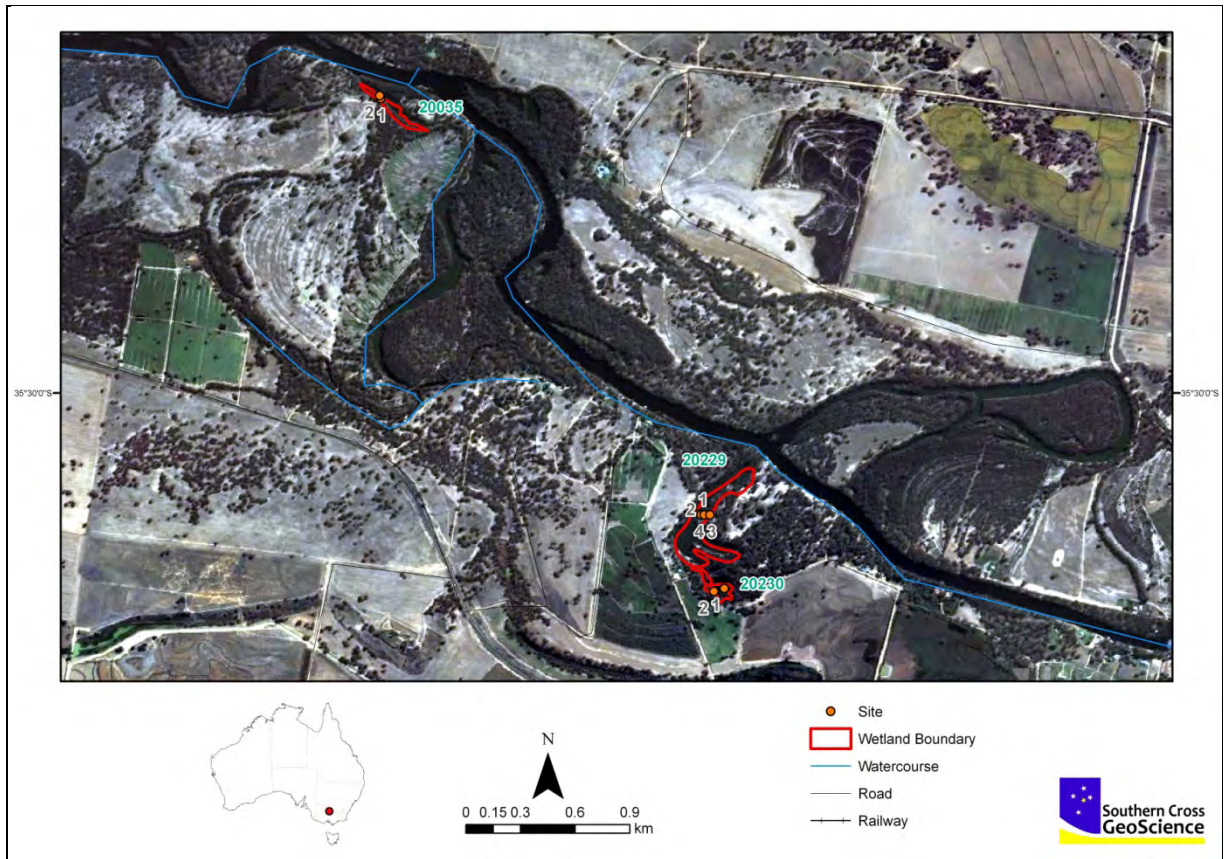


Figure 8-1. Wetland ID 20035 and sample site locations.

8.1.2. Soil profile description and distribution

Two sites were described and sampled. Sites occurred on the sloping bank adjacent to the waterbody and were distributed on a transect based on elevation and surface differences. The soil subtype and general location description are presented in Table 8-1.

The profile 20035_1 (Figure 8-3) was subaqueous (40 cm water depth) and occurred in the middle of the narrow waterbody, the soil consisted of grey light silty clay with prominent orange mottles in the top 10 cm. The profile 20035_2 (Figure 8-4) occurred on the sloping bank adjacent the waterbody, the soil consisted of grey sand over layers of grey mottled sandy clay loam, sandy clay and clayey sand. Additional site and profile description data are presented in Tables 8-5 and 8-6, respectively.

Table 8-1. Soil identification, subtype and general location description for Wetland ID 20035.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20035_1	308092	6071066	subaqueous soil	subaqueous, in centre of the narrow water body
20035_2	308087	6071081	hydrosol	on bank adjacent to water body

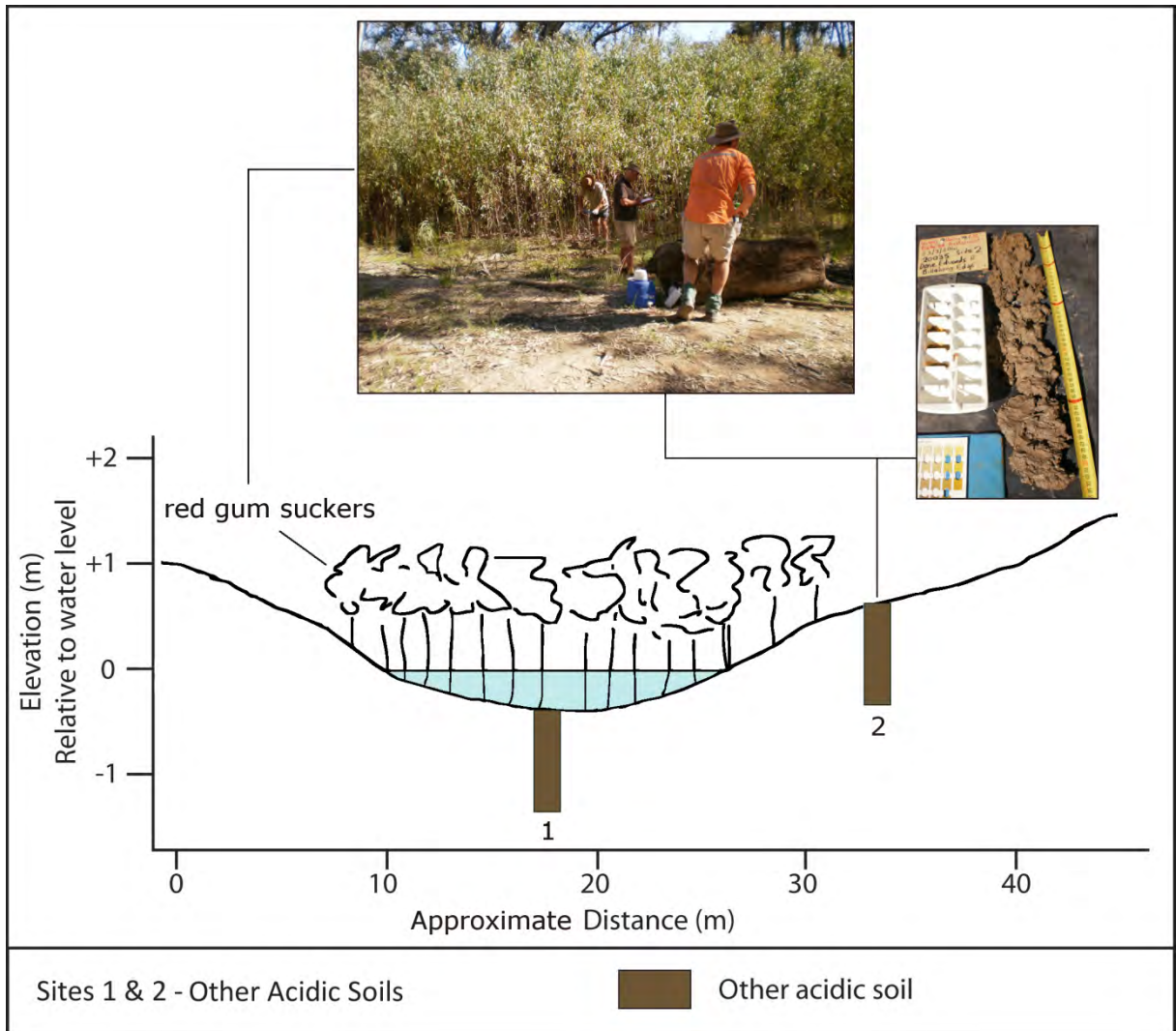


Figure 8-2. Conceptual cross section diagram showing the toposequence relationship of the Wetland ID 20035 sediments/soil materials.



Figure 8-3. Photographs of site 20035_1, showing the area of red gum suckers from which the sample was taken, and the Aquic Vertisol soil core.



Figure 8-4. Photographs of site 20035_2, showing the fringing grassland, and the soil core.

8.1.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Table 8-2 and profiles for all the sites sampled are presented in Figure 8-5. The pH_W values ranged between 4.10 and 5.84. Sulfuric materials (i.e. $pH_W < 4$) were not present. The pH_{FOX} values ranged between 2.83 and 3.35. The pH_{FOX} results indicate that all surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. However, the S_{CR} data shows these soils contained no detectable sulfide (i.e. $S_{CR} < 0.01\% S$). Other acidic soil materials were identified throughout the profile at both sites, indicating acidity in the soil profile at levels where aluminium may mobilise. Seven of the other acidic soils acidified to $pH < 4$ after at least 8 weeks of incubation.

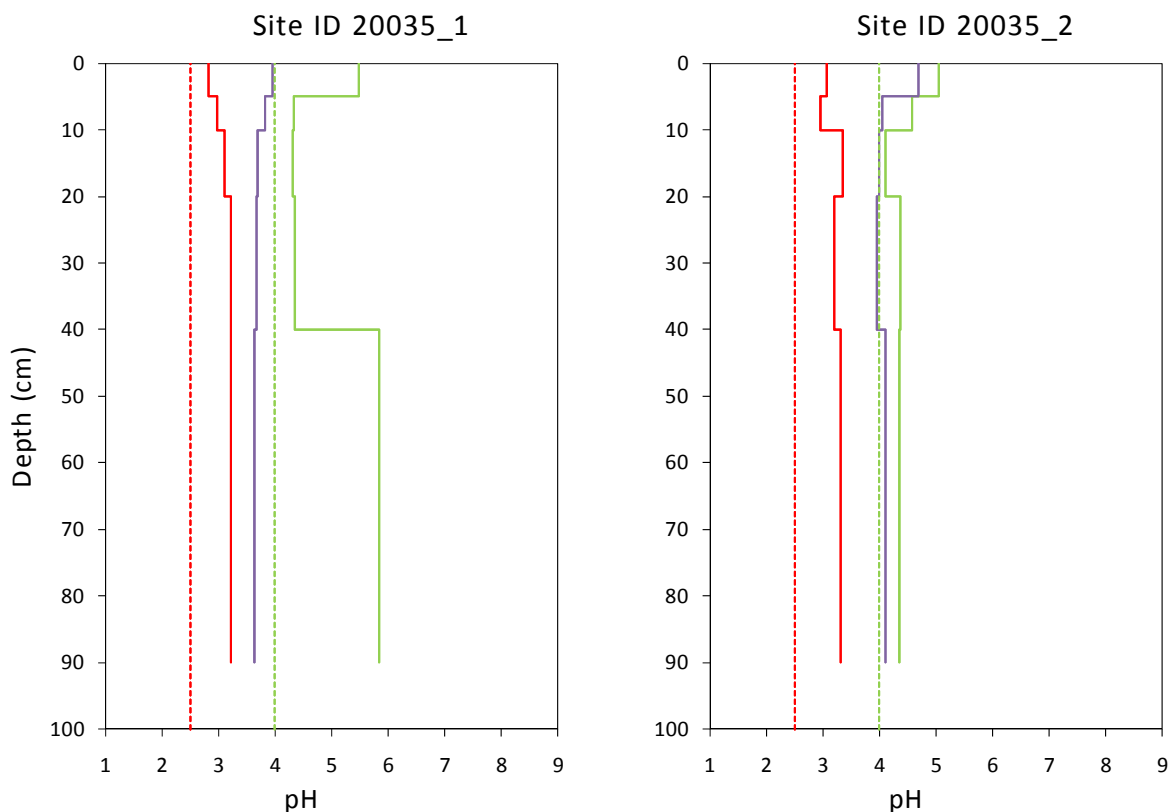


Figure 8-5. Depth profiles of soil pH for Wetland ID 20035 (20035_1 – 20035_2), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-2 and summarised in Figure 8-6.

Chromium reducible sulfur

Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were not found within this wetland.

Acid volatile sulfide

Monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were not found within this wetland.

Acid neutralising capacity

All soil materials had no acid neutralising capacity (ANC).

Titratable actual acidity

The titratable actual acidity (TAA) ranged between 11 and 82 mole H^+ /tonne, with the majority of soil layers having a TAA > 40 mole H^+ /tonne. A decrease in the TAA with depth was generally observed.

Retained acidity

Retained acidity was only measured in three layers and ranged between 2 and 15 mole H^+ /tonne. There was no retained acidity in any of the other materials as all samples had a $pH_{KCl} > 4.5$.

Net acidity

The net acidity ranged between 11 and 85 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the two surface soils (i.e. 0-5 cm) examined was 36 and 161 mg/kg. One of the surface soil layers had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

The surface water data measured in the field and in the laboratory at site 20035_1 are presented in Tables 8-3 and 8-4, respectively. The field pH was 5.88 and below the most relevant ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5. The surface water sulfate concentration was 38 mg/L. Dissolved oxygen, turbidity and some nutrient (i.e. NH_4 , PO_4) and metal (i.e. Cd, Co, Cr, Cu, Fe, Mn, Zn) values were found to be outside the most relevant ANZECC/ARMCANZ (2000) guideline value. Groundwater was not collected within this wetland.

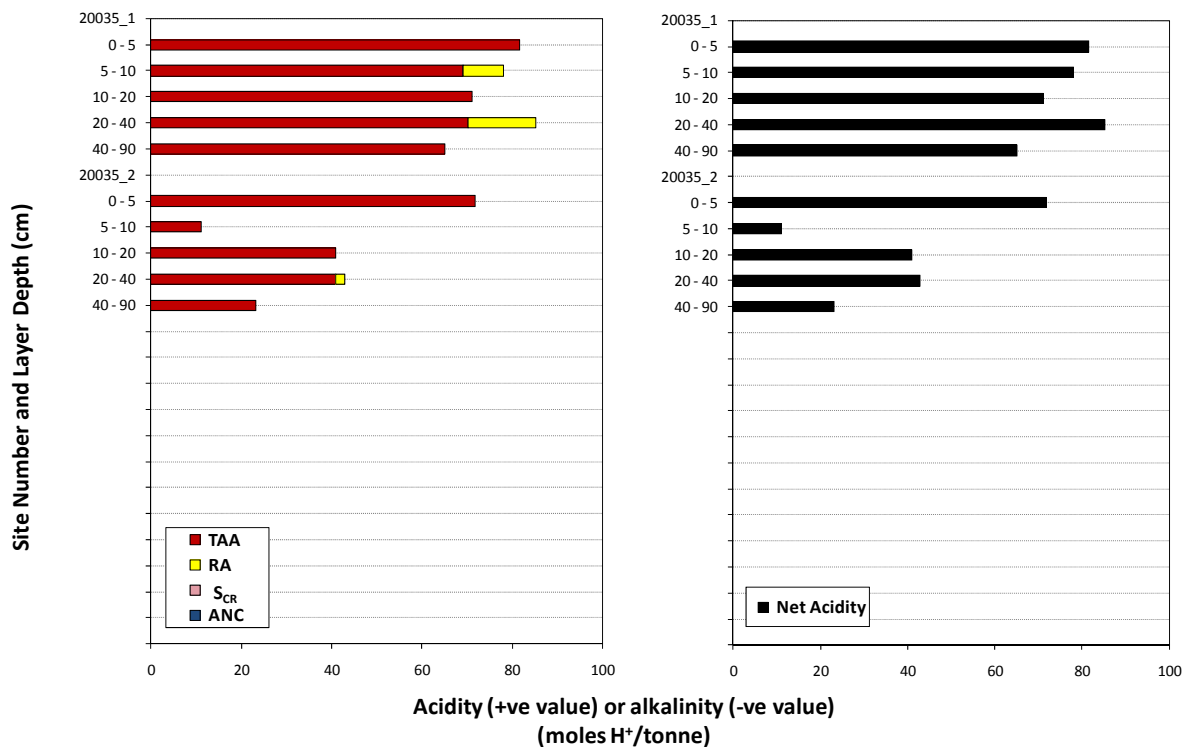


Figure 8-6. Acid-base accounting depth profiles for Wetland ID 20035 (20035_1 – 20035_2). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.1.4. Discussion

Acid sulfate soils materials were not found at Wetland ID 20035. All soil materials were classified as other acidic soils.

One of the surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, one sampling site had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at Wetland ID 20035 are:

- Acidification hazard: The data indicate that with no sulfuric or sulfidic materials that the degree of acidification hazard is low.
- Deoxygenation hazard: The soluble sulfate content of the surface soil material at one site was over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The low acidification hazard indicates that soil acidification is not likely to increase the solubility of metals. However, the potential for MBO formation identified in this wetland may result in an appreciable metal release hazard depending on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium.

Summary of key findings for the Wetland ID 20035:

<i>Soil materials:</i>	Sulfuric and sulfidic materials were not observed within this wetland. Other acidic soil materials observed at 2 sites. Moderate net acidities dominant within wetland.
<i>Acid sulfate soil identification:</i>	<ul style="list-style-type: none"> • Other acidic soil materials present at both sites
<i>Hazard assessment</i>	<ul style="list-style-type: none"> • Acidification hazard - low level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – low to moderate level of concern

Table 8-2. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 20035.

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	5.48	2.83	3.96*	160.5	4.58	81.65	<0.01	0	0.00	81.65	<0.01	other acidic
1.2	5-10	fine	4.33	2.97	3.83*		4.45	69.07	<0.01	9	0.00	78.07	<0.01	other acidic
1.3	10-20	fine	4.32	3.10	3.69*		4.50	71.16	<0.01	0	0.00	71.16	<0.01	other acidic
1.4	20-40	fine	4.35	3.23	3.67*		4.46	70.14	<0.01	15	0.00	85.14	<0.01	other acidic
1.5	40-90	fine	5.84	3.23	3.64*		4.57	65.01	<0.01	0	0.00	65.01	<0.01	other acidic
2.1	0-5	coarse	5.05	3.07	4.69*	36.15	5.70	71.71	<0.01	0	0.00	71.71	<0.01	other acidic
2.2	5-10	coarse	4.58	2.96	4.06*		5.03	11.17	<0.01	0	0.00	11.17	<0.01	other acidic
2.3	10-20	medium	4.10	3.35	3.99*		4.56	40.86	<0.01	0	0.00	40.86	<0.01	other acidic
2.4	20-40	medium	4.37	3.20	3.96*		4.43	40.91	<0.01	2	0.00	42.91	<0.01	other acidic
2.5	40-52	coarse	4.35	3.32	4.11*		4.96	23.19	<0.01	0	0.00	23.19	<0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 16 weeks).

Table 8-3. Field hydrochemistry data for acid sulfate soil assessment of Wetland ID 20035.

Site and Layer ID.	Temperature (Deg C)	Specific Electrical Conductivity (μS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	ORP	Redox potential (mV)	Turbidity (NTU)	HCO ₃ (mg/L)	Comment
<i>Lowland River*</i>		125-2200	85-110		6.5-8.0			6-50		
<i>Freshwater Lakes*</i>		20-30	90-110		6.5-8.0			1-20		
20035 (SW)	15.1	283	25.7	2.39	5.88			400	140	

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively.

Table 8-4. Laboratory hydrochemistry data for acid sulfate soil assessment of Wetland ID 20035.

Parameter	units	ANZECC Guidelines	Site 1 (SW)
depth	cm		
Na	mg l ⁻¹		12.2
K	mg l ⁻¹		5.1
Ca	mg l ⁻¹		18.2
Mg	mg l ⁻¹		10.2
Si	mg l ⁻¹		1.74
Br	mg l ⁻¹		0.118
Cl	mg l ⁻¹		219
NO ₃	mg l ⁻¹	0.7	0.011
NH ₄ -N	mg l ⁻¹	0.01	0.094
PO ₄ -P ^E	mg l ⁻¹	0.005	0.029
SO ₄	mg l ⁻¹		38
Ag	µg l ⁻¹	0.05	<1
Al ^A	µg l ⁻¹	55	32
As ^B	µg l ⁻¹	13	10
Cd	µg l ⁻¹	0.2	123
Co	µg l ⁻¹	2.8	13
Cr ^C	µg l ⁻¹	1	6
Cu ^H	µg l ⁻¹	1.4	6
Fe	µg l ⁻¹	300	8,061
Mn	µg l ⁻¹	1700	2,783
Ni ^H	µg l ⁻¹	11	8
Pb ^H	µg l ⁻¹	3.4	1
Se	µg l ⁻¹	11	<10
Zn ^H	µg l ⁻¹	8	78
DOC	mg l ⁻¹		56.1

Notes.

The ANZECC guideline values for toxicants refer to the Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH₄ and PO₄, guideline values are provided for Freshwater Lakes and Reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^A Guideline is for Aluminium in freshwater where pH > 6.5.

^B Guideline assumes As in solution as Arsenic (AsV).

^C Guideline is for Chromium is applicable to Chromium (CrVI) only.

^E Guideline is for filterable reactive phosphorous (FRP).

^H Hardness affected (refer to Guidelines).

Table 8-5. Site description data for acid sulfate soil assessment of Wetland ID 20035.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-30	Underwater; muddy with rotting leaf material	water/common	Low; sample taken from bottom of pool in area cleared of vegetation for fence line	Only accessible site in water clear of vegetation	other acidic	Site has been connected to Edward River within past two weeks. Thick sapling growth in wetland.
2	30	Silty with leaf litter	common	Mid; old high water mark	Upslope of site 1, before bank gradient rapidly increases.	other acidic	Little sapling growth in this zone.

Table 8-6. Profile description data for acid sulfate soil assessment of Wetland ID 20035.

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features - Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	5Y 4/2	ZLC		W	2	FM		RPO	SB	2		6.22	
1.2	5-10	5Y 6/1	ZC		T	2	FM		RPO	SB	2		5.66	
1.3	10-20	5Y 4/1	ZC		T					AB	1		5.34	
1.4	20-40	5Y 4/1	ZC		W					AB	1		5.14	
1.5	40-90	5Y 4/1	ZC		W					AB	1		5.96	
2.1	0-5	10YR 7/3	S		T					SG	0		5.27	
2.2	5-10	10YR 5/2	LS		T					GR	1		5.04	
2.3	10-20	10YR 5/2	SCL		T	2	FM		BPF	GR	1		4.80	
2.4	20-40	5Y 6/3	SC		W					MA	0		4.61	
2.5	40-52	5Y 4/2	CS		W					MA	0		4.60	

8.2. Wetland ID 20111

8.2.1. Location and setting description

This is a club-shaped wetland on the northern side of the Wakool River. The wetland is about 2.5 km long, 200 m wide and 8 ha. It is incised with very steep banks dropping directly into the main channel. The wetland is part of the complex of meanders, scrolls and chutes within this section of the Wakool. At the time of the soil survey in May 2010 the wetland had very noticeable flow and was acting as an anabranch of the Wakool (and appeared to be the main channel). A subsidiary flood chute outside but connected to the mapped wetland on its eastern side was also sampled due to the lack of any possible hydro-toposequences within the main channel. The subsidiary wetland, about 600 m long and 200 m wide, had some ponded water but was generally dry.

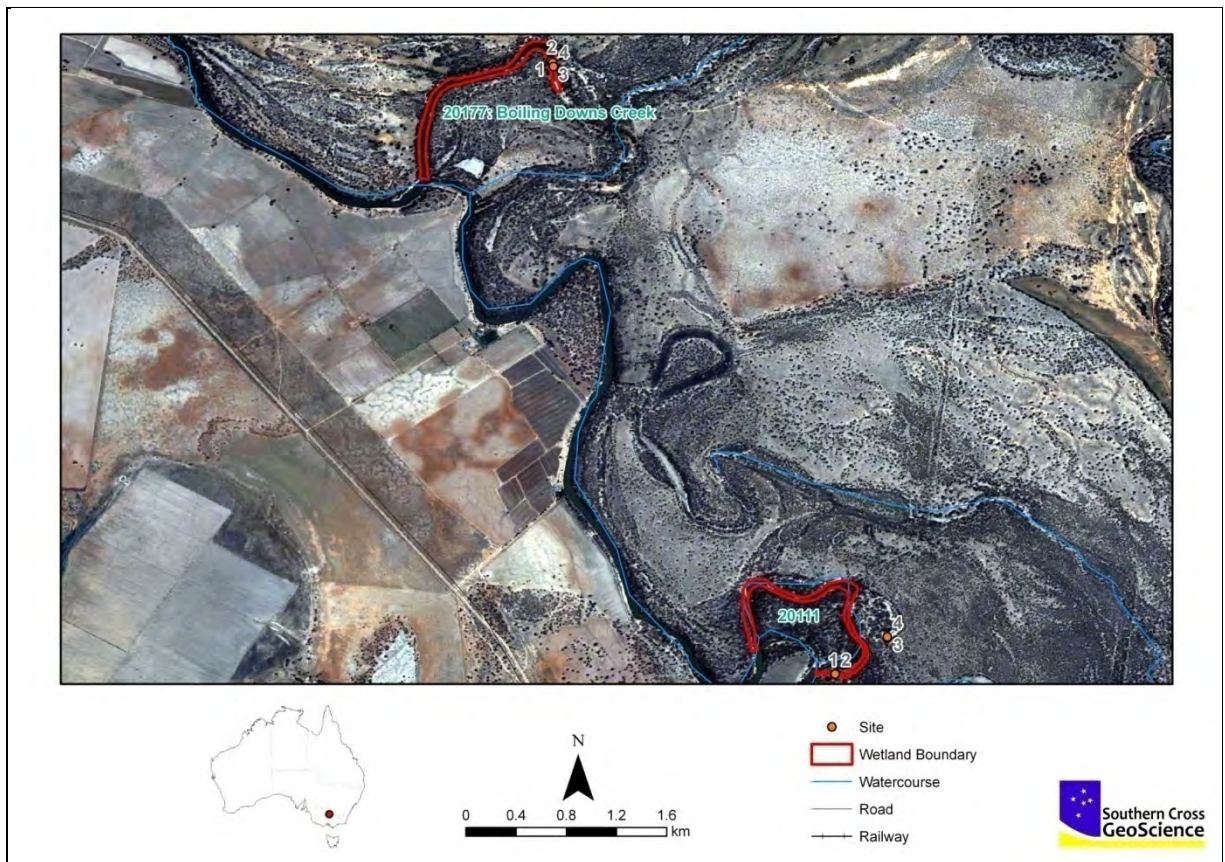


Figure 8-7. Wetland ID 20111 and sample site locations.

8.2.2. Soil profile description and distribution

Four sites were sampled, two within the mapped wetland and two within the subsidiary wetland. Sites were based on different surface features and locations in the wetland; a transect approach was not used. Sites 3 and 4 were located outside the mapped wetland, in a flood chute – the narrow and steep-sided channel of the mapped wetland restricted sampling possibilities. The soil subtype and general location description are presented in Table 8-7.

The profile 20111_1 (Figure 8-9) was subaqueous and located within the main channel, the soil consisted of grey wet sand. The profile 20111_2 occurred on the narrow bank area, the soil consisted of grey mottled sand. The profile 20111_3 (Figure 8-10) was subaqueous and

occurred within a waterbody in the lowest part of a chute adjoining the wetland, the soil consisted of grey silty clay. The profile 20111_4 occurred in the area fringing the waterbody and consisted of grey silty clay. Additional site and profile description data are presented in Tables 8-11 and 8-12, respectively.

Table 8-7. Soil identification, subtype and general location description for Wetland ID 20111.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20111_1	736835	6116075	hypermonosulfidic subaqueous soil	subaqueous, main channel
20111_2	736827	6116076	sulfuric soil	higher elevation, on bank
20111_3	737175	6116355	subaqueous soil	subaqueous, in lowest part of a chute adjoining wetland
20111_4	737175	6116363	hydrosol	area fringing the waterbody

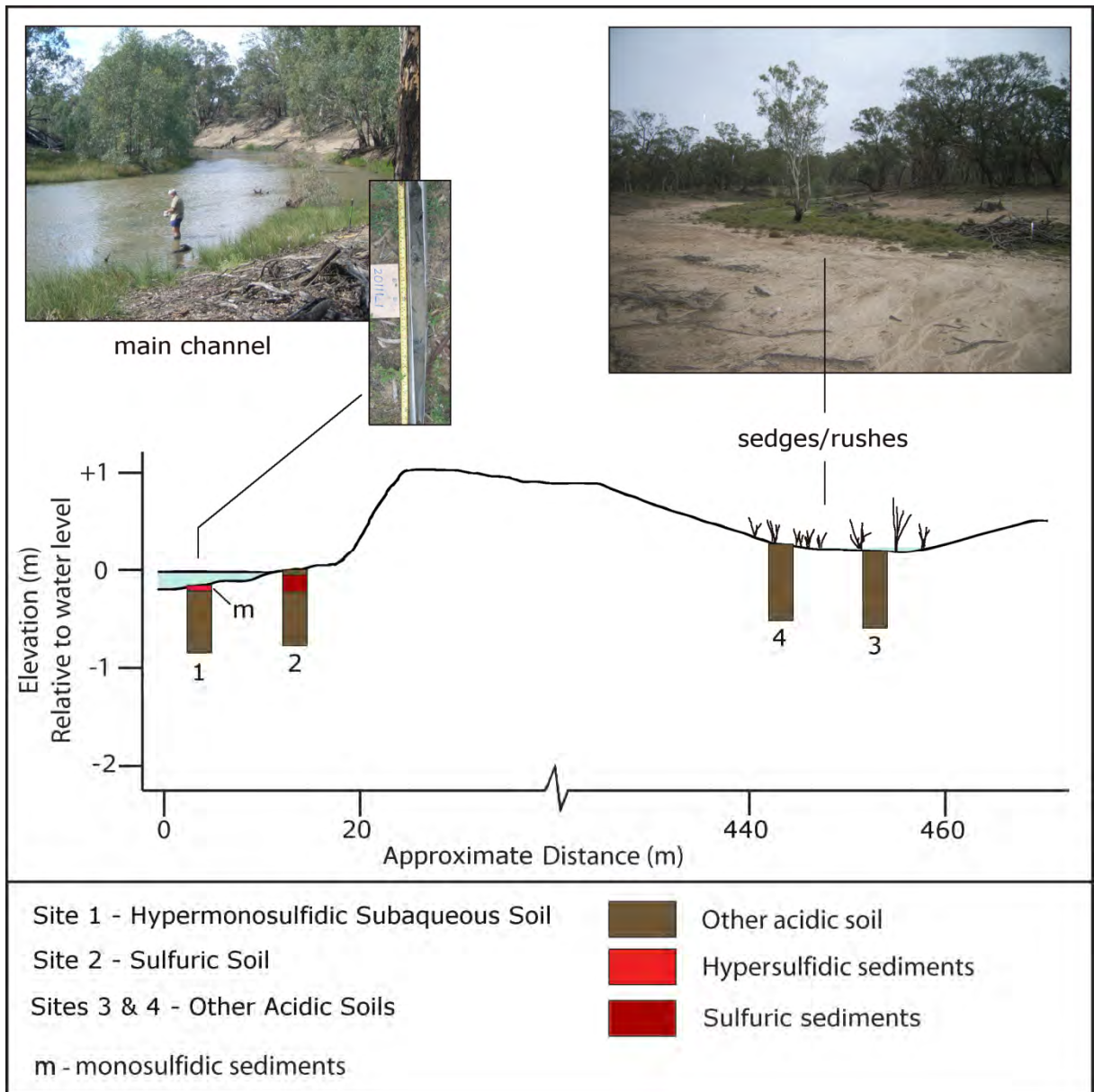


Figure 8-8. Conceptual cross section diagram showing the toposequence relationship of the Wetland ID 20111 sediments/soil materials throughout the wetland.



Figure 8-9. Photographs of sites 20111_1 and 20111_2, showing the subaqueous site (20111_1) and the narrow fringing sedgeland (20111_2) in the Wakool River channel, and the soil core (20111_1).



Figure 8-10. Photographs of sites 20111_3 and 20111_4, showing the vegetated section in the lowest part of the wetland from which the samples were taken, and the soil profile (20111_4).

8.2.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Table 8-8 and profiles for all the sites sampled are presented in Figure 8-11. The pH_W values ranged between 3.34 and 6.82. Sulfuric materials (i.e. $pH_W < 4$) were present at site 20111_2 (5-20 cm). The pH_{FOX} values ranged between 2.08 and 3.89. The pH_{FOX} results indicate that all surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. However, the S_{CR} data shows only one soil layer at site 20111_1 (0-5 cm) contained detectable sulfide (i.e. $S_{CR} \geq 0.01\%$ S). Four soil materials had a $pH_{FOX} < 2.5$ (i.e. sites 20111_1 and 20111_2). The sulfidic soil material (i.e. $S_{CR} \geq 0.01\%$ S) did not acidify to $pH < 4$ after at least 8 weeks of incubation. Other acidic soil materials were identified at all four sites examined, indicating acidity in the soil profile at levels where aluminium may mobilise. Two of the other acidic soils acidified to $pH < 4$ after at least 8 weeks of incubation.

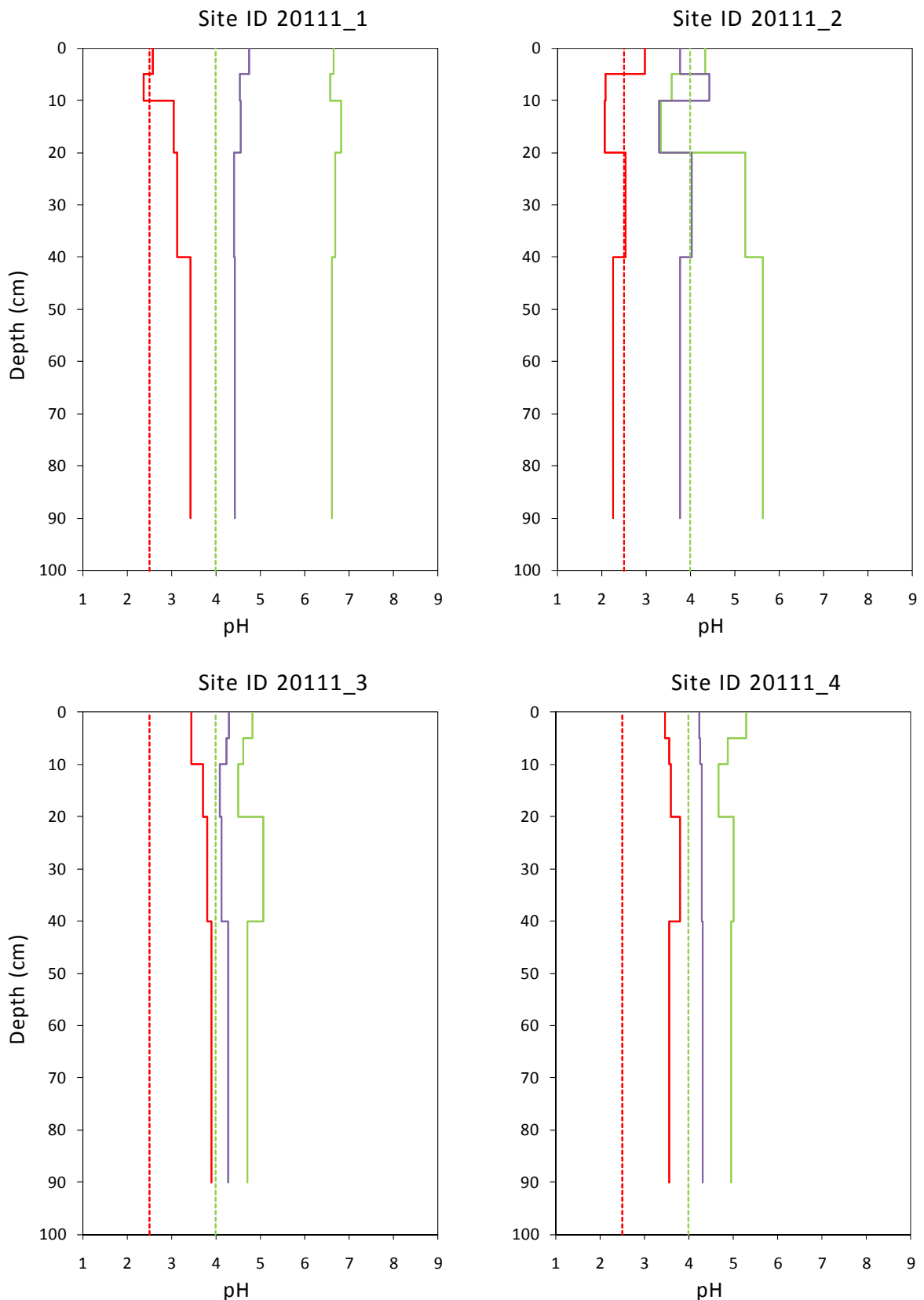


Figure 8-11. Depth profiles of soil pH for Wetland ID 20111 (20111_1 – 20111_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-8 and summarised in Figure 8-12.

Chromium reducible sulfur

Chromium reducible sulfur (S_{CR}) values ranged between < 0.01 and 0.03% S. A sulfidic soil material (i.e. $S_{CR} \geq 0.01\%$ S) was only identified at site 20111_1 (0-5 cm).

Acid volatile sulfide

The acid volatile sulfide (S_{AV}) values ranged between < 0.01 and 0.01% S. A monosulfidic soil material (i.e. $S_{AV} \geq 0.01\%$ S) was only found at site 20111_1 (0-5 cm).

Acid neutralising capacity

All soil materials had no acid neutralising capacity (ANC).

Titratable actual acidity

The titratable actual acidity (TAA) ranged between 2 and 58 mole H^+ /tonne. A trend in the TAA with depth was not observed.

Retained acidity

All soil materials had no retained acidity.

Net acidity

Net acidity ranged between 2 and 58 mole H^+ /tonne. The one hypersulfidic soil material had a moderate net acidity of 21 mole H^+ /tonne. Two sulfuric soil materials had low to moderate net acidities of 4 and 31 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 50 and 519 mg/kg. One of the four surface soil layers examined had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

The surface water data measured in the field and in the laboratory are presented in Tables 8-9 and 8-10, respectively. The field pH of the surface water collected was 7.41. The water data indicates that the surface water has not been affected by acidification. The surface water sulfate concentrations were 53 and 87 mg/L. Some nutrient (i.e. NH_4 , PO_4), metal (i.e. Cd, Cu, Zn) and turbidity values were found to exceed the most relevant ANZECC/ARMCANZ (2000) guideline value. Groundwater was not collected within this wetland.

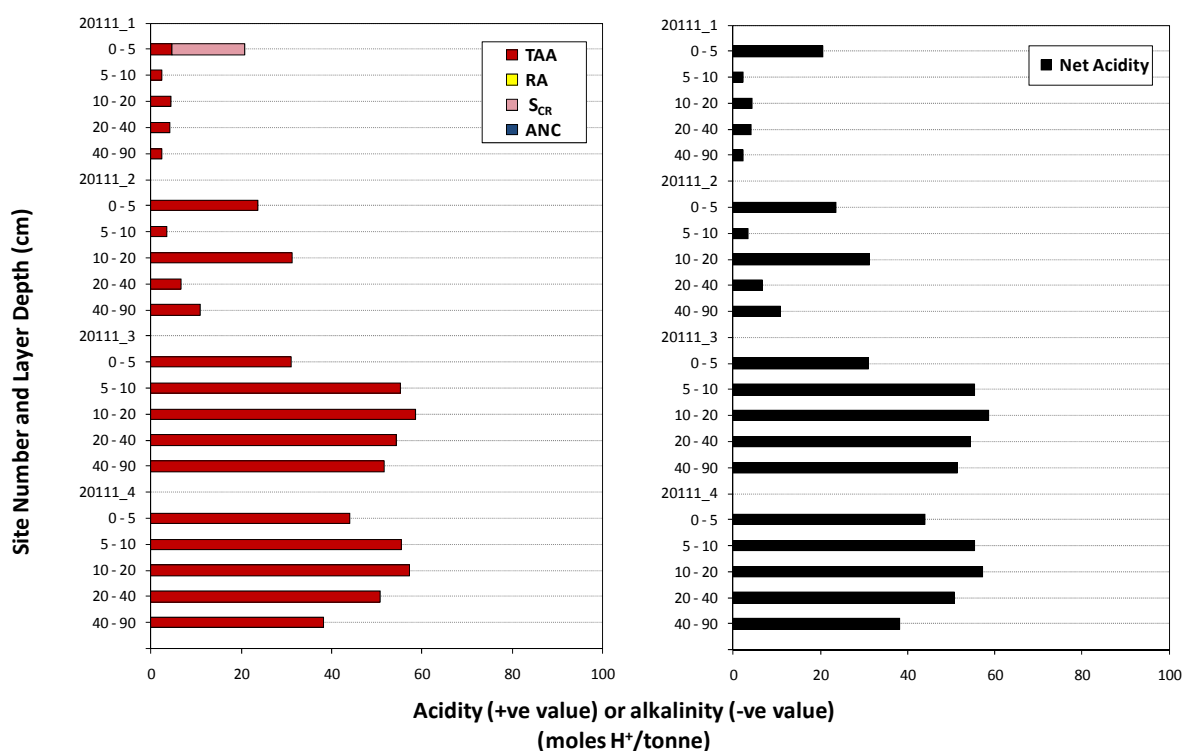


Figure 8-12. Acid-base accounting depth profiles for Wetland ID 20111 (20111_1 – 20111_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.2.4. Discussion

Acid sulfate soils occurred at two sites within Wetland ID 20111 (i.e. sites 20111_1 and 20111_2). Sulfuric materials with low to moderate net acidities (i.e. ≤ 31 mole H⁺/tonne) were present at site 20111_2 (5-20 cm). The reduced inorganic sulfur content of the single sulfidic sample at site 20111_1 was low (i.e. S_{CR} = 0.03% S), and had a moderate net acidity of 21 mole H⁺/tonne. This soil material was also identified as a monosulfidic soil material, with a S_{AV} content of 0.01% S. These results indicate that minimal acidity would be produced upon oxidation of sulfides in this material.

One of the surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential. Other acidic soil materials were also observed at an additional two sites.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there was one high priority site based on sulfuric soil material, one high priority site based on hypersulfidic material, and one high priority site based on monosulfidic material. In addition, one sampling site had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at the Wetland ID 20111 are:

- Acidification hazard: The data indicate that with only one sulfuric material with a moderate net acidity, and a single sulfidic material with a S_{CR} of only 0.03% S, that the degree of acidification hazard is low.

- Deoxygenation hazard: The soluble sulfate content of the surface soil material at one site was over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The low acidification hazard indicates that soil acidification is not likely to increase the solubility of metals. However, the potential for MBO formation identified in this wetland may result in an appreciable metal release hazard depending on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium at some sites.

Summary of key findings for the Wetland ID 20111:

<i>Soil materials:</i>	Sulfuric materials were observed at 1 site. Sulfidic soil materials identified included: hypersulfidic (1 site) and monosulfidic (1 site). Other acidic soil materials observed at an additional 2 sites. Moderate net acidities dominant within wetland.
<i>Acid sulfate soil identification:</i>	<ul style="list-style-type: none"> • Hypermonosulfidic subaqueous soil –in the main water channel (20111_1) • Sulfuric soil –on the banks of the main channel (20111_2)
<i>Hazard assessment</i>	<ul style="list-style-type: none"> • Acidification hazard - low level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – low to moderate level of concern

Table 8-8. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 20111.

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	coarse	6.64	2.58	4.74	80.85	5.46	4.56	0.03	0	0.00	20.69	0.01	hypermonosulfidic [#]
1.2	5-10	coarse	6.58	2.37	4.53		5.65	2.38	<0.01	0	0.00	2.38	<0.01	other acidic
1.3	10-20	coarse	6.82	3.05	4.55		5.51	4.28	<0.01	0	0.00	4.28	<0.01	other acidic
1.4	20-40	coarse	6.69	3.13	4.41*		5.50	4.05	<0.01	0	0.00	4.05	<0.01	other acidic
1.5	40-65	coarse	6.62	3.42	4.42		5.59	2.38	<0.01	0	0.00	2.38	<0.01	other acidic
2.1	0-5	coarse	4.33	2.97	3.77	519	5.23	23.58	<0.01	0	0.00	23.58	<0.01	other acidic
2.2	5-10	coarse	3.58	2.10	4.42*		4.65	3.54	<0.01	0	0.00	3.54	<0.01	sulfuric
2.3	10-20	coarse	3.34	2.08	3.30		4.88	31.15	<0.01	0	0.00	31.15	<0.01	sulfuric
2.4	20-40	coarse	5.23	2.54	4.03*		5.01	6.64	<0.01	0	0.00	6.64	<0.01	other acidic
2.5	40-75	coarse	5.64	2.26	3.77*		5.11	10.82	<0.01	0	0.00	10.82	<0.01	other acidic
3.1	0-5	fine	4.83	3.45	4.30	61.35	4.95	31.09	<0.01	0	0.00	31.09	<0.01	other acidic
3.2	5-10	fine	4.61	3.45	4.24		4.55	55.31	<0.01	0	0.00	55.31	<0.01	other acidic
3.3	10-20	fine	4.50	3.72	4.09*		4.40	58.49	<0.01	0	0.00	58.49	<0.01	other acidic
3.4	20-40	fine	5.06	3.80	4.12		4.40	54.32	<0.01	0	0.00	54.32	<0.01	other acidic
3.5	40-75	fine	4.70	3.89	4.27		4.52	51.51	<0.01	0	0.00	51.51	<0.01	other acidic
4.1	0-5	medium	5.30	3.46	4.24	49.8	4.73	44.02	<0.01	0	0.00	44.02	<0.01	other acidic
4.2	5-10	medium	4.88	3.55	4.26		4.58	55.38	<0.01	0	0.00	55.38	<0.01	other acidic
4.3	10-20	medium	4.67	3.60	4.30		4.51	57.12	<0.01	0	0.00	57.12	<0.01	other acidic
4.4	20-40	medium	5.01	3.80	4.29		4.52	50.76	<0.01	0	0.00	50.76	<0.01	other acidic
4.5	40-75	medium	4.95	3.55	4.31		4.47	38.22	<0.01	0	0.00	38.22	<0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 14 weeks). [#] Classified as hypermonosulfidic based on positive net acidity.

Table 8-9. Field hydrochemistry data for acid sulfate soil assessment of Wetland ID 20111.

Site and Layer ID.	Temperature (Deg C)	Specific Electrical Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	ORP	Redox potential (mV)	Turbidity (NTU)	HCO ₃ (mg/L)	Comment
<i>Lowland River*</i>		125-2200	85-110		6.5-8.0			6-50		
<i>Freshwater Lakes*</i>		20-30	90-110		6.5-8.0			1-20		
20111_1 (SW)	21.5	241		6.82	7.41	-27		80	140	
20111_2 (SW)										Unfiltered. Delays in freezing. No field measurements recorded

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively.

Table 8-10. Laboratory hydrochemistry data for acid sulfate soil assessment of Wetland ID 20111.

Parameter	units	ANZECC Guidelines	Site 1 (SW)	Site 2 (SW)
depth	cm			
Na	mg l ⁻¹		32.9	204.7
K	mg l ⁻¹		2.6	9.4
Ca	mg l ⁻¹		6.4	13.0
Mg	mg l ⁻¹		8.5	6.6
Si	mg l ⁻¹		1.31	5.13
Br	mg l ⁻¹		0.172	0.185
Cl	mg l ⁻¹		613	628
NO ₃	mg l ⁻¹	0.7	0.021	0.089
NH ₄ -N	mg l ⁻¹	0.01	0.063	0.774
PO ₄ -P ^E	mg l ⁻¹	0.005	0.010	0.056
SO ₄	mg l ⁻¹		53	87
Ag	µg l ⁻¹	0.05	<1	<1
Al ^A	µg l ⁻¹	55	35	24
As ^B	µg l ⁻¹	13	<10	<10
Cd	µg l ⁻¹	0.2	221	142
Co	µg l ⁻¹	2.8	<1	<1
Cr ^C	µg l ⁻¹	1	<5	<5
Cu ^H	µg l ⁻¹	1.4	8	9
Fe	µg l ⁻¹	300	248	<5
Mn	µg l ⁻¹	1700	92	19
Ni ^H	µg l ⁻¹	11	1	4
Pb ^H	µg l ⁻¹	3.4	<1	<1
Se	µg l ⁻¹	11	<10	<10
Zn ^H	µg l ⁻¹	8	69	46
DOC	mg l ⁻¹		10.6	36.8

Notes.

The ANZECC guideline values for toxicants refer to the Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH₄ and PO₄, guideline values are provided for Freshwater Lakes and Reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^A Guideline is for Aluminium in freshwater where pH > 6.5.

^B Guideline assumes As in solution as Arsenic (AsV).

^C Guideline is for Chromium is applicable to Chromium (CrVI) only.

^E Guideline is for filterable reactive phosphorous (FRP).

^H Hardness affected (refer to Guidelines).

Table 8-11. Site description data for acid sulfate soil assessment of Wetland ID 20111.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-50	Underwater, sandy	water	channel	safest access for representative sample of subaqueous material.	hypermonosulfidic	Limited access (confined channel, vertical banks) - main Wakool channel?
2	20	sandy	bare	shoreline	only example, otherwise vertical banks	sulfuric	Limited access (confined channel, vertical banks) - main Wakool channel?
3	40	wet, slippery	bare	low, base of wetland	base of subsidiary wetland	other acidic	Subsidiary wetland (not mapped) attached to 20111
4	not detected	wet, slippery and sticky	bare	slightly elevated fringe of wetland	margin of subsidiary wetland	other acidic	Subsidiary wetland (not mapped) attached to 20111

Table 8-12. Profile description data for acid sulfate soil assessment of Wetland ID 20111.

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	5Y 4/1	S		W					SG	0		6.77	
1.2	5-10	5Y 4/1	S		W					SG	0		6.90	
1.3	10-20	5Y 4/1	S		W					SG	0		7.41	
1.4	20-40	5Y 5/1	S		W					SG	0		7.09	
1.5	40-65	5Y 5/1	S		W					SG	0		7.17	
2.1	0-5	10YR 5/3	LFS		M	4	FM		MAT	SG	0		6.06	
2.2	5-10	10YR 5/3	LFS		M	4	FM		MAT	SG	0		4.10	
2.3	10-20	10YR 5/3	S	coarse	M					SG	0		3.80	
2.4	20-40	10YR 5/2	S	coarse	W					SG	0		5.43	
2.5	40-75	10YR 5/1	S	coarse	W					SG	0		6.01	
3.1	0-5	10YR 4/2	ZC	medium	T	2	FM		MAT	SB	1		5.74	
3.2	5-10	10YR 4/2	ZC	medium	T	2	FM		MAT	SB	1		5.85	
3.3	10-20	10YR 4/2	ZC	medium	T					SB	1		5.81	
3.4	20-40	10YR 5/2	ZC	medium	T					SB	1		5.57	
3.5	40-75	10YR 5/2	ZC	medium	T					SB	1		5.15	
4.1	0-5	2.5Y 6/2	ZC	light	M					MA	0		6.74	
4.2	5-10	2.5Y 6/2	ZC	light	M					MA	0		6.25	
4.3	10-20	2.5Y 6/2	ZC	light	M					MA	0		6.66	
4.4	20-40	2.5Y 6/2	ZC	light	M					MA	0		6.60	
4.5	40-75	2.5Y 6/2	ZC	light	M					MA	0		6.90	

8.3. Boiling Downs Creek (Wetland ID 20177)

8.3.1. Location and setting description

Boiling Downs Creek wetland is 18 km up river from Kyalite Township, it is situated between the Wakool River to the north and to the west of Yarrien Creek. Leading from the Wakool River the wetland is linear and hooked-shaped, almost 2 km in length and 70 m at the widest point, with a total area of 9 ha. The wetland functions as a stream channel between the Wakool River and Yarrien Creek during higher than present flows, it has moderately steep banks and is surrounded by floodplains. At the time when the soil survey was conducted in April 2010, the wetland had surface water in low areas. There were areas of the channel with no surface water due to slightly higher elevation and in some of these areas schwertmannite was observed. Also, deceased sapling trees were observed on the higher elevation stream channel, healthy mature river red gum (*Eucalyptus camaldulensis*) lined the upper bank/floodplain. Four sites were sampled as shown in Figure 8-13.

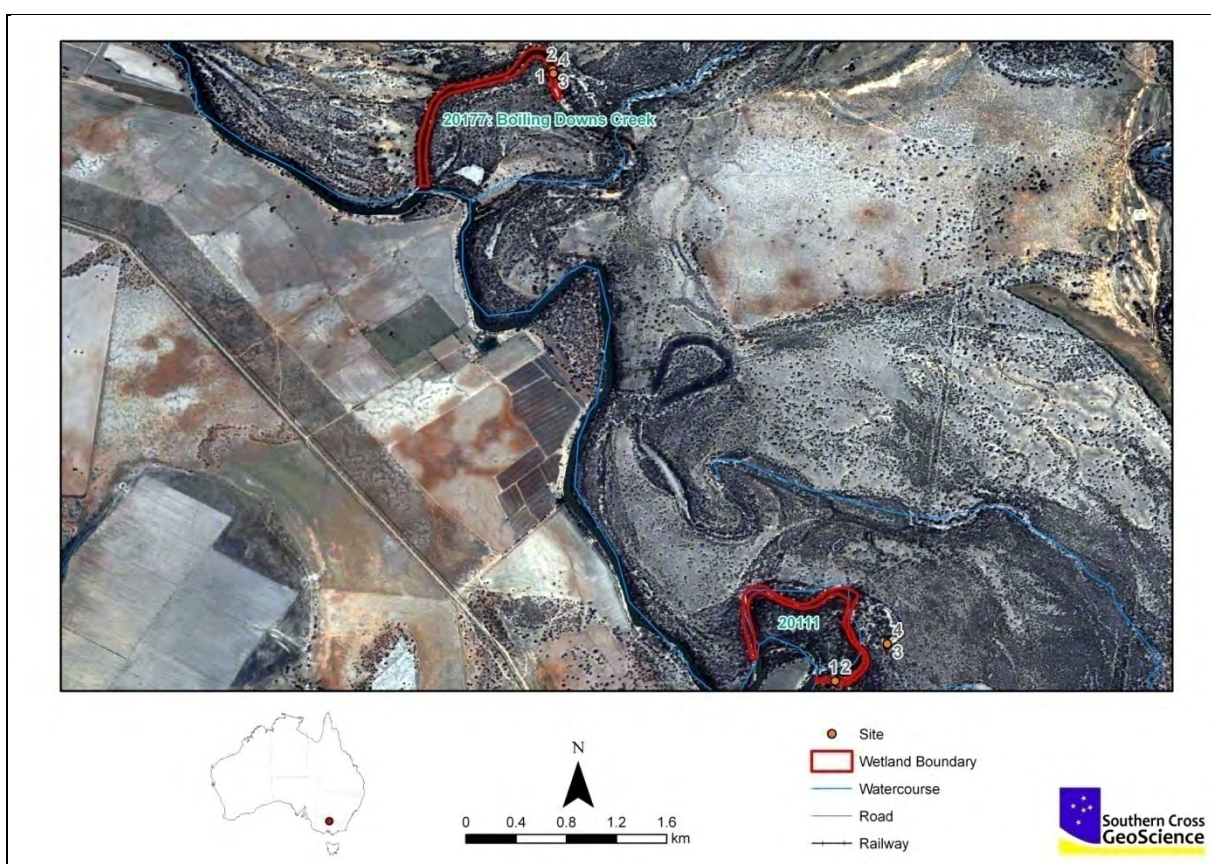


Figure 8-13. Boiling Downs Creek and sample site locations.

8.3.2. Soil profile description and distribution

Four sites were described and sampled. The soil subtype and general location description are presented in Table 8-13. Sites were distributed throughout the wetland based on different surface features and locations in the wetland, a transect approach was used.

The profile 20177_1 (Figure 8-15) occurred within the water body of the channel, toward the deeper section, the soil consisted of soft grey brown clay in the top layers, changing abruptly to a gelatinous black clay. The profile 20177_2 (Figure 8-16) occurred adjacent to and slightly elevated from the water body, on a soft, wet, bare surface, the soil consisted of firm, heavily mottled, grey brown clay. The profile 20177_3 (Figure 8-17) occurred up bank, below the tree-line, the soil consisted of very firm heavily mottled grey brown clay. The profile

20177_4 (Figure 8-18) occurred in the centre of stream channel up stream of water body on wet, soft, bare surface, coated in 3 mm of schwertmannite, the soil consisted of a soft mottled grey clay, changing abruptly to a black gelatinous black clay at the profile base. Additional site and profile description data are presented in Tables 8-17 and 8-18, respectively.

Table 8-13. Soil identification, subtype and general location description for Boiling Downs Creek.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20177_1	735093	6120996	hypermonosulfidic subaqueous soil with MBO	low elevation, centre of water body, clay stream sediment; MBO
20177_2	735095	6120998	hypermonosulfidic cracking clay	low elevation, adjacent to water body area clay soil area
20177_3	735106	6120988	sulfuric cracking clay	higher elevation, lower stream bank clay soil area
20177_4	735110	6120956	hypermonosulfidic cracking clay with MBO	low elevation, up stream of water body, soft clay; MBO.

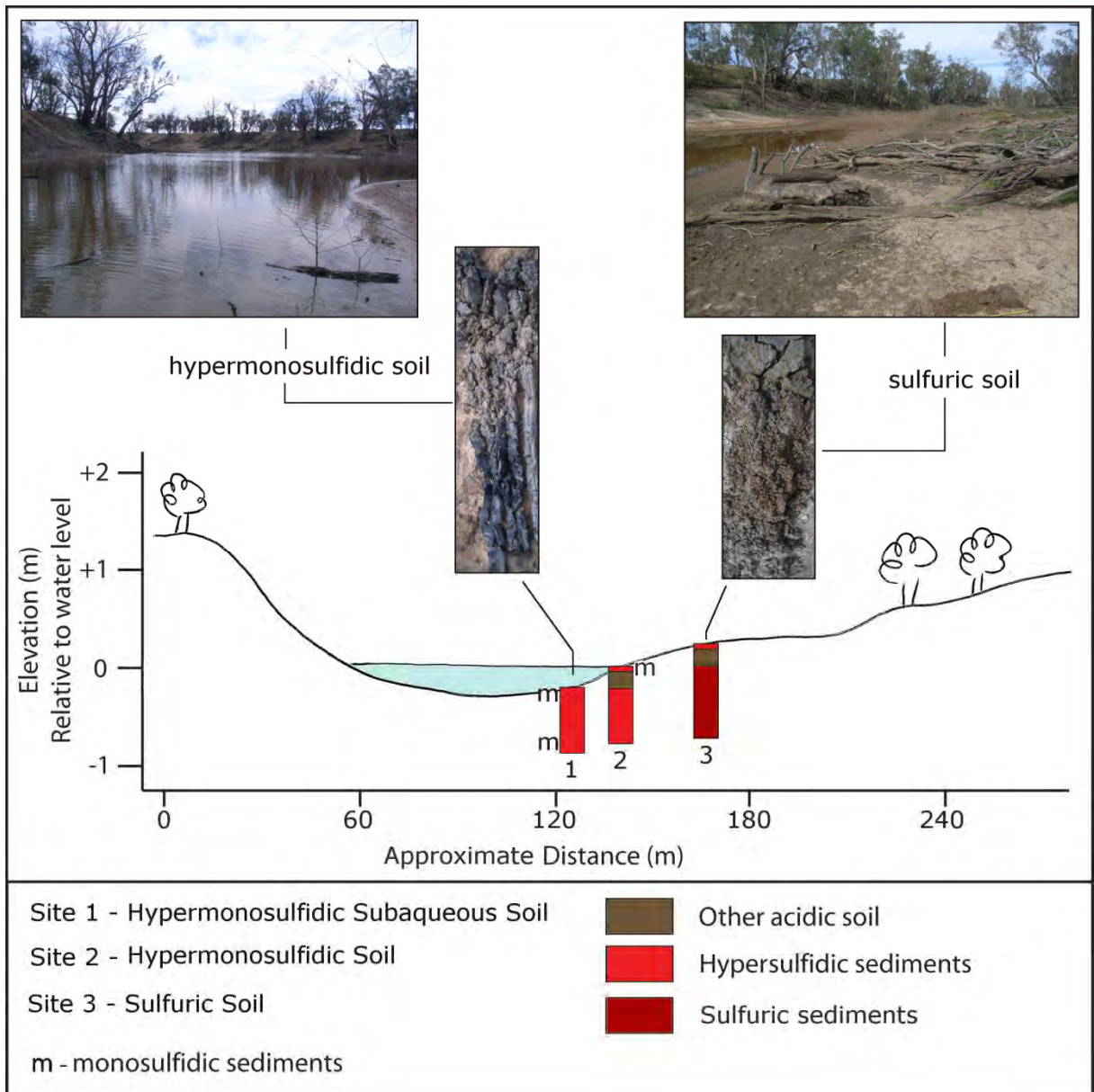


Figure 8-14. Conceptual cross section diagram showing the toposequence relationship of the Boiling Downs Creek sediments/soil materials for sites 20177_1 to 20177_3.



Figure 8-15. Photographs of site 20177_1, showing the subaqueous site, and the soil core.



Figure 8-16. Photographs of site 20177_2, showing the location of the sample site adjacent to the water body, and the soil core.



Figure 8-17. Photographs of site 20177_3, showing the sampling site, and the soil core.



Figure 8-18. Photographs of site 20177_4, showing the soft, wet, bare surface, and the soil core.

8.3.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Table 8-14 and profiles for all the sites sampled are presented in Figure 8-19. The pH_W values ranged between 3.81 and 7.10. Sulfuric materials (i.e. $pH_W < 4$) were only present at site 20177_3 (20-90 cm). The pH_{FOX} values ranged between 1.75 and 3.90. The pH_{FOX} results indicate that all surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. However, the S_{CR} data shows only 12 of the 20 layers examined contained detectable sulfide (i.e. $S_{CR} \geq 0.01\% S$). Two sulfidic soil materials had a $pH_{FOX} < 2.5$ (i.e. sites 20177_1 and 20177_2). Only four of the sulfidic soil materials (i.e. $S_{CR} \geq 0.01\% S$) acidified to $pH < 4$ after at least 8 weeks of incubation (i.e. sites 20177_1 (0-5 cm and 40-90 cm), 20177_2 (40-90 cm) and 20177_4 (40-90 cm)). Other acidic soil materials were identified at three of the four sites examined, indicating acidity in the soil profile at levels where aluminium may mobilise.

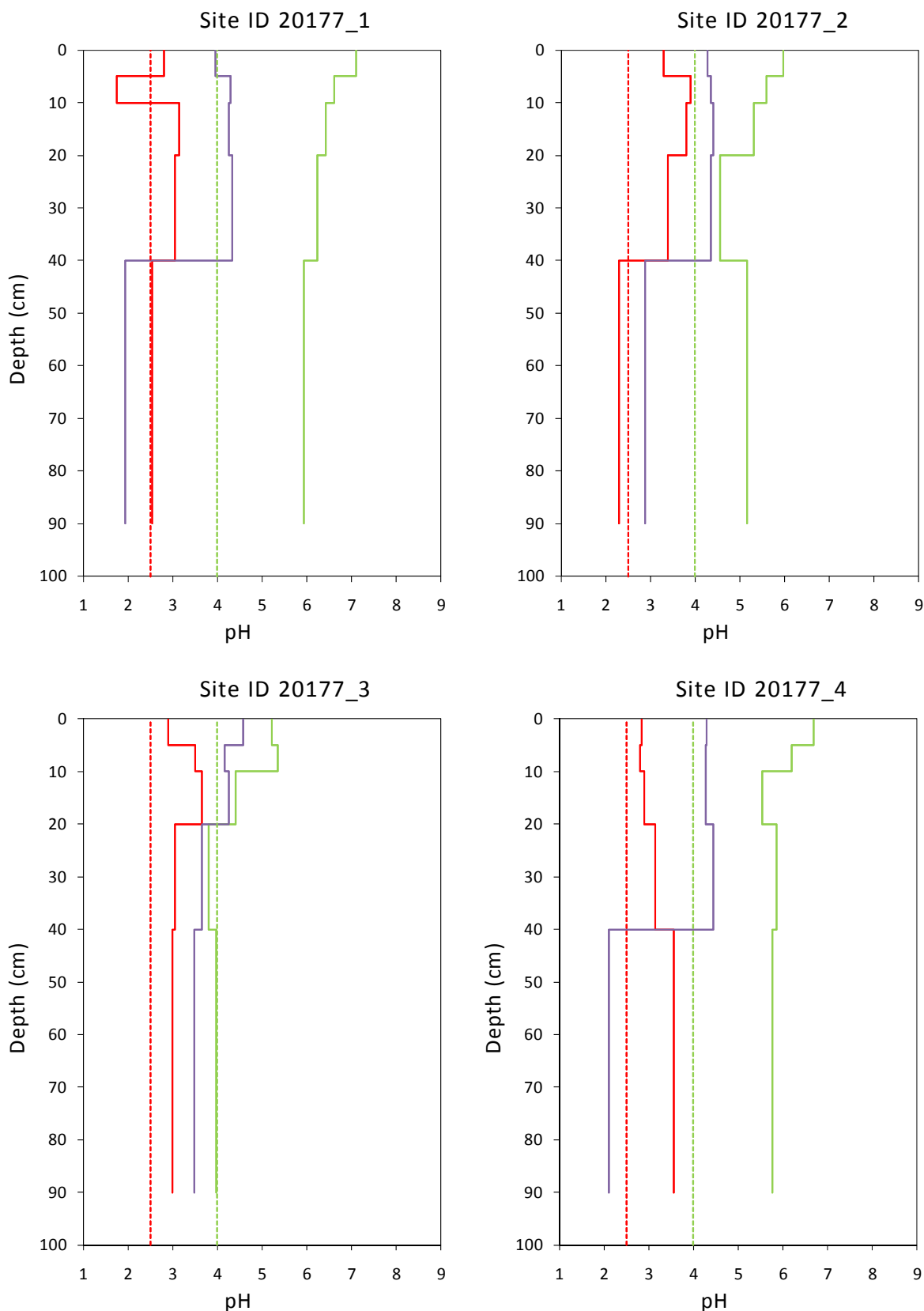


Figure 8-19. Depth profiles of soil pH for Boiling Downs Creek (20177_1 – 20177_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-14 and summarised in Figure 8-20.

Chromium reducible sulfur

Chromium reducible sulfur (S_{CR}) values ranged between < 0.01 and 0.58% S. Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were identified at all four sampling sites, with 12 materials of the 20 samples collected equal to or greater than the sulfidic criterion.

Acid volatile sulfide

The acid volatile sulfide (S_{AV}) values ranged between < 0.01 and 0.12% S. A total of 6 monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were found at three sites (sites 20177_1, 20177_2 and 20177_4).

Acid neutralising capacity

All soil materials had no acid neutralising capacity (ANC).

Titratable actual acidity

The titratable actual acidity (TAA) ranged between 11 and 45 mole H^+ /tonne. An increase in the TAA with depth was observed.

Retained acidity

The retained acidity was zero, except in one soil material at site 20177_3 (i.e. 20-40 cm) which had a retained acidity of 4 mole H^+ /tonne.

Net acidity

Net acidity ranged between 18 and 389 mole H^+ /tonne. The 12 hypersulfidic soil materials had moderate to high net acidities ranging between 22 and 389 mole H^+ /tonne, with three materials having high net acidities. The two sulfuric soil materials had moderate net acidities ranging of 45 and 49 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 209 and 572 mg/kg. All of the surface soil layers examined had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

The surface water and groundwater data measured in the field and laboratory are presented in Tables 8-15 and 8-16, respectively. The field pH of the surface water collected was 8.63, exceeding the most relevant ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 8.0. The water data indicates that the surface water has not been affected by acidification. The surface water sulfate concentration was 77 mg/L. Dissolved oxygen, SEC, turbidity, and some nutrient (i.e. NH_4 , PO_4) and metal (i.e. Cd, Zn) values were found to exceed the most relevant ANZECC/ARMCANZ (2000) guideline value. The field pH of the groundwater ranged between 5.50 and 6.08. The groundwater had a high SEC (18,970 – 21,540 $\mu S/cm$) and a sulfate concentration of 652 mg/L.

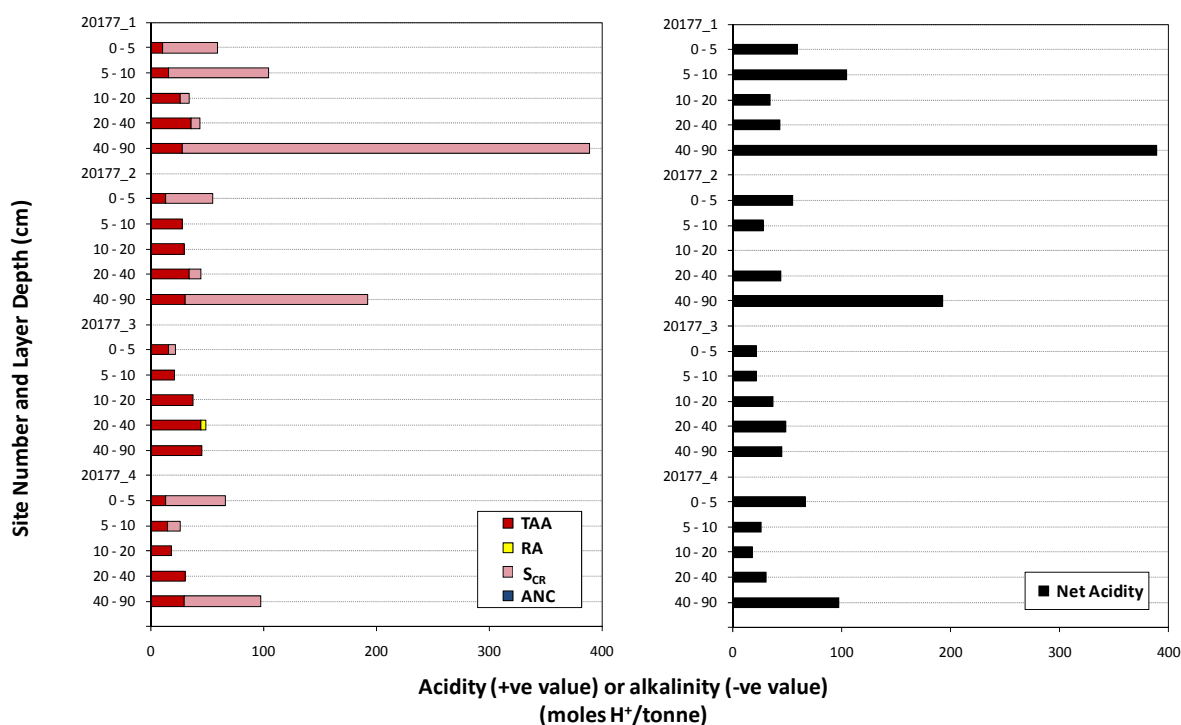


Figure 8-20. Acid-base accounting depth profiles for Boiling Downs Creek (20177_1 – 20177_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.3.4. Discussion

Acid sulfate soils occurred at all four sites examined in the Boiling Downs Creek wetland (i.e. sites 20177_1 – 20177_4). Sulfuric materials with moderate net acidities (i.e. ≤ 49 mole H^+ /tonne) were observed at 20177_3. The presence of reduced inorganic sulfur was identified at all four sites with a S_{CR} of up to 0.58% S, and was throughout the profile at site 20177_1. Hypersulfidic soil materials (sometimes with high net acidities) were present in all soil profiles. Monosulfidic soil materials were observed in the surface soil at three sampling sites (i.e. site 20177_1 20177_2 and 20177_4), with S_{AV} contents of up to 0.12% S. These results indicate that acidity would be produced upon oxidation of all sulfidic soil materials. All four surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there was one high priority site based on sulfuric material, four high priority sites based on hypersulfidic material, and three high priority sites based on monosulfidic material. In addition, all four sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at the Boiling Downs Creek wetland are:

- Acidification hazard: While moderate net acidities were dominant in this wetland, three hypersulfidic materials had high net acidities (i.e. 15% of layers), indicating that the overall degree of acidification hazard is high.
- Deoxygenation hazard: High monosulfide concentrations ($S_{AV} \leq 0.12\% S$) in surface soils at three sites represent a high deoxygenation hazard. In addition, the soluble sulfate content of surface soil materials at all four sites were over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The high acidification hazard indicates that soil acidification may increase the solubility of metals. The presence of monosulfidic materials in some surface soils and the potential for MBO formation identified in this wetland may also result in an appreciable metal release hazard. This would depend on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium.

Summary of key findings for the Boiling Downs Creek:

Soil materials:	Sulfuric materials were observed at 1 site. Sulfidic soil materials identified included: hypersulfidic (4 sites) and monosulfidic (3 sites). Moderate net acidities dominant within wetland, although 3 hypersulfidic soil materials had high net acidities.
Acid sulfate soil identification:	<ul style="list-style-type: none"> • Hypermonosulfidic subaqueous soils – in the water body (20177_1); MBO present • Hypermonosulfidic cracking clays – adjacent to (20177_2) and upstream (20177_4) of water body; MBO present at one site • Sulfuric cracking clays – on higher ground (20177_3)
Hazard assessment	<ul style="list-style-type: none"> • Acidification hazard - high level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – high level of concern

Table 8-14. Laboratory analytical data for acid sulfate soil assessment of Boiling Downs Creek (Wetland ID 20177).

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	7.10	2.80	3.95*	337.5	5.91	10.52	0.08	0	0.00	59.62	0.05	hypermonosulfidic
1.2	5-10	fine	6.61	1.75	4.29*		5.84	15.59	0.14	0	0.00	104.38	0.11	hypermonosulfidic [#]
1.3	10-20	fine	6.42	3.15	4.25*		5.22	26.59	0.01	0	0.00	34.36	<0.01	hypersulfidic [#]
1.4	20-40	fine	6.24	3.05	4.34*		4.98	35.59	0.01	0	0.00	43.26	<0.01	hypersulfidic [#]
1.5	40-60	fine	5.94	2.55	1.94*		5.31	27.87	0.58	0	0.00	388.99	0.12	hypermonosulfidic
2.1	0-5	medium	5.98	3.30	4.27*	391.5	5.80	12.83	0.07	0	0.00	55.26	0.04	hypermonosulfidic [#]
2.2	5-10	fine	5.59	3.90	4.36*		5.09	27.96	<0.01	0	0.00	27.96	<0.01	other acidic
2.3	10-20	fine	5.32	3.80	4.40*		4.99	29.95	<0.01	0	0.00	29.95	<0.01	other acidic
2.4	20-40	fine	4.56	3.40	4.36*		4.90	33.75	0.02	0	0.00	44.04	<0.01	hypersulfidic [#]
2.5	40-75	fine	5.16	2.30	2.89*		5.19	30.63	0.26	0	0.00	192.52	<0.01	hypersulfidic
3.1	0-5	fine	5.22	2.90	4.57*	208.5	5.81	15.37	0.01	0	0.00	22.21	<0.01	hypersulfidic [#]
3.2	5-10	fine	5.34	3.50	4.16*		5.19	21.35	<0.01	0	0.00	21.35	<0.01	other acidic
3.3	10-20	fine	4.40	3.65	4.26*		4.72	37.30	<0.01	0	0.00	37.30	<0.01	other acidic
3.4	20-40	fine	3.81	3.05	3.66*		4.43	44.75	<0.01	4	0.00	48.75	<0.01	sulfuric
3.5	40-90	fine	3.98	3.00	3.48*		4.61	45.07	<0.01	0	0.00	45.07	<0.01	sulfuric
4.1	0-5	medium	6.69	2.85	4.30*	571.5	5.75	13.52	0.08	0	0.00	66.42	0.04	hypermonosulfidic [#]
4.2	5-10	medium	6.19	2.80	4.27*		5.51	15.12	0.02	0	0.00	26.47	<0.01	hypersulfidic [#]
4.3	10-20	medium	5.53	2.90	4.27		5.35	18.34	<0.01	0	0.00	18.34	<0.01	other acidic
4.4	20-40	fine	5.86	3.15	4.45*		5.11	30.73	<0.01	0	0.00	30.73	<0.01	other acidic
4.5	40-80	fine	5.77	3.55	2.10*		5.37	29.66	0.11	0	0.00	97.14	0.03	hypermonosulfidic

* Indicates that a stable pH has not yet been reached for this sample (after 13 weeks). [#] Classified as hypersulfidic/hypermonosulfidic based on positive net acidity.

Table 8-15. Field hydrochemistry data for acid sulfate soil assessment of Boiling Downs Creek (Wetland ID 20177).

Site and Layer ID.	Temperature (Deg C)	Specific Electrical Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	ORP	Redox potential (mV)	Turbidity (NTU)	HCO ₃ (mg/L)	Comment
<i>Lowland River*</i>		125-2200	85-110		6.5-8.0			6-50		
<i>Freshwater Lakes*</i>		20-30	90-110		6.5-8.0			1-20		
20177_1 (SW)	19.7	4,390	154.4	14.24	8.63	240.6		55	136	
20177_2 (PW)	19	21,540	6.7	0.62	5.50	95		648	164	
20177_4 (PW)	17.5	18,970	4.3	0.41	6.08	-67		177		No sample collected

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively.

Table 8-16. Laboratory hydrochemistry data for acid sulfate soil assessment of Boiling Downs Creek (Wetland ID 20177).

Parameter	units	ANZECC Guidelines	Site 1 (SW)	Site 2 (PW)
depth	cm			
Na	mg l ⁻¹		295.1	1,263.2
K	mg l ⁻¹		4.6	8.1
Ca	mg l ⁻¹		40.3	182.0
Mg	mg l ⁻¹		72.9	327.0
Si	mg l ⁻¹		0.85	8.45
Br	mg l ⁻¹		1.551	7.159
Cl	mg l ⁻¹		796	2,860
NO ₃	mg l ⁻¹	0.7	0.020	0.294
NH ₄ -N	mg l ⁻¹	0.01	0.031	10.413
PO ₄ -P ^E	mg l ⁻¹	0.005	0.016	0.078
SO ₄	mg l ⁻¹		77	652
Ag	µg l ⁻¹	0.05	<1	<1
Al ^A	µg l ⁻¹	55	<5	<5
As ^B	µg l ⁻¹	13	<10	<10
Cd	µg l ⁻¹	0.2	61	44
Co	µg l ⁻¹	2.8	1	102
Cr ^C	µg l ⁻¹	1	<5	<5
Cu ^H	µg l ⁻¹	1.4	<5	<5
Fe	µg l ⁻¹	300	4	124,902
Mn	µg l ⁻¹	1700	687	15,118
Ni ^H	µg l ⁻¹	11	1	55
Pb ^H	µg l ⁻¹	3.4	<1	<1
Se	µg l ⁻¹	11	<10	<10
Zn ^H	µg l ⁻¹	8	14	93
DOC	mg l ⁻¹		23.8	24.1

Notes.

The ANZECC guideline values for toxicants refer to the Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH₄ and PO₄, guideline values are provided for Freshwater Lakes and Reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^A Guideline is for Aluminium in freshwater where pH > 6.5.

^B Guideline assumes As in solution as Arsenic (AsV).

^C Guideline is for Chromium is applicable to Chromium (CrVI) only.

^E Guideline is for filterable reactive phosphorous (FRP).

^H Hardness affected (refer to Guidelines).

Table 8-17. Site description data for acid sulfate soil assessment of Boiling Downs Creek (Wetland ID 20177).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-40	Underwater; smooth fine feel; grey/black in colour	water	Low; sample collected from shallow water at one end of larger water body	Safest access for representative sample of subaqueous material .	hypermonosulfidic	MBO found at depth, may have connection to river in high floods
2	14	wet and slippery and sticky	bare	mid	upslope from site 1	hypermonosulfidic	Close to edge of current waterline, may have connection to river in high floods
3	75	damp, clay-rich, cracking	bare	mid-upper	approaching old high water mark	sulfuric	may have connection to river in high floods
4	5	wet and slippery and sticky, orange oxidised layer on surface	bare	low	base of wetland that is drying out	hypermonosulfidic	MBO found at depth, may have connection to river in high floods

Table 8-18. Profile description data for acid sulfate soil assessment of Boiling Downs Creek (Wetland ID 20177).

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features - Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	10Y 3/1	ZCL		W	1	FM		MAT				6.69	
1.2	5-10	10Y 3/1	ZCL		W	1	FM		MAT				6.74	
1.3	10-20	2.5Y 4/1	C	light medium	W	1	FM		MAT				6.55	
1.4	20-40	2.5Y 5/1	C	medium	W	3	FM		MAT				6.39	
1.5	40-60	2.5Y 5/1	C	light medium	W	2	FM		MAT				6.48	
2.1	0-5	10Y 3/1	C	light	W	1	FM		MAT	MA	0		6.65	
2.2	5-10	2.5Y 5/1	C	medium	W	1	FM		MAT	MA	0		6.40	
2.3	10-20	2.5Y 5/1	C	medium heavy	W	2	FM		APF	SB	1	very weak	6.29	
2.4	20-40	2.5Y 5/1	C	medium	W	4	FM		APF	SB	1	very weak	5.51	
2.5	40-75	2.5Y 5/1	C	medium	W	2	FM		MAT	MA	0		5.19	
3.1	0-5	10YR 4/2	C	light medium	T	2	FM			PO	1	mod firm	5.88	
3.2	5-10	10YR 5/2	C	medium heavy	T	4	FM			PO	1	mod firm	5.32	
3.3	10-20	10YR 5/2	C	medium heavy	T	4	FM			PO	1	mod firm	5.10	
3.4	20-40	10YR 5/2	C	medium heavy	M					PO	1	mod firm	4.60	
3.5	40-90	10YR 5/2	C	medium heavy	M					PO	1	mod firm	4.27	
4.1	0-5	N3/	ZC	light	W	1	FM			MA			6.16	
4.2	5-10	2.5Y 5/1	ZC	light	W	1	FM			MA			6.17	
4.3	10-20	2.5Y 5/1	C	light	W	2	FM			MA			6.24	
4.4	20-40	2.5Y 5/1	C	medium	W	4	FM			MA			6.15	
4.5	40-80	2.5Y 5/1	C	medium	W					MA			6.08	80-90 cm - Gley1 2.5/N (ZC)

8.4. Glen Esk-Rusty Waterhole (Wetland ID 28200)

8.4.1. Location and setting description

Rusty Waterhole wetland is approx. 13 km up river from the Gee Gee Bridge on, Nacurrie Road North, 36 km east of Swan Hill Township. The billabong is connected to the south west side of the Wakool River, the wetland is linear and meandering, almost 2 km in length and 40 m at the widest point, with a total area of 5 ha. The wetland has steep banks and is bordered by floodplains incised with shallow narrow dry water channels to the south, west and east. Two narrow and shallower water channels connect to a u-bend and deep section in the centre of the wetland locally known as the 'Rusty Waterhole'. At the time when the soil survey was conducted in March 2010, the wetland had surface water within the deep section. The majority of the channel contained no surface water and was well vegetated with saplings, in the region of the 'Rusty Waterhole' desiccated vegetation, schwertmannite, sulfuric surface water and MBO was observed. Four sites were sampled as shown in Figure 8-17.

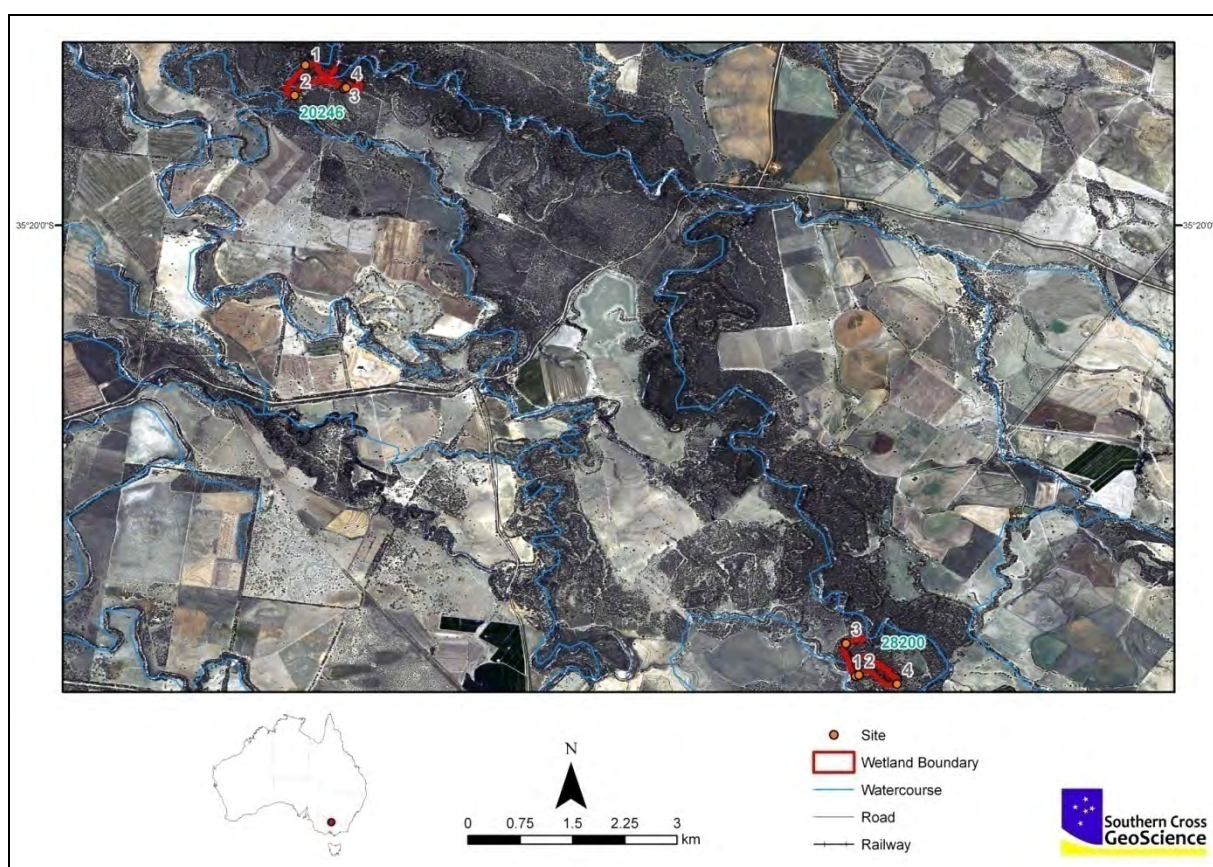


Figure 8-21. Glen Esk-Rusty Waterhole and sample site locations.

8.4.2. Soil profile description and distribution

Four sites were described and sampled. The soil subtype and general location description are presented in Table 8-19. Sites were distributed throughout the wetland based on different surface features and locations in the wetland, a transect approach was not used.

The profile 28200_1 (Figure 8-23) occurred in a water body in the deepest section of the wetland, the soil consisted of schwertmannite, MBO and soft grey clay. The profile 28200_2 (Figure 8-24) occurred on a bare surface adjacent to a water body, the soil consisted of schwertmannite in the top layer and soft grey clay beyond. The profile 28200_3 (Figure 8-25) occurred in the centre of dry stream channel on partial vegetated surface, the soil

consisted firm mottled grey brown clay. The profile 28200_4 (Figure 8-26) occurred in the centre of dry stream channel on mostly bare surface, the soil consisted firm mottled grey brown clay. Additional site and profile description data are presented in Tables 8-23 and 8-24, respectively.

Table 8-19. Soil identification, subtype and general location description for Glen Esk-Rusty Waterhole.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
28200_1	767914	6079541	sulfuric subaqueous soil with MBO	low elevation, schwertmannite, MBO and soft clay submerged in sulfuric water body
28200_2	767954	6079555	hypermonosulfidic soil	low elevation, schwertmannite, and soft clay on edge of sulfuric water body
28200_3	767816	6080011	sulfuric soil	higher elevation, sapling trees and clay soil area
28200_4	768398	6079413	sulfuric soil	higher elevation, sapling trees and clay soil area

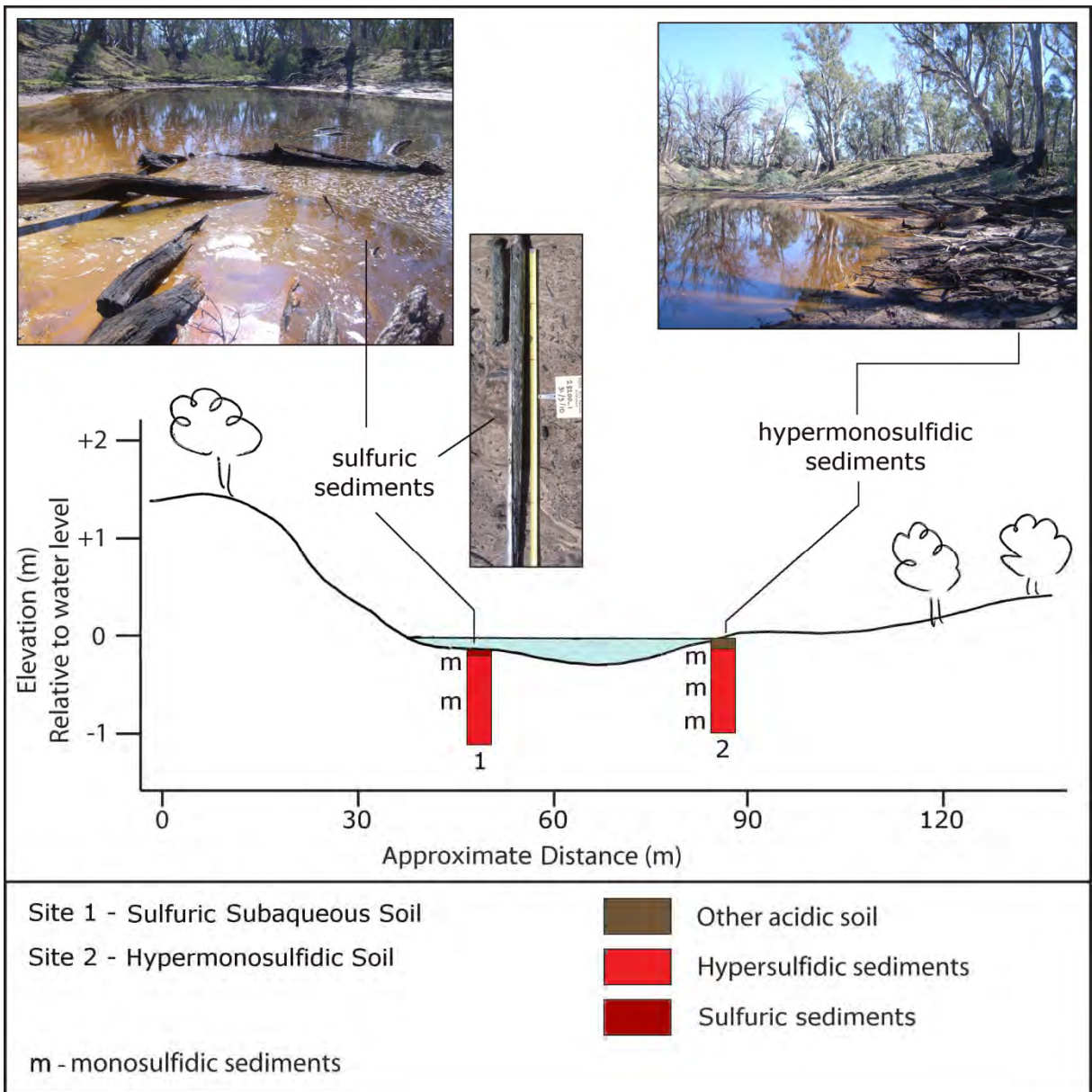


Figure 8-22. Conceptual cross section diagram showing the toposequence relationship of the Glen Esk-Rusty Waterhole sediments/soil materials for sites 28200_1 and 28200_2.



Figure 8-23. Photographs of site 28200_1, showing the subaqueous site, and the soil core.



Figure 8-24. Photographs of site 28200_2, showing the bare channel fringe, and the soil core.



Figure 8-25. Photographs of site 28200_3, showing the partly vegetated, dry stream channel, and the soil core.



Figure 8-26. Photographs of site 28200_4, showing the dry stream channel, and the soil core.

8.4.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Table 8-20 and profiles for all the sites sampled are presented in Figure 8-27. The pH_W values ranged between 3.28 and 6.26. Sulfuric materials (i.e. $pH_W < 4$) were present at sites 28200_1 (0-5 cm), 28200_3 (5-10 cm, 40-90 cm) and 28200_4 (40-90 cm). The pH_{FOX} values ranged between 1.52 and 3.02. The pH_{FOX} results indicate that all the surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. However, the S_{CR} data shows only seven of the 20 layers examined contained detectable sulfide (i.e. $S_{CR} \geq 0.01\% S$). Twelve soil materials had a $pH_{FOX} < 2.5$ (i.e. sites 28200_1 - 28200_4). Five of the sulfidic soil materials (i.e. $S_{CR} \geq 0.01\% S$) acidified to $pH < 4$ after at least 8 weeks of incubation (i.e. 28200_1 (5-10 cm and 40-90 cm) and 28200_2 (10-90 cm)). Other acidic soil materials were identified at three of the four sites examined, indicating acidity in the soil profile at levels where aluminium may mobilise. Six of the other acidic soils acidified to $pH < 4$ after at least 8 weeks of incubation.

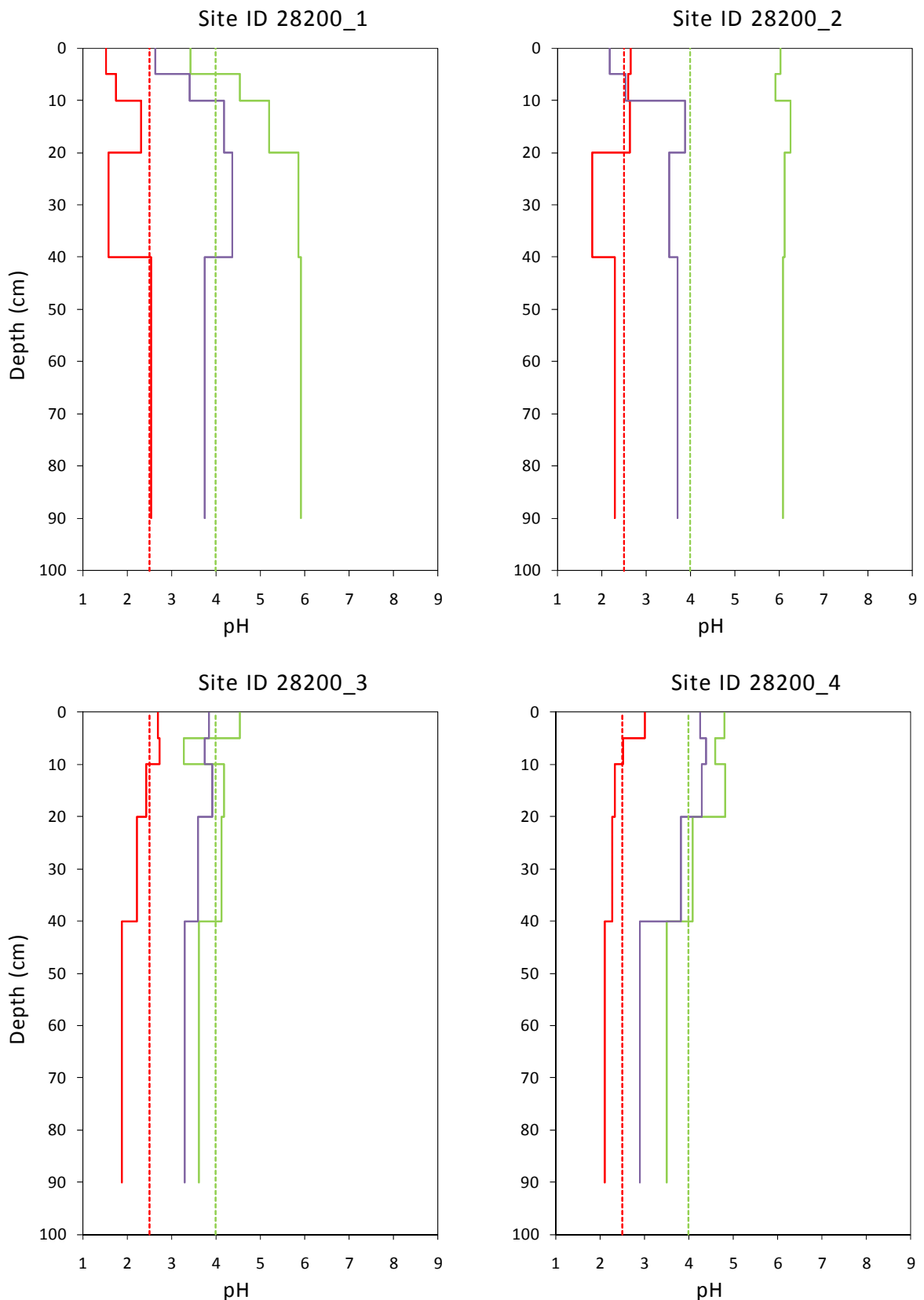


Figure 8-27. Depth profiles of soil pH for Glen Esk-Rusty Waterhole (28200_1 – 28200_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-20 and summarised in Figure 8-28.

Chromium reducible sulfur

Chromium reducible sulfur (S_{CR}) values ranged between < 0.01 and 0.33% S. Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were identified at two sampling sites (i.e. sites 28200_1 and 28200_2), with only seven materials of the 20 samples collected equal to or greater than the sulfidic criterion.

Acid volatile sulfide

The acid volatile sulfide (S_{AV}) values ranged between < 0.01 and 0.12% S. A total of six monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were found at two sites (i.e. sites 28200_1 and 28200_2).

Acid neutralising capacity

All soil materials had no acid neutralising capacity (ANC).

Titrateable actual acidity

The titrateable actual acidity (TAA) ranged between 14 and 123 mole H^+ /tonne. At two of the sites an increase in the TAA with depth was clearly observed (i.e. 28200_3 and 28200_4).

Retained acidity

Retained acidity was only detected in five layers from site 28200_3 (i.e. 0-90 cm), ranging between zero and 228 mole H^+ /tonne.

Net acidity

Net acidity ranged between 18 and 297 mole H^+ /tonne. The seven hypersulfidic soils had moderate to high net acidities ranging between 22 and 222 mole H^+ /tonne. The four sulfuric soils also had moderate to high net acidities of between 28 and 297 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 100 and 948 mg/kg. All of the surface soil layers examined had a soluble sulfate content either equal to or exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

The surface water and groundwater data measured in the field and laboratory are presented in Tables 8-21 and 8-22, respectively. The field pH of the surface water collected was 2.52 and below the most relevant ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5. The water data indicates that the surface water has been affected by acidification. The surface water sulfate concentration was 1,661 mg/L. Dissolved oxygen, SEC, some nutrient (i.e. NH_4 , PO_4) and metal (i.e. Cd, Co, Cr, Fe, Mn, Ni, Pb, Zn) values were found to exceed the most relevant ANZECC/ARMCANZ (2000) guideline value. The field pH of the groundwater was 5.94 and had a sulfate concentration of 650 mg/L.

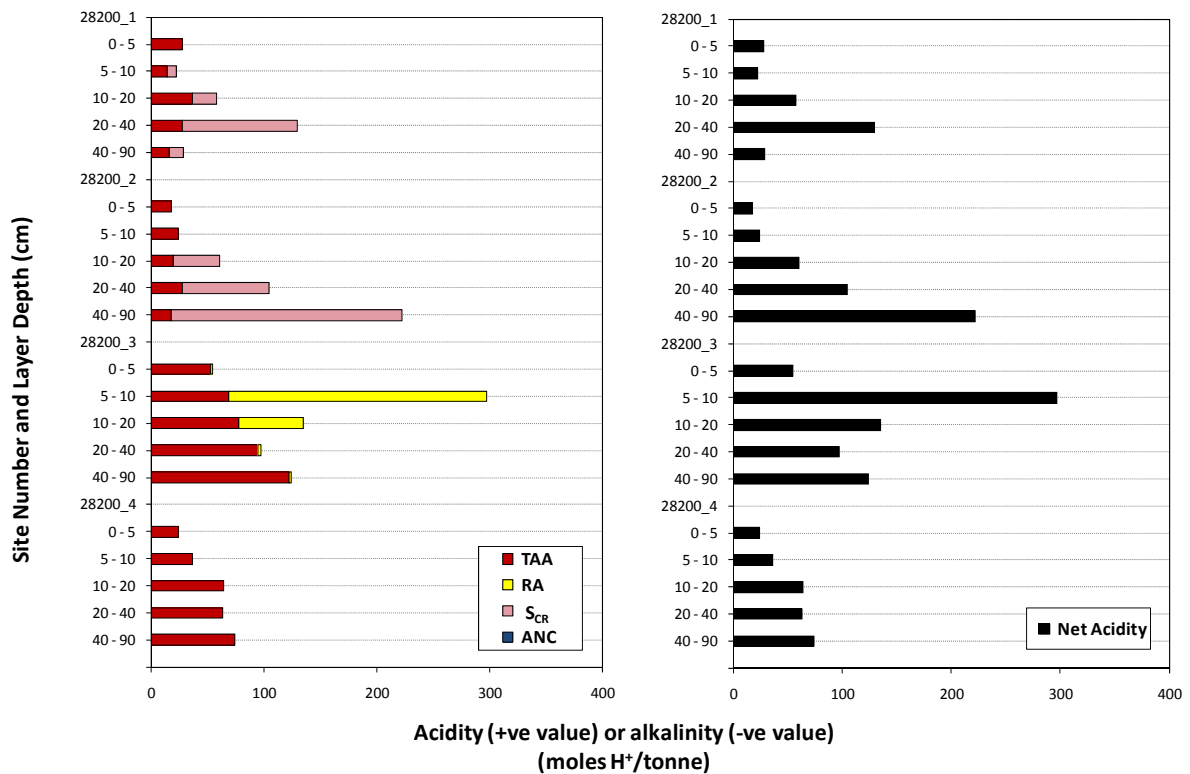


Figure 8-28. Acid-base accounting depth profiles for Glen Esk-Rusty Waterhole (28200_1 – 28200_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.4.4. Discussion

Acid sulfate soils occurred at all four sites in the Glen Esk-Rusty Waterhole wetland (i.e. sites 28200_1 - 28200_4). Sulfuric materials with moderate to high net acidities (i.e. 28 - 297 mole H^+ /tonne) were observed at three sites (i.e. sites 28200_1, 28200_3 and 28200_4). The presence of reduced inorganic sulfur was identified at two sites (i.e. sites 28200_1 and 28200_2), with a S_{CR} of up to 0.33% S. Hypersulfidic soil materials with moderate to high net acidities (i.e. 22 - 222 mole H^+ /tonne) were present in the two soil profiles. Monosulfidic soil materials were also observed in the subsoils (i.e. below a depth of 10 cm) at the sulfidic sites, with S_{AV} contents of up to 0.12% S. These results indicate that acidity would be produced upon oxidation of the sulfidic materials. All surficial soil materials contained soluble sulfate either equal to or exceeding the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there were three high priority sites based on the presence of sulfuric material, two high priority sites based on hypersulfidic material and two high priority sites based on monosulfidic material. All four sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at the Glen Esk-Rusty Waterhole wetland are:

- Acidification hazard: While moderate net acidities were dominant in this wetland, two sulfuric and three hypersulfidic materials had high net acidities (i.e. 25% of layers), indicating that the overall degree of acidification hazard is high.
- Deoxygenation hazard: Monosulfidic soil materials ($S_{AV} \leq 0.12\% S$) were observed at a depth of greater than 10 cm and therefore represent a low deoxygenation hazard. However, the soluble sulfate content of surface soil materials at all eight sites were over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The high acidification hazard indicates that soil acidification may increase the solubility of metals. The potential for MBO formation identified in this wetland may also result in an appreciable metal release hazard depending on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium.

Summary of key findings for the Glen Esk-Rusty Waterhole:

Soil materials:	Sulfuric materials were observed 3 sites. Sulfidic soil materials identified included: hypersulfidic (2 sites) and monosulfidic (2 sites). Moderate net acidities dominant within wetland although 2 sulfuric and 3 hypermonosulfidic soil materials had high acidities.
Acid sulfate soil identification:	<ul style="list-style-type: none"> • Sulfuric subaqueous soil – in waterbody (28200_1) • Hypermonosulfidic soil – adjacent to waterbody (28200_2) • Sulfuric soils – on higher ground supporting young saplings (28200_3-4)
Hazard assessment	<ul style="list-style-type: none"> • Acidification hazard - high level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard - high level of concern

Table 8-20. Laboratory analytical data for acid sulfate soil assessment of Glen Esk-Rusty Waterhole (Wetland ID 28200).

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	fine	3.42	1.52	2.63*	240	4.88	27.61	< 0.01	0	0.00	27.61	< 0.01	sulfuric
1.2	5-10	fine	4.54	1.75	3.41*		5.37	14.37	0.01	0	0.00	22.32	< 0.01	hypermonosulfidic
1.3	10-20	fine	5.19	2.32	4.18*		4.99	36.50	0.03	0	0.00	57.82	0.01	hypermonosulfidic [#]
1.4	20-40	fine	5.85	1.58	4.37		4.99	27.37	0.16	0	0.00	129.66	0.04	hypermonosulfidic [#]
1.5	40-90	fine	5.92	2.55	3.75*		5.29	16.08	0.02	0	0.00	28.92	< 0.01	hypersulfidic
2.1	0-5	coarse	6.02	2.65	2.18	668	5.35	17.88	< 0.01	0	0.00	17.88	< 0.01	other acidic
2.2	5-10	coarse	5.91	2.60	2.55*		5.30	23.85	< 0.01	0	0.00	23.85	< 0.01	other acidic
2.3	10-20	coarse	6.26	2.64	3.88*		5.41	19.72	0.07	0	0.00	60.75	0.04	hypermonosulfidic
2.4	20-40	fine	6.12	1.80	3.53*		5.25	27.69	0.12	0	0.00	104.40	0.06	hypermonosulfidic
2.5	40-90	fine	6.09	2.30	3.72*		5.18	17.63	0.33	0	0.00	222.04	0.12	hypermonosulfidic
3.1	0-5	fine	4.53	2.70	3.84*	948	4.41	52.35	< 0.01	2	0.00	54.35	< 0.01	other acidic
3.2	5-10	fine	3.28	2.73	3.74*		4.31	68.89	< 0.01	228	0.00	296.89	< 0.01	sulfuric
3.3	10-20	fine	4.19	2.43	3.91*		4.24	77.75	< 0.01	57	0.00	134.75	< 0.01	other acidic
3.4	20-40	fine	4.13	2.22	3.60*		4.17	94.41	< 0.01	3	0.00	97.41	< 0.01	other acidic
3.5	40-90	fine	3.61	1.89	3.29*		4.07	122.50	< 0.01	2	0.00	124.50	< 0.01	sulfuric
4.1	0-5	medium	4.81	3.02	4.25	100	5.10	23.95	< 0.01	0	0.00	23.95	< 0.01	other acidic
4.2	5-10	medium	4.60	2.53	4.38*		4.98	36.60	< 0.01	0	0.00	36.60	< 0.01	other acidic
4.3	10-20	medium	4.82	2.33	4.29		4.66	64.19	< 0.01	0	0.00	64.19	< 0.01	other acidic
4.4	20-40	fine	4.08	2.27	3.83		4.34	63.44	< 0.01	0	0.00	63.44	< 0.01	other acidic
4.5	40-90	fine	3.50	2.11	2.90		4.22	74.34	< 0.01	0	0.00	74.34	< 0.01	sulfuric

* Indicates that a stable pH has not yet been reached for this sample (after 15 weeks). [#] Classified as hypermonosulfidic based on positive net acidity.

Table 8-21. Field hydrochemistry data for acid sulfate soil assessment of Glen Esk-Rusty Waterhole (Wetland ID 28200).

Site and Layer ID.	Temperature (Deg C)	Specific Electrical Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	ORP	Redox potential (mV)	Turbidity (NTU)	HCO ₃ (mg/L)	Comment
<i>Lowland River*</i>		125-2200	85-110		6.5-8.0			6-50		
<i>Freshwater Lakes*</i>		20-30	90-110		6.5-8.0			1-20		
28200_1 (SW)	31.9	77,700	228.4	16.73	2.52	469.8		13	0	
28200_2 (PW)	21.1	26,900	8.9	0.79	5.94	9.5		711	136	

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively.

Table 8-22. Laboratory hydrochemistry data for acid sulfate soil assessment of Glen Esk-Rusty Waterhole (Wetland ID 28200).

Parameter	units	ANZECC Guidelines	Site 1 (SW)	Site 2 (PW)
depth	cm			
Na	mg l ⁻¹		11,113.8	2,587.1
K	mg l ⁻¹		109.8	13.1
Ca	mg l ⁻¹		2,926.9	420.7
Mg	mg l ⁻¹		3,614.5	744.9
Si	mg l ⁻¹		31.66	11.49
Br	mg l ⁻¹		87.230	20.333
Cl	mg l ⁻¹		39,892	7,596
NO ₃	mg l ⁻¹	0.7	0.212	0.325
NH ₄ -N	mg l ⁻¹	0.01	127.294	34.115
PO ₄ -P ^E	mg l ⁻¹	0.005	0.095	0.085
SO ₄	mg l ⁻¹		1,661	650
Ag	µg l ⁻¹	0.05	<1	<1
Al ^A	µg l ⁻¹	55	10,919	<5
As ^B	µg l ⁻¹	13	<10	<10
Cd	µg l ⁻¹	0.2	161	151
Co	µg l ⁻¹	2.8	251	7
Cr ^C	µg l ⁻¹	1	110	<5
Cu ^H	µg l ⁻¹	1.4	<5	<5
Fe	µg l ⁻¹	300	574,905	446,138
Mn	µg l ⁻¹	1700	186,292	22,304
Ni ^H	µg l ⁻¹	11	172	12
Pb ^H	µg l ⁻¹	3.4	58	<1
Se	µg l ⁻¹	11	<10	<10
Zn ^H	µg l ⁻¹	8	175	42
DOC	mg l ⁻¹		47.4	6.3

Notes.

The ANZECC guideline values for toxicants refer to the Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH₄ and PO₄, guideline values are provided for Freshwater Lakes and Reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^A Guideline is for Aluminium in freshwater where pH > 6.5.

^B Guideline assumes As in solution as Arsenic (AsV).

^C Guideline is for Chromium is applicable to Chromium (CrVI) only.

^E Guideline is for filterable reactive phosphorous (FRP).

^H Hardness affected (refer to Guidelines).

Table 8-23. Site description data for acid sulfate soil assessment of Glen Esk-Rusty Waterhole (Wetland ID 28200).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-10	underwater, smooth fine feel; grey/black in colour	water	low, in shallow water on margin of ASS site	safe access, main ASS in wetland	sulfuric	
2	20	silty feel	bare	mid to upper slope	upslope from site 1	hypermonosulfidic	contains colluvial material washed down into wetland area
3	dry	dry, silty feel, bare patches	common	low, base of wetland channel	characterise lateral extent of wetland	sulfuric	old sulfidic layer at depth
4	dry	dry, silty feel, bare patches	common	low, base of wetland channel	characterise lateral extent of wetland	sulfuric	old sulfidic layer at depth

Table 8-24. Profile description data for acid sulfate soil assessment of Glen Esk-Rusty Waterhole (Wetland ID 28200).

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	10YR 3/1	C		W		FM		TOH	n/r			5.55	
1.2	5-10	10YR 3/1	C		W					n/r			6.08	
1.3	10-20	10YR 3/1	C		W					n/r			6.10	
1.4	20-40	10YR 3/1	C		W					n/r			6.12	
1.5	40-90	10YR 3/1	C		W					n/r			6.08	
2.1	0-5	10YR 4/2	CS		M	3	FM			n/r			3.20	
2.2	5-10	10YR 4/2	CS		M	3	FM			n/r			4.78	
2.3	10-20	10YR 4/2	CS		W					n/r			5.25	
2.4	20-40	10YR 3/1	C		W					n/r			5.63	
2.5	40-90	10YR 3/1	C		W					n/r			5.76	
3.1	0-5	10YR 4/2	C	medium	T	2	FM			n/r		mod-strong	4.87	
3.2	5-10	10YR 4/2	C	medium	T	2	FM			n/r		mod-strong	5.23	
3.3	10-20	10YR 4/2	C	medium	T	2	FM			n/r	3	mod firm	4.42	
3.4	20-40	10YR 4/2	C	medium	M	2	FM			n/r	3	mod weak	4.12	
3.5	40-90	10YR 3/1	C	medium	W	3	FM			n/r	3	very weak	3.93	
4.1	0-5	10YR 3/2	SL		T					n/r			5.51	
4.2	5-10	10YR 3/2	SL		T					n/r			5.11	
4.3	10-20	10YR 3/2	SL		T					n/r			5.06	
4.4	20-40	10YR 4/2	C	medium	T	4	FM			n/r	3		4.94	
4.5	40-90	10YR 4/2	C	medium	M	4	FM			n/r	3		3.62	

8.5. Wetland ID 20229

8.5.1. Location and setting description

The wetland is an arcuate feature on the southern side of the Edward River. It is about 500 m long, 100-200 m wide and 6 ha and is a section of an ox-bow. The Edward River alluvial plain bounds the wetland on the western side, the ox-bow/scroll system on east and north. Wetland 20230 adjoins the southern side. At the time of soil survey in April 2010 the wetland was dry and occupied by dense stands of red gum sucker communities. The surface was severely cracked with prominent prismatic and very crumbly structural units. Cracks were about 5-10 cm wide and walking on this surface was difficult. Four sites were sampled as shown in Figure 8-29.

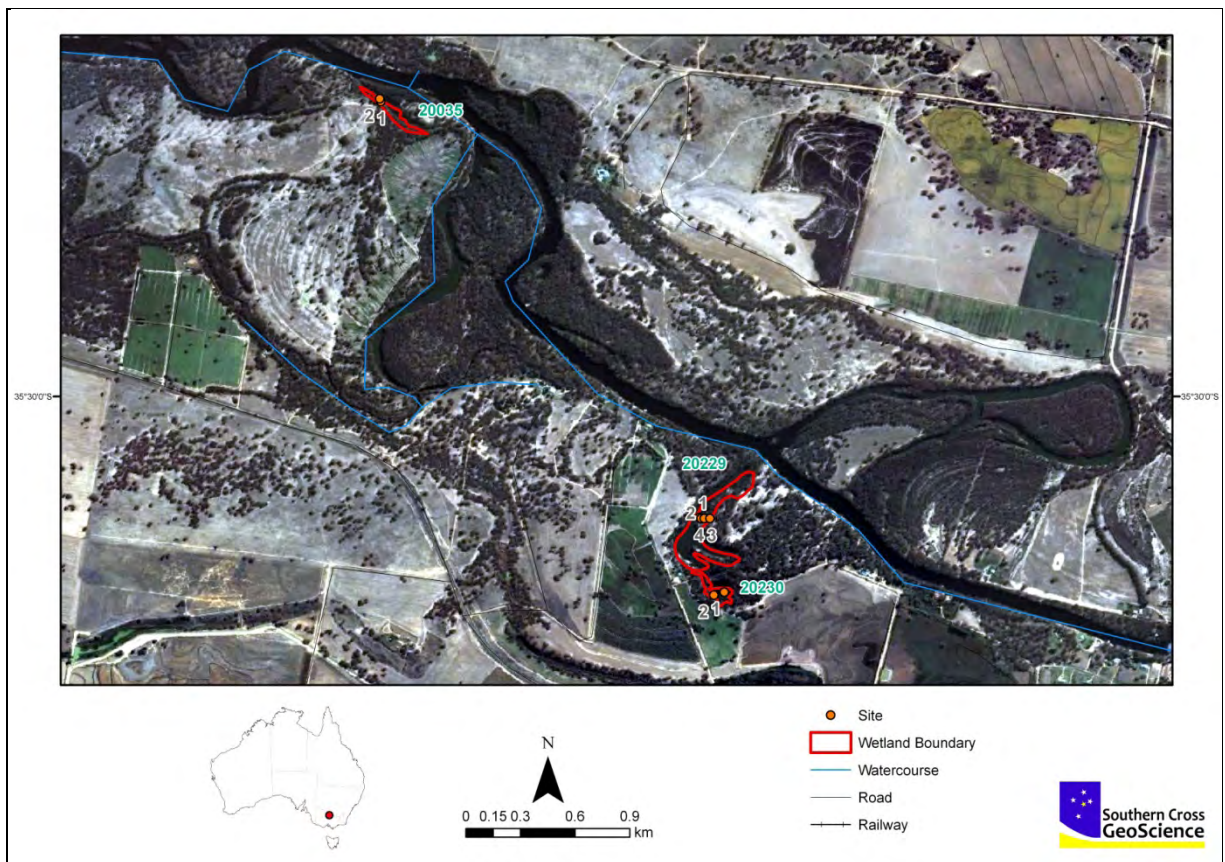


Figure 8-29. Wetland ID 20229 and sample site locations.

8.5.2. Soil profile description and distribution

Four sites were described and sampled. Sites were distributed across the wetland based on elevation using a transect approach. The soil subtype and general location description are presented in Table 8-25.

The profile 40156_1 (Figure 8-31) occurred within the lowest part of the wetland where the surface was moist and water present at 15 cm depth, the soil consisted of cracking grey mottled light medium silty clay forming distinct prismatic units. The profile 40156_2 (Figure 8-32) occurred in the dry cracked surface of the wetland where water was present at 90cm depth, the soil consisted of cracking grey mottled light medium clay. The profile 40156_3 (Figure 8-33) occurred on the elevated fringing sedgeland community, the soil consisted of sandy clay loam over grey mottled light medium silty clay. The profile 40156_4 (Figure 8-34)

occurred within the uppermost section of the wetland edge in a red gum sucker community, the soil consisted of loamy sand to clay loam over grey mottled medium clay. Additional site and profile description data are presented in Tables 8-29 and 8-30, respectively.

Table 8-25. Soil identification, subtype and general location description for Wetland ID 20229.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20229_1	309570	6068816	cracking clay soil	lowest part of wetland, surface moist, cracked
20229_2	309577	6068811	cracking clay soil	dry, cracked clay area
20229_3	309592	6068807	sulfuric soil	elevated section of fringing sedgeland
20229_4	309616	6068812	sulfuric soil	uppermost section of wetland in red gum community

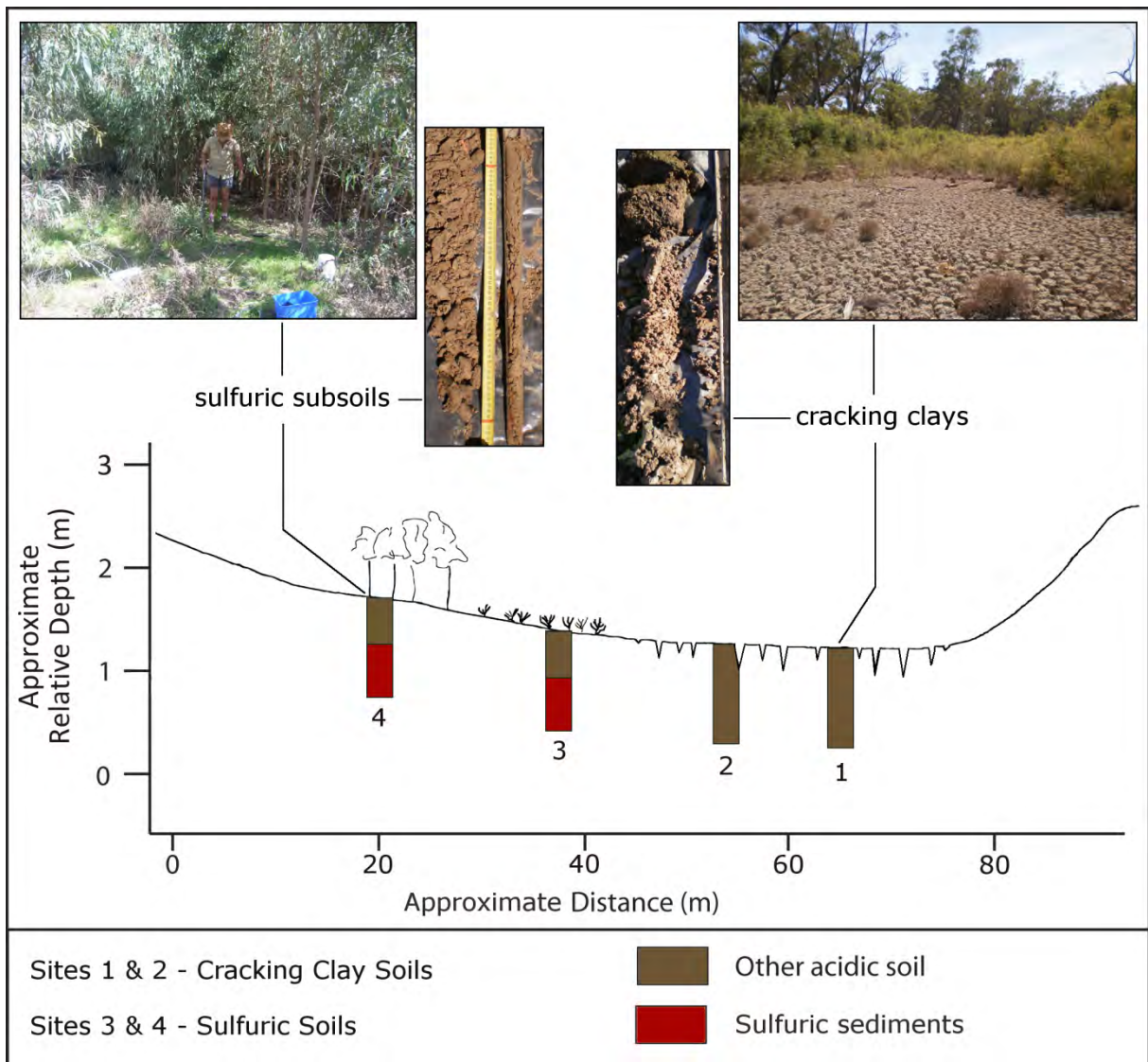


Figure 8-30. Conceptual cross section diagram showing the toposuccession relationship of the Wetland ID 20229 sediments/soil materials throughout the wetland.



Figure 8-31. Photographs of site 20229_1, showing the severely cracked surface at the sampling site, situated at the lowest point in the transect, and the soil core.



Figure 8-32. Photographs of site 20229_2, showing the dry, cracked surface, and the soil core.



Figure 8-33. Photographs of site 20229_3, showing the slightly elevated fringing sedgeland, and the soil core.



Figure 8-34. Photographs of site 20229_4, showing the upper section of the fringing sedgeland adjacent to the alluvial plain, and the dry soil core.

8.5.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Table 8-26 and profiles for all the sites sampled are presented in Figure 8-35. The pH_W values ranged between 3.85 and 6.63. Sulfuric materials (i.e. $pH_W < 4$) were present at sites 20229_3 (40-90 cm) and 20229_4 (40-90 cm). The pH_{FOX} values ranged between 1.79 and 3.52. The pH_{FOX} results indicate that all surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. Eight soil materials had a $pH_{FOX} < 2.5$ (i.e. sites 20229_2 - 20229_4). However, the S_{CR} data shows all layers sampled within this wetland contained no detectable sulfide (i.e. $S_{CR} < 0.01\%$ S). Other acidic soil materials were identified at all four sites, indicating acidity in the soil profile at levels where aluminium may mobilise. Twelve of the other acidic soils acidified to $pH < 4$ after at least 8 weeks of incubation.

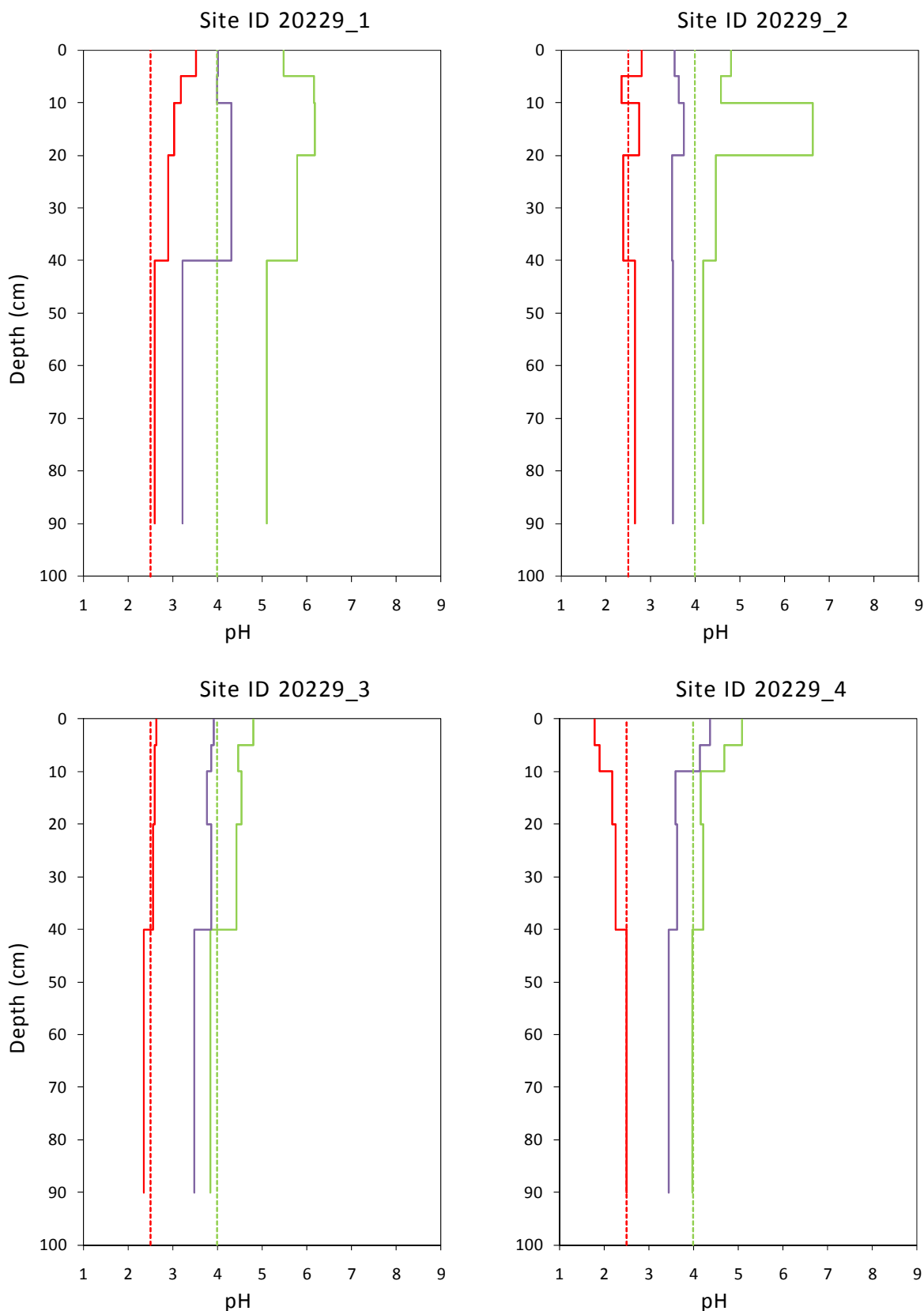


Figure 8-35. Depth profiles of soil pH for Wetland ID 20229 (20229_1 – 20229_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-26 and summarised in Figure 8-36.

Chromium reducible sulfur

Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were not found within this wetland.

Acid volatile sulfide

Monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were not found within this wetland.

Acid neutralising capacity

All soil materials had no acid neutralising capacity (ANC).

Titratable actual acidity

The titratable actual acidity (TAA) ranged between 10 and 82 mole H^+ /tonne. An increase in the TAA with depth was observed.

Retained acidity

All soil materials had no retained acidity.

Net acidity

Net acidity ranged between 10 and 82 mole H^+ /tonne. The two sulfuric soils had moderate net acidities of 63 and 69 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 215 and 339 mg/kg. All of the surface soil layers examined had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

The surface water data measured in the field and in the laboratory at site 20229_1 are presented in Tables 8-27 and 8-28, respectively. The field pH was 5.47 and below the most relevant ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5. The water data indicates that the surface water may have been affected by acidification. The surface water sulfate concentration was 111 mg/L. Dissolved oxygen, turbidity, some nutrient (i.e. NO_3 , NH_4 , PO_4) and metal (i.e. Cd, Co, Cu, Mn, Zn) values were found to be outside the most relevant ANZECC/ARMCANZ (2000) guideline value. Groundwater was not collected within this wetland.

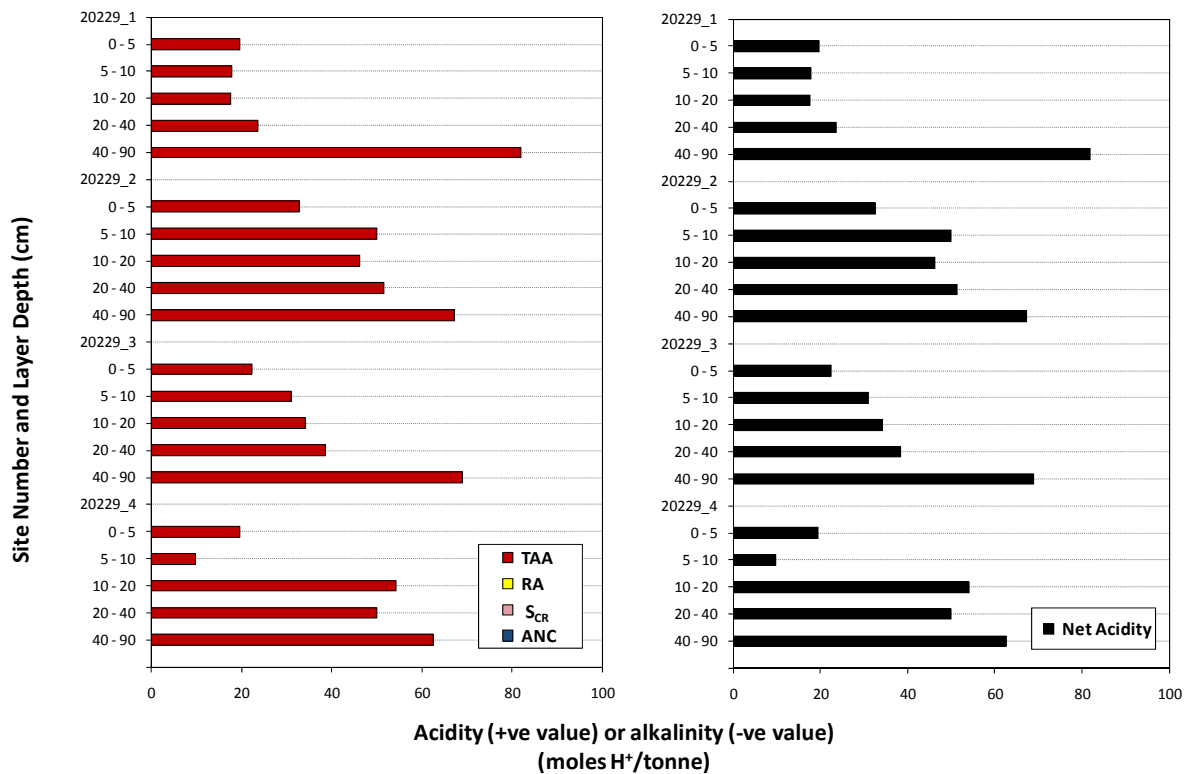


Figure 8-36. Acid-base accounting depth profiles for Wetland ID 20229 (20229_1 – 20229_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.5.4. Discussion

Acid sulfate soils occurred at depth (i.e. 40-90 cm) at two sites within Wetland ID 20229 (i.e. sites 20229_3 and 20229_4). These two sites contained sulfuric soil materials, and the remaining two sites contained other acidic soils. The two sulfuric materials had moderate net acidities of 63 and 69 mole H^+ /tonne.

No sulfidic materials were identified within this wetland. All four surficial soil materials examined contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there were two high priority sites based on the presence of sulfuric material, and four high priority ranking sites for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by the acid sulfate soil materials at Wetland ID 20229 are:

- Acidification hazard: The data indicate that with two sulfuric soil materials with moderate net acidities that the degree of acidification hazard is moderate.
- Deoxygenation hazard: The soluble sulfate contents of surface soil materials at all four sites were over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.

- Metal mobilisation: The moderate acidification hazard indicates that soil acidification may increase the solubility of metals. The potential for MBO formation identified in this wetland may also result in an appreciable metal release hazard depending on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium at all sites.

Summary of key findings for the Wetland ID 20229:

<i>Soil materials:</i>	Sulfuric materials observed at 2 sites. No sulfidic materials identified. Other acidic soil materials observed at the other 2 sites. Moderate net acidities dominant within wetland.
<i>Acid sulfate soil identification:</i>	<ul style="list-style-type: none"> • Sulfuric soils – occurring at sites 20229_2 and 20229_3, elevated sites with sedgeland or red gum communities.
<i>Hazard assessment</i>	<ul style="list-style-type: none"> • Acidification hazard – moderate level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – high level of concern

Table 8-26. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 20229.

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	fine	5.48	3.52	4.01*	272	5.29	19.65	< 0.01	0	0.00	19.65	< 0.01	other acidic
1.2	5-10	fine	6.16	3.18	4.00*		5.39	17.92	< 0.01	0	0.00	17.92	< 0.01	other acidic
1.3	10-20	fine	6.17	3.04	4.32*		5.33	17.70	< 0.01	0	0.00	17.70	< 0.01	other acidic
1.4	20-40	fine	5.78	2.90	4.32*		5.07	23.62	< 0.01	0	0.00	23.62	< 0.01	other acidic
1.5	40-90	fine	5.11	2.60	3.22*		4.31	81.88	< 0.01	0	0.00	81.88	< 0.01	other acidic
2.1	0-5	fine	4.81	2.80	3.55*	339	4.98	32.71	< 0.01	0	0.00	32.71	< 0.01	other acidic
2.2	5-10	fine	4.58	2.36	3.63*		4.59	49.94	< 0.01	0	0.00	49.94	< 0.01	other acidic
2.3	10-20	fine	6.63	2.75	3.75*		4.66	46.15	< 0.01	0	0.00	46.15	< 0.01	other acidic
2.4	20-40	fine	4.47	2.39	3.48*		4.45	51.45	< 0.01	0	0.00	51.45	< 0.01	other acidic
2.5	40-90	fine	4.18	2.65	3.50*		4.24	67.24	< 0.01	0	0.00	67.24	< 0.01	other acidic
3.1	0-5	medium	4.81	2.64	3.92*	318	5.32	22.41	< 0.01	0	0.00	22.41	< 0.01	other acidic
3.2	5-10	medium	4.47	2.60	3.87*		4.90	31.03	< 0.01	0	0.00	31.03	< 0.01	other acidic
3.3	10-20	medium	4.53	2.60	3.76*		4.65	34.19	< 0.01	0	0.00	34.19	< 0.01	other acidic
3.4	20-40	fine	4.42	2.56	3.86*		4.60	38.52	< 0.01	0	0.00	38.52	< 0.01	other acidic
3.5	40-90	fine	3.85	2.36	3.48*		4.27	68.86	< 0.01	0	0.00	68.86	< 0.01	sulfuric
4.1	0-5	coarse	5.09	1.79	4.36*	215	5.52	19.57	< 0.01	0	0.00	19.57	< 0.01	other acidic
4.2	5-10	medium	4.68	1.91	4.14*		5.83	9.85	< 0.01	0	0.00	9.85	< 0.01	other acidic
4.3	10-20	medium	4.17	2.18	3.60*		4.54	54.18	< 0.01	0	0.00	54.18	< 0.01	other acidic
4.4	20-40	fine	4.21	2.25	3.63*		4.52	49.89	< 0.01	0	0.00	49.89	< 0.01	other acidic
4.5	40-90	fine	3.98	2.50	3.44*		4.24	62.60	< 0.01	0	0.00	62.60	< 0.01	sulfuric

* Indicates that a stable pH has not yet been reached for this sample (after 16 weeks).

Table 8-27. Field hydrochemistry data for acid sulfate soil assessment of Wetland ID 20229.

Site and Layer ID.	Temperature (Deg C)	Specific Electrical Conductivity ($\mu\text{S/cm}$)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	ORP	Redox potential (mV)	Turbidity (NTU)	HCO ₃ (mg/L)	Comment
<i>Lowland River*</i>		125-2200	85-110		6.5-8.0			6-50		
<i>Freshwater Lakes*</i>		20-30	90-110		6.5-8.0			1-20		
20229_1 (SW)	16.5	920	8.6	0.96	5.47			490	40	

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively.

Table 8-28. Laboratory hydrochemistry data for acid sulfate soil assessment of Wetland ID 20229.

Parameter	units	ANZECC Guidelines	Site 1 (SW)
depth	cm		
Na	mg l ⁻¹		24.7
K	mg l ⁻¹		12.3
Ca	mg l ⁻¹		26.5
Mg	mg l ⁻¹		17.8
Si	mg l ⁻¹		0.63
Br	mg l ⁻¹		0.121
Cl	mg l ⁻¹		212
NO ₃	mg l ⁻¹	0.7	57.592
NH ₄ -N	mg l ⁻¹	0.01	10.153
PO ₄ -P ^E	mg l ⁻¹	0.005	0.135
SO ₄	mg l ⁻¹		111
Ag	µg l ⁻¹	0.05	<1
Al ^A	µg l ⁻¹	55	15
As ^B	µg l ⁻¹	13	<10
Cd	µg l ⁻¹	0.2	65
Co	µg l ⁻¹	2.8	8
Cr ^C	µg l ⁻¹	1	<5
Cu ^H	µg l ⁻¹	1.4	8
Fe	µg l ⁻¹	300	202
Mn	µg l ⁻¹	1700	2,866
Ni ^H	µg l ⁻¹	11	4
Pb ^H	µg l ⁻¹	3.4	<1
Se	µg l ⁻¹	11	<10
Zn ^H	µg l ⁻¹	8	89
DOC	mg l ⁻¹		49.0

Notes.

The ANZECC guideline values for toxicants refer to the Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH₄ and PO₄, guideline values are provided for Freshwater Lakes and Reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^A Guideline is for Aluminium in freshwater where pH > 6.5.

^B Guideline assumes As in solution as Arsenic (AsV).

^C Guideline is for Chromium is applicable to Chromium (CrVI) only.

^E Guideline is for filterable reactive phosphorous (FRP).

^H Hardness affected (refer to Guidelines).

Table 8-29. Site description data for acid sulfate soil assessment of Wetland ID 20229.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	dry	grey cracking clay, large cracks	bare	low, base of wetland	lowest point in wetland	other acidic	cracking clay produces large but fragile clay columns, probable connection to river during floods
2	90	grey cracking clay, large cracks	bare	low, edge of cracking clays	margin of affected wetland	other acidic	cracking clay produces large but fragile clay columns, probable connection to river during floods
3	dry	silty feel	common	low-midslope, vegetation present	slightly higher, less affected	sulfuric soil	inside zone of sapling regrowth
4	dry	silty feel	common	mid-upper slope, edge of wetland	outside zone of regrowth	sulfuric soil	outside zone of sapling regrowth

Table 8-30. Profile description data for acid sulfate soil assessment of Wetland ID 20229.

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features - Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	10YR 4/1	ZC		T	4	FM			PR	3	VW	6.47	
1.2	5-10	10YR 4/1	ZC		T	4	FM			PR	3	W	6.40	
1.3	10-20	10YR 4/2	ZC		T	4	FM			PR	3	W	5.84	
1.4	20-40	10YR 4/2	ZC		T	4	FM			PR	3	W	5.77	
1.5	40-90	2.5YR 5/2	ZC		W	4	FM			MA	0	VW	4.81	
2.1	0-5	10YR 4/2	ZC	light medium		2	FM			AB	3		5.11	
2.2	5-10	10YR 4/2	ZC	light medium		3	FM			PO	2		4.80	
2.3	10-20	2.5YR 4/2	ZC	light medium		3	FM			MA	0		4.80	
2.4	20-40	10YR 4/2	ZC	light medium		3	FM			MA	0		4.01	
2.5	40-90	10YR 4/2	ZC	light medium		3	FM			MA	0		4.18	
3.1	0-5	10YR 4/2	SCL		D					SB	1		4.92	
3.2	5-10	n/r	SCL		D	2	FM			AB	2		4.74	
3.3	10-20	n/r	ZCL		T	2	FM			AB	3		4.57	
3.4	20-40	n/r	ZC	light medium	T	3	FM			AB	3		4.56	
3.5	40-90	n/r	ZC	light medium	T					AB	3		4.21	
4.1	0-5	10YR 3/2	LS		D	1	FM			GR	1		5.22	
4.2	5-10	10YR 4/2	SL		D	2	FM			GR	2		4.64	
4.3	10-20	10YR 4/2	CL		T	2	FM			PO	2		4.29	
4.4	20-40	10YR 5/2	C	light medium	T	3	FM			PO	2		4.32	
4.5	40-90	10YR 5/2	C	light medium	T					PO	1		4.01	

8.6. Wetland ID 20230

8.6.1. Location and setting description

This is a very small wetland adjoining the southern end of 20229. It is about 400 m long, 50-100 m wide and 1 ha. At the time of the soil survey in April 2010 the wetland was dry. The lowest part had a prominently cracked surface and was completely covered by red gum suckers. The slightly elevated fringe of the wetland was a grassland lacking cracks. Two sites were sampled as shown in Figure 8-37.

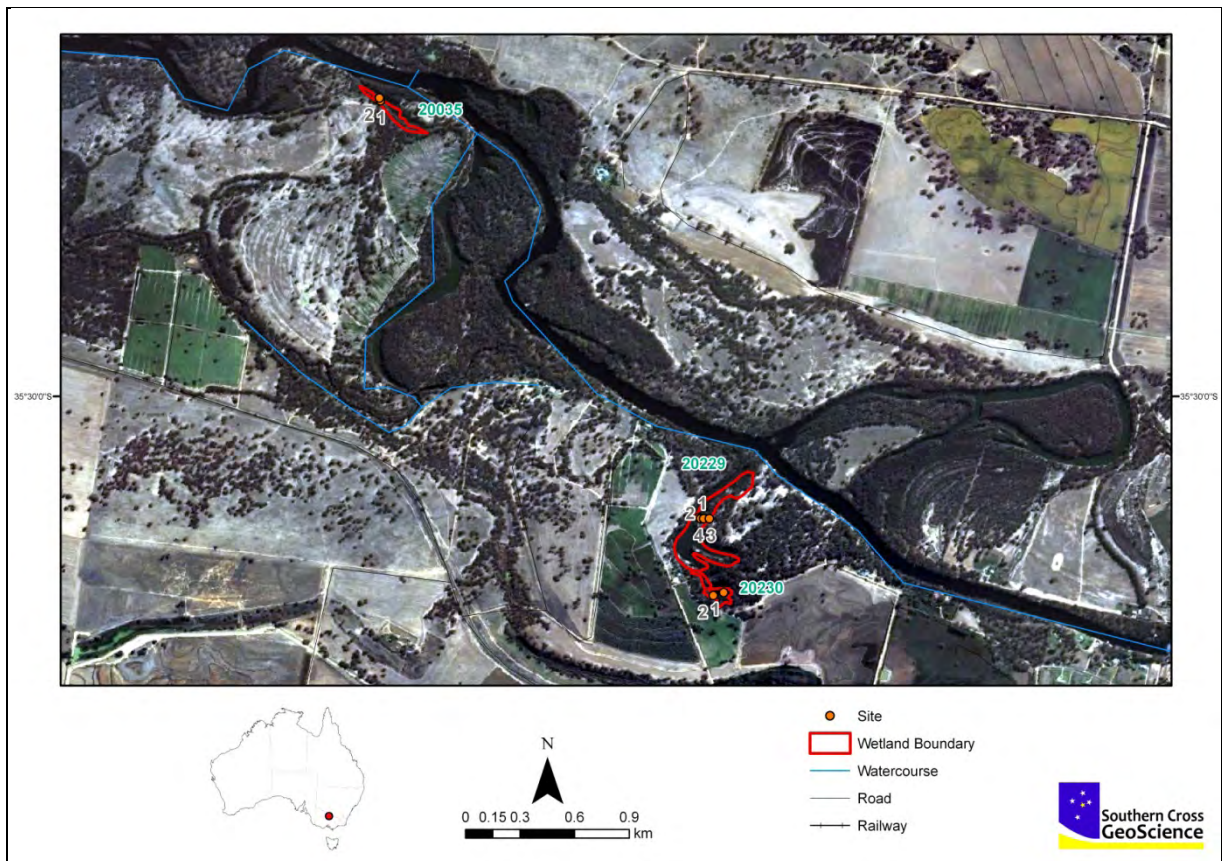


Figure 8-37. Wetland ID 20230 and sample site locations.

8.6.2. Soil profile description and distribution

Two sites were described and sampled. Sites were distributed throughout the wetland based on elevation and surface features using a transect approach. The soil subtype and general location description are presented in Table 8-31.

The profile 20230_1 (Figure 8-39) occurred on bare, prominently cracked surface amidst a community of red gum suckers, the soil consisted of self-mulched dark grey clay loam/silty loam over dark grey mottled medium silty clay. The profile 20230_2 (Figure 8-40) occurred on the slightly elevated area fringing the cracked soil area, the soil consisted of dark grey silty loam/silty clay loam over dark grey mottled silty clay. Additional site and profile description data are presented in Tables 8-33 and 8-34, respectively.

Table 8-31. Soil identification, subtype and general location description for Wetland ID 20230.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20230_1	309689	6068409	cracking clay soil	bare, cracked surface amongst red gum saplings
20230_2	309643	6068392	cracking clay soil	slightly elevated area

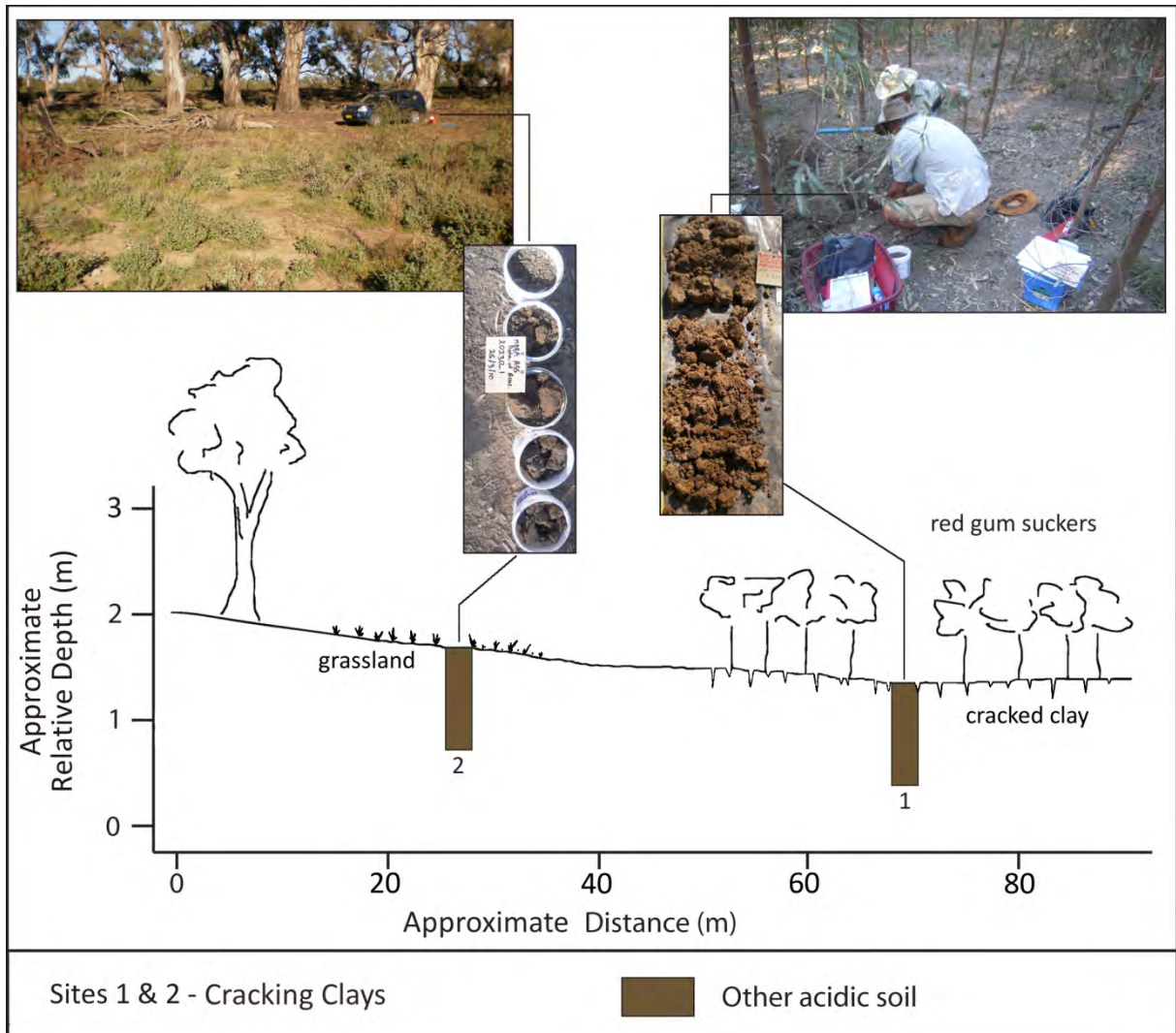


Figure 8-38. Conceptual cross section diagram showing the toposequence relationship of the Wetland ID 20230 sediments/soil materials.



Figure 8-39. Photographs of site 20230_1, showing the bare, cracked surface amidst red gum sucker community, and the dry soil core.



Figure 8-40. Photographs of site 20230_2, showing the fringing grassland, and the soil core.

8.6.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Table 8-32 and profiles for all the sites sampled are presented in Figure 8-41. The pH_W values ranged between 4.16 and 5.90. Sulfuric materials (i.e. $pH_W < 4$) were not present. The pH_{FOX} values ranged between 2.75 and 4.35. The pH_{FOX} results indicate that eight of the 10 surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. However, the S_{CR} data shows the layers examined within this wetland contained no detectable sulfide (i.e. $S_{CR} < 0.01\% S$). Other acidic soil materials were identified throughout the profile at both sites examined, indicating acidity in the soil profile at levels where aluminium may mobilise. Four of the other acidic soils acidified to $pH < 4$ after at least 8 weeks of incubation.

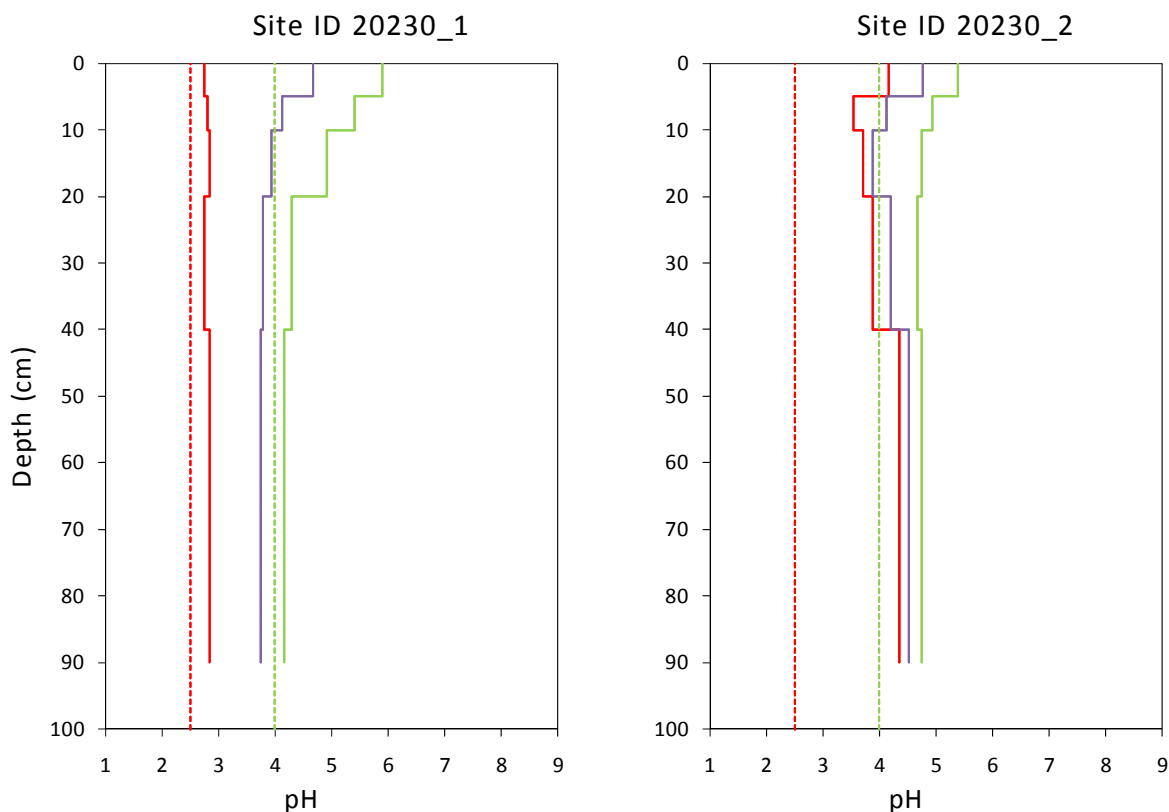


Figure 8-41. Depth profiles of soil pH for Wetland ID 20230 (20230_1 – 20230_2), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-32 and summarised in Figure 8-42.

Chromium reducible sulfur

Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were not found within this wetland.

Acid volatile sulfide

Monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were not found within this wetland.

Acid neutralising capacity

All soil materials had no acid neutralising capacity (ANC).

Titratable actual acidity

The titratable actual acidity (TAA) ranged between 9 and 67 mole H^+ /tonne. An increase in the TAA with depth was observed.

Retained acidity

All soil materials had no retained acidity.

Net acidity

Net acidity ranged between 9 and 67 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the two surface soils (i.e. 0-5 cm) examined was 197 and 698 mg/kg. Both of the surface soil layers had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

No water samples were collected for analysis.

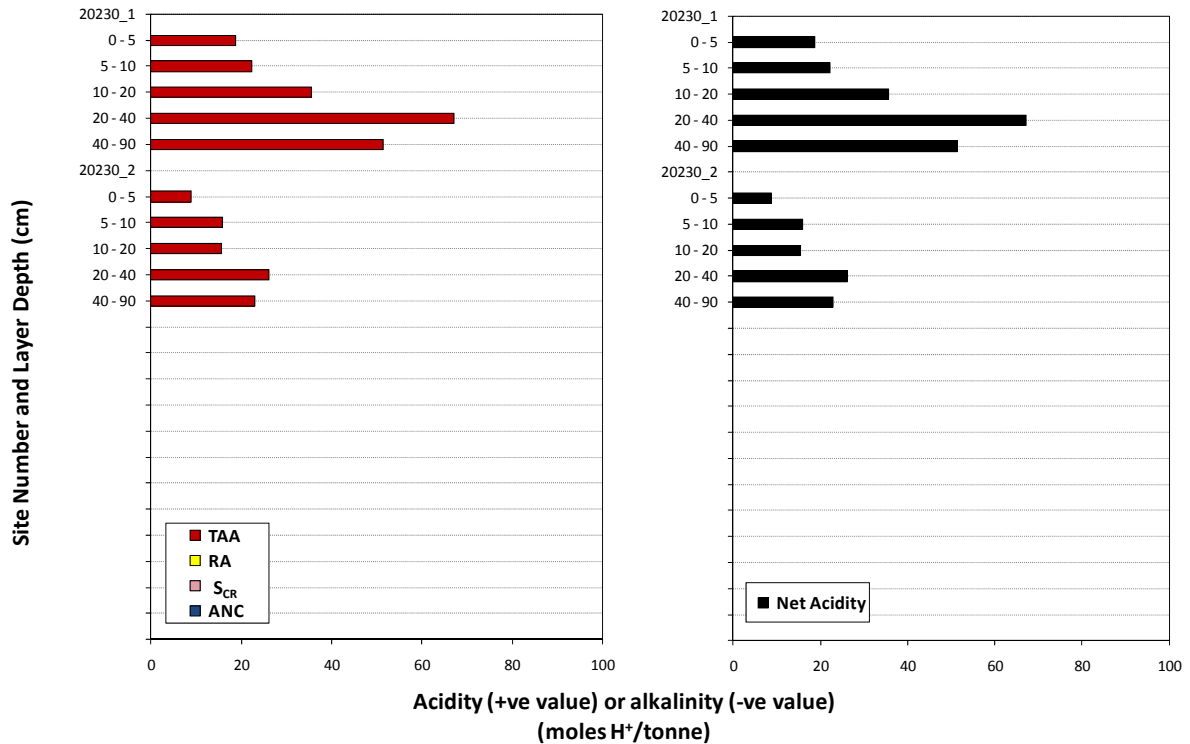


Figure 8-42. Acid-base accounting depth profiles for Wetland ID 20230 (20230_1 – 20230_2). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.6.4. Discussion

Acid sulfate soils materials were not found at Wetland ID 20230. All soil materials were classified as other acidic soils.

Both of the surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, two sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at Wetland ID 20230 are:

- Acidification hazard: The data indicate that with no sulfuric or sulfidic materials that the degree of acidification hazard is low.
- Deoxygenation hazard: The soluble sulfate content of both of the surface soil materials was over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The low acidification hazard indicates that soil acidification is not likely to increase the solubility of metals. However, the potential for MBO formation identified in this wetland may result in an appreciable metal release hazard depending on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium.

Summary of key findings for the Wetland ID 20230:

<i>Soil materials:</i>	Sulfuric and sulfidic materials were not observed within this wetland. Other acidic soil materials observed at 2 sites. Moderate net acidities dominant within wetland.
<i>Acid sulfate soil identification:</i>	<ul style="list-style-type: none"> • Other acid soils present at both sites.
<i>Hazard assessment</i>	<ul style="list-style-type: none"> • Acidification hazard - low level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – low to moderate level of concern

Table 8-32. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 20230.

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	5.90	2.75	4.67	698	5.40	18.64	< 0.01	0	0.00	18.64	< 0.01	other acidic
1.2	5-10	medium	5.41	2.80	4.13*		5.19	22.20	< 0.01	0	0.00	22.20	< 0.01	other acidic
1.3	10-20	medium	4.92	2.85	3.94*		4.88	35.57	< 0.01	0	0.00	35.57	< 0.01	other acidic
1.4	20-40	fine	4.29	2.75	3.79*		4.37	67.14	< 0.01	0	0.00	67.14	< 0.01	other acidic
1.5	40-90	fine	4.16	2.85	3.75*		4.44	51.51	< 0.01	0	0.00	51.51	< 0.01	other acidic
2.1	0-5	medium	5.38	4.16	4.76*	197	5.93	8.76	< 0.01	0	0.00	8.76	< 0.01	other acidic
2.2	5-10	medium	4.93	3.54	4.12*		5.44	15.85	< 0.01	0	0.00	15.85	< 0.01	other acidic
2.3	10-20	medium	4.75	3.71	3.89*		5.50	15.52	< 0.01	0	0.00	15.52	< 0.01	other acidic
2.4	20-40	medium	4.68	3.88	4.20*		4.78	26.18	< 0.01	0	0.00	26.18	< 0.01	other acidic
2.5	40-90	fine	4.74	4.35	4.53*		4.86	22.98	< 0.01	0	0.00	22.98	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 16 weeks).

Table 8-33. Site description data for acid sulfate soil assessment of Wetland ID 20230.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	dry	grey cracking clay	bare	low, base of wetland	lowest point in wetland	other acidic	leaf imprints in profile, no connection to river, surface runoff only
2	dry	grey cracking clay	common	mid slope, edge of wetland	upslope of site 1	other acidic	no connection to river, surface runoff only

Table 8-34. Profile description data for acid sulfate soil assessment of Wetland ID 20230.

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	10YR 4/2	CL		D	2	FM			PO	3		5.41	
1.2	5-10	7.5YR 4/3	ZCL		D	3	FM			PO	3		5.30	
1.3	10-20	10YR 4/2	ZC	light medium	D	3	FM			AB	3		4.39	
1.4	20-40	10YR 5/2	ZC	medium	T	3	FM			AB	2		4.17	
1.5	40-90	10YR 5/2	ZC	medium	T					AB	2		4.28	
2.1	0-5	7.5YR 4/2	ZL		D					MA	0		5.34	
2.2	5-10	7.5YR 5/2	ZL		D	2	FM			MA	0		5.13	
2.3	10-20	7.5YR 5/2	ZCL		D	3	FM			AB	2		4.59	
2.4	20-40	10YR 5/1	ZCL		M	3	FM			AB	2		4.46	
2.5	40-90	10YR 6/1	ZC		M	4	FM			MA	0		4.02	

8.7. Wetland ID 20246

8.7.1. Location and setting description

Wakool River billabong wetland is approximately 8 km down river from the Gee Gee Bridge on Nacurrie Road North, 29 km east of Swan Hill Township. The billabong is connected to the south side of the Wakool River, the wetland is linear and meandering, almost 2 km in length and 50 m at the widest point, with a total area of 6 hectares. The wetland has steep banks and is bordered by floodplains incised with shallow narrow dry water channels to the south and west and levee of the Wakool River to the northeast. Two narrow and shallower water channels connect the u-bend in the centre of the wetland. During high flows the wetland functions as a through-channel delivering flows from the Wakool River to the surrounding floodplain. At the time when the soil survey was conducted in April 2010, the wetland had surface water in sections of low elevation; sections of slightly higher elevation contained no surface water. In the upper section close to the mouth entering the Wakool River, Typha and Phragmites were growing in surface water with healthy river red gum (*Eucalyptus camaldulensis*) on the upper banks. However, desiccation of vegetation was observed in the mid section worsening along to the tail section, in these areas schwertmannite was observed along with sulfuric surface water. Four sites were sampled as shown in Figure 8-43.

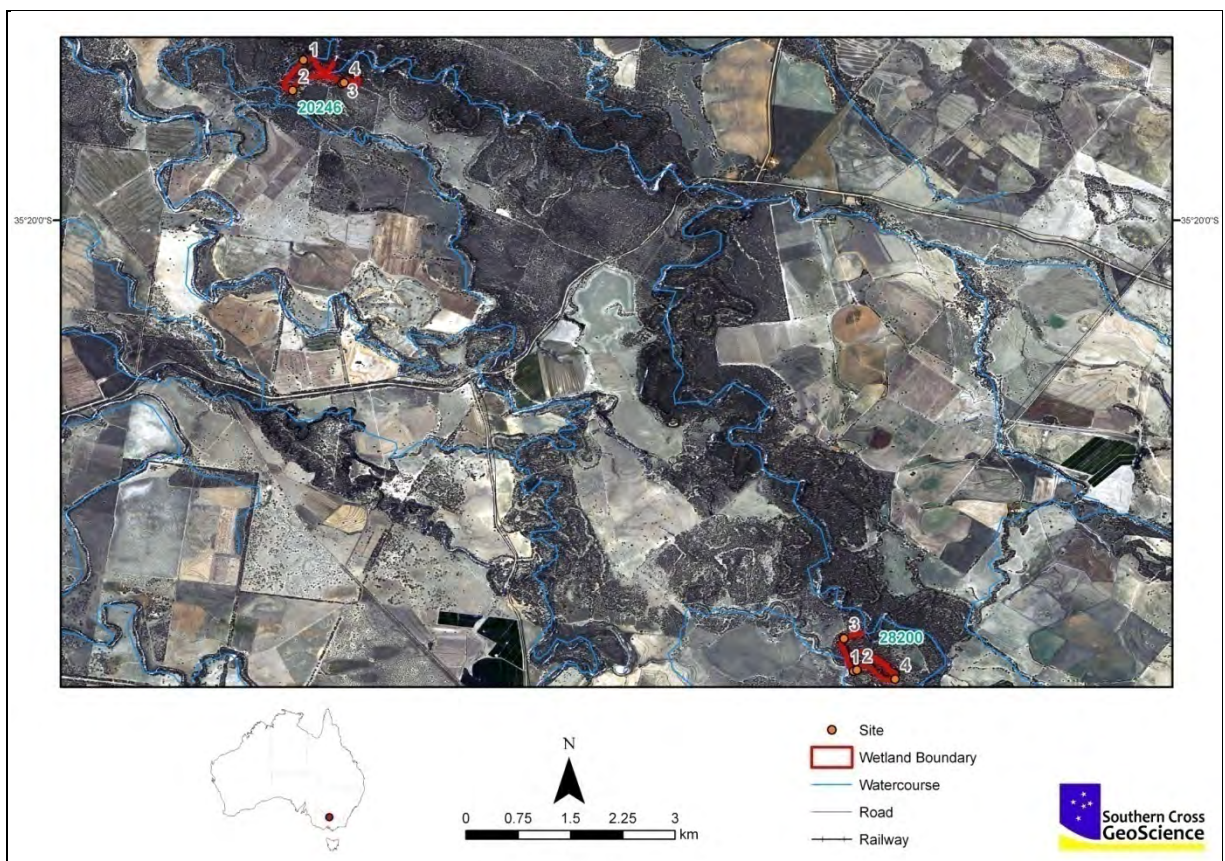


Figure 8-43. Wetland ID 20246 and sample site locations.

8.7.2. Soil profile description and distribution

Four sites were described and sampled. The soil subtype and general location description are presented in Table 8-35. Sites were distributed throughout the wetland based on different surface features and locations in the wetland, a transect approach was not used.

The profile 20246_1 (Figure 8-45) occurred in the centre of a submerged channel at the downstream end of the wetland, the soil consisted of soft grey clay. The profile 20246_2 (Figure 8-46) occurred on the edge of a water body, the soil consisted of a cover of schwertmannite, followed by MBO and a soft grey clay beyond. The profile 20246_3 (Figure 8-47) occurred within an acidic water body, the soil consisted of a cover of schwertmannite, followed by MBO and a soft grey clay beyond. The profile 20246_4 (Figure 8-48) occurred on a bare surface up bank from a waterbody, the soil consisted of schwertmannite in the top layer and soft grey clay beyond. Additional site and profile description data are presented in Tables 8-39 and 8-40, respectively.

Table 8-35. Soil identification, subtype and general location description for Wetland ID 20246.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20246_1	761720	6088483	hypersulfidic subaqueous soil	low elevation, submerged clay soil area
20246_2	761583	6088051	hypermonosulfidic soil with MBO	low elevation, edge of water body, schwertmannite, MBO and soft clay area
20246_3	762165	6088132	hypermonosulfidic subaqueous soil with MBO	low elevation, schwertmannite, MBO and soft clay submerged in sulfuric water body
20246_4	762189	6088143	sulfuric soil	higher elevation, adjacent to water body soft clay

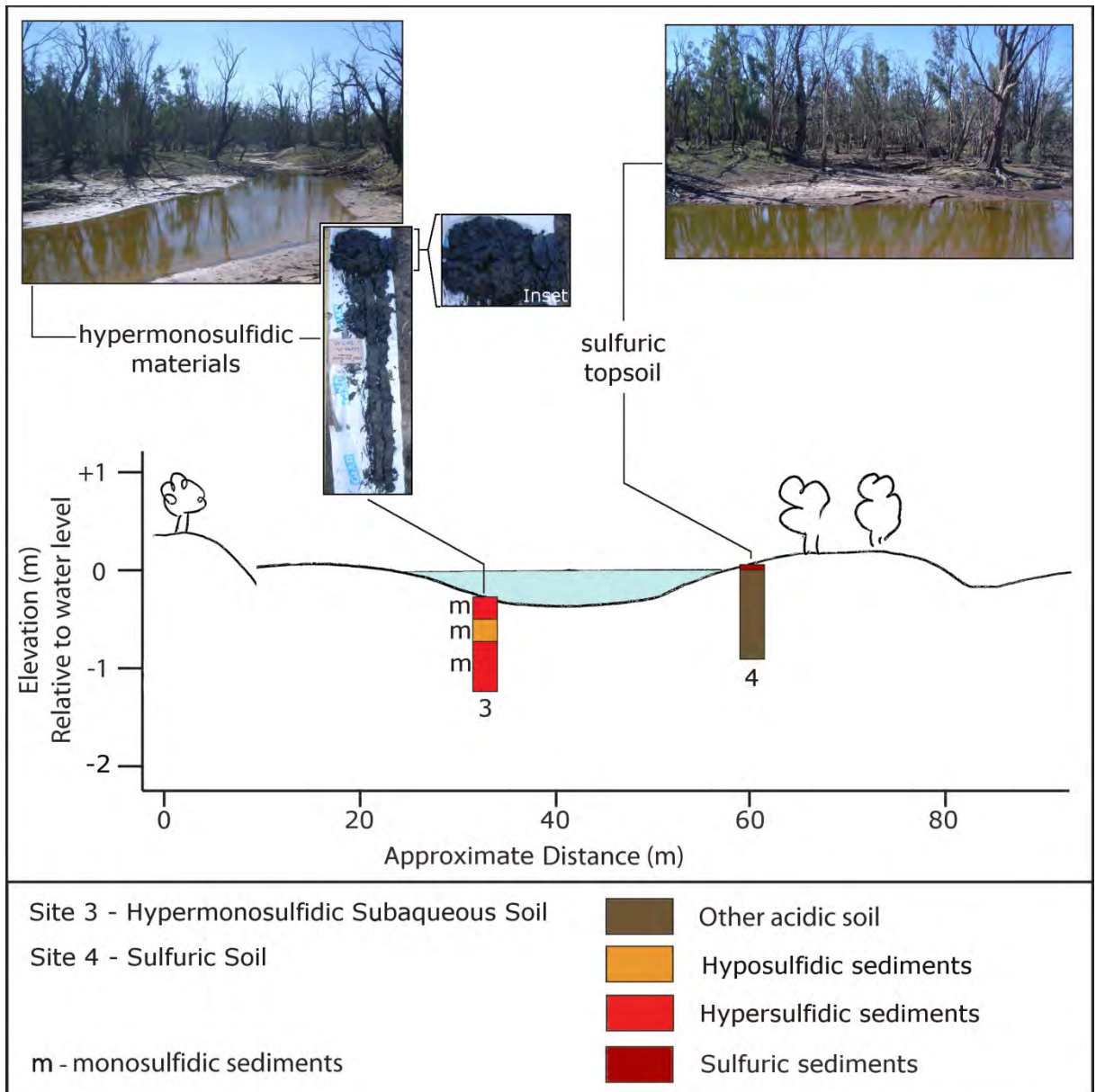


Figure 8-44. Conceptual cross section diagram showing the toposquence relationship of the Wetland ID 20246 sediments/soil materials for sites 20246_3 and 20246_4.



Figure 8-45. Photographs of site 20246_1, showing the channel to the left of image from which the subaqueous sample was taken, and the soil core.



Figure 8-46. Photographs of site 20246_2, showing the edge of the water body from which the sample was taken, and the soil core.



Figure 8-47. Photographs of site 20246_3, showing the water body from which the subaqueous sample was taken, and the soil core.



Figure 8-48. Photographs of site 20246_4, sampled on the bare shoreline, and the soil core.

8.7.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $\text{pH}_{\text{INCUBATION}}$)

The pH data is provided in Table 8-36 and profiles for all the sites sampled are presented in Figure 8-49. The pH_W values ranged between 3.94 and 6.27. A sulfuric material (i.e. $\text{pH}_W < 4$) was present at site 20246_4 (0-5 cm). The pH_{FOX} values ranged between 1.52 and 3.60. The pH_{FOX} results indicate that all surface soils may have the potential to acidify to $\text{pH} < 4$ as a result of sulfide oxidation. However, the S_{CR} data shows only 11 of the 20 layers examined contained detectable sulfide (i.e. $S_{\text{CR}} \geq 0.01\% \text{ S}$). Thirteen soil materials had a $\text{pH}_{\text{FOX}} < 2.5$ (i.e. sites 20246_1 - 20246_4). Seven of the sulfidic soil materials (i.e. $S_{\text{CR}} \geq 0.01\% \text{ S}$) acidified to $\text{pH} < 4$ after at least 8 weeks of incubation (i.e. sites 20246_1 (40-90 cm), 20246_2 (0-90 cm) and 20246_3 (40-90 cm)). Two soil layers with negative net acidities acidified to $\text{pH} < 4$ after at least 8 weeks of incubation (i.e. site 20246_2 (20-90 cm)). Other acidic soil materials were identified at two of the four sites examined, indicating acidity in the soil profile at levels where aluminium may mobilise. Four of the other acidic soils acidified to $\text{pH} < 4$ after at least 8 weeks of incubation.

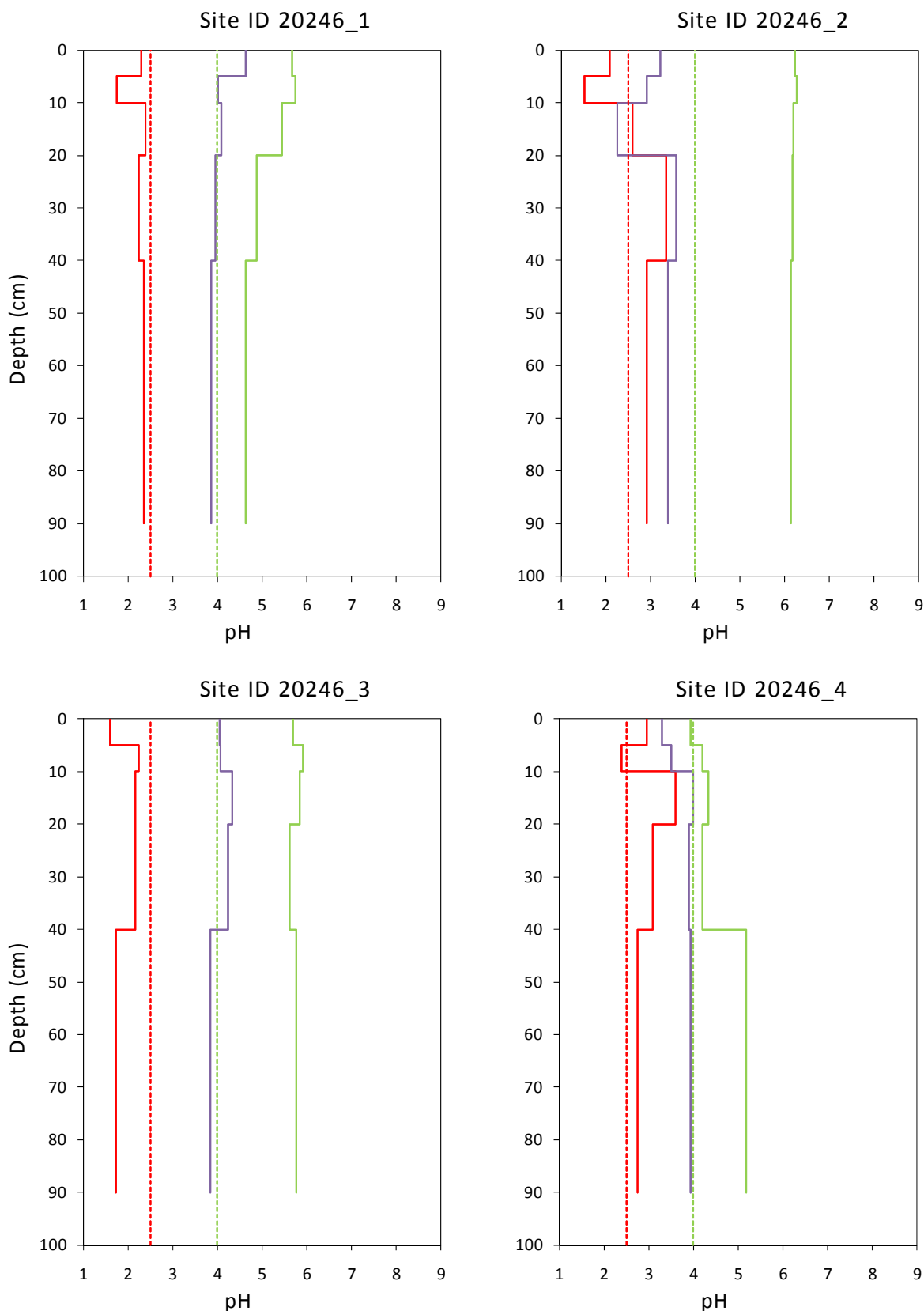


Figure 8-49. Depth profiles of soil pH for Wetland ID 20246 (20246_1 – 20246_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-36 and summarised in Figure 8-50.

Chromium reducible sulfur

Chromium reducible sulfur (S_{CR}) values ranged between < 0.01 and 0.83% S. Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were identified at three sampling sites (sites 20246_1 - 20246_3), with 11 materials of the 20 samples collected equal to or greater than the sulfidic criterion.

Acid volatile sulfide

The acid volatile sulfide (S_{AV}) values ranged between < 0.01 and 0.40% S. A total of 10 monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were found throughout the soil profile at two sites (sites 20246_2 and 20246_3).

Acid neutralising capacity

The acid neutralising capacity (ANC) ranged between zero and 1.4% $CaCO_3$.

Titratable actual acidity

The titratable actual acidity (TAA) ranged between zero and 65 mole H^+ /tonne. A trend in the TAA with depth was not observed.

Retained acidity

All soil materials had no retained acidity.

Net acidity

Net acidity ranged between -37 and 326 mole H^+ /tonne. The ten hypersulfidic soils had low to high net acidities of between -19 and 326 mole H^+ /tonne, with five soils having a high net acidity. The single sulfuric soil material had a low net acidity of 3 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 183 and 6,315 mg/kg. All of the surface soil layers examined had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

The surface water data measured in the field and in the laboratory are presented in Tables 8-37 and 8-38, respectively. The field pH of the three surface waters collected ranged between 2.87 and 6.38, and was below the most relevant ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5 at all sites. The water data indicates that the surface water at site 20246_1 has been affected by acidification. The surface water sulfate concentrations were 54 and 1,408 mg/L. Dissolved oxygen, SEC, turbidity, and some nutrient (i.e. NO_3 , NH_4 , PO_4) and metal (i.e. Ag, Cd, Co, Fe, Mn, Ni, Pb, Zn) values were found to be outside the most relevant ANZECC/ARMCANZ (2000) guideline value at some sites. Groundwater was not collected within this wetland.

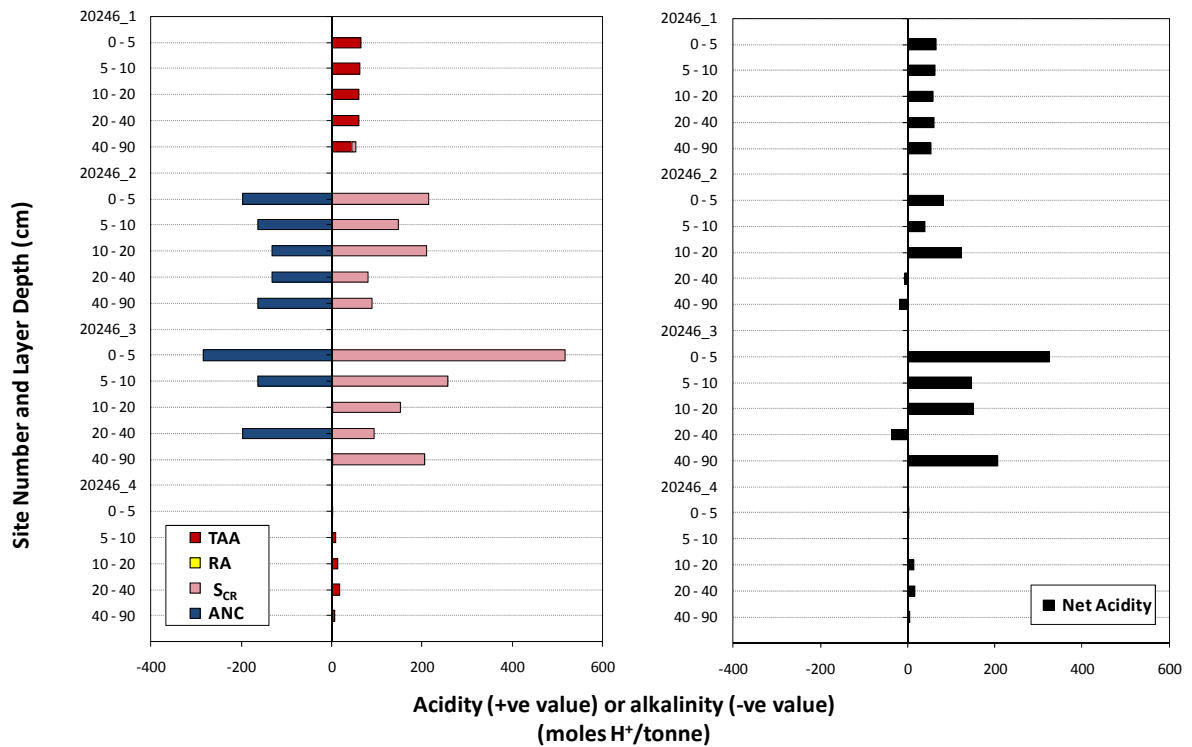


Figure 8-50. Acid-base accounting depth profiles for Wetland ID 20246 (20246_1 – 20246_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.7.4. Discussion

Acid sulfate soils occurred at all four sites examined in the Wetland ID 20246 (i.e. sites 20246_1 – 20246_4). A single sulfuric material with a low net acidity (i.e. 3 mole H^+ /tonne) was observed at site 20246_4. Reduced inorganic sulfur contents of up to 0.83% S_{CR} were observed at three sulfidic sites (i.e. sites 20246_1 – 20246_3). Hypersulfidic soil materials (sometimes with moderate to high net acidities) were present in three soil profiles, and one of these profiles also contained a hyposulfidic material with $S_{CR} \geq 0.10\%$. Monosulfidic soil materials were observed throughout the profile at the two sulfidic sites (i.e. sites 20246_2 – 20246_3), with S_{AV} contents of up to 0.40% S. These results indicate that acidity would be produced upon oxidation of sulfides in some of these materials. All four surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there was one high priority site based on sulfuric material, three high priority sites based on hypersulfidic material, one high priority site based on hyposulfidic ($S_{CR} \geq 0.10\%$) material, and two high priority sites based on monosulfidic material. In addition, all four sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at the Wetland ID 20246 wetland are:

- Acidification hazard: While low to moderate net acidities were dominant in this wetland, five hypersulfidic materials at two sites had high net acidities (i.e. 25 % of layers), indicating that the overall degree of acidification hazard is high.
- Deoxygenation hazard: High monosulfide concentrations ($S_{AV} \leq 0.40\% S$) in surface soils at two sites represent a high deoxygenation hazard. In addition, the soluble sulfate contents of four surface soil materials were over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The high acidification hazard indicates that soil acidification may increase the solubility of metals. The presence of monosulfidic materials in some surface soils and the potential for MBO formation identified in this wetland may also result in an appreciable metal release hazard. This would depend on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium at all sites.

Summary of key findings for the Wetland ID 20246:

Soil materials:	Sulfuric materials were observed at 1 site. Sulfidic soil materials identified included: hypersulfidic (3 sites), monosulfidic (2 sites), hyposulfidic $\geq 0.10\%$ (1 site). Low to moderate net acidities dominant within wetland, although 5 hypersulfidic soil materials (i.e. 25 % of layers) had high net acidities.
Acid sulfate soil identification:	<ul style="list-style-type: none"> • Hypersulfidic soils – subaqueous site (site 1) • Hypermonosulfidic soils – at a subaqueous site (site 1) and a site adjacent to the water body (site 2); MBO present at both sites • Sulfuric soil – on higher ground at site 4
Hazard assessment	<ul style="list-style-type: none"> • Acidification hazard - high level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – high level of concern

Table 8-36. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 20246.

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	fine	5.67	2.30	4.63*	183	4.59	64.50	< 0.01	0	0.00	64.50	< 0.01	other acidic
1.2	5-10	fine	5.75	1.75	4.01		4.58	62.42	< 0.01	0	0.00	62.42	< 0.01	other acidic
1.3	10-20	fine	5.44	2.40	4.09*		4.41	59.13	< 0.01	0	0.00	59.13	< 0.01	other acidic
1.4	20-40	fine	4.88	2.24	3.95		4.37	61.06	< 0.01	0	0.00	61.06	< 0.01	other acidic
1.5	40-90	fine	4.64	2.36	3.87*		4.51	45.34	0.01	0	0.00	53.99	< 0.01	hypersulfidic
2.1	0-5	fine	6.24	2.09	3.22*	1860	6.76	0.00	0.34	0	0.99	82.16	0.13	hypermonosulfidic
2.2	5-10	fine	6.27	1.52	2.93*		7.38	0.00	0.24	0	0.82	39.82	0.11	hypermonosulfidic
2.3	10-20	fine	6.19	2.60	2.27*		6.96	0.00	0.34	0	0.66	122.13	0.13	hypermonosulfidic
2.4	20-40	fine	6.17	3.35	3.58*		6.75	0.00	0.13	0	0.66	-6.91	0.04	hypermonosulfidic
2.5	40-90	fine	6.14	2.92	3.39*		6.56	0.00	0.14	0	0.81	-18.50	0.02	hypermonosulfidic
3.1	0-5	medium	5.69	1.60	4.05*	2115	7.45	0.00	0.83	0	1.43	325.96	0.40	hypermonosulfidic [#]
3.2	5-10	medium	5.91	2.24	4.07*		6.59	0.00	0.41	0	0.82	147.34	0.22	hypermonosulfidic [#]
3.3	10-20	medium	5.84	2.16	4.34*		6.44	1.25	0.24	0	0.00	152.16	0.11	hypermonosulfidic [#]
3.4	20-40	medium	5.61	2.17	4.23*		6.63	0.00	0.15	0	0.99	-36.83	0.07	hypomonosulfidic (≥ 0.10)
3.5	40-90	medium	5.77	1.73	3.84*		6.46	1.80	0.33	0	0.00	206.34	0.03	hypermonosulfidic
4.1	0-5	medium	3.94	2.95	3.29*	6315	6.39	2.82	< 0.01	0	0.00	2.82	< 0.01	sulfuric
4.2	5-10	medium	4.19	2.40	3.51*		5.84	7.88	< 0.01	0	0.00	7.88	< 0.01	other acidic
4.3	10-20	fine	4.33	3.60	4.00*		5.43	13.34	< 0.01	0	0.00	13.34	< 0.01	other acidic
4.4	20-40	fine	4.19	3.08	3.90*		5.22	16.70	< 0.01	0	0.00	16.70	< 0.01	other acidic
4.5	40-90	fine	5.17	2.75	3.93*		6.10	5.63	< 0.01	0	0.00	5.63	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 15 weeks). [#] Classified as hypermonosulfidic based on positive net acidity.

Table 8-37. Field hydrochemistry data for acid sulfate soil assessment of Wetland ID 20246.

Site and Layer ID.	Temperature (Deg C)	Specific Electrical Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	ORP	Redox potential (mV)	Turbidity (NTU)	HCO ₃ (mg/L)	Comment
<i>Lowland River*</i>		125-2200	85-110		6.5-8.0			6-50		
<i>Freshwater Lakes*</i>		20-30	90-110		6.5-8.0			1-20		
20246_1 (SW)	18.5	136.9	4.4	0.42	6.38	246		61	46	
20246_2 (SW)	26.7	77,200	>107.2	>8.6	6.09	116.2		156	32	DO wouldn't stabilise/pit - soil filter water
20246_3 (SW)	32.5	150,200	>100.6	>8.02	2.87	429		40	0	DO wouldn't stabilise

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively.

Table 8-38. Laboratory hydrochemistry data for acid sulfate soil assessment of Wetland ID 20246.

Parameter	units	ANZECC Guidelines	Site 1 (SW)	Site 2 (SW)	Site 3 (SW)
depth	cm				
Na	mg l ⁻¹		12.4	12,532.8	24,731.3
K	mg l ⁻¹		3.3	59.0	118.4
Ca	mg l ⁻¹		7.9	2,038.4	4,479.3
Mg	mg l ⁻¹		5.7	3,229.3	6,248.1
Si	mg l ⁻¹		2.48	7.52	28.47
Br	mg l ⁻¹		0.065	82.146	183.638
Cl	mg l ⁻¹		589	37,769	90,241
NO ₃	mg l ⁻¹	0.7	0.034	0.726	0.337
NH ₄ -N	mg l ⁻¹	0.01	0.101	30.758	91.471
PO ₄ -P ^E	mg l ⁻¹	0.005	0.029	0.011	0.024
SO ₄	mg l ⁻¹		54	1,408	1,362
Ag	µg l ⁻¹	0.05	<1	<1	1
Al ^A	µg l ⁻¹	55	39	<5	7,256
As ^B	µg l ⁻¹	13	<10	<10	<10
Cd	µg l ⁻¹	0.2	203	247	146
Co	µg l ⁻¹	2.8	4	84	211
Cr ^C	µg l ⁻¹	1	<5	<5	<5
Cu ^H	µg l ⁻¹	1.4	<5	<5	<5
Fe	µg l ⁻¹	300	2,096	26,445	293,098
Mn	µg l ⁻¹	1700	585	49,085	189,439
Ni ^H	µg l ⁻¹	11	4	71	168
Pb ^H	µg l ⁻¹	3.4	3	1	120
Se	µg l ⁻¹	11	<10	<10	<10
Zn ^H	µg l ⁻¹	8	66	84	257
DOC	mg l ⁻¹		31.8	19.9	32.2

Notes.

The ANZECC guideline values for toxicants refer to the Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH₄ and PO₄, guideline values are provided for Freshwater Lakes and Reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^A Guideline is for Aluminium in freshwater where pH > 6.5.

^B Guideline assumes As in solution as Arsenic (AsV).

^C Guideline is for Chromium is applicable to Chromium (CrVI) only.

^E Guideline is for filterable reactive phosphorous (FRP).

^H Hardness affected (refer to Guidelines).

Table 8-39. Site description data for acid sulfate soil assessment of Wetland ID 20246.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-20	underwater, muddy with rotting leaf material	water	low, base of water body at lower end of wetland	characterise lateral extent of wetland	hypersulfidic	looks relatively healthy compared to ASS sites in this wetland
2	5	wet, slippery and sticky, orange oxidised surface	bare	low, margin of badly affected site midway along wetland	characterise second ASS site in wetland	hypermonosulfidic	
3	30	underwater; smooth fine feel; grey/black in colour	water	low, in shallow water on margin of main ASS site in wetland	safe access, main ASS site in wetland	hypermonosulfidic	
4	dry	silty feel	bare	mid to upper slope	upslope from site 3	sulfuric	contains colluvial material washed down into wetland area

Table 8-40. Profile description data for acid sulfate soil assessment of Wetland ID 20246.

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	10YR ?	C		W						0		7.39	
1.2	5-10	10YR 4/3	C		W	2	FM				0		6.53	
1.3	10-20	10YR 4/2	C		W	2	FM				0		6.38	
1.4	20-40	10YR 4/2	C		W	2	FM				0		6.24	
1.5	40-90	10YR 4/2	C		M	2	FM				3		6.36	
2.1	0-5	10YR 2/1	C				FM		TOH				6.50	
2.2	5-10	10YR 3/1	C										6.50	
2.3	10-20	10YR 4/1	SC										7.00	
2.4	20-40	10YR 4/1	SC										7.00	
2.5	40-90	10YR 4/1	C										8.00	
3.1	0-5	10YR 2/1	C	light	W		FM		TOH				6.30	
3.2	5-10	10YR 2/1	C	light	W								6.33	
3.3	10-20	10YR 3/1	C	light	W								6.27	
3.4	20-40	10YR 3/1	C	light	W								6.16	
3.5	40-90	10YR 3/2	C	light	W								6.69	
4.1	0-5	10YR 4/2	SL		T								4.36	
4.2	5-10	10YR 4/2	SCL		T								4.52	
4.3	10-20	10YR 3/2	C	medium	M								4.61	
4.4	20-40	10YR 3/2	C	medium	M								4.46	
4.5	40-90	10YR 3/1	C	medium	M								5.68	

8.8. Wetland ID 20264

8.8.1. Location and setting description

The billabong wetland is situated on the eastern side of the Edward River and is approximately 30 km down river of Denilliquin Township. The wetland is somewhat linear in shape, approx 300 m in length parallel to the river and 30 m at the widest point, with a total area of 1 ha. The wetland is situated on a floodplain levee and is within 50 m of the Edward River bank. There is a narrow water connection channel of low elevation with the river. At the time when the soil survey was conducted in April 2010, the wetland had no surface water, the ground surface was completely cover with dryland grass species flanked by mature river red gum (*Eucalyptus camaldulensis*). This wetland has been identified previously as a billabong, however the majority of the channel is significantly higher in elevation to the area connecting the wetland channel to the river, any surface water would flow unimpeded to the Edward River, hence it appears this wetland has the geomorphology of a levee drainage depression. Two sites were sampled as shown in Figure 8-51.

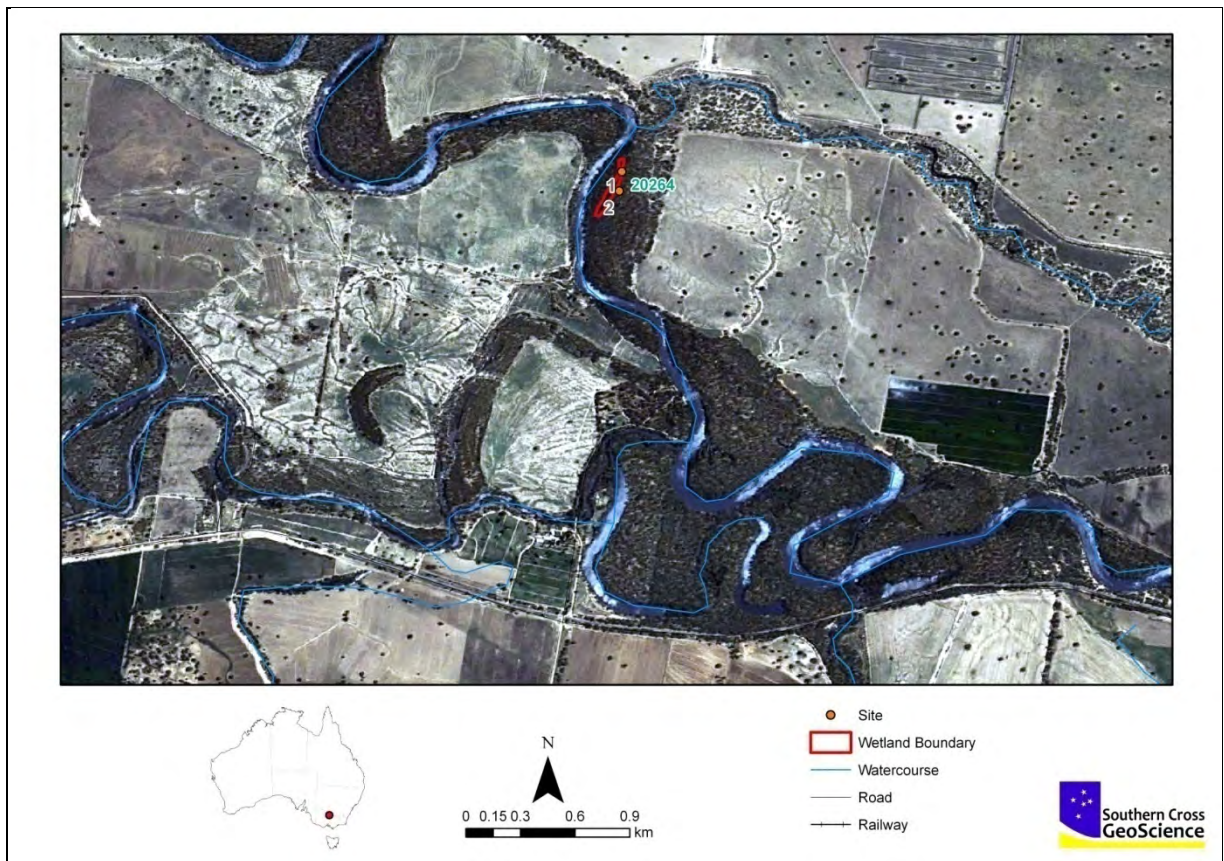


Figure 8-51. Wetland ID 20264 and sample site locations.

8.8.2. Soil profile description and distribution

Two sites were described and sampled. The soil subtype and general location description are presented in Table 8-41. Sites were distributed throughout the wetland based on different surface features and locations in the wetland, a transect approach was used.

The profile 20264_1 (Figure 8-53) occurred in the channel base on a completely vegetated surface, the soil consisted of grey brown firm clay. The profile 20264_2 (Figure 8-54)

occurred on a fully vegetated surface, the soil consisted of grey brown firm clay. Additional site and profile description data are presented in Tables 8-43 and 8-44, respectively.

Table 8-41. Soil identification, subtype and general location description for Wetland ID 20264.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20264_1	296675	6077207	hydrosol	low elevation, channel base clay soil area
20264_2	296666	6077101	hydrosol	levee clay soil area

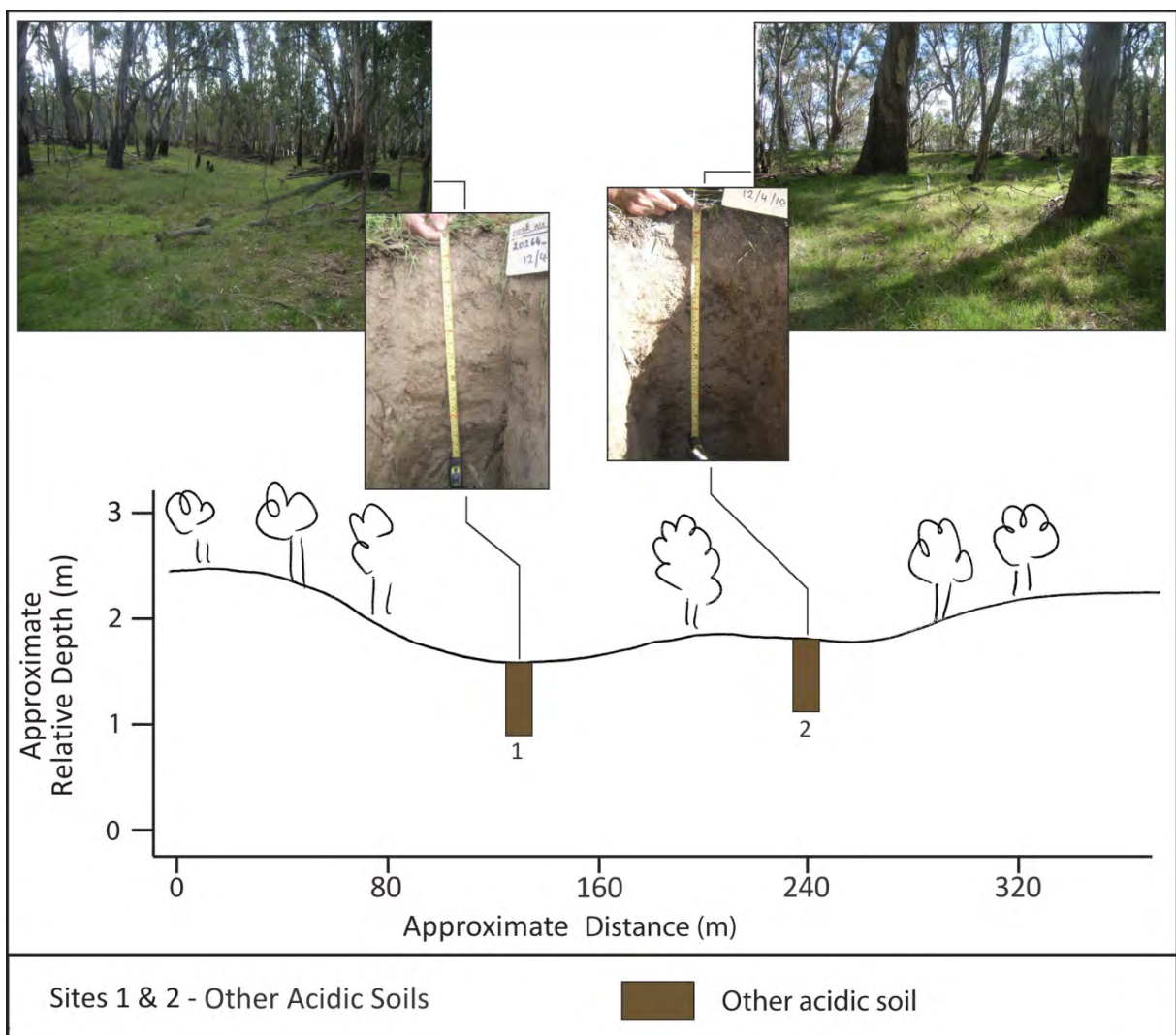


Figure 8-52. Conceptual cross section diagram showing the toposequence relationship of the Wetland ID 20264 soil materials.



Figure 8-53. Photographs of site 20264_1, showing the grassland, and the soil profile.



Figure 8-54. Photographs of site 20264_2, showing the grassland, and the soil profile.

8.8.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Table 8-42 and profiles for all the sites sampled are presented in Figure 8-55. The pH_W values ranged between 4.47 and 4.90. Sulfuric materials (i.e. $pH_W < 4$) were not present. The pH_{FOX} values ranged between 2.20 and 3.55. The pH_{FOX} results indicate that all surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. However, the S_{CR} data shows these soils contained no detectable sulfide (i.e. $S_{CR} < 0.01\% S$). Other acidic soil materials were identified throughout the profile at both sites, indicating acidity in the soil profile at levels where aluminium may mobilise. Four of the other acidic soils acidified to $pH < 4$ after at least 8 weeks of incubation.

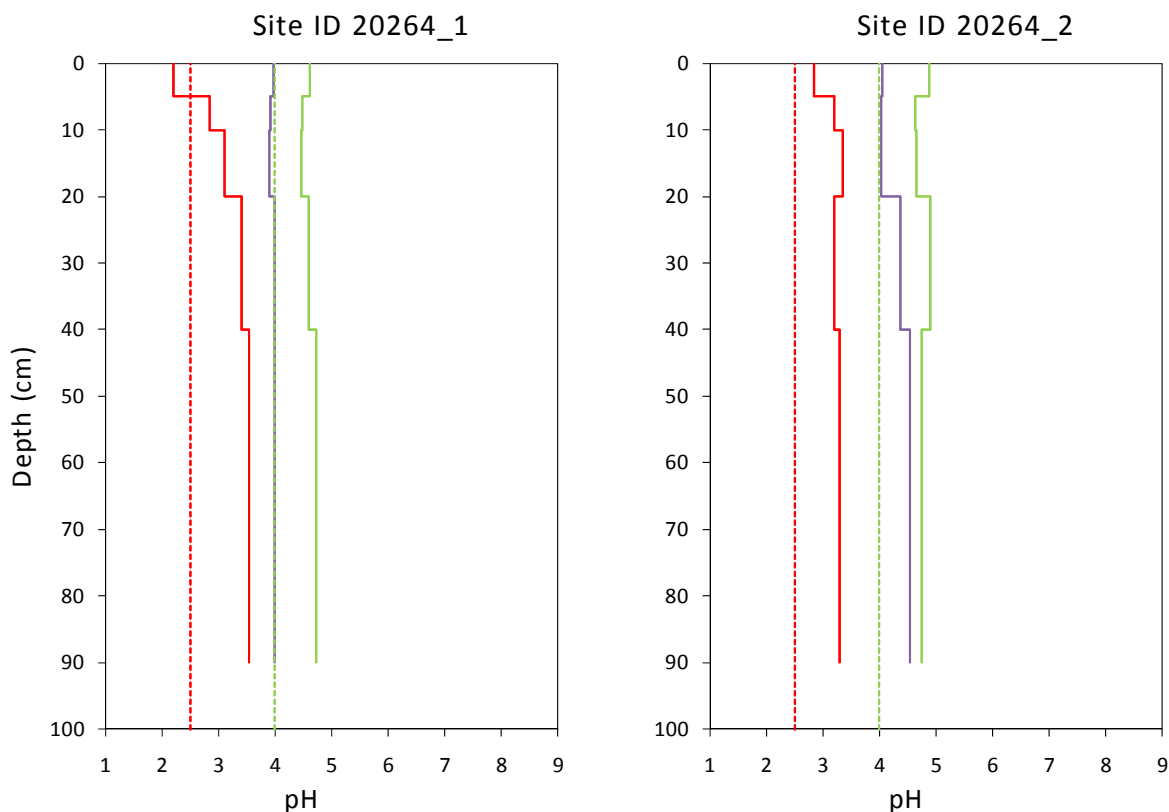


Figure 8-55. Depth profiles of soil pH for Wetland ID 20264 (20264_1 – 20264_2), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-42 and summarised in Figure 8-56.

Chromium reducible sulfur

Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were not found within this wetland.

Acid volatile sulfide

Monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were not found within this wetland.

Acid neutralising capacity

All soil materials had no acid neutralising capacity (ANC).

Titratable actual acidity

The titratable actual acidity (TAA) ranged between 30 and 64 mole H^+ /tonne. A trend in the TAA with depth was not observed.

Retained acidity

Retained acidity was only measured in one layer at site 20264_2 (i.e. 10-20 cm) of 1 mole H^+ /tonne.

Net acidity

The net acidities ranged between 30 and 65 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the two surface soils (i.e. 0-5 cm) examined was 180 and 192 mg/kg. Both of the surface soil layers had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential.

Water Data

No water samples were collected for analysis.

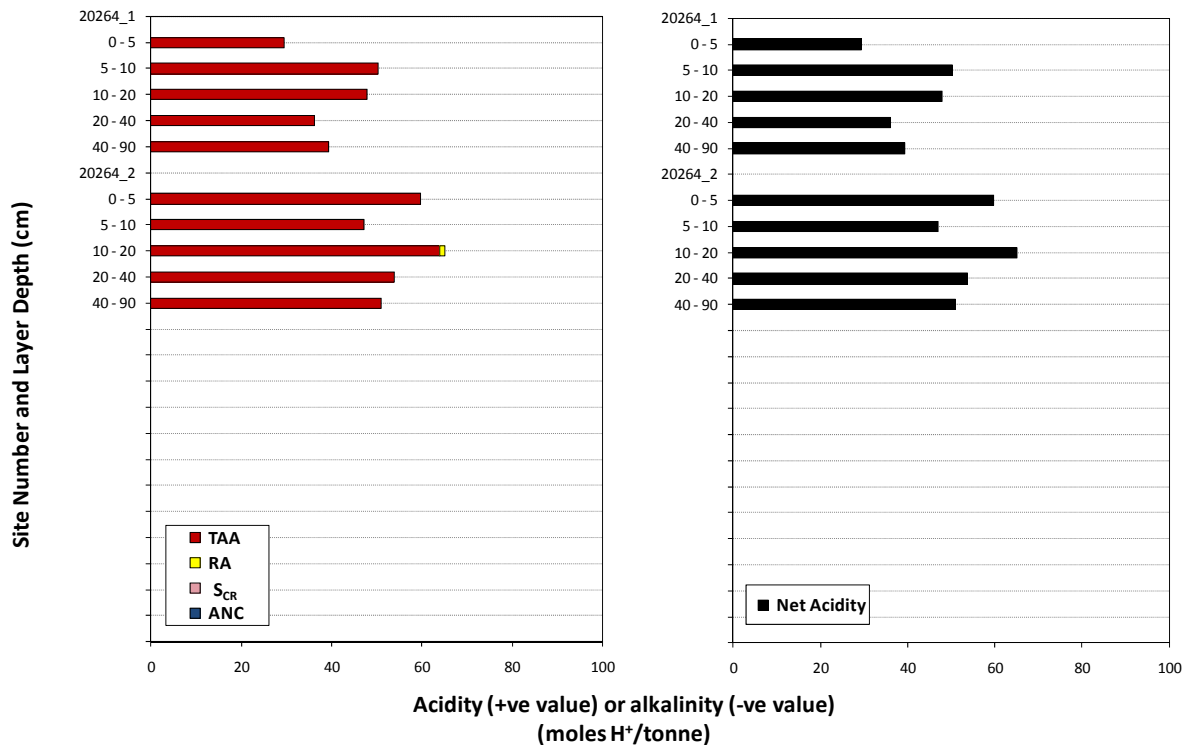


Figure 8-56. Acid-base accounting depth profiles for Wetland ID 20264 (20264_1 – 20264_2). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.8.4. Discussion

Acid sulfate soils materials were not found at Wetland ID 20264. Soil materials were classified as other acidic soils.

Both of the surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, two sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at Wetland ID 20264 are:

- Acidification hazard: The data indicate that with no sulfuric or sulfidic materials that the degree of acidification hazard is low.
- Deoxygenation hazard: The soluble sulfate content of the surface soil materials at both sites was over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The low acidification hazard indicates that soil acidification is not likely to increase the solubility of metals. However, the potential for MBO formation identified in this wetland may result in an appreciable metal release hazard depending on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium.

Summary of key findings for the Wetland ID 20264:

<i>Soil materials:</i>	Sulfuric and sulfidic materials were not observed within this wetland. Other acidic soil materials observed at 2 sites. Moderate net acidities dominant within wetland.
<i>Acid sulfate soil identification:</i>	<ul style="list-style-type: none"> • Other acid soils present at both sites.
<i>Hazard assessment</i>	<ul style="list-style-type: none"> • Acidification hazard - low level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – low to moderate level of concern

Table 8-42. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 20264.

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	4.61	2.20	3.97*	180	5.07	29.50	< 0.01	0	0.00	29.50	< 0.01	other acidic
1.2	5-10	medium	4.49	2.85	3.92*		4.56	50.33	< 0.01	0	0.00	50.33	< 0.01	other acidic
1.3	10-20	fine	4.47	3.10	3.90*		4.55	47.92	< 0.01	0	0.00	47.92	< 0.01	other acidic
1.4	20-40	fine	4.60	3.40	3.99*		4.58	36.11	< 0.01	0	0.00	36.11	< 0.01	other acidic
1.5	40-65	fine	4.72	3.55	4.00*		4.53	39.34	< 0.01	0	0.00	39.34	< 0.01	other acidic
2.1	0-5	medium	4.88	2.85	4.05*	192	4.52	59.78	< 0.01	0	0.00	59.78	< 0.01	other acidic
2.2	5-10	medium	4.64	3.20	4.03*		4.40	47.10	< 0.01	0	0.00	47.10	< 0.01	other acidic
2.3	10-20	medium	4.65	3.35	4.03*		4.34	64.04	< 0.01	1	0.00	65.04	< 0.01	other acidic
2.4	20-40	fine	4.90	3.20	4.37*		4.41	53.83	< 0.01	0	0.00	53.83	< 0.01	other acidic
2.5	40-65	fine	4.75	3.30	4.54*		4.48	50.94	< 0.01	0	0.00	50.94	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 13 weeks).

Table 8-43. Site description data for acid sulfate soil assessment of Wetland ID 20264.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	dry	fully vegetated, dry loamy soil surface	common	low point in old channel	appears to be one of the lower points in the old channel	other acidic	Has not been wet for many years, appears to be a flood runner rather than a wetland
2	dry	fully vegetated, dry loamy soil surface	common	mid slope in old channel	upslope of site 1	other acidic	Has not been wet for many years, appears to be a flood runner rather than a wetland

Table 8-44. Profile description data for acid sulfate soil assessment of Wetland ID 20264.

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	2.5Y 5/2	SC	light	D					SB	1	mod weak	4.56	
1.2	5-10	2.5Y 5/2	SC	light	D	2	FM			SB	1	mod weak	4.88	
1.3	10-20	2.5Y 5/3	SC	light medium	D	2	FM			SB	2	mod firm	4.51	
1.4	20-40	2.5Y 4/2	C	light medium	D	2	FM			SB	2	mod firm	4.59	
1.5	40-65	2.5Y 4/2	C	medium	D	2	FM			SB	3	very firm	4.87	
2.1	0-5	10YR 5/3	SCL		D					PO	1	very weak	5.19	
2.2	5-10	10YR 4/3	SC	light	D	2	FM			PO	2	very weak	4.83	
2.3	10-20	10YR 4/3	SC	light	D	3	FM			SB	2	mod weak	4.78	
2.4	20-40	10YR 4/2	SC	light medium	D	3	FM			SB	2	mod firm	4.94	
2.5	40-65	10YR 4/3	C	medium	D	2	FM			SB	2	mod firm	5.14	

8.9. Wakool-Tullakool Evaporation Basins (Wetland ID 20580 / 20832 / 20833 / 21761)

8.9.1. Location and setting description

Wetland 20580 is an extremely small area on the flanks of a lunette system, roughly circular. As mapped it is about 500 m diameter and 3 ha, but appears to be much smaller on the ground. At the time of the soil survey in May 2010 water was absent. Apart from a distinctive cluster of dead trees no salting was evident. The ground surface was well grassed and firm. One site was sampled.

Wetland 20832 is a very small, somewhat artificial wetland located within a saltbush reclamation area. The wetland is a small dam and surrounding shoreline and is a low point within the surrounding plain. The fringing scalded shoreline is about 10 m wide, the waterbody about 30 m wide. At the time of the soil survey in May 2010 gypsum fragments were present and black MBO was close to the surface. Although not confirmed, a very hard layer beneath the waterbody sediment was thought to be a gypsic hardpan.

Wetland 20833 is situated within a landscape depression of very low gradient, 3 km west via road from Wakool Township. The wetland is an irregular oblong in shape, almost 2 km in length and approximately 300 m at the widest point, with a total area of 27 hectares. The wetland is completely bounded by floodplains, no stream or river channels traverse the depression. At the time when the soil survey was conducted in April 2010, the wetland had no surface water. Most of the ground surface is vegetated with low woody vegetation such as Nitre Goosefoot (*Chenopodium nitrariaceum*), no tree existed except for a few deceased mature trees (*Eucalyptus sp.*) in the widest section of the wetland.

Wetland 21761 is not a true wetland but is a saline discharge area at the base of a lunette. The area sampled is a saltbush saline reclamation site and is about 1.5 km long, 500 m wide and 7 ha. The site is within a lunette and sand sheet landform pattern, local relief being up to 30 m. At the time of the soil survey in May 2010 some ponded water was present in a poached scalded area but the site was otherwise dry.

The locations of sample sites are shown in Figure 8-57.

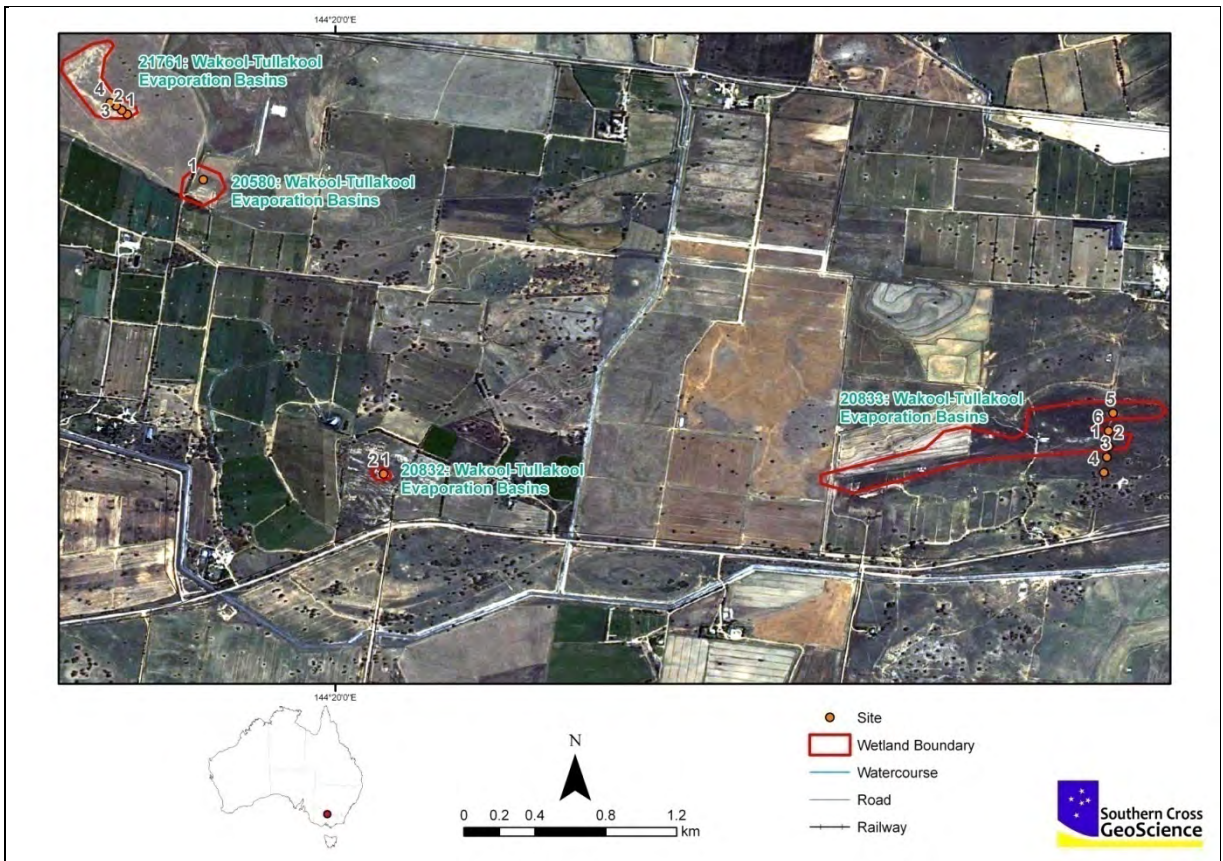


Figure 8-57. Wakool-Tullakool Evaporation Basins Wetland and sample site locations.

8.9.2. Soil profile description and distribution

Fifteen sites were sampled across this wetland complex, and the soil subtype and general location descriptions are presented in Table 8-45.

One site was described and sampled at wetland 20580 due to the extremely small extent of the wetland. The profile 20580_1 (Figure 8-59) occurred within the centre of a small area of dead trees with a well grassed surface, the soil consisted of a dark sandy clay loam over a dark medium heavy sandy clay.

Two sites were described and sampled at wetland 20832. Sites were located within the waterbody and on the fringing scalded area. The profile 20832_1 (Figure 8-60) was subaqueous (15 cm water depth) and located within the waterbody about 3 m from the shore, the soil consisted of grey to dark silty ooze with gypsum fragments and thinly stratified with black MBO lamellae. A possibly gypsic pan at 45 cm prevented further sampling. The profile 20832_2 (Figure 8-61) was located on the bare scald fringing the waterbody, the soil consisted of varved layers of grey silty clay, gypsum and black MBO to 35 cm where equipment refusal prevented further sampling.

Six sites were described and sampled at wetland 20833. Sites were distributed throughout the wetland based on different surface features (e.g. vegetation type) and locations in the wetland, a transect approach was used. The profiles all occurred on semi-vegetated surface, the soil consisted of firm brown clay (Figures 8-62 - 8-67).

Four sites were described and sampled at wetland 21761. Sites were distributed along a transect through a saltbush reclamation area and based on elevation. The profile 21761_1 (Figure 8-68) occurred within a poached saline scald, the soil consisted of brown sandy clay over brown earthy sandy clay. The profiles 21761_2, 21761_3 and 21761_4 occurred at

intervals along a very gentle lunette lower slope. The soil in the profiles consisted of brown sandy clay loam over brown earthy sandy clay.

Additional site and profile description data are presented in Tables 8-52 to 8-60.

Table 8-45. Soil identification, subtype and general location description for Wakool-Tullakool Evaporation Basins.

Site ID	Easting UTM Zone 54H	Northing UTM Zone 54H	Acid sulfate soil subtype class	General location description
20580_1	257383	6073073	hydrosol	centre of the small wetland
20832_1	258257	6071442	hypermonosulfidic subaqueous soil with MBO	subaqueous, in the waterbody
20832_2	258258	6071440	hypomonosulfidic soil with MBO	fringing scald
20833_1	261579	6071691	cracking clay soil	level elevation, semi vegetated area
20833_2	261592	6071684	cracking clay soil	level elevation, semi vegetated area
20833_3	261585	6071624	cracking clay soil	level elevation, semi vegetated area
20833_4	261574	6071538	cracking clay soil	level elevation, semi vegetated area
20833_5	261607	6071872	cracking clay soil	level elevation, semi vegetated area
20833_6	261589	6071772	cracking clay soil	level elevation, semi vegetated area
21761_1	257023	6073431	hydrosol	salt bush reclamation area, highest site in transect
21761_2	256997	6073453	hydrosol	salt bush reclamation area
21761_3	256971	6073477	hydrosol	salt bush reclamation area
21761_4	256944	6073494	hydrosol	salt bush reclamation area

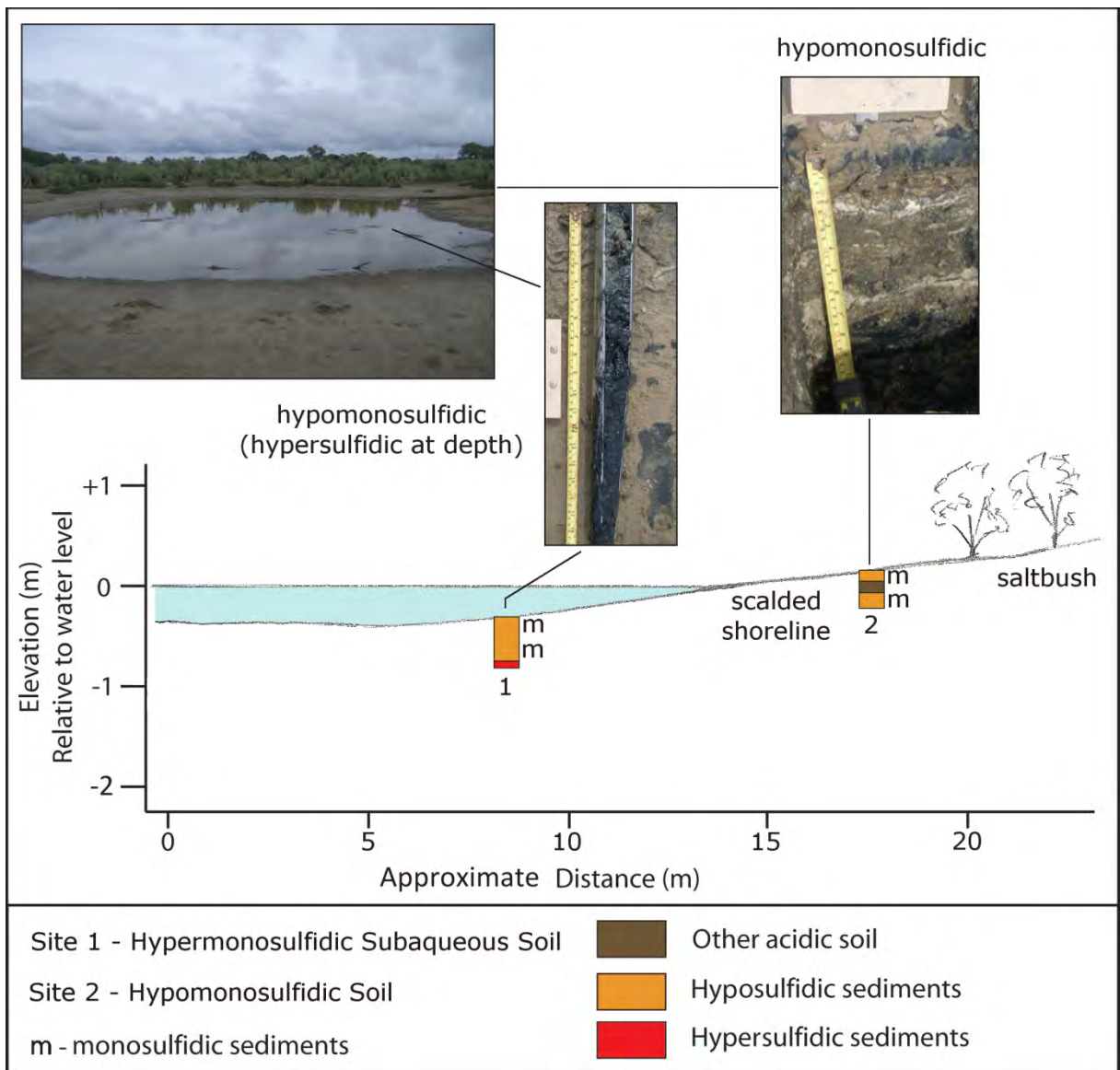


Figure 8-58. Conceptual cross section diagram showing the toposequence relationship of the Wakool-Tullakool Evaporation Basins sediments/soil materials for sites 20832_1 and 20832_2.



Figure 8-59. Photographs of site 20580_1, showing the extent of the wetland from which the sample was taken.



Figure 8-60. Photographs of site 20832_1, showing the subaqueous site from which the sample was taken, and the soil core.



Figure 8-61. Photographs of site 20832_2, showing the bare shoreline from which the sample was taken, and the soil core showing MBO and gypsum layers.



Figure 8-62. Photographs of site 20833_1, showing the flat, well vegetated area, and the soil core.



Figure 8-63. Photographs of site 20833_2, showing the flat, well vegetated area, and the soil core.



Figure 8-64. Photographs of site 20833_3, showing the flat, well vegetated area, and the soil core.



Figure 8-65. Photographs of site 20833_4, showing the dense groundcover, and the soil profile.



Figure 8-66. Photographs of site 20833_5, showing the dense groundcover, and the soil profile.



Figure 8-67. Photographs of site 20833_6, showing the low, hummocky vegetation, and the dry soil profile.



Figure 8-68. Photograph of site 21761, showing the transect site extending beyond the vehicle into the salt bush plantation in the background.

8.9.3. Laboratory data assessment

Soil pH testing (pH_W , pH_{FOX} , pH_{KCl} , $pH_{INCUBATION}$)

The pH data is provided in Tables 8-46 to 8-49 and profiles for all the sites sampled are presented in Figures 8-69 to 8-72. The pH_W values ranged between 5.09 and 8.44. Sulfuric materials (i.e. $pH_W < 4$) were not present. The pH_{FOX} values ranged between 4.05 and 8.58. The pH_{FOX} results indicate that none of the surface soils may have the potential to acidify to $pH < 4$ as a result of sulfide oxidation. The S_{CR} data shows eight layers at site 20832 contained detectable sulfide (i.e. $S_{CR} < 0.01\% S$), including one hypersulfidic soil material. None of the sulfidic soil materials (i.e. $S_{CR} \geq 0.01\% S$) acidified to $pH < 4$ after at least 8 weeks of incubation. Other acidic soil materials were identified in the surface soil at three sites (i.e. sites 20580_1 (0-5 cm), 20833_5 (0-5 cm) and 20833_6 (0-10 cm)), indicating acidity in the soil profile at levels where aluminium may mobilise.

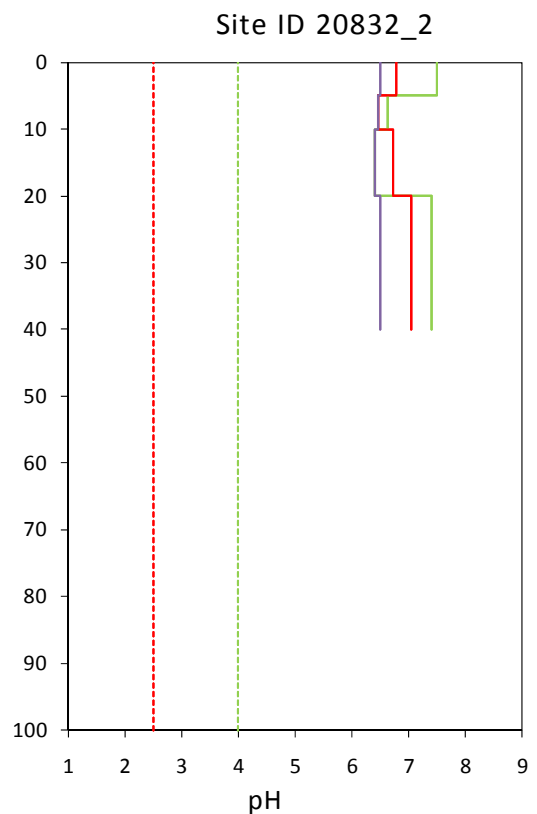
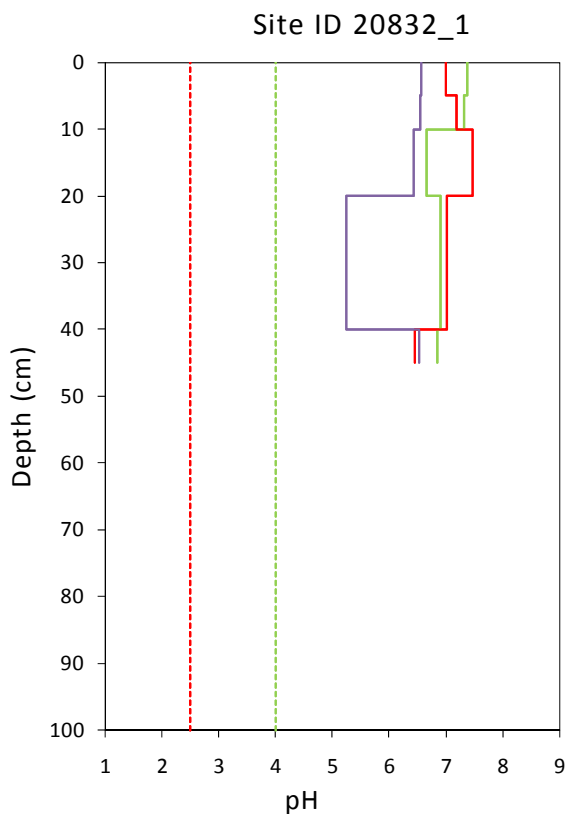
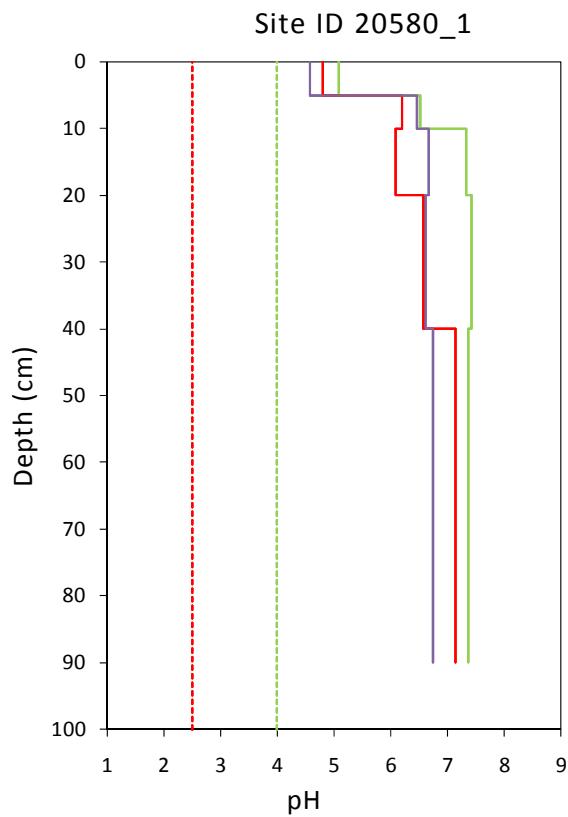


Figure 8-69. Depth profiles of soil pH for Wakool-Tullakool Evaporation Basins (20580_1 – 20580_2 and 20832_1 – 20832_2), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

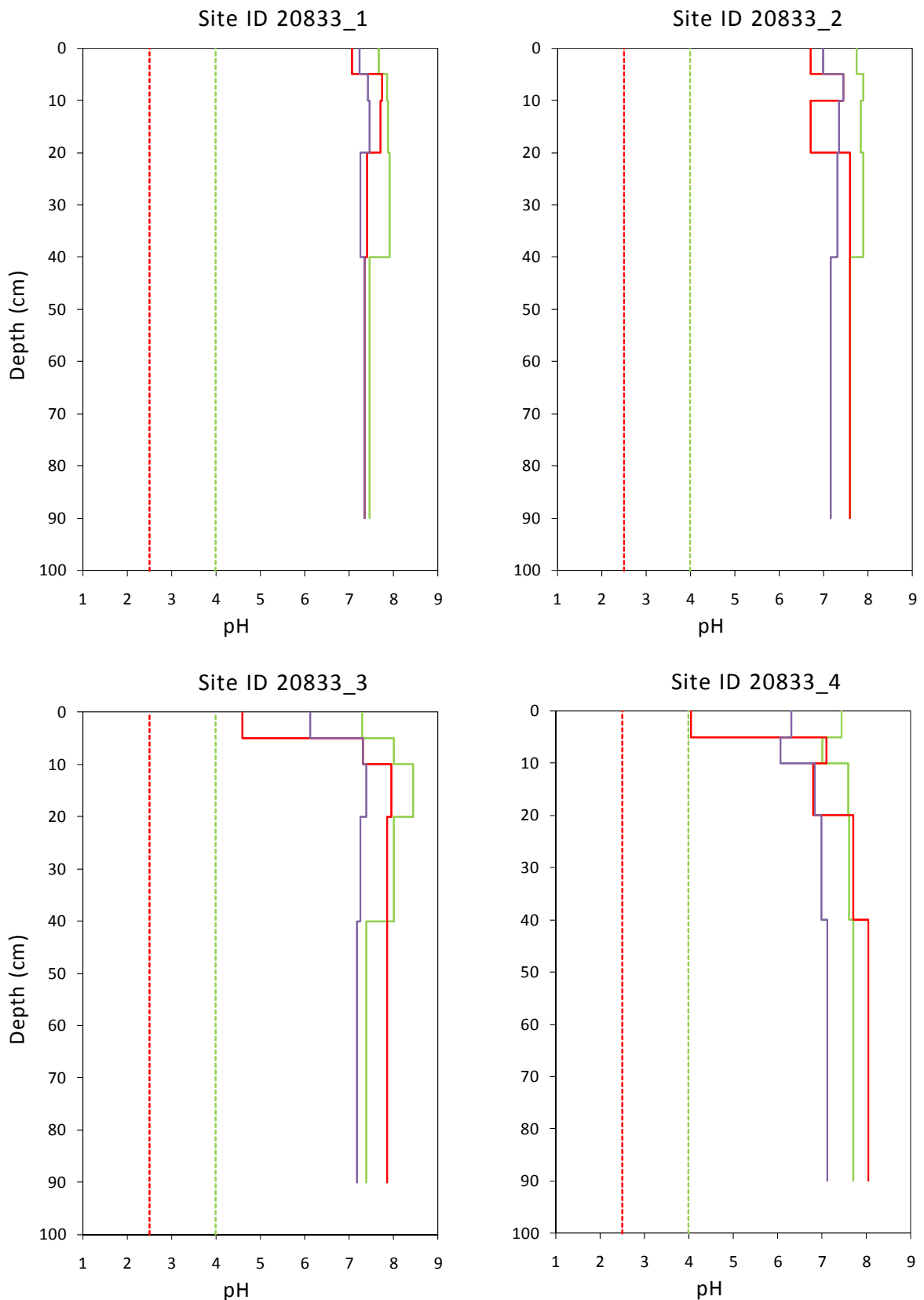


Figure 8-70. Depth profiles of soil pH for Wakool-Tullakool Evaporation Basins (20833_1 – 20833_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH (pH_{incubation} after at least 8 weeks as purple line). Critical pH_W and pH_{incubation} value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

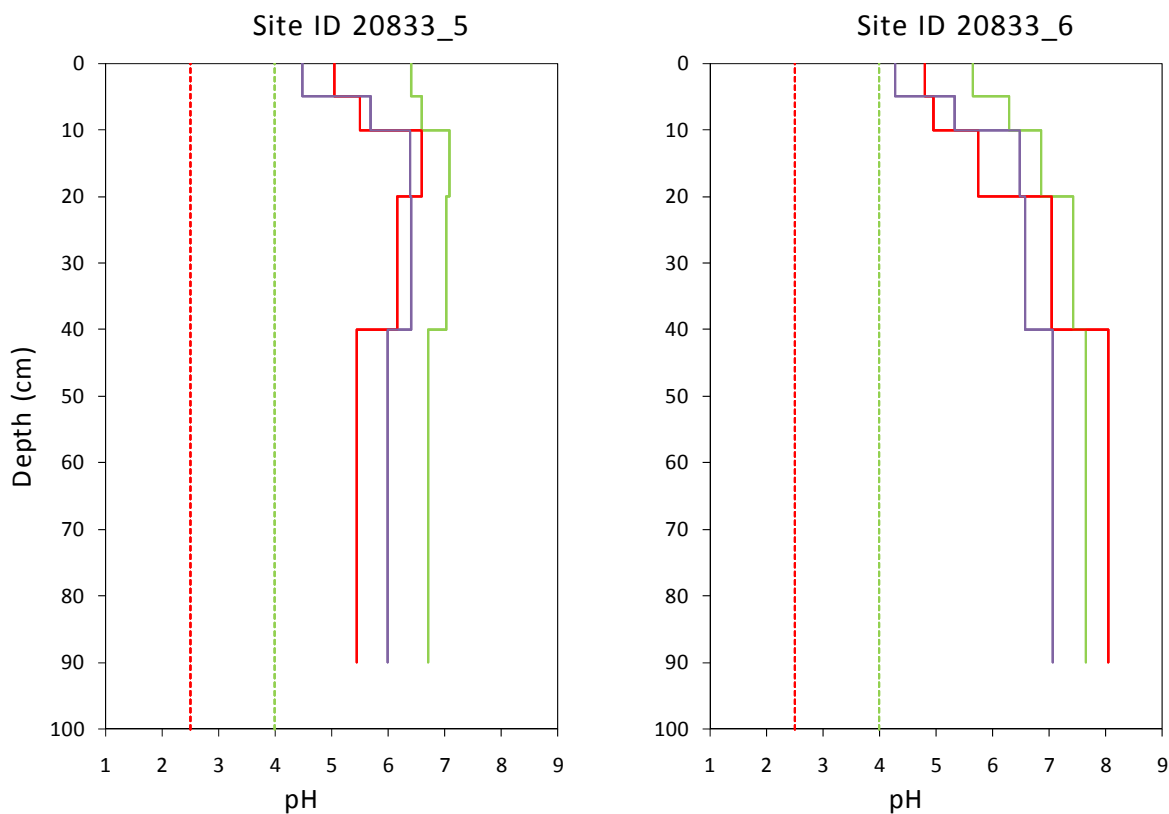


Figure 8-71. Depth profiles of soil pH for Wakool-Tullakool Evaporation Basins (20833_5 – 20833_6), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

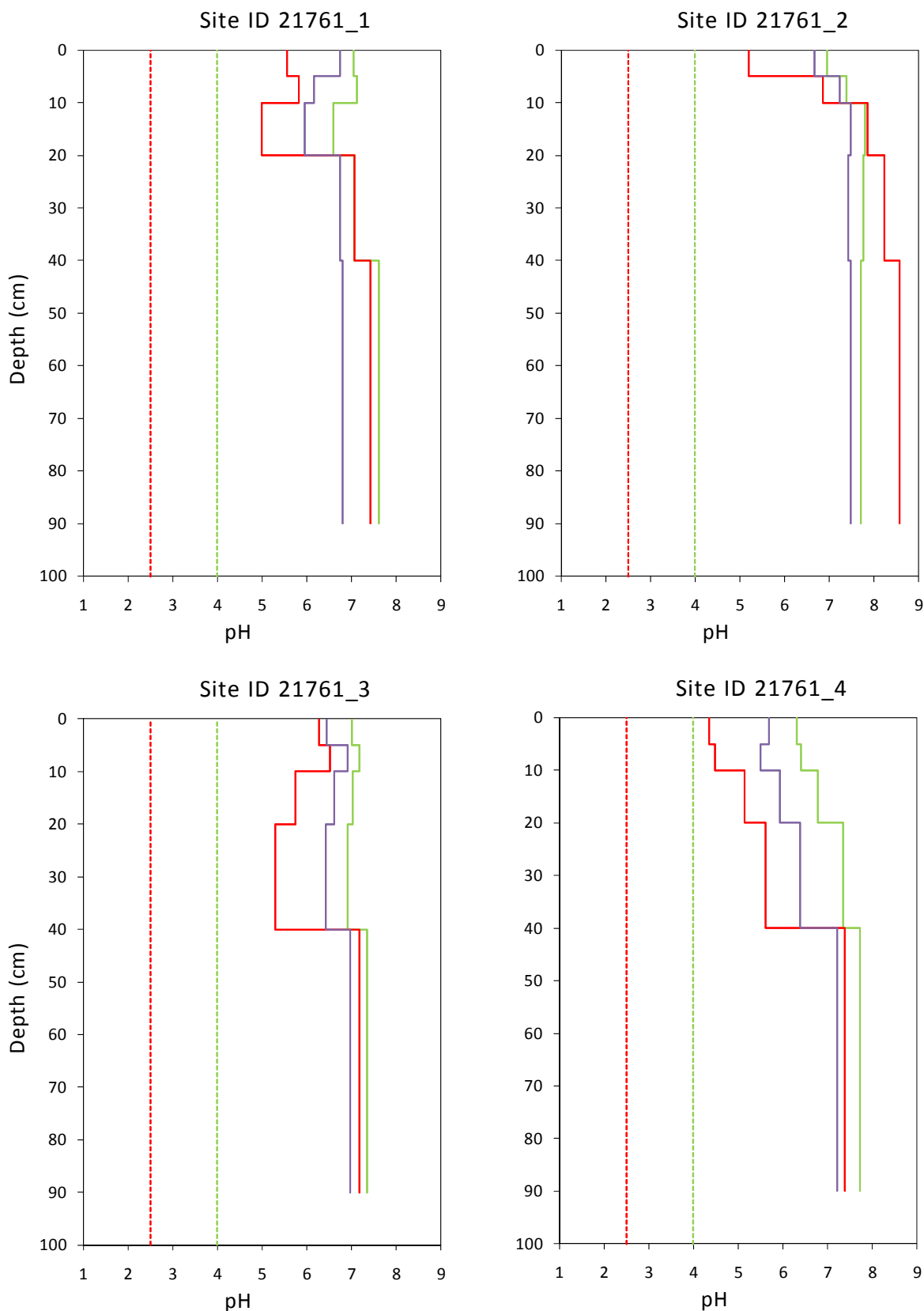


Figure 8-72. Depth profiles of soil pH for Wakool-Tullakool Evaporation Basins (21761_1 – 21761_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Tables 8-46 to 8-49 and summarised in Figures 8-73 to 8-76.

Chromium reducible sulfur

Chromium reducible sulfur (S_{CR}) values ranged between < 0.01 and 0.28% S. Sulfidic soil materials (i.e. $S_{CR} \geq 0.01\%$ S) were only identified at both sampling sites within wetland 20832 (i.e. sites 20832_1 and 20832_2), with only eight materials of the 64 samples collected equal to or greater than the sulfidic criterion.

Acid volatile sulfide

The acid volatile sulfide (S_{AV}) values ranged between < 0.01 and 0.16% S. A total of seven monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were found within wetland 20832 (i.e. sites 20832_1 and 20832_2). The other wetlands within this wetland complex contained no detectable monosulfide.

Acid neutralising capacity

The acid neutralising capacity (ANC) ranged between zero and 10.2% CaCO_3 .

Titratable actual acidity

The titratable actual acidity (TAA) ranged between zero and 10 mole H^+ /tonne, with the majority of soil layers having no TAA.

Retained acidity

All soil materials had no retained acidity.

Net acidity

Net acidity ranged between $-1,345$ and 10 mole H^+ /tonne, with the majority of samples having negative net acidities. A single hypersulfidic soil had net acidity of 2 mole H^+ /tonne.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 49 and 26,100 mg/kg. Eight of the 13 surface soil layers examined had a soluble sulfate content exceeding the 100 mg/kg trigger value for MBO formation potential. At least one site in the 4 wetlands examined in this complex exceeded the soluble sulfate trigger value.

Water Data

The surface water data was only measured in the field and laboratory at site 20832_1 and are presented in Tables 8-50 and 8-51, respectively. The field pH was 8.09 and just exceeded the most relevant ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 8.0. The water data indicates that the surface water has not been affected by acidification. The surface water sulfate concentration was 3,914 mg/L. Dissolved oxygen, SEC, turbidity, and some nutrient (i.e. NH_4 , PO_4) and metal (i.e. Ag, Cd, Co) values were found to exceed the most relevant ANZECC/ARMCANZ (2000) guideline value. Groundwater was not collected within this wetland.

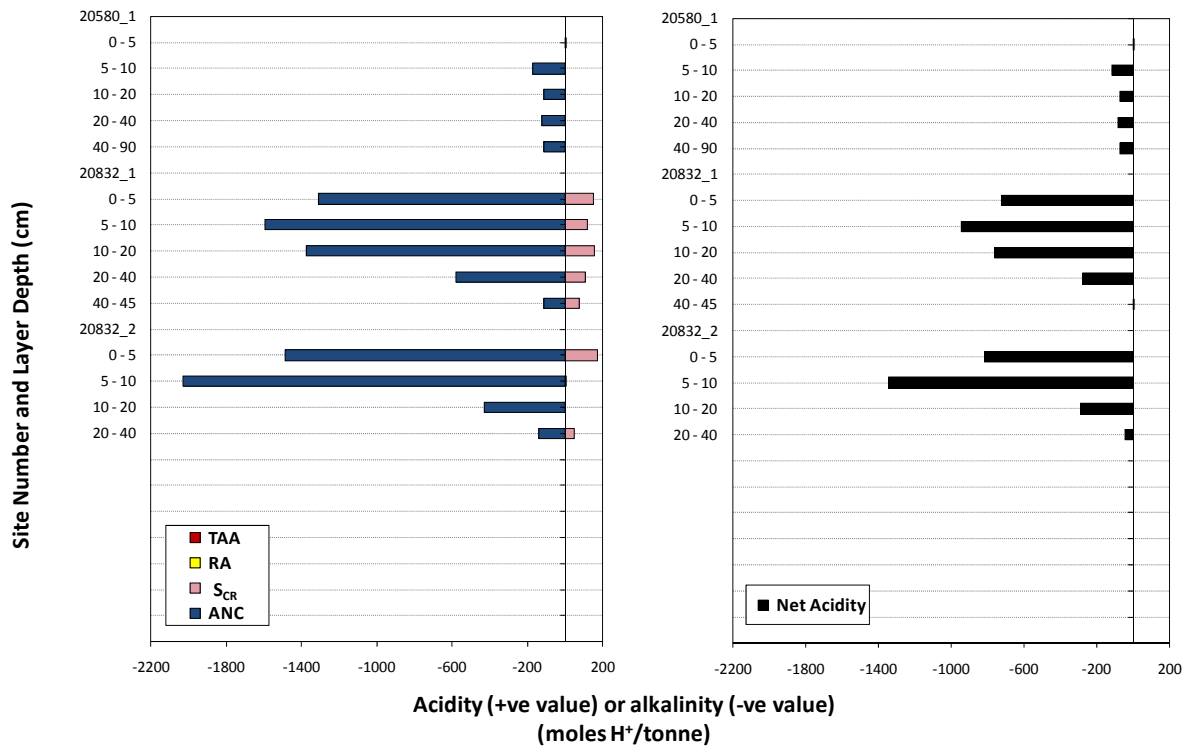


Figure 8-73. Acid-base accounting depth profiles for Wakool-Tullakool Evaporation Basins (20580_1, 20832_1 – 20832_2). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

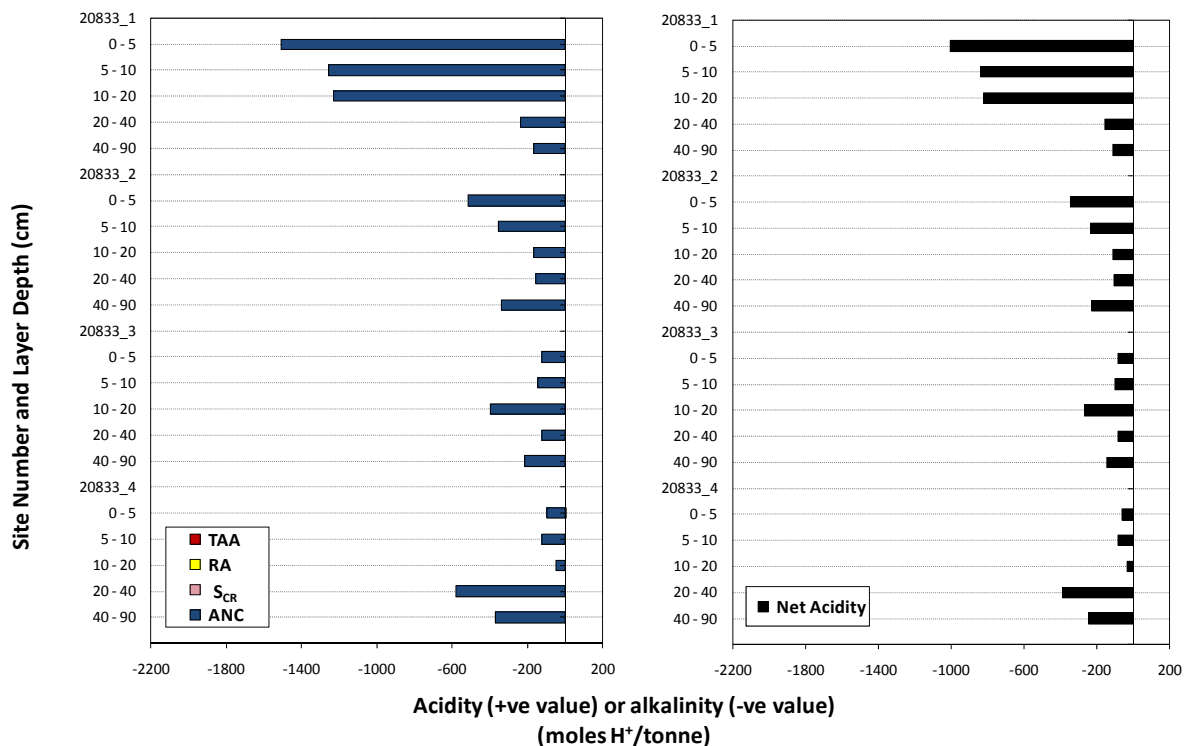


Figure 8-74. Acid-base accounting depth profiles for Wakool-Tullakool Evaporation Basins (20833_1 – 20833_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

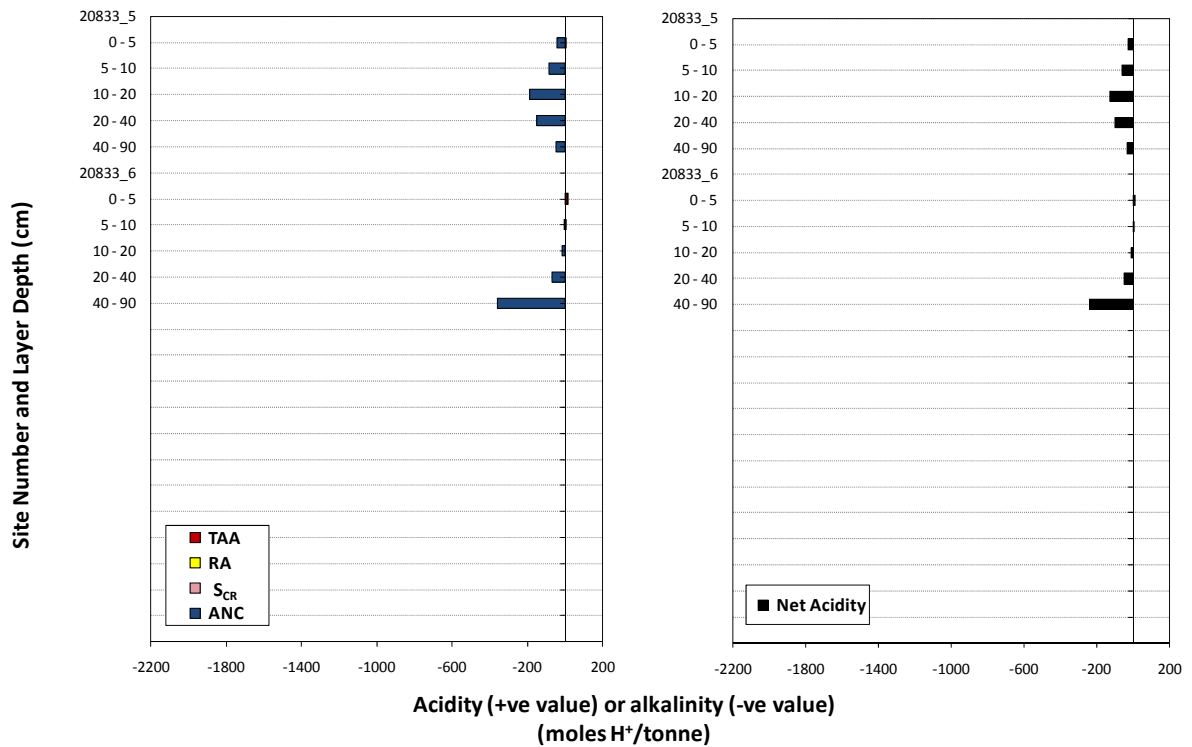


Figure 8-75. Acid-base accounting depth profiles for Wakool-Tullakool Evaporation Basins (20833_5 – 20833_6). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

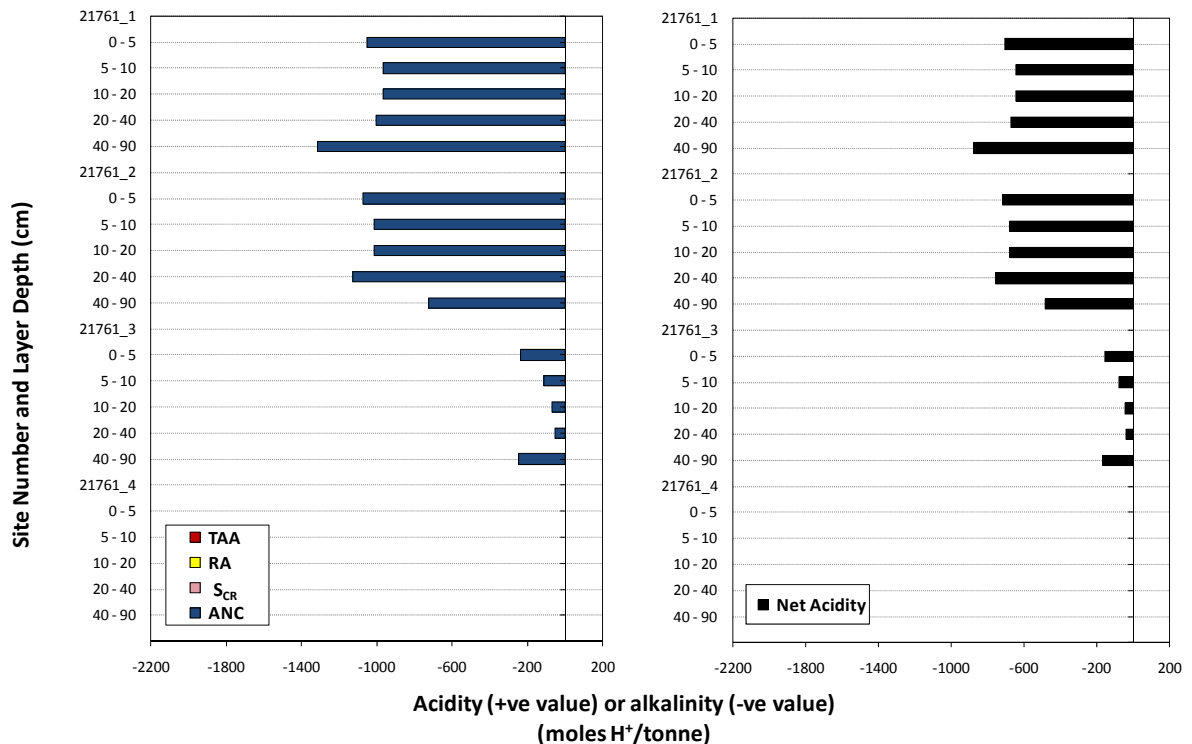


Figure 8-76. Acid-base accounting depth profiles for Wakool-Tullakool Evaporation Basins (21761_1 – 21761_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.9.4. Discussion

Acid sulfate soils only occurred at two of the 13 sites examined in the Wakool-Tullakool Evaporation Basin wetland complex (i.e. sites 20832_1 and 20832_2). Other acidic soil materials were identified in a single soil material at three sites (i.e. 20580_1, 20833_5 and 20833_6). All other soils classed as other soil materials.

Sulfuric materials were not observed. Reduced inorganic sulfur contents of up to 0.28% S_{CR} were observed at the two sulfidic sites. A hypersulfidic soil material with a low net acidity (i.e. 2 mole H^+ /tonne) was present in one soil profile (this profile also contained hyposulfidic materials), and another soil profile contained hyposulfidic materials with both $S_{CR} \geq 0.10\%$ and $< 0.10\%$. Monosulfidic soil materials were observed in the surface and subsurface layers at the two sulfidic sampling sites, with S_{AV} contents of up to 0.16% S. The net acidity results indicate that minimal acidity would be produced upon oxidation of sulfides in these materials. A total of eight surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential.

Based on the priority ranking criteria adopted by the Scientific Reference Panel of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project, there was one high priority site based on hypersulfidic material, two high priority sites based on hyposulfidic ($S_{CR} \geq 0.10\%$) material, and two high priority sites based on monosulfidic material. There were one moderate priority sites based on the presence of a hyposulfidic material with $S_{CR} < 0.10\%$. In addition, eight sampling sites had a high priority ranking for Phase 2 detailed assessment based on MBO formation hazard.

The potential hazards at the wetland-scale posed by acid sulfate soil materials at the Wakool-Tullakool Evaporation Basin wetland complex are:

- Acidification hazard: The data indicate that with low net acidities, and only one hypersulfidic material with a low net acidity, that the degree of acidification hazard is low.
- Deoxygenation hazard: High monosulfide concentrations ($S_{AV} \leq 0.16\%$ S) in surface soils at two sites represent a high deoxygenation hazard. In addition, the soluble sulfate content of surface soil materials at eight sites were over the trigger value for MBO formation indicating the possible development of an appreciable deoxygenation hazard at those locations after prolonged wet conditions.
- Metal mobilisation: The low acidification hazard indicates that soil acidification is not likely to increase the solubility of metals. However, the presence of monosulfidic materials in some surface soils and the potential for MBO formation identified in these wetlands may also result in an appreciable metal release hazard. This would depend on factors such as the potential for MBO formation and the metal loading in this wetland. Soil acidity may be sufficient for mobilisation of aluminium at three sites.

Summary of key findings for the Wakool-Tullakool Evaporation Basins:

<i>Soil materials:</i>	Sulfuric materials were not observed. Sulfidic soil materials identified included: hypersulfidic (1 site), monosulfidic (2 sites), hyposulfidic \geq 0.10% (2 site), and hyposulfidic $<$ 0.10% S (1 site). Other acidic soil materials observed at an additional 3 sites. Low net acidities throughout this wetland complex.
<i>Acid sulfate soil identification:</i>	<ul style="list-style-type: none">• Hypermonosulfidic materials – subaqueous site (site 20832_1); MBO present• Hypomonosulfidic materials – adjacent to waterbody (20832_2); MBO present
<i>Hazard assessment</i>	<ul style="list-style-type: none">• Acidification hazard - low level of concern• Deoxygenation hazard - high level of concern• Metal mobilisation hazard – low to moderate level of concern

Table 8-46. Laboratory analytical data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20580).

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	5.09	4.80	4.57*	185	6.07	6.12	< 0.01	0	0.00	6.12	< 0.01	other acidic
1.2	5-10	fine	6.52	6.19	6.46*		7.21	0.00	< 0.01	0	0.87	-115.64	< 0.01	other soil materials
1.3	10-20	fine	7.33	6.08	6.66*		7.14	0.00	< 0.01	0	0.55	-73.08	< 0.01	other soil materials
1.4	20-40	fine	7.43	6.57	6.61*		6.95	0.00	< 0.01	0	0.60	-80.21	< 0.01	other soil materials
1.5	40-50	fine	7.37	7.14	6.75*		7.08	0.00	< 0.01	0	0.55	-73.17	< 0.01	other soil materials

* Indicates that a stable pH has not yet been reached for this sample (after 14 weeks).

Table 8-47. Laboratory analytical data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20832).

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	7.37	7.00	6.57*	26100	8.71	0.00	0.24	0	6.56	-723.80	0.14	hypomonosulfidic (≥ 0.10)
1.2	5-10	medium	7.32	7.18	6.55*		8.61	0.00	0.19	0	7.99	-944.64	0.10	hypomonosulfidic (≥ 0.10)
1.3	10-20	medium	6.66	7.47	6.44*		8.65	0.00	0.25	0	6.88	-759.01	0.16	hypomonosulfidic (≥ 0.10)
1.4	20-40	medium	6.90	7.02	5.24*		8.94	0.00	0.17	0	2.90	-279.34	0.11	hypomonosulfidic (≥ 0.10)
1.5	40-45	n.a.	6.85	6.45	6.52*		8.21	0.00	0.12	0	0.55	1.74	0.08	hypermonosulfidic [#]
2.1	0-5	medium	7.49	6.77	6.50*	22050	8.79	0.00	0.28	0	7.45	-818.70	0.10	hypomonosulfidic (≥ 0.10)
2.2	5-10	medium	6.63	6.46	6.45*		8.72	0.00	0.01	0	10.15	-1345.06	< 0.01	hyposulfidic (< 0.10)
2.3	10-20	medium	6.41	6.72	6.41*		8.90	0.00	< 0.01	0	2.15	-286.40	< 0.01	other soil materials
2.4	20-35	medium	7.41	7.04	6.49*		7.89	0.00	0.08	0	0.71	-45.75	0.02	hypomonosulfidic (< 0.10)

* Indicates that a stable pH has not yet been reached for this sample (after 14 weeks). [#] Classified as hypermonosulfidic based on positive net acidity.

Table 8-48. Laboratory analytical data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20833).

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titratable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	7.67	7.06	7.23*	177	8.67	0.00	< 0.01	0	7.55	-1005.57	< 0.01	other soil materials
1.2	5-10	medium	7.86	7.75	7.43*		7.68	0.00	< 0.01	0	6.30	-839.36	< 0.01	other soil materials
1.3	10-20	medium	7.87	7.70	7.46*		7.65	0.00	< 0.01	0	6.15	-819.75	< 0.01	other soil materials
1.4	20-40	fine	7.92	7.40	7.26*		8.61	0.00	< 0.01	0	1.18	-156.53	< 0.01	other soil materials
1.5	40-90	fine	7.46	7.35	7.34*		8.48	0.00	< 0.01	0	0.83	-111.08	< 0.01	other soil materials
2.1	0-5	medium	7.75	6.70	6.99*	263	8.65	0.00	< 0.01	0	2.58	-343.64	< 0.01	other soil materials
2.2	5-10	medium	7.90	7.45	7.45*		8.71	0.00	< 0.01	0	1.76	-234.33	< 0.01	other soil materials
2.3	10-20	medium	7.84	6.70	7.34*		7.78	0.00	< 0.01	0	0.83	-110.51	< 0.01	other soil materials
2.4	20-40	medium	7.89	7.60	7.30*		8.57	0.00	< 0.01	0	0.77	-102.69	< 0.01	other soil materials
2.5	40-90	medium	7.59	7.60	7.16*		8.68	0.00	< 0.01	0	1.70	-226.33	< 0.01	other soil materials
3.1	0-5	medium	7.28	4.60	6.12	78.9	6.97	0.00	< 0.01	0	0.61	-81.55	< 0.01	other soil materials
3.2	5-10	medium	8.01	7.30	7.31*		7.30	0.00	< 0.01	0	0.73	-97.43	< 0.01	other soil materials
3.3	10-20	medium	8.44	7.95	7.39*		8.66	0.00	< 0.01	0	1.98	-263.20	< 0.01	other soil materials
3.4	20-40	fine	8.01	7.85	7.25*		7.29	0.00	< 0.01	0	0.60	-80.50	< 0.01	other soil materials
3.5	40-90	fine	7.38	7.85	7.17*		8.47	0.00	< 0.01	0	1.08	-144.15	< 0.01	other soil materials
4.1	0-5	medium	7.43	4.05	6.30	68.6	6.42	2.41	< 0.01	0	0.48	-61.34	< 0.01	other soil materials
4.2	5-10	medium	7.00	7.10	6.06*		7.09	0.00	< 0.01	0	0.61	-81.10	< 0.01	other soil materials
4.3	10-20	medium	7.59	6.80	6.84*		6.84	0.00	< 0.01	0	0.23	-31.03	< 0.01	other soil materials
4.4	20-40	fine	7.60	7.70	6.99*		8.78	0.00	< 0.01	0	2.90	-386.34	< 0.01	other soil materials
4.5	40-90	fine	7.71	8.05	7.11*		8.84	0.00	< 0.01	0	1.85	-245.94	< 0.01	other soil materials
5.1	0-5	medium	6.40	5.05	4.49*	76.4	6.46	1.98	< 0.01	0	0.21	-25.60	< 0.01	other acidic
5.2	5-10	medium	6.59	5.50	5.69*		6.73	0.00	< 0.01	0	0.44	-58.05	< 0.01	other soil materials
5.3	10-20	medium	7.09	6.60	6.38*		6.94	0.00	< 0.01	0	0.94	-124.55	< 0.01	other soil materials
5.4	20-40	medium	7.03	6.15	6.40*		6.82	0.00	< 0.01	0	0.74	-97.93	< 0.01	other soil materials
5.5	40-90	medium	6.71	5.45	5.99*		6.54	0.00	< 0.01	0	0.24	-32.52	< 0.01	other soil materials
6.1	0-5	medium	5.65	4.80	4.28	48.6	5.56	10.15	< 0.01	0	0.00	10.15	< 0.01	other acidic
6.2	5-10	medium	6.29	4.95	5.34*		6.36	3.78	< 0.01	0	0.02	0.49	< 0.01	other acidic
6.3	10-20	medium	6.86	5.75	6.48*		6.81	0.00	< 0.01	0	0.08	-10.72	< 0.01	other soil materials
6.4	20-40	medium	7.43	7.05	6.57*		7.28	0.00	< 0.01	0	0.36	-47.42	< 0.01	other soil materials
6.5	40-90	medium	7.64	8.05	7.07*		8.88	0.00	< 0.01	0	1.79	-238.54	< 0.01	other soil materials

* Indicates that a stable pH has not yet been reached for this sample (after 13 weeks).

Table 8-49. Laboratory analytical data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 21761).

(red printed values indicate data results of potential concern)

Site and Layer ID.	Depth Range (cm)	Soil Texture	pH water	pH peroxide	pH incubation	Sulfate (mg SO ₄ / kg)	pH KCl	Titrateable Actual Acidity (mole H ⁺ /t)	Chromium Reducible Sulfur (%S _{CR})	Retained Acidity (mole H ⁺ /t)	Acid Neutralising Capacity (%CaCO ₃)	Net Acidity (mole H ⁺ /t)	Acid Volatile Sulfide (%S _{AV})	Acid Sulfate Soil Material Classification
1.1	0-5	medium	7.05	5.56	6.75*	1058	8.32	0.00	< 0.01	0	5.28	-703.02	< 0.01	other soil materials
1.2	5-10	medium	7.12	5.82	6.16*		7.31	0.00	< 0.01	0	4.83	-643.96	< 0.01	other soil materials
1.3	10-20	medium	6.59	5.00	5.96*		6.90	0.00	< 0.01	0	4.82	-642.55	< 0.01	other soil materials
1.4	20-40	fine	7.07	7.06	6.74*		6.75	0.00	< 0.01	0	5.02	-669.03	< 0.01	other soil materials
1.5	40-75	fine	7.60	7.42	6.80*		9.01	0.00	< 0.01	0	6.58	-876.27	< 0.01	other soil materials
2.1	0-5	medium	6.95	5.20	6.66*	79.7	7.16	0.00	< 0.01	0	5.38	-716.87	< 0.01	other soil materials
2.2	5-10	medium	7.39	6.86	7.24*		7.48	0.00	< 0.01	0	5.09	-677.76	< 0.01	other soil materials
2.3	10-20	medium	7.80	7.85	7.47		7.46	0.00	< 0.01	0	5.08	-677.23	< 0.01	other soil materials
2.4	20-40	medium	7.77	8.24	7.43*		8.84	0.00	< 0.01	0	5.65	-752.75	< 0.01	other soil materials
2.5	40-75	fine	7.71	8.58	7.48*		8.96	0.00	< 0.01	0	3.63	-483.70	< 0.01	other soil materials
3.1	0-5	medium	7.00	6.27	6.44*	195	7.82	0.00	< 0.01	0	1.17	-156.49	< 0.01	other soil materials
3.2	5-10	medium	7.17	6.51	6.91*		7.83	0.00	< 0.01	0	0.57	-75.41	< 0.01	other soil materials
3.3	10-20	medium	7.03	5.75	6.61*		7.20	0.00	< 0.01	0	0.34	-44.66	< 0.01	other soil materials
3.4	20-40	medium	6.92	5.30	6.43*		6.73	0.00	< 0.01	0	0.27	-36.00	< 0.01	other soil materials
3.5	40-75	fine	7.35	7.18	6.97*		8.80	0.00	< 0.01	0	1.24	-164.51	< 0.01	other soil materials
4.1	0-5	coarse	6.31	4.35	5.68	264	6.68	0.00	< 0.01	0	0.08	-10.91	< 0.01	other soil materials
4.2	5-10	coarse	6.41	4.48	5.50		6.69	0.00	< 0.01	0	0.04	-4.69	< 0.01	other soil materials
4.3	10-20	coarse	6.77	5.14	5.94*		6.86	0.00	< 0.01	0	0.06	-7.68	< 0.01	other soil materials
4.4	20-40	fine	7.35	5.61	6.39*		6.92	0.00	< 0.01	0	0.20	-26.84	< 0.01	other soil materials
4.5	40-75	fine	7.73	7.39	7.21*		9.13	0.00	< 0.01	0	5.91	-787.78	< 0.01	other soil materials

* Indicates that a stable pH has not yet been reached for this sample (after 14 weeks).

Table 8-50. Field hydrochemistry data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20580/20832/20833/21761).

Site and Layer ID.	Temperature (Deg C)	Specific Electrical Conductivity (µS/cm)	Dissolved Oxygen (%)	Dissolved Oxygen (mg/L)	pH	ORP	Redox potential (mV)	Turbidity (NTU)	HCO ₃ (mg/L)	Comment
<i>Lowland River*</i>		125-2200	85-110		6.5-8.0			6-50		
<i>Freshwater Lakes*</i>		20-30	90-110		6.5-8.0			1-20		
20832_1 (SW)	23	163,200	129.9	11.08	8.09	367.6		55	34	

* ANZECC water quality guidelines for lowland rivers and freshwater lakes/reservoirs in South-east Australia are provided for relevant parameters (there are currently no trigger values defined for 'Wetlands') (ANZECC/ARMCANZ, 2000). Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pore-water, respectively.

Table 8-51. Laboratory hydrochemistry data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20580/20832/20833/21761).

Parameter	units	ANZECC Guidelines	Site 1 (SW)
depth	cm		
Na	mg l ⁻¹		24,770.6
K	mg l ⁻¹		36.1
Ca	mg l ⁻¹		1,523.7
Mg	mg l ⁻¹		218.1
Si	mg l ⁻¹		2.25
Br	mg l ⁻¹		14.056
Cl	mg l ⁻¹		52,254
NO ₃	mg l ⁻¹	0.7	0.323
NH ₄ -N	mg l ⁻¹	0.01	0.047
PO ₄ -P ^E	mg l ⁻¹	0.005	0.015
SO ₄	mg l ⁻¹		3,914
Ag	µg l ⁻¹	0.05	1
Al ^A	µg l ⁻¹	55	15
As ^B	µg l ⁻¹	13	<10
Cd	µg l ⁻¹	0.2	77
Co	µg l ⁻¹	2.8	4
Cr ^C	µg l ⁻¹	1	<5
Cu ^H	µg l ⁻¹	1.4	<5
Fe	µg l ⁻¹	300	124
Mn	µg l ⁻¹	1700	336
Ni ^H	µg l ⁻¹	11	8
Pb ^H	µg l ⁻¹	3.4	<1
Se	µg l ⁻¹	11	<10
Zn ^H	µg l ⁻¹	8	6
DOC	mg l ⁻¹		19.7

Notes.

The ANZECC guideline values for toxicants refer to the Ecosystem Protection – Freshwater Guideline for protection of 95% of biota in 'slightly-moderately disturbed' systems, as outlined in the Australian Water Quality Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ, 2000). For the nutrients NH₄ and PO₄, guideline values are provided for Freshwater Lakes and Reservoirs. Surface water values outside the ranges defined in the ANZECC guidelines are indicated with red text. (SW) and (PW) indicate whether the sample was taken from surface water or pit-water (groundwater that entered an excavated pit), respectively.

^A Guideline is for Aluminium in freshwater where pH > 6.5.

^B Guideline assumes As in solution as Arsenic (AsV).

^C Guideline is for Chromium is applicable to Chromium (CrVI) only.

^E Guideline is for filterable reactive phosphorous (FRP).

^H Hardness affected (refer to Guidelines).

Table 8-52. Site description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20580).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	dry	soft	common	centre of small area of dead trees	tiny area, only 1 site possible	other acidic	Not a wetland; extremely small extent

Table 8-53. Site description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20832).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-15	Underwater, soft ooze	water	base of water-filled depression	water body	hypermonosulfidic	Possible gypsic pan at 45cm
2	dry	wet, sticky mud/ooze	bare	scalded shoreline of water body	fringing shoreline	hypermonosulfidic	Lamellae of MBO and gypsum

Table 8-54. Site description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20833).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	dry	dry, silty feel, bare patches	common	base of depression	accessibility, ownership of majority of wetland unknown	other soil materials	Salinity indicators present, has not been connected to river for some time
2	dry	dry, silty feel, bare patches	common	lower-mid slope of depression	accessibility, ownership of majority of wetland unknown	other soil materials	Salinity indicators present, has not been connected to river for some time
3	dry	dry, silty feel, bare patches	common	mid slope of depression	accessibility, ownership of majority of wetland unknown	other soil materials	Salinity indicators present, has not been connected to river for some time
4	dry	dry, silty feel, bare patches	common	upper slope of depression	accessibility, ownership of majority of wetland unknown	other soil materials	Salinity indicators present, has not been connected to river for some time
5	dry	dry, silty feel, bare patches	common	base of second depression	accessibility, ownership of majority of wetland unknown	other acidic	Salinity indicators present, has not been connected to river for some time
6	dry	dry, silty feel, bare patches	common	small rise between depressions	accessibility, ownership of majority of wetland unknown	other acidic	Salinity indicators present, has not been connected to river for some time

Table 8-55. Site description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 21761).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	dry	poached	partial	salt discharge area at base of slope	part of transect of lower slope of lunette	other soil materials	Not a wetland, saltbush plantation
2	dry	soft	partial	lower slope	part of transect of lower slope of lunette	other soil materials	Not a wetland, saltbush plantation
3	dry	soft	partial	midslope	part of transect of lower slope of lunette	other soil materials	Not a wetland, saltbush plantation
4	dry	firm	partial	upper/midslope	part of transect of lower slope of lunette	other soil materials	Not a wetland, saltbush plantation

Table 8-56. Profile description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20580).

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	7.5YR 3/2	SCL	fine	T					Crumb	2	very weak	6.56	
1.2	5-10	7.5YR 4/2	SC	fine/medium heavy	D					MA	0		6.49	
1.3	10-20	7.5YR 4/2	SC	fine/medium heavy	D					MA	0		6.97	
1.4	20-40	7.5YR 4/2	SC	fine/medium heavy	D					MA	0		7.06	
1.5	40-50	7.5YR 4/2	SC	fine/medium heavy	D					MA	0		7.21	

Table 8-57. Profile description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20832).

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	5Y 5/1	ZCL		W					PL	2		7.95	
1.2	5-10	5Y 5/1	ZCL		W					PL	2		8.19	
1.3	10-20	10YR 2/1	ZCL	light	W					MA	0		7.63	
1.4	20-40	10YR 2/1	ZCL	light	W					MA	0		7.37	Gypsic pan at 45cm (identification is uncertain)
1.5	40-45	n/r	n/r	n/r	n/r					n/r	n/r		n/r	
2.1	0-5	10YR 2/1	ZCL	light	T					MA	0		8.15	MBO
2.2	5-10	10YR 6/2	CLS	light	T					PL	3		7.52	Layers of silty clay, MBO and gypsum
2.3	10-20	10YR 6/2	CLS	light	T					PL	3		7.58	Layers of silty clay, MBO and gypsum
2.4	20-35	10YR 2/1	ZCL	light	T					MA	0		7.73	MBO

Table 8-58. Profile description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20833).

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	10YR 4/2	CL		D					AB	2		7.62	
1.2	5-10	10YR 4/1	C	light	D					AB	2		7.95	Carbonate nodules
1.3	10-20	10YR 3/1	C	light	D					AB	2		7.60	Carbonate nodules
1.4	20-40	10YR 3/1	C	medium	D					AB	2		7.87	Carbonate nodules
1.5	40-90	10YR 4/1	C	medium	D	1	FM			AB	2		7.58	Carbonate nodules
2.1	0-5	10YR 4/1	ZCL		D					PO	1		7.08	
2.2	5-10	10YR 4/1	CL		D					SB	1		7.55	Carbonate nodules
2.3	10-20	10YR 4/1	ZC	light	D					AB	2		7.65	Carbonate nodules
2.4	20-40	10YR 5/1	C	light	D					AB	2		7.59	Carbonate nodules
2.5	40-90	10YR 5/2	C	light	D	1	FM			AB	2		7.39	Carbonate nodules
3.1	0-5	10YR 3/2	L		D					PO	2	loose	7.80	
3.2	5-10	10YR 4/2	ZC	light	D					SB	1	mod firm	7.99	Carbonate nodules
3.3	10-20	10YR 4/2	C	light	D					SB	2	mod firm	8.19	Carbonate nodules
3.4	20-40	10YR 4/2	C	light medium	D					SB	2	mod firm	8.13	Carbonate nodules
3.5	40-90	10YR 5/2	C	light medium	D	1	FM			SB	2	mod firm	7.65	Carbonate nodules
4.1	0-5	7.5YR 4/3	ZCL		D					SB	2	very weak	6.75	
4.2	5-10	7.5YR 4/3	CL		D					SB	1	mod weak	7.01	
4.3	10-20	7.5YR 3/3	C	light	D					SB	1	mod firm	7.19	
4.4	20-40	7.5YR 4/4	C	light medium	D					SB	1	mod firm	7.58	Carbonate nodules
4.5	40-90	10YR 4/3	C	light medium	D					SB	1	very firm	7.63	Carbonate nodules

Table 8-59. Profile description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 20833).

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
5.1	0-5	10YR 4/3	ZCL	light	D					MA	0	mod firm	6.44	
5.2	5-10	10YR 4/2	ZC	light	D					MA	0	mod firm	6.48	
5.3	10-20	7.5YR 3/3	ZC	light	D					SB	1	mod weak	6.69	
5.4	20-40	7.5YR 3/2	C	light	D					SB	1	mod weak	6.70	Carbonate nodules, Fe nodules
5.5	40-90	7.5YR 4/2	C	light	D					SB	1	mod weak	6.45	Carbonate nodules, Fe nodules
6.1	0-5	10YR 4/2	ZL		D					MA	0	mod weak	6.39	
6.2	5-10	10YR 4/3	ZCL		D					MA	0	mod firm	6.20	
6.3	10-20	7.5YR 3/3	ZC	light	D					SB	1	mod weak	6.50	
6.4	20-40	7.5YR 4/3	C	light	D	1	FM			SB	2	mod firm	6.81	Carbonate nodules
6.5	40-90	7.5YR 4/4	C	light	D	1	FM			SB	1	mod firm	7.42	Carbonate nodules

Table 8-60. Profile description data for acid sulfate soil assessment of Wakool-Tullakool Evaporation Basins (Wetland ID 21761).

Site and Sample No.	Horizon Depth Range (cm)	Soil Colour - moist	Texture Class	Texture Modifiers	Moisture State	Redoximorphic Features Abundance	Redoximorphic Features – Kind	Redoximorphic Features - Colour	Redoximorphic Features - Location	Structure - Type	Structure - Grade	Consistency (moist or dry) - Rupture Resistance	pH (field measurement)	Comments (odour, fragments, minerals, plant material, inclusions, other)
1.1	0-5	10YR 4/2	SCL		T					MA	0	very weak	7.23	
1.2	5-10	10YR 4/2	SCL		T					MA	0	very weak	7.14	
1.3	10-20	10YR 4/2	SCL		T					MA	0	very weak	7.37	
1.4	20-40	7.5YR 4/3	SC		T					MA	0	mod firm	7.42	
1.5	40-75	7.5YR 4/3	SC		T					MA	0	mod firm	7.83	
2.1	0-5	7.5YR 4/2	SCL							MA	0	very weak	8.35	
2.2	5-10	7.5YR 4/2	SCL							MA	0	very weak	8.25	
2.3	10-20	7.5YR 4/2	SCL							MA	0	very weak	8.47	
2.4	20-40	7.5YR 4/2	SCL							MA	0	very weak	8.39	
2.5	40-75	7.5YR 5/3	SC							MA	0	mod firm	8.78	
3.1	0-5	7.5YR 3/2	SCL		T					MA	0		7.57	
3.2	5-10	7.5YR 3/2	SCL		T					MA	0		7.59	
3.3	10-20	7.5YR 3/2	SCL		T					MA	0		7.64	
3.4	20-40	7.5YR 3/2	SCL		T					MA	0		7.68	
3.5	40-75	10YR 5/3	SC		T					MA	0		7.52	
4.1	0-5	7.5YR 4/2	LS		T					MA	0		7.40	
4.2	5-10	7.5YR 4/2	LS		T					MA	0		7.15	
4.3	10-20	7.5YR 4/2	LS		T					MA	0		7.45	
4.4	20-40	7.5YR 5/3	SC		T					MA	0		7.43	
4.5	40-75	7.5YR 5/3	SC		T					MA			8.16	

APPENDIX 2. ASSRAP screening criteria

Table 8-61: Screening criteria for selecting detailed acid sulfate soil assessment study areas developed by the Scientific Reference Panel of the Acid Sulfate Soils Risk Assessment Project (source: MDBA 2010).

Parameter	Trigger value	Action required	Priority
pH soil*	<4	Detailed assessment	Extreme
	4 – 5.5	Detailed assessment	Moderate
	>5	No further assessment	N/A
pH water	<5.5	Detailed assessment	High
	5.5 – 6.5	Detailed assessment	Moderate
	>6.5	No further assessment	N/A
EC soil (1:5)	>1000 $\mu\text{S}/\text{cm}$	Detailed assessment	High
	400 – 1000 $\mu\text{S}/\text{cm}$	Detailed assessment	Moderate
	<400 $\mu\text{S}/\text{cm}$	No further assessment	N/A
EC water	>5000 $\mu\text{S}/\text{cm}$	Detailed assessment	High
	1750 – 5000 $\mu\text{S}/\text{cm}$	Detailed assessment	Moderate
	<1750 $\mu\text{S}/\text{cm}$	No further assessment	N/A
Sulfate soil	>500 mg/kg	Detailed assessment	High
	100 – 500 mg/kg	Detailed assessment	Moderate
	<100 mg/kg	No further assessment	N/A
Sulfate water	>50 mg/L	Detailed assessment	High
	10 – 50 mg/L	Detailed assessment	Moderate
	<10 mg/L	No further assessment	N/A

* As determined by both in-field measurements and subsequent analysis of samples collected in chip-trays.

