Assessment of Acid Sulfate Soil Materials in the River Murray, Hume to Yarrawonga Region of the Murray-Darling Basin

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Cover Photograph

Photograph of site 40205_2, showing the location of the sampling site adjacent to reed vegetation.
Photographer: David Morand

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EXECUTIVE SUMMARY

The Hume to Yarrawonga reach of the upper River Murray is approximately 230 km in length, and flows downstream from Lake Hume to the Yarrawonga Weir pool. Lake Hume is located approximately 16 km east of Albury-Wodonga, and the Yarrawonga Weir is near the towns of Yarrawonga in Victoria and Mulwala in NSW. The river channel falls approximately 30 m over this section of the River Murray, and occupies a meander belt several hundred metres wide (containing meander scrolls, billabongs and lagoons) within a floodplain up to 5 km wide (MDBC 2008). The flow regime in this reach of the River Murray has been heavily modified by the large storages of Lake Hume and Lake Dartmouth and by the Snowy Mountains Scheme (MDBC 2008).

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 River Murray, Hume to Yarrawonga Region. This Phase 1 report is aimed solely at determining whether or not acid sulfate soil materials are present in the River Murray, Hume to Yarrawonga Region priority wetlands.

This study identified the presence of acid sulfate soil materials in four of the 38 sites examined in the River Murray, Hume to Yarrawonga 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 only identified at Dairy Lagoon (21942) and one of the un-named wetlands (40231).

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)					
	20132	21928	21942	40205	40231	40790
Sulfuric	0	0	0	0	1	0
Hypersulfidic	0	0	3	0	0	0
Hyposulfidic (S_{CR} ≥ 0.10%)	0	0	0	0	0	0
Monosulfidic (observed)	0	0	0	0	0	0
Monosulfidic (potential)	0	5	7	4	2	0
Hyposulfidic (S_{CR} < 0.10%)	0	0	0	0	0	0
Other acidic (pH_w &/or $pH_{INCUBATION}$) 4 – 5.5	8	8	5	4	1	8
Other soil materials	0	0	0	0	0	0

Sulfuric materials were only observed at one site, and although 11% of the sampling sites contained sulfidic materials, the reduced inorganic sulfur concentrations of these samples were very low (i.e. the highest S_{CR} was only 0.02% S). Hypersulfidic soil materials were present in three soil profiles, and hyposulfidic materials were not identified within these wetlands. These results indicate that minimal acidity would be produced upon oxidation of sulfides in these materials.

While monosulfidic soil materials were not observed at the time of sampling, 18 surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for monosulfidic black ooze (MBO) formation potential. The potential formation of MBO was identified in four of the wetlands examined. Other acidic soil materials were also observed at an additional 34 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 the presence of sulfuric material. There were three high priority sites based on the presence of hypersulfidic material. In addition, 18 of the 38 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 in priority wetlands in the Murray River, Hume to Yarrawonga Region are as below:

- Acidification: The data indicate that with only a few sulfidic materials (where the highest S_{CR} was only 0.02% S), the overall degree of acidification hazard is low. A high acidification hazard was only identified in two sulfuric subsoils at one wetland site.

- Deoxygenation: The soluble sulfate content of surface soil materials at 18 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 potential for MBO formation identified in these wetlands 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.

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1. INTRODUCTION

1.1. Region overview

The Hume to Yarrawonga reach of the upper River Murray is approximately 230 km in length, and flows downstream from Lake Hume to the Yarrawonga Weir pool. Lake Hume is located approximately 16 km east of Albury-Wodonga, and the Yarrawonga Weir is near the towns of Yarrawonga in Victoria and Mulwala in NSW. The river channel falls approximately 30 m over this section of the River Murray, and occupies a meander belt several hundred metres wide (containing meander scrolls, billabongs and lagoons) within a floodplain up to 5 km wide (MDBC 2008). The soil types are predominantly Aquic Vertosols and Hydrosols, with Kurosols and Chromosols on the higher margins. The main channel has a strong gravel influence (i.e. Travellers Creek and Dairy Lagoon). The vegetation varies between grassland and sedgeland to Red Gum saplings. The flow regime in this reach of the River Murray has been heavily modified by the large storages of Lake Hume and Lake Dartmouth and by the Snowy Mountains Scheme (MDBC 2008).

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. A series of rapid acid sulfate soil assessments were completed throughout the River Murray, Hume to Yarrawonga Region as part of the Murray-Darling Basin Acid Sulfate Soil Risk Assessment Project (MDB ASSRAP). A total of six wetlands were selected for further detailed assessment based on being identified as having a high priority as a result of both soil and water parameters exceeding screening trigger values (see Appendix 2), and having a risk profile. The parameters found to exceed the ASSRAP trigger values in the River Murray, Hume to Yarrawonga Region 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.

Wetland ID	pH Soil	pH Water	EC Soil	EC Water	Sulfate Soil	Sulfate Water	Priority
20132	Extreme	-	-	-	-	-	Extreme
21928	Moderate	High	Moderate	-	High	-	High
21942	Extreme	-	-	-	-	Moderate	Extreme
40205	Extreme	-	-	-	High	-	Extreme
40231	Extreme	-	High	-	High	-	Extreme
40790	Extreme	Moderate	-	-	-	-	Extreme

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 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 Yarrawonga, NSW and Vic (6 wetlands),
- Talwood-Mungindi region, Queensland (1 wetland), and
- Victorian Northern Flowing Rivers (17 wetlands).

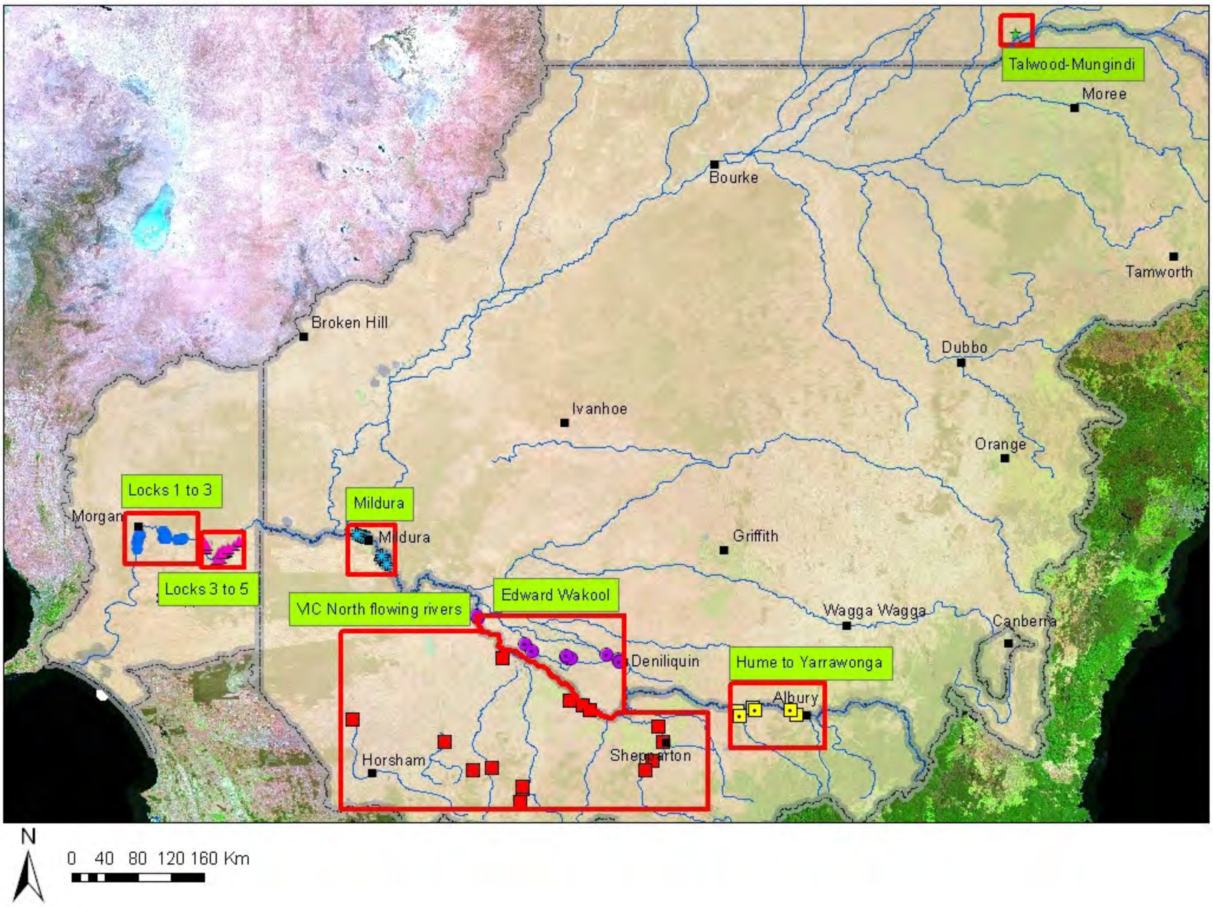

Figure 1-1. Map showing priority wetlands surveyed in the Murray-Darling Basin (source: MDBA).

New South Wales Department of Environment, Climate Change and Water (NSW DECCW) carried out a detailed assessment at 38 representative sites within six wetlands in the River

Murray, Hume to Yarrawonga Region in April-May 2010 to determine whether acid sulfate soils were present, or if there was a potential for acid sulfate soils to form within these wetlands (Figure 1-2). 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.

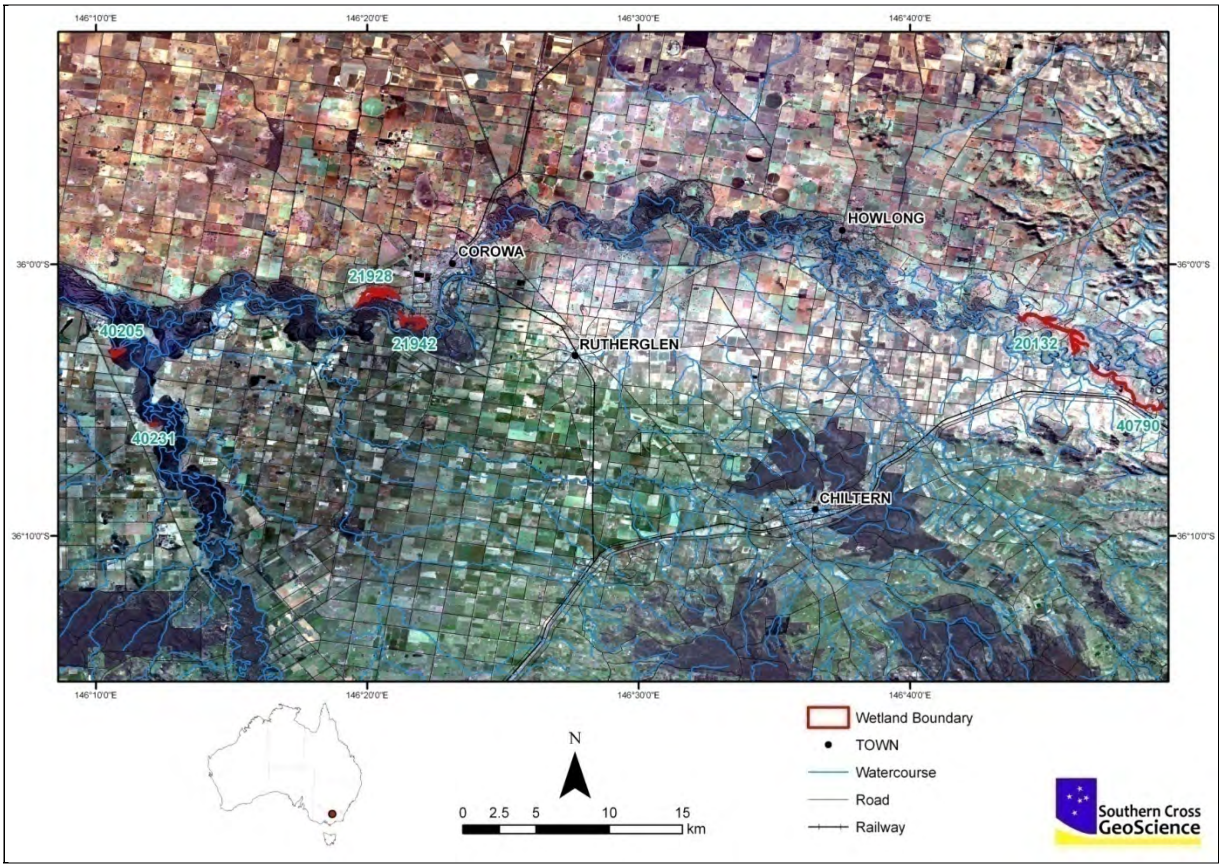

Figure 1-2. Map showing the areas assessed in the River Murray, Hume to Yarrawonga Region.

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 River Murray, Hume to Yarrawonga 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: FeS_2) may occur which produce acidity, including:

$$2FeS_2 + 7O_2 + 2H_2O \text{ ---> } 2Fe^{2+} + 4SO_4^{2-} + 4H^+$$

$$4FeS_2 + 15O_2 + 10H_2O \text{ ---> } 4FeOOH + 8H_2SO_4$$

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 $CaCO_3$ 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 $pH_W \geq 4$ 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 six River Murray, Hume to Yarrawonga Region priority wetlands was undertaken between 20th April and 6th May 2010. A total of 185 soil layers were collected and analysed from 38 representative soil profiles within the River Murray, Hume to Yarrawonga 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 Hume to Yarrawonga 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 and Appendix 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 Hume to Yarrawonga priority wetlands.

Wetland ID	State	Main Name	Location	Area (m^2)	Area (ha)	No. of sites
20132	NSW	Travellers Creek	Murray River Billabongs Albury - Lake Mulwala	533,638	53	8
21928	NSW	Croppers Lagoon	Murray River Billabongs Albury - Lake Mulwala	634,430	63	8
21942	NSW	Dairy Lagoon	Murray River Billabongs Albury - Lake Mulwala	211,778	21	8
40205	VIC	un-named wetland	lower Ovens River floodplain	169,715	17	4
40231	VIC	un-named wetland	lower Ovens River floodplain	36,446	4	2
40790	VIC	un-named wetland	Murray River Billabongs Albury - Lake	269,355	27	8

At the majority of wetlands 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. All soil samples were maintained at ≤ 4°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 ($pH_{INCUBATION}$) 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 14 sites in the River Murray, Hume to Yarrawonga 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 surface 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 ≤ 4°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 (NO_3^-) (APHA 4500 NO_3^-) (APHA 2005),
- dissolved ammonia (NH_4) (APHA 4500 NH_3-H) (APHA 2005),
- dissolved phosphate (PO_4) (APHA 4500 P-E) (APHA 2005),
- dissolved sulfate (SO_4^{2-}) (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 Hume to Yarrawonga priority wetlands were Mitch Tulau, Belinda Allman, David Morand and Rob Muller. Sampling was undertaken between 20th April and 6th May 2010 by David Morand, Belinda Allman, Rob Muller, Brian Jenkins, Mitch Tulau and Michael Eddie. 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 Hume to Yarrawonga priority wetlands.

Wetland ID	Main Name	Date Sampled	Comments on site/layer selection
20132	Travellers Creek	04/05/10 - 05/05/10	Three transects of typical sites, sampled according to protocol
21928	Croppers Lagoon	28/04/10 - 29/04/10	Two transects of low and higher elevation typical site conditions, sampled according to protocol
21942	Dairy Lagoon	22/04/10 - 27/04/10	Two four site transects, typical sites, sampled according to protocol
40205	un-named wetland	20/04/10 - 21/04/10	Four site transect, typical site, sampled according to protocol
40231	un-named wetland	20/04/10	Two site transect, typical site, sampled according to protocol
40790	Travellers Creek	05/05/10 - 06/05/10	Three transects of typical sites, 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, ≥ 10% laboratory duplicates, and 5% laboratory controls. The analytical precision was ±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 ≥ 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 River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. The pH_W values ranged between 3.23 and 7.40, with the majority of the samples having a pH_W > 4.5. One site within the River Murray, Hume to Yarrawonga Region (i.e. site 40231_1 (20-90 cm)) would be classified as being sulfuric (i.e. pH_W < 4). None of the other soils in the River Murray, Hume to Yarrawonga Region priority wetlands are classified as sulfuric materials as they all had a pH_W > 4.

The pH_{FOX} values ranged between 1.54 and 7.04. The majority of soils showed a pH drop after treatment with peroxide (e.g. Figure 3-1), with a maximum decrease of 4.1 pH units. The pH_{FOX} results also indicate that many of the surface soils in the River Murray, Hume to Yarrawonga Region may have the potential to acidify to pH < 4 as a result of sulfide oxidation. However, the S_{CR} data shows many of these layers contain no detectable sulfide (i.e. S_{CR} < 0.01% S). While such 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. In addition, all of the soil materials that had a pH_{FOX} < 2.5 also contained no detectable sulfide.

The $pH_{INCUBATION}$ values ranged between 2.83 and 6.63. Only one of the sulfidic soil materials (i.e. S_{CR} ≥ 0.01% S) with an initial pH_W > 4 acidified to pH < 4 after at least 8 weeks of incubation (i.e. site 21942 (40-90 cm)). However, several non-sulfidic soils (i.e. other acidic) acidified to pH < 4 over the 8 week incubation period (Appendix 1). Several sulfidic soil materials in Dairy Lagoon wetland (21942) 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]		3.23	5.33	7.40	185
pH_{FOX}[3]		1.54	3.46	7.04	185
pH_{KCl}[4]		4.24	5.11	7.04	185
$pH_{INCUBATION}$[5]		2.83	4.63	6.63	185
TAA[6]	mole H^+/t	0.00	19.04	144.33	185
Soluble SO_4[7]	mg SO_4/kg	16.35	88.58	6180	38
S_{CR}[8]	Wt. %S	<0.01	<0.01	0.02	185
S_{AV}[9]	Wt. %S	<0.01	<0.01	<0.01	185
RA[10]	mole H^+/t	0.00	0.00	22.00	185
ANC[11]	$\%CaCO_3$	0.00	0.00	25.64	185
NA[12]	mole H^+/t	-3415.25	19.90	164.39	185

[1] n: number of samples. [2] pH_W: pH in saturated paste with water. [3] pH_{FOX}: pH after treatment with 30% H_2O_2. [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.

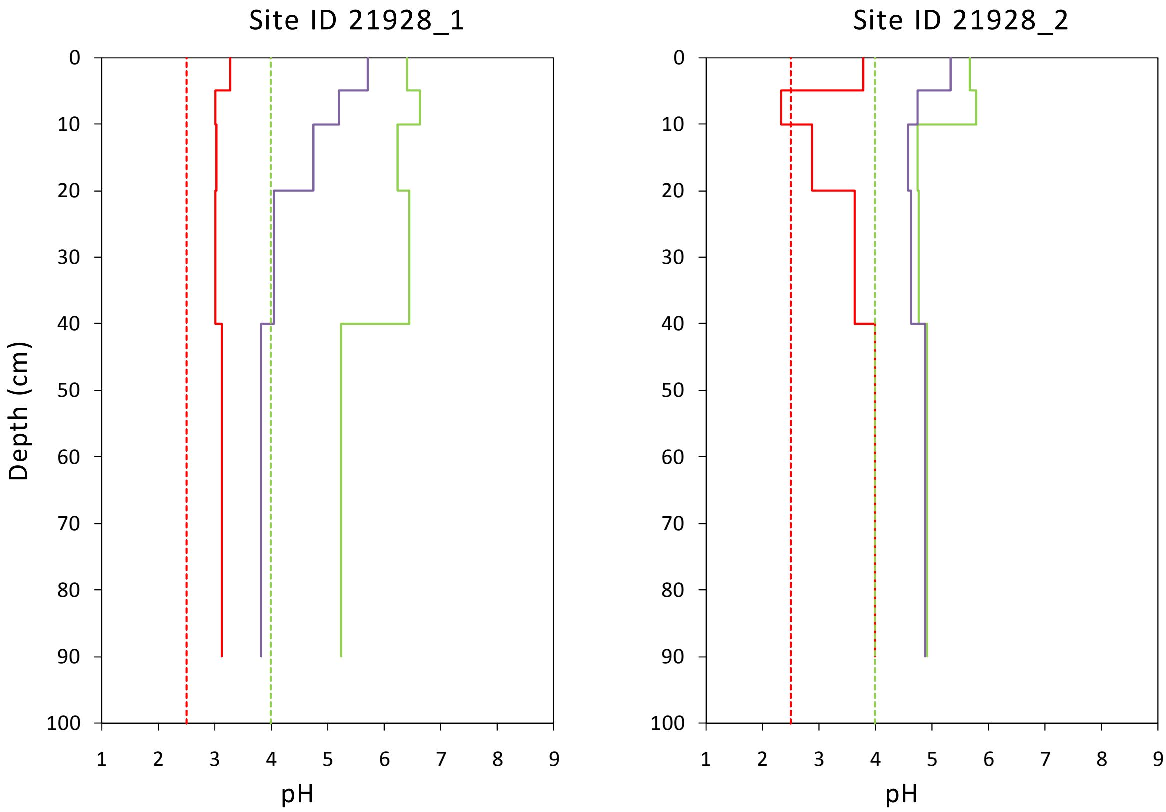

Figure 3-1. Depth profiles of soil pH for (21928_1 – 21928_2), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} 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 River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. The S_{CR} values ranged between < 0.01 and 0.02% S. Sulfidic soil materials (i.e. S_{CR} ≥ 0.01% S) were only identified in Dairy Lagoon wetland (21942) and Wetland ID 40231, with only 9 materials of the 185 samples collected equal to or greater than the sulfidic criterion. A total of four sites of the 38 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. Three sites in the Dairy Lagoon wetland contained sulfidic soil materials, including sites 21942_1 (0-10 cm and 20-90 cm), 21942_2 (5-10 cm and 20-65 cm) and 21942_6 (40-90 cm). Only one of the sulfuric soil layers at site 40231_1 (40-60 cm) contained sulfides.

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 Hume to Yarrawonga priority wetlands.

Wetland ID	Main Name	S_{CR} Range (%S)	No. of sulfidic sites	No. of sulfidic layers	Site No.
20132	Travellers Creek	< 0.01	0 (0%)	0 (0%)	
21928	Croppers Lagoon	< 0.01	0 (0%)	0 (0%)	
21942	Dairy Lagoon	< 0.01 – 0.02	3 (38%)	8 (19%)	1, 2, 6
40205	un-named wetland	< 0.01	0 (0%)	0 (0%)	
40231	un-named wetland	< 0.01 – 0.02	1 (50%)	1 (8%)	1
40790	Travellers Creek	< 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 River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. Monosulfidic soil materials (i.e. $S_{AV} \geq 0.01\%$ S) were absent from all of the wetlands examined at the time of sampling.

3.1.4. Acid Neutralising Capacity (ANC)

The acid neutralising capacity (ANC) data for the wetland sites examined in River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. The ANC ranged between zero and 25.6 %$CaCO_3$ (see Table 3-1), with the majority of samples having no ANC.

3.1.5. Net Acidity (NA)

The net acidity data for the wetland sites examined in River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. 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). Acid-base accounting calculations showed the net acidity ranged between -3,415 and 164 mole H^+/tonne, with a median net acidity of 20 mole H^+/tonne. A summary of the net acidity data for each wetland is given in Table 3-3, and shows low to moderate net acidities (i.e. ≤ 95 mole H^+/tonne) in all wetlands except Wetland ID 40231. Only two sulfuric soil materials in Wetland ID 40231 (i.e. site 40231_1 (20-60 cm)) had high net acidities.

The acidification hazard from acid sulfate soil disturbance posed by the wetland containing three sulfuric soil materials (i.e. Wetland ID 40231) is moderate, with only two of these materials having a high net acidity. The acidification hazard from acid sulfate soil disturbance posed by the one wetland containing hypersulfidic soil materials (i.e. Dairy Lagoon (21942)) was moderate, with net acidities ranging between 26 and 52 mole H^+/tonne.

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).

Table 3-3. Summary of the net acidity data for all soil materials in each wetland in the River Murray, Hume to Yarrawonga priority wetlands.

Wetland ID	Main Name	Net Acidity (mole H^+/tonne)		
		Minimum	Median	Maximum
20132	Travellers Creek	-3,415	5	58
21928	Croppers Lagoon	4	31	86
21942	Dairy Lagoon	-46	32	69
40205	un-named wetland	11	46	95
40231	un-named wetland	3	10	164
40790	Travellers Creek	-55	3	29

3.1.6. Water soluble SO_4

The water soluble SO_4 data for the wetland sites examined in River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. The water soluble SO_4 in the surface soils (i.e. 0-5 cm) in the River Murray, Hume to Yarrawonga Region wetlands ranged between 16 and 6,180 mg/kg. The surface soil layer in 18 of the 38 sites examined had a soluble SO_4 content exceeding the trigger value of 100 mg/kg indicating the potential formation of monosulfidic materials.

3.1.7. Titratable actual acidity (TAA)

The titratable actual acidity (TAA) data for the wetland sites examined in River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. The TAA ranged between zero and 144 mole H^+/tonne, with the majority of soil layers having a TAA < 40 mole H^+/tonne. An increase in the TAA with depth was often observed (Figure 3-2).

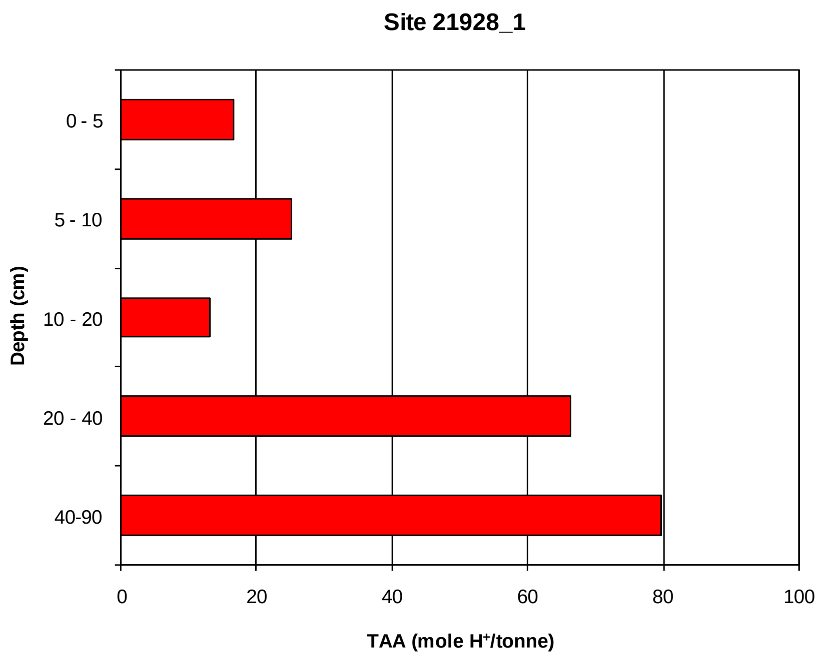

Figure 3-2. Variation in TAA (mole H^+/tonne) with depth at site 21928_1.

3.1.8. Retained acidity (RA)

The retained acidity data for the wetland sites examined in River Murray, Hume to Yarrawonga Region are presented in Appendix 1 and summarised in Table 3-1. The retained acidity ranged between zero and 22 mole H^+/tonne, with the majority of soil layers having no retained acidity (i.e. 176 materials of the 185 samples collected). Retained acidity was only measured in nine samples collected from Croppers Lagoon (21928), Wetland ID 40205 and 40231. Many of the soil materials had no retained acidity as samples had a pH_{KCl} > 4.5.

3.2. Hydrochemistry

The hydrochemical characteristics of the surface water and groundwater in the River Murray, Hume to Yarrawonga 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 River Murray, Hume to Yarrawonga Region.

Surface water quality data was collected from eight locations in the River Murray, Hume to Yarrawonga Region priority wetlands (including wetlands 20132, 21928, 21942 and 40790) (Appendix 1). Groundwater data was also collected from six locations in the River Murray, Hume to Yarrawonga Region priority wetlands (including wetlands 20132, 21928 and 40790) (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 5.39 and 8.40 (Table 3-4) with two sites (sites 21942_1 and 40970_1) outside the most relevant ANZECC/ARMCANZ (2000) trigger values for aquatic ecosystems of 6.5 and 8.0. The water data indicates that only one of the surface waters collected has been affected by acidification (i.e. site 21942_1 which also contained sulfidic soil materials). The surface waters had a low salinity with a median SEC of 45.0 µS/cm. The surface water sulfate concentrations ranged between 1.1 and 184 mg/L (Appendix 1). Some nutrient (i.e. NH_4, PO_4), metal (i.e. Ag, Al, Cd, Co, Cr, Cu, Fe, Mn, Pb, Zn), dissolved oxygen and turbidity values were found to be outside the most relevant ANZECC/ARMCANZ (2000) guideline value at certain locations (see Appendix 1).

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

	pH	**SEC** µS/cm	**DO** mg/L	**ORP** mV	**Turbidity** NTU	**Alkalinity** (mg/L as HCO_3)
Minimum	5.39	9.9	0.25	-107	7	8
Median	7.25	45.0	6.71	328	18	19
Maximum	8.40	203.1	9.43	375	250	104
n[1]	8	8	8	8	7	8

[1] n: number of samples

The field pH of the groundwater ranged between 5.60 and 7.20, indicating that the groundwater at some locations may have been affected by acidification (Table 3-5). The groundwater had sulfate concentrations of 1.1 and 28.3 mg/L.

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

	pH	SEC µS/cm	DO mg/L	ORP mV	Turbidity NTU	Alkalinity (mg/L as HCO_3)
Minimum	5.60	84.9	0.40	123	960	24
Median	6.40	200.5	2.78	267	960	34
Maximum	7.20	344.0	4.80	398	960	248
n[1]	6	6	6	6	1	4

[1] n: number of samples

4. DISCUSSION

A detailed assessment was undertaken in the River Murray, Hume to Yarrawonga Region in April-May 2010 to determine whether acid sulfate soils were present, or if there was a potential for acid sulfate soil to form within these wetlands. This study identified the presence of acid sulfate soil materials in four of the 38 sites examined in the River Murray, Hume to Yarrawonga Region. The soluble sulfate contents of 18 surficial soil materials in four of the wetlands sampled 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. Sulfuric soil materials were only identified below a depth of 20 cm (i.e. 20-90 cm) at site 40231_1. Two of these sulfuric soil materials had high net acidities of 163 and 164 mole H^+/tonne. Sulfidic soil materials (where the highest S_{CR} was only 0.02% S) were only identified in Dairy Lagoon wetland (21942) and Wetland ID 40231. The potential formation of MBO was identified in four of the six wetlands examined. Other acidic soil materials were observed at an additional 34 sites, indicating 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)					
	20132	**21928**	**21942**	**40205**	**40231**	**40790**
Sulfuric	0	0	0	0	1	0
Hypersulfidic	0	0	3	0	0	0
Hyposulfidic (S_{CR} ≥ 0.10%)	0	0	0	0	0	0
Monosulfidic (observed)	0	0	0	0	0	0
Monosulfidic (potential)	0	5	7	4	2	0
Hyposulfidic (S_{CR} < 0.10%)	0	0	0	0	0	0
Other acidic (pH_w &/or $pH_{INCUBATION}$) 4 – 5.5	8	8	5	4	1	8
Other soil materials	0	0	0	0	0	0

5. HAZARD ASSESSMENT

5.1. Interpretation of soil and water data

Sulfuric soil materials were only encountered at one sampling site in Wetland ID 40231 (Table 5-1).

Hypersulfidic materials occurred in the soil profile at three of the 38 sampling locations (Table 5-1).

The data indicate that with only a few sulfidic materials (where the highest S_{CR} was only 0.02% S), the overall degree of acidification hazard is low. A high acidification hazard was only identified in two sulfuric subsoils at one wetland site (i.e. site 40231_1).

Hyposulfidic and monosulfidic soil materials were not present at any of the sampling sites. Other acidic soil materials were observed at an additional 34 sites, indicating soil acidity may be sufficient for mobilisation of aluminium at some sites.

The soluble sulfate contents of 18 surficial soil materials in four of the wetlands sampled 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 four of the wetlands examined.

The water data indicates that only one of the surface waters collected may have been affected by acidification (i.e. site 21942_1 which also contained hypersulfidic soil materials).

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 = 38)	Proportion of total sampling sites (%)
Sulfuric	1	3
Hypersulfidic	3	8
Hyposulfidic (S_{CR} ≥ 0.10%)	0	0
Monosulfidic (observed)	0	0
Monosulfidic (potential)	18	47
Hyposulfidic (S_{CR} < 0.10%)	0	0
Other acidic (pH_w &/or $pH_{INCUBATION}$) 4 – 5.5	34	89
Other soil materials	0	0

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 River Murray, Hume to Yarrawonga Region. This Phase 1 report is aimed solely at determining whether or not acid sulfate soil materials are present in the River Murray, Hume to Yarrawonga Region priority wetlands.

This study identified the presence of acid sulfate soil materials in four of the 38 sites examined in the River Murray, Hume to Yarrawonga Region. Sulfuric materials were only observed at one site, and although 11% of the sampling sites contained sulfidic materials, the reduced inorganic sulfur concentrations of these samples were very low (i.e. the highest S_{CR} was only 0.02% S). Hypersulfidic soil materials were present in three soil profiles, and hyposulfidic materials were not identified within these wetlands. These results indicate that minimal acidity would be produced upon oxidation of sulfides in these materials.

While monosulfidic soil materials were not observed at the time of sampling, 18 surficial soil materials contained soluble sulfate in excess of the 100 mg/kg trigger value for MBO formation potential. The potential formation of MBO was identified in four of the wetlands examined. Other acidic soil materials were also observed at an additional 34 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 the presence of sulfuric material. There were three high priority sites based on the presence of hypersulfidic material. In addition, 18 of the 38 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 in priority wetlands in the Murray River, Hume to Yarrawonga Region are as below:

- Acidification: The data indicate that with only a few sulfidic materials (where the highest S_{CR} was only 0.02% S), the overall degree of acidification hazard is low. A high acidification hazard was only identified in two sulfuric subsoils at one wetland site.

- Deoxygenation: The soluble sulfate content of surface soil materials at 18 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 potential for MBO formation identified in these wetlands 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.

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8. APPENDICES

APPENDIX 1. Wetland reports

8.1. Travellers Creek (Wetland ID 20132)

8.1.1. Location and setting description

Travellers Creek is a channel consisting of two relatively straight segments (Figure 8-1). The wetland is about 5km long, 100-200 m wide and 53 ha. It occurs on the north side of the Murray, west of Albury, and is part of a section of complex anastomising channels, cut offs and ox-bows. At the time of the soil survey in May 2010 the system was flowing and appeared to be acting as an anabranch of the Murray. Much of the wetland is flanked by steep banks, although this is not consistent. Gravels are very common throughout the wetland, often forming bars. Eight sites were sampled in 3 transects, 4 sites in one transect and 2 each in the other transects.

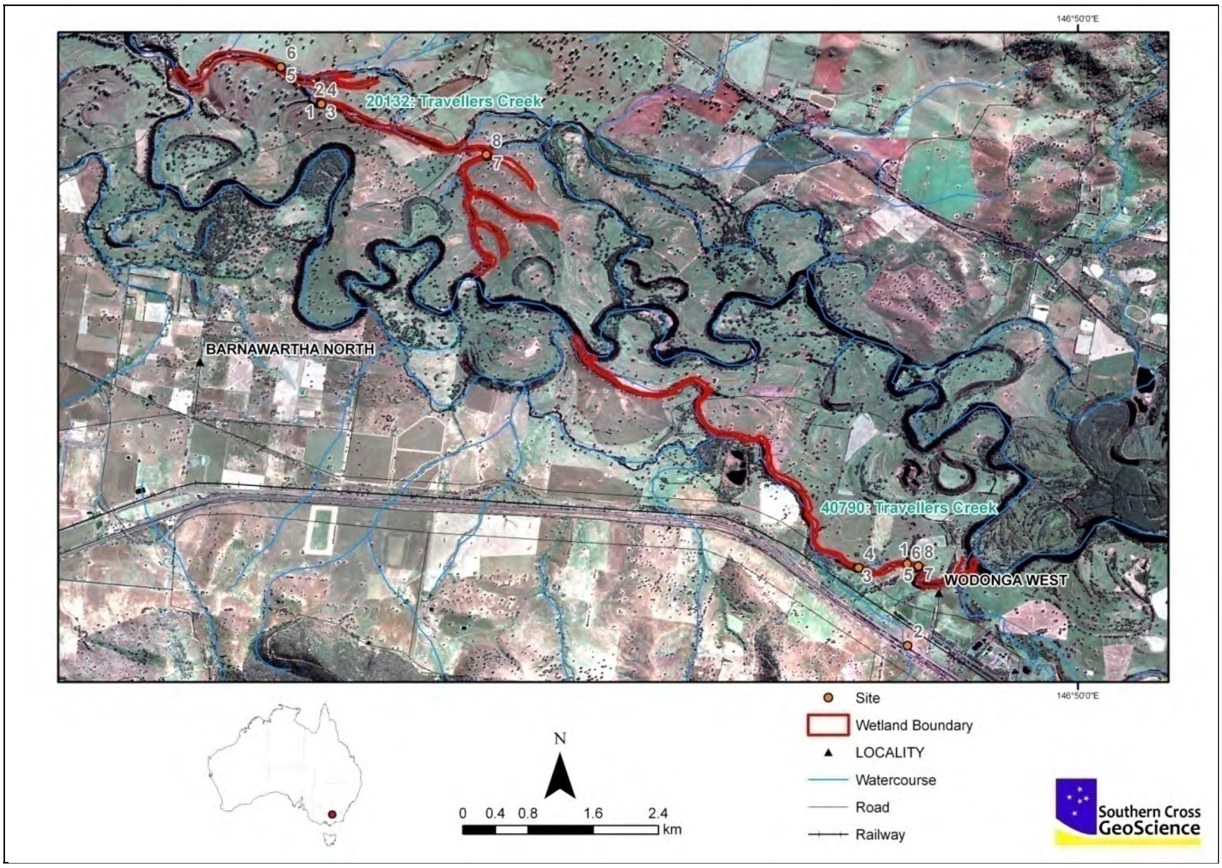

Figure 8-1. Travellers Creek and sample site locations.

8.1.2. Soil profile description and distribution

Eight profiles were described and sampled (Table 8-1). Sites were distributed across the wetland based on elevation and surface features. A transect approach was used, 3 transects being completed (Profiles 1, 2, 3 and 4; Profiles 5 and 6; Profiles 7 and 8).

The profile 20132_1 was subaqueous (40 cm water depth) and occurred within the main channel, the soil consisted of dark grey clayey sand (Figure 8-3). The profile 20132_2 (Figure 8-4) occurred on the margin of a bar about 2m from the water's edge, the soil consisted of dark grey sand. The profile 20132_3 occurred on the crest of the bar, the soil consisted of dark grey mottled silty clay loam (Figure 8-5). The profile 20132_4 occurred at the base of the streambank at the channel margin, the soil consisted of dark grey silty loam over grey mottled light silty clay (Figure 8-6). The profile 21032_5 was subaqueous (50 cm water depth) and occurred within the main channel, the soil consisted of dark grey silty loam over dark grey silty clay. The profile 20132_6 occurred on the bare section of sloping bank between the channel and the elevated fringing sedgeland, the soil consisted of dark grey sand over dark grey silty loam/silty clay loam over dark grey mottled light silty clay (Figure 8-7). The profile 20132_7 (Figure 8-8) was subaqueous (75cm water depth) and occurred within the main channel, the soil consisted of very gravelly sand over compact gravels at 20 cm. The profile 20132_8 occurred about 3 m from the bank, the soil consisted of a thin layer of dark grey silty loam over gravelly sand and compact gravels at 20 cm (Figure 8-8). 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 Travellers Creek.

Site ID	Easting UTM zone 55H	Northing UTM zone 55H	Acid sulfate soil subtype class	General location description
20132_1	477454	6012030	subaqueous soil	subaqueous, in the main channel
20132_2	477463	6012023	hydrosol	on bar, within 2 m of water's edge
20132_3	477455	6012020	hydrosol	on crest of bar
20132_4	477463	6012021	hydrosol	base of stream bank
20132_5	477054	6012461	subaqueous soil	subaqueous, in the main channel
20132_6	477059	6012471	hydrosol	mid slope of bank
20132_7	479112	6011385	subaqueous soil	subaqueous, in the main channel
20132_8	479104	6011403	hydrosol	on bank, ~3 m from water's edge

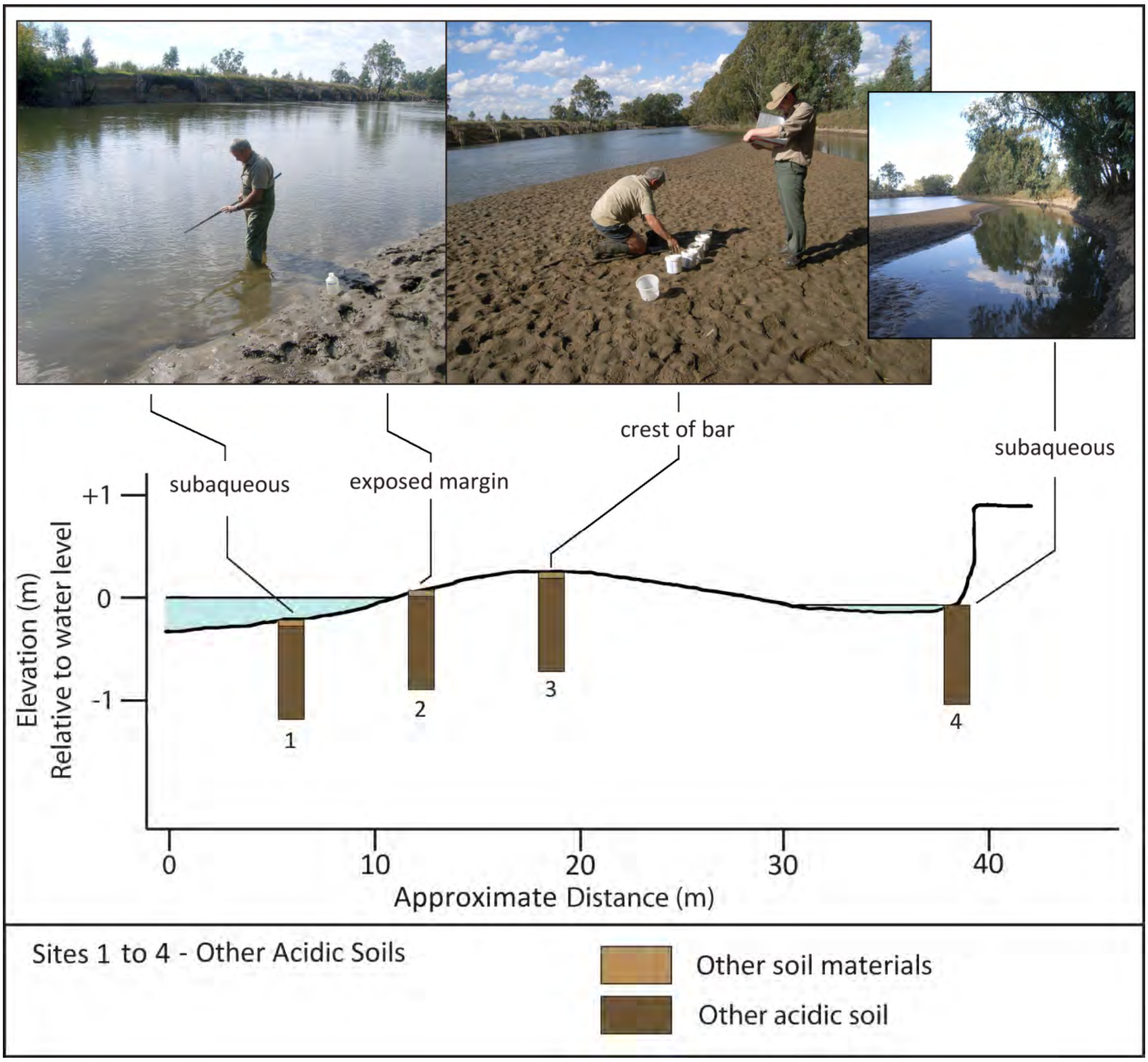

Figure 8-2. Conceptual cross section diagram showing the toposequence relationship of the Travellers Creek sediments/soil materials at sites 20132_1 to 20132_4.


Figure 8-3. Photograph of site 20132_1, showing the subaqueous sampling location.

Figure 8-4. Photograph of site 20132_2, showing the location of the sampling site on the lower slope of the sand bar.

Figure 8-5. Photograph of site 20132_3, showing the sampling location on the crest of the sand bar, and the soil samples.

Figure 8-6. Photographs of site 20132_4, showing the location of the sampling site in a side channel to the main watercourse, and the cracked soil surface.

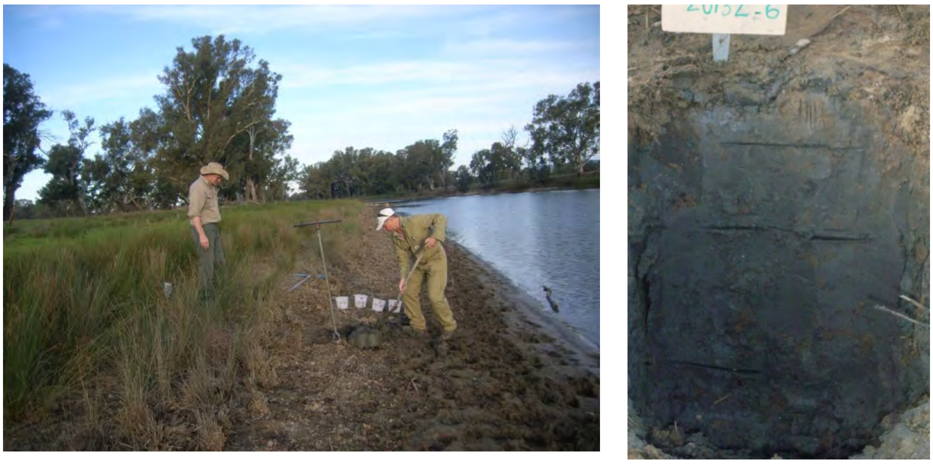

Figure 8-7. Photograph of site 20132_6, showing the sampling site and the soil profile.

Figure 8-8. Photograph of sites 20132_7 and 20132_8.

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 Figures 8-9 and 8-10. The pH_W values ranged between 4.52 and 7.13. Sulfuric materials (i.e. pH_W < 4) were not present. The pH_{FOX} values ranged between 2.38 and 6.53. The pH_{FOX} results indicate that 21 of the 36 surface soils examined may have the potential to acidify to pH < 4 as a result of sulfide oxidation. However, the S_{CR} data shows these layers contained no detectable sulfide (i.e. S_{CR} < 0.01% S). One soil material had a pH_{FOX} < 2.5 (i.e. site 20132_4). Other acidic soil materials were identified at all eight sites, indicating acidity in the soil profile at levels where aluminium may mobilise. None of the soil materials acidified to a pH < 4 after at least 8 weeks of incubation.

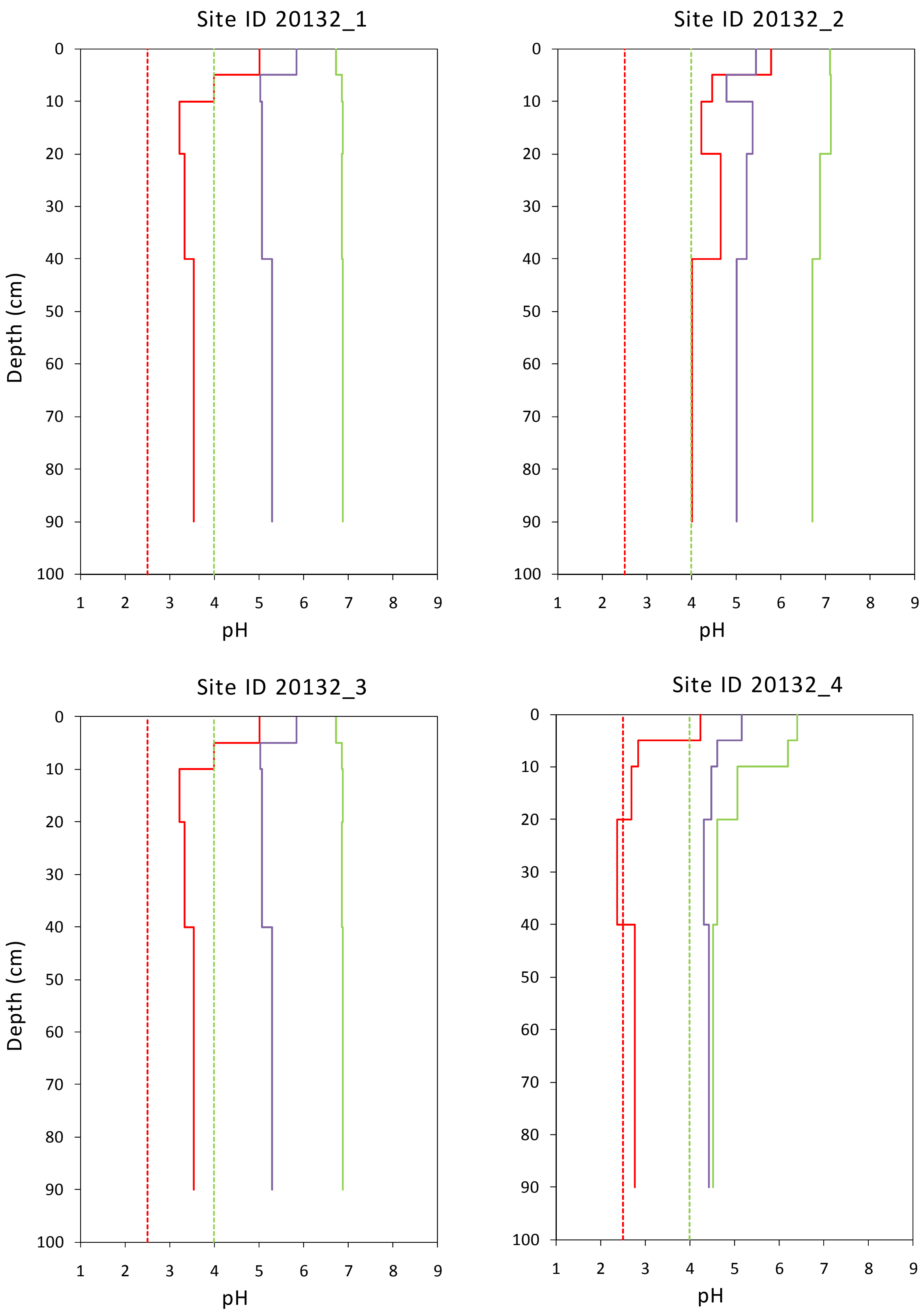

Figure 8-9. Depth profiles of soil pH for Travellers Creek (20132_1 – 20132_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

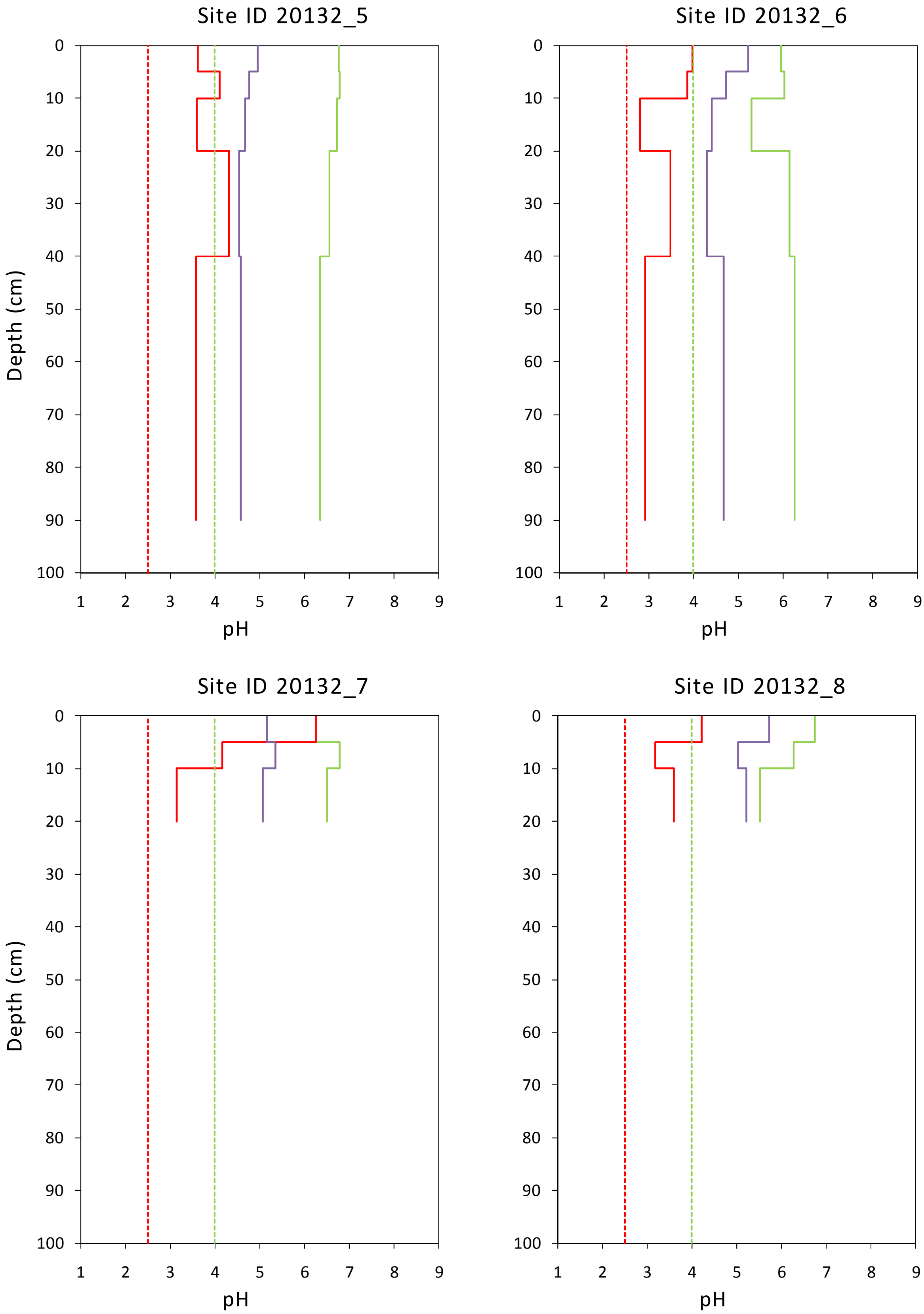

Figure 8-10. Depth profiles of soil pH for Travellers Creek (20132_5 – 20132_8), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) 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 Figures 8-11 and 8-12.

Chromium reducible sulfur

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

Acid volatile sulfide

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

Acid neutralising capacity

The acid neutralising capacity (ANC) ranged between zero and 25.6 % $CaCO_3$, with all except two materials having no ANC.

Titratable actual acidity

The titratable actual acidity (TAA) ranged between zero and 58 mole H^+/tonne. An increase in the TAA with depth was sometimes observed.

Retained acidity

There was no retained acidity at any of the sites as all samples had a pH_{KCl} > 4.5.

Net acidity

Net acidity ranged between -3,415 and 58 mole H^+/tonne, with the majority of samples having low net acidities (i.e. ≤ 18 mole H^+/tonne).

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 16 and 50 mg/kg. None 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 8-3 and 8-4, respectively. The field pH of the surface waters collected ranged between 7.3 and 7.7. The water data indicates that the surface water has not been affected by acidification. The surface water had low sulfate concentrations of between 1.1 and 3.6 mg/L. Some metal values (i.e. Al, Cd, Zn) were found to exceed the most relevant ANZECC/ARMCANZ (2000) guideline value. The field pH of the groundwater was 6.3 indicating that the groundwater has not been affected by acidification. The groundwater had a low sulfate concentration of 1.1 mg/L.

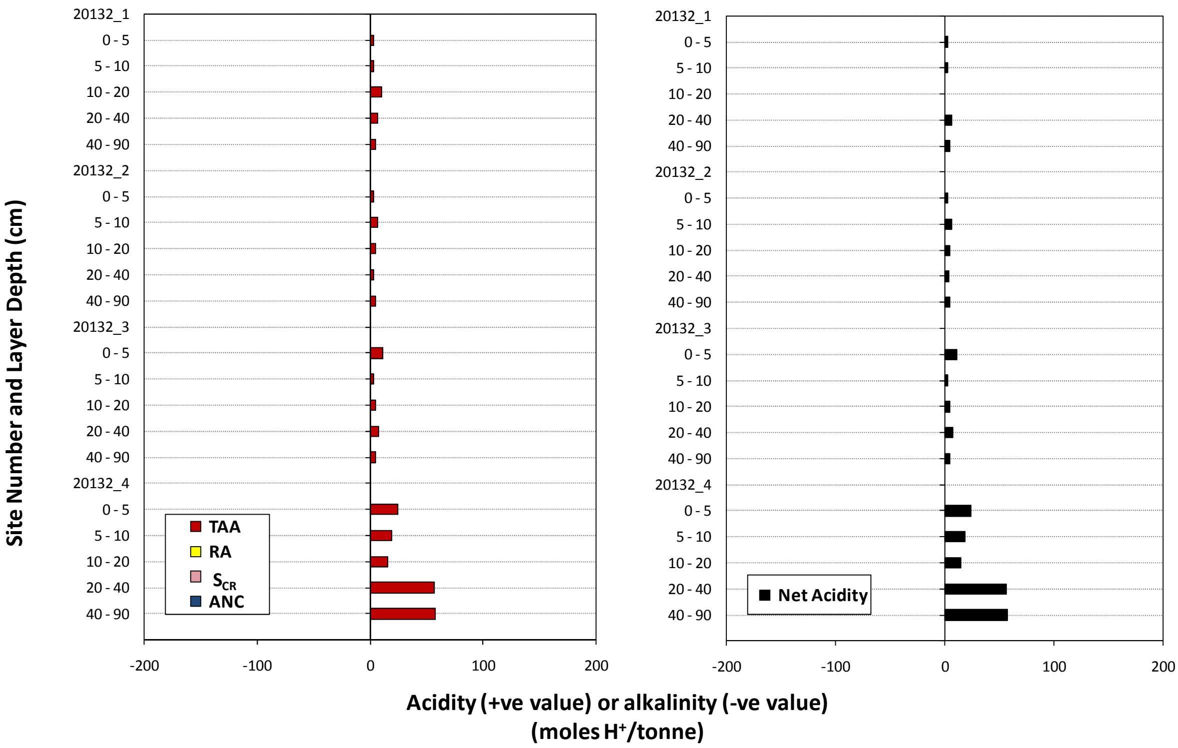

Figure 8-11. Acid-base accounting depth profiles for Travellers Creek (20132_1 – 20132_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

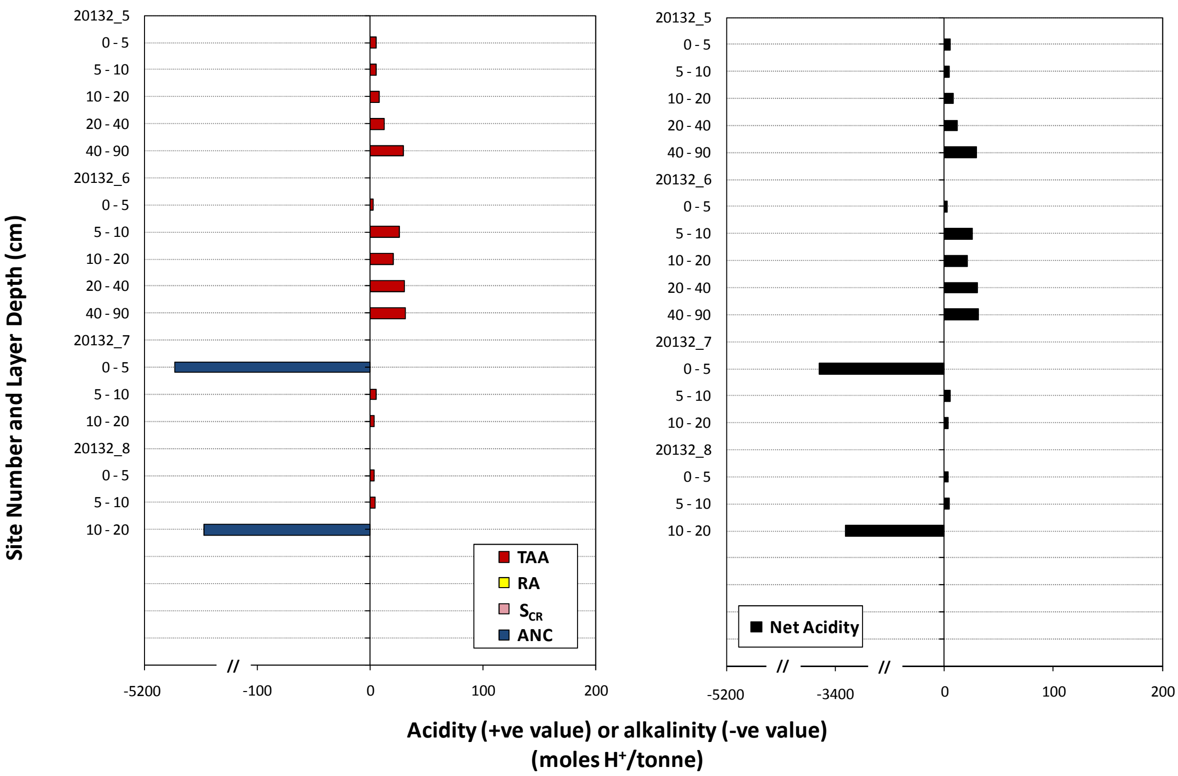

Figure 8-12. Acid-base accounting depth profiles for Travellers Creek (20132_5 – 20132_8). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.1.4. Discussion

Acid sulfate soils materials were not found at Travellers Creek. All soil materials were classified as either other acidic soils or other soil materials.

None of 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, all sites within this wetland require no further assessment.

Summary of key findings for the Travellers Creek:

Soil materials:	Sulfuric and sulfidic materials were not observed within this wetland. Other acidic soil materials observed at all 8 sites. Low net acidities dominant within wetland.
Acid sulfate soil identification:	• Other acidic soil present at all sites.
Hazard assessment	• Acidification hazard - low level of concern • Deoxygenation hazard - low level of concern • Metal mobilisation hazard – low level of concern

Table 8-2. Laboratory analytical data for acid sulfate soil assessment of Travellers Creek (Wetland ID 20132).
(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	coarse	6.72	5.01	5.83*	33.9	6.41	2.73	< 0.01	0.00	0.00	2.73	< 0.01	other soil materials
1.2	5-10	coarse	6.85	3.99	5.02*		6.14	3.17	< 0.01	0.00	0.00	3.17	< 0.01	other acidic
1.3	10-20	coarse	6.87	3.22	5.06*		5.60	9.93	< 0.01	0.00	0.00	9.93	< 0.01	other acidic
1.4	20-40	coarse	6.86	3.34	5.06*		5.61	6.10	< 0.01	0.00	0.00	6.10	< 0.01	other acidic
1.5	40-90	coarse	6.87	3.55	5.29*		5.73	4.59	< 0.01	0.00	0.00	4.59	< 0.01	other acidic
2.1	0-5	coarse	7.10	5.79	5.44*	33.0	6.21	3.01	< 0.01	0.00	0.00	3.01	< 0.01	other acidic
2.2	5-10	coarse	7.13	4.47	4.78*		5.64	6.35	< 0.01	0.00	0.00	6.35	< 0.01	other acidic
2.3	10-20	coarse	7.13	4.22	5.36*		5.72	5.07	< 0.01	0.00	0.00	5.07	< 0.01	other acidic
2.4	20-40	coarse	6.88	4.66	5.24*		6.06	3.30	< 0.01	0.00	0.00	3.30	< 0.01	other acidic
2.5	40-90	coarse	6.70	4.01	5.01*		5.61	5.10	< 0.01	0.00	0.00	5.10	< 0.01	other acidic
3.1	0-5	medium	6.40	2.78	5.93	26.3	5.12	10.99	< 0.01	0.00	0.00	10.99	< 0.01	other soil materials
3.2	5-10	medium	6.89	6.53	5.05		6.10	2.65	< 0.01	0.00	0.00	2.65	< 0.01	other acidic
3.3	10-20	medium	6.90	4.42	5.44*		5.47	4.58	< 0.01	0.00	0.00	4.58	< 0.01	other acidic
3.4	20-40	medium	6.03	4.41	5.36*		5.59	7.26	< 0.01	0.00	0.00	7.26	< 0.01	other acidic
3.5	40-90	medium	6.37	3.90	4.57*		5.79	4.75	< 0.01	0.00	0.00	4.75	< 0.01	other acidic
4.1	0-5	medium	6.40	4.24	5.16*	49.8	5.11	24.55	< 0.01	0.00	0.00	24.55	< 0.01	other acidic
4.2	5-10	medium	6.20	2.84	4.61*		5.16	18.96	< 0.01	0.00	0.00	18.96	< 0.01	other acidic
4.3	10-20	medium	5.07	2.69	4.48*		5.33	15.14	< 0.01	0.00	0.00	15.14	< 0.01	other acidic
4.4	20-40	fine	4.61	2.38	4.31*		4.67	56.84	< 0.01	0.00	0.00	56.84	< 0.01	other acidic
4.5	40-90	fine	4.52	2.77	4.42*		4.56	57.87	< 0.01	0.00	0.00	57.87	< 0.01	other acidic
5.1	0-5	medium	6.77	3.62	4.95*	39.0	5.68	5.55	< 0.01	0.00	0.00	5.55	< 0.01	other acidic
5.2	5-10	medium	6.79	4.10	4.76*		5.77	4.87	< 0.01	0.00	0.00	4.87	< 0.01	other acidic
5.3	10-20	medium	6.72	3.60	4.68*		5.48	8.30	< 0.01	0.00	0.00	8.30	< 0.01	other acidic
5.4	20-40	fine	6.55	4.31	4.53*		5.32	12.30	< 0.01	0.00	0.00	12.30	< 0.01	other acidic
5.5	40-90	fine	6.34	3.58	4.57*		5.04	29.46	< 0.01	0.00	0.00	29.46	< 0.01	other acidic
6.1	0-5	coarse	5.95	3.98	5.21*	44.9	6.17	2.91	< 0.01	0.00	0.00	2.91	< 0.01	other acidic
6.2	5-10	medium	6.03	3.86	4.72*		5.11	25.49	< 0.01	0.00	0.00	25.49	< 0.01	other acidic
6.3	10-20	medium	5.29	2.81	4.40*		5.18	20.73	< 0.01	0.00	0.00	20.73	< 0.01	other acidic
6.4	20-40	medium	6.15	3.49	4.29*		5.04	30.72	< 0.01	0.00	0.00	30.72	< 0.01	other acidic
6.5	40-90	medium	6.26	2.92	4.68*		5.00	31.24	< 0.01	0.00	0.00	31.24	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 10 weeks).

Table 8-2 (continued). Laboratory analytical data for acid sulfate soil assessment of Travellers Creek (Wetland ID 20132).
(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
7.1	0-5	coarse	6.26	6.26	5.17*	16.4	6.92	0.00	< 0.01	0.00	25.64	-3415.25	< 0.01	other acidic
7.2	5-10	coarse	6.79	4.16	5.35*		5.71	5.12	< 0.01	0.00	0.00	5.12	< 0.01	other acidic
7.3	10-20	coarse	6.49	3.15	5.07*		6.40	3.18	< 0.01	0.00	0.00	3.18	< 0.01	other acidic
8.1	0-5	medium	6.74	4.22	5.72*	42.8	6.05	3.17	< 0.01	0.00	0.00	3.17	< 0.01	other soil materials
8.2	5-10	coarse	6.28	3.19	5.03*		5.97	4.66	< 0.01	0.00	0.00	4.66	< 0.01	other acidic
8.3	10-20	coarse	5.51	3.59	5.22*		6.70	0.00	< 0.01	0.00	25.46	-3391.14	< 0.01	other soil materials

* Indicates that a stable pH has not yet been reached for this sample (after 10 weeks).

Table 8-3. Field hydrochemistry data for acid sulfate soil assessment of Travellers Creek (Wetland ID 20132).

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
*Lowland River**		*125-2200*	*85-110*		*6.5-8.0*			*6-50*		
*Freshwater Lakes**		*20-30*	*90-110*		*6.5-8.0*			*1-20*		
20132_1 (SW)	18.0	38.4		5.8	7.25	353		29.4	19	
20132_3 (PW)	21.0	344		3.73	6.26	175		960	248	
20132_5 (SW)	15.6	43.4		0.43	7.25	310.5		10	19	
20132_7 (SW)	16.1	43.4		9.06	7.65	300.9		7	16	

* 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 Travellers Creek (Wetland ID 20132).

Parameter	units	ANZECC Guidelines	Site 1 (SW)	Site 3 (PW)	Site 5 (SW)	Site 7 (SW)
depth	cm					
Na	mg l^{-1}		1.81	4.93	4.75	6.60
K	mg l^{-1}		1.24	4.26	1.44	1.88
Ca	mg l^{-1}		3.70	47.87	2.92	16.93
Mg	mg l^{-1}		0.59	27.84	1.45	2.18
Si	mg l^{-1}		0.12	4.86	0.57	0.51
Br	mg l^{-1}		0.02	0.106	0.035	0.048
Cl	mg l^{-1}		37	609	664	143
NO_3	mg l^{-1}	0.7	0.110	<0.005	0.084	0.047
NH_4-N	mg l^{-1}	0.01	0.011	1.573	0.014	0.008
PO_4-P[E]	mg l^{-1}	0.005	0.005	0.004	0.004	0.013
SO_4	mg l^{-1}		1.14	1.14	1.05	3.62
Ag	µg l^{-1}	0.05	<1	<1	<1	<1
Al[A]	µg l^{-1}	55	29	10	10	67
As[B]	µg l^{-1}	13	<1	2	1	1
Cd	µg l^{-1}	0.2	45	57	<1	103
Co	µg l^{-1}	2.8	<1	6	<1	<1
Cr[C]	µg l^{-1}	1	<1	1	1	1
Cu[H]	µg l^{-1}	1.4	<1	1	1	1
Fe	µg l^{-1}	300	79	40	24	147
Mn	µg l^{-1}	1700	15	26,797	62	26
Ni[H]	µg l^{-1}	11	1	5	<1	1
Pb[H]	µg l^{-1}	3.4	<1	<1	<1	1
Se	µg l^{-1}	11	<1	1	<1	<1
Zn[H]	µg l^{-1}	8	28	27	14	43
DOC	mg l^{-1}		1.64	3.89	1.43	0.81

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 NH_4 and PO_4, 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 Travellers Creek (Wetland ID 20132).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-40	subaqueous		Main channel	lowest part of transect across channel/bar/bank	Other acidic	Strong flow, acting as anabranch of the Murray
2	20	bare, soft	bare	Bar adjacent channel	part of transect across channel/bar/bank	Other acidic	
3	50	bare, soft	bare	Broad crest of bar	part of transect across channel/bar/bank	Other acidic	
4	45	bare, soft	bare	Base of streambank	part of transect across channel/bar/bank	Other acidic	
5	-50	subaqueous		Main channel	channel/bank transect, steep banks absent	Other acidic	
6		bare, soft	bare	Channel fringe	channel/bank transect, steep banks absent	Other acidic	
7	-75	subaqueous		Main channel	channel/bank transect	Other acidic	
8		bare, soft	bare	Low point on channel fringe	channel/bank transect	Other acidic	

Table 8-6. Profile description data for acid sulfate soil assessment of Travellers Creek (Wetland ID 20132).

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 3/2	CS		W					MA	0		6.76	unripe
1.2	5-10	2.5Y 3/2	CS		W					MA	0		6.93	unripe
1.3	10-20	2.5Y 3/1	CS		W					MA	0		6.84	unripe
1.4	20-40	2.5Y 3/1	CS		W					MA	0		6.93	unripe
1.5	40-90	2.5Y 4/1	CS		W					MA	0		6.79	unripe
2.1	0-5	2.5Y 5/2	S		W					SG	0		6.97	
2.2	5-10	2.5Y 4/1	S		W					SG	0		6.76	
2.3	10-20	2.5Y 4/2	S		W					SG	0		6.68	
2.4	20-40	2.5Y 4/2	S		W					SG	0		6.74	
2.5	40-90	2.5Y 4/1	S		W					SG	0		6.55	
3.1	0-5	2.5Y 4/2	ZL		W					MA	0		6.53	
3.2	5-10	2.5Y 4/1	ZL		W	2	FM			MA	0		6.54	
3.3	10-20	10YR 4/1	ZL		W	2	FM			MA	0		6.46	
3.4	20-40	2.5Y 4/3	ZL		W	1	FM			MA	0		6.70	
3.5	40-90	2.5Y 4/2	ZL		W	1	FM			MA	0		6.64	
4.1	0-5	2.5Y 4/2	ZL		W	1	FM			MA	0		6.52	some dark organic accumulations
4.2	5-10	2.5Y 4/2	ZC	light	W	2	FM			MA	0		6.20	
4.3	10-20	2.5Y 4/2	ZC	light	W	2	FM			MA	0		5.92	
4.4	20-40	10YR 5/1	C	light medium	W	3	FM			MA	0		5.45	
4.5	40-90	10YR 4/1	C	medium	W	3	FM			MA	0		6.28	mottles on roots channels and ped faces; charcoal

Table 8-6 (continued). Profile description data for acid sulfate soil assessment of Travellers Creek (Wetland ID 20132).

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	2.5Y 3/2	ZL		W					MA	0		6.49	
5.2	5-10	2.5Y 3/1	ZL		W					MA	0		6.63	
5.3	10-20	2.5Y 4/1	ZL		W					MA	0		6.70	
5.4	20-40	2.5Y 3/1	ZC		W					MA	0		6.73	
5.5	40-90	2.5Y 4/1	ZC		W					MA	0		6.79	
6.1	0-5	10YR 5/3	S		T					SG	0		6.12	
6.2	5-10	2.5Y 4/1	ZL		M	20	FM			MA	0		6.72	
6.3	10-20	2.5Y 4/1	ZCL		M					MA	0		6.81	
6.4	20-40	2.5Y 4/1	ZCL		M					MA	0		6.76	
6.5	40-90	2.5Y 4/1	ZC	light	M					MA	0		6.64	
7.1	0-5	n/r	S		W					SG	0		6.77	very gravelly
7.2	5-10	n/r	S		W					SG	0		6.85	very gravelly
7.3	10-20	n/r	S		W					SG	0		6.73	very gravelly; auger refusal
8.1	0-5	10YR 4/2	ZL		T					MA	0		6.80	few gravels
8.2	5-10	10YR 4/2	S		T					SG	0		6.52	extremely gravelly
8.3	10-20	10YR 5/4	S		T					SG	0		6.53	extremely gravelly; auger refusal

8.2. Croppers Lagoon (Wetland ID 21928)

8.2.1. Location and setting description

Croppers Lagoon wetland is situated on the northern side of the River Murray, down river from Corowa Township. The wetland is an irregular crescent-shape (Figure 8-13), over 3 km in length parallel to the river and approximately 400 m at the widest point, with a total area of 63 ha. The wetland is bounded by floodplain terrace along its northern perimeter and low elevation floodplain incised with drainage depression on the southern perimeter and across to the levee bank of the River Murray. At the western edge there is a natural water connection channel to the river, also observed were man-made drainage/stormwater channels that appear to have been constructed to divert surface water to the wetland from surrounding higher elevations. At the time when the soil survey was conducted in May 2010, the wetland had surface water in the centre, which was probably more related to recent rainfall rather than inflow from the river. There were large areas of vegetated surfaces surrounding on the wetland margins at a slightly higher elevation where Water Primrose *(Ludwigia peploides subsp. montevidensis)*, Knotweed (*Persicaria sp*.), sapling trees *(Eucalyptus spp.)* and *Juncus spp.* were growing on low elevations, and River Red Gum *(Eucalyptus camaldulensis)* on the raised bank/floodplain that separated the wetland and floodplain. Eight sites were sampled as shown in Table 8-16.

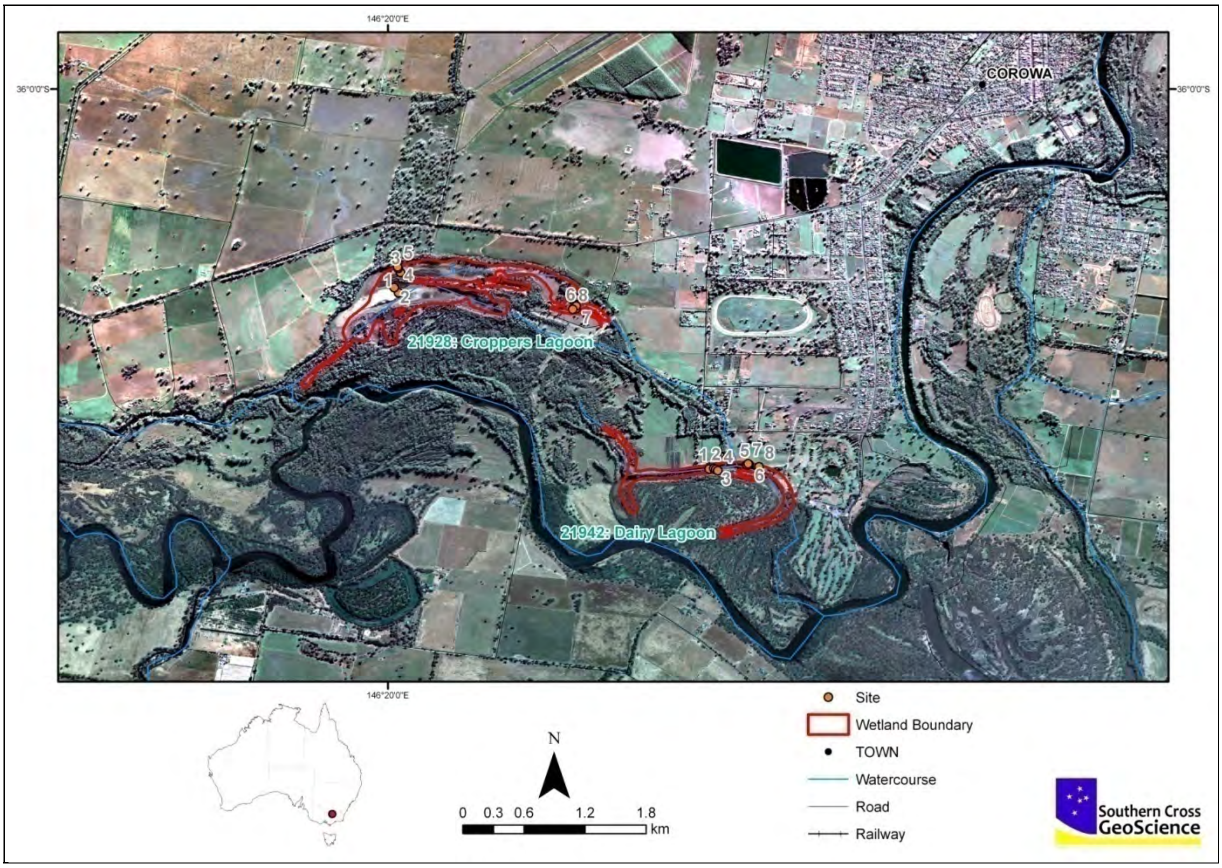

Figure 8-13. Croppers Lagoon and sample site locations.

8.2.2. Soil profile description and distribution

Eight sites were described and sampled. The soil subtype and general location description are presented in Table 8-7. Sites were distributed throughout the wetland based on different surface features and locations in the wetland, a transect approach was used.

The profile 21928_1 (Figure 8-15) occurred within a water body in the centre of the wetland, the soil consisted of soft dark grey clay. The profile 21928_2 (Figure 8-16) occurred within the vegetated surface on the water body margin, the soil consisted of soft grey brown clay. The profile 21928_3 (Figure 8-17) occurred amongst Juncus and Knotweed on a wet surface slightly elevated from the water body; the soil consisted of firm grey brown clay. The profile 21928_4 (Figure 8-18) occurred on a wet surface slightly elevated from the water body below the terrace bank, the soil consisted of a soft grey clay. The profile 21928_5 (Figure 8-19) occurred on a grassed surface on the edge of the northern bank, the soil consisted of grey brown sandy loam to grey clay. The profile 21928_6 (Figure 8-20) occurred on a low elevation, level grassed surface, the soil consisted of grey clay. The profile 21928_7 (Figure 8-21) occurred on a low elevation, level grassed surface, the soil consisted of grey clay. The profile 21928_8 (Figure 8-22) occurred on a low elevation, level grassed surface, the soil consisted of grey 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 Croppers Lagoon.

Site ID	Easting UTM zone 55H	Northing UTM zone 55H	Acid sulfate soil subtype class	General location description
21928_1	440012	6013851	subaqueous soil	low elevation, submerged clay soil area
21928_2	439977	6013901	hydrosol	low elevation, vegetated clay soil area
21928_3	440026	6014051	hydrosol	low elevation, vegetated clay soil area
21928_4	440007	6014089	hydrosol	low elevation, vegetated wet clay soil area
21928_5	440003	6014105	hydrosol	high elevation, on upper northern bank clay soil area
21928_6	441426	6013706	hydrosol	low elevation, grassed clay soil area
21928_7	441427	6013730	hydrosol	low elevation, grassed clay soil area
21928_8	441399	6013698	hydrosol	low elevation, grassed clay soil area

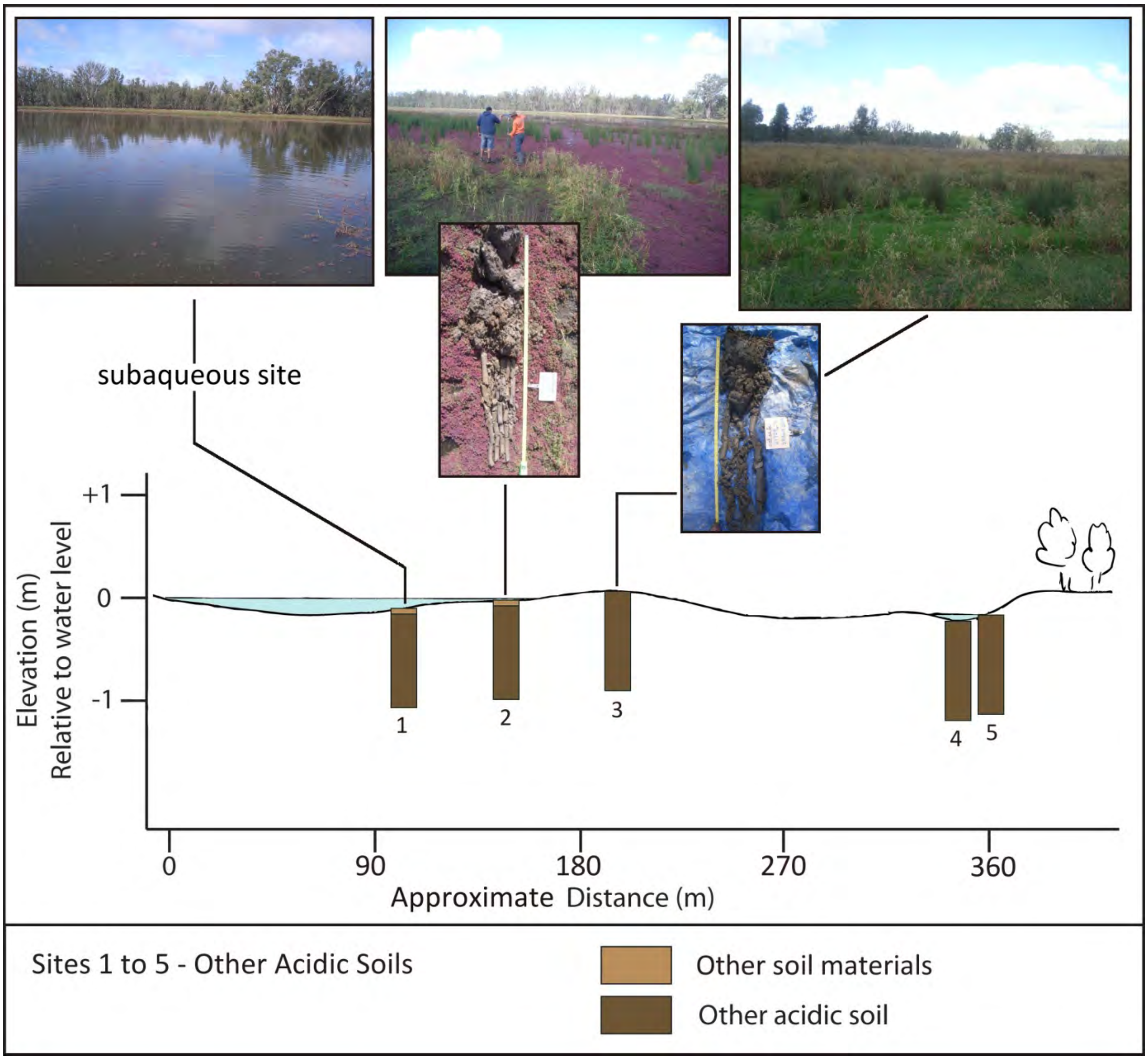

Figure 8-14. Conceptual cross section diagram showing the toposequence relationship of the Croppers Lagoon sediments/soil materials at sites 21928_1 to 21928_5.

Figure 8-15. Photographs of site 21928_1, showing the subaqueous site and the soil core.

Figure 8-16. Photographs of site 21928_2, showing the location of the site in a vegetated area adjacent to the water body, and the soil core.

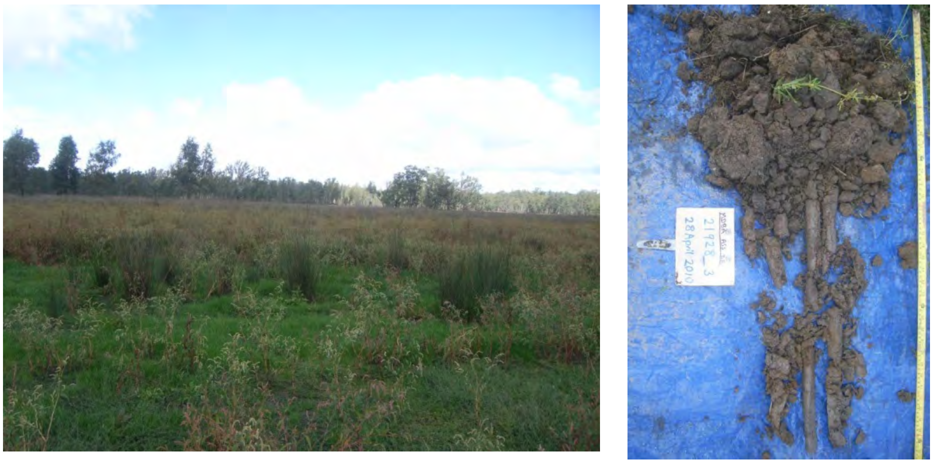

Figure 8-17. Photographs of site 21928_3, showing the sedgeland at the sampling site, and the soil core.

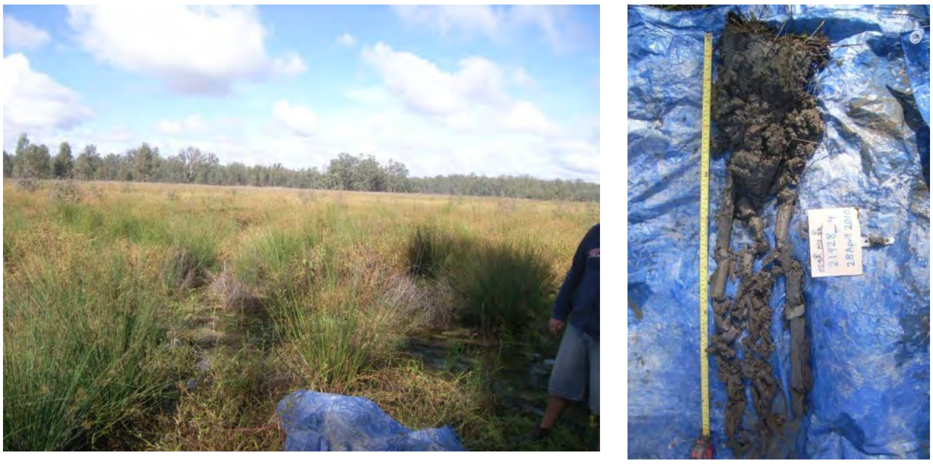

Figure 8-18. Photographs of site 21928_4, showing the grassland at the sampling site, and the soil core.

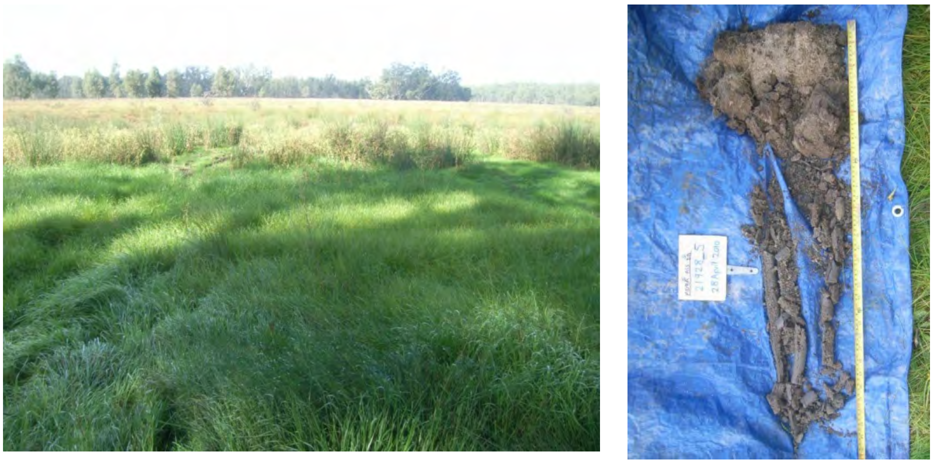

Figure 8-19. Photographs of site 21928_5, showing the slightly elevated grassland at the sampling site, and the soil core.

Figure 8-20. Photographs of site 21928_6, showing the upper slope site and the soil core.

Figure 8-21. Photographs of site 21928_7, showing the midslope site and the soil core.

Figure 8-22. Photographs of site 21928_8, showing the lower slope site and the soil core.

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 Figures 8-23 and 8-24. The pH_W values ranged between 4.51 and 6.63. Sulfuric materials (i.e. $pH_W < 4$) were not present. The pH_{FOX} values ranged between 1.73 and 4.56. The pH_{FOX} results indicate that 33 of the 40 surface soils examined may have the potential to acidify to pH < 4 as a result of sulfide oxidation. However, the S_{CR} data shows these layers contained no detectable sulfide (i.e. S_{CR} < 0.01% S). Ten soil materials had a pH_{FOX} < 2.5. Other acidic soil materials were identified at all eight sites, 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.

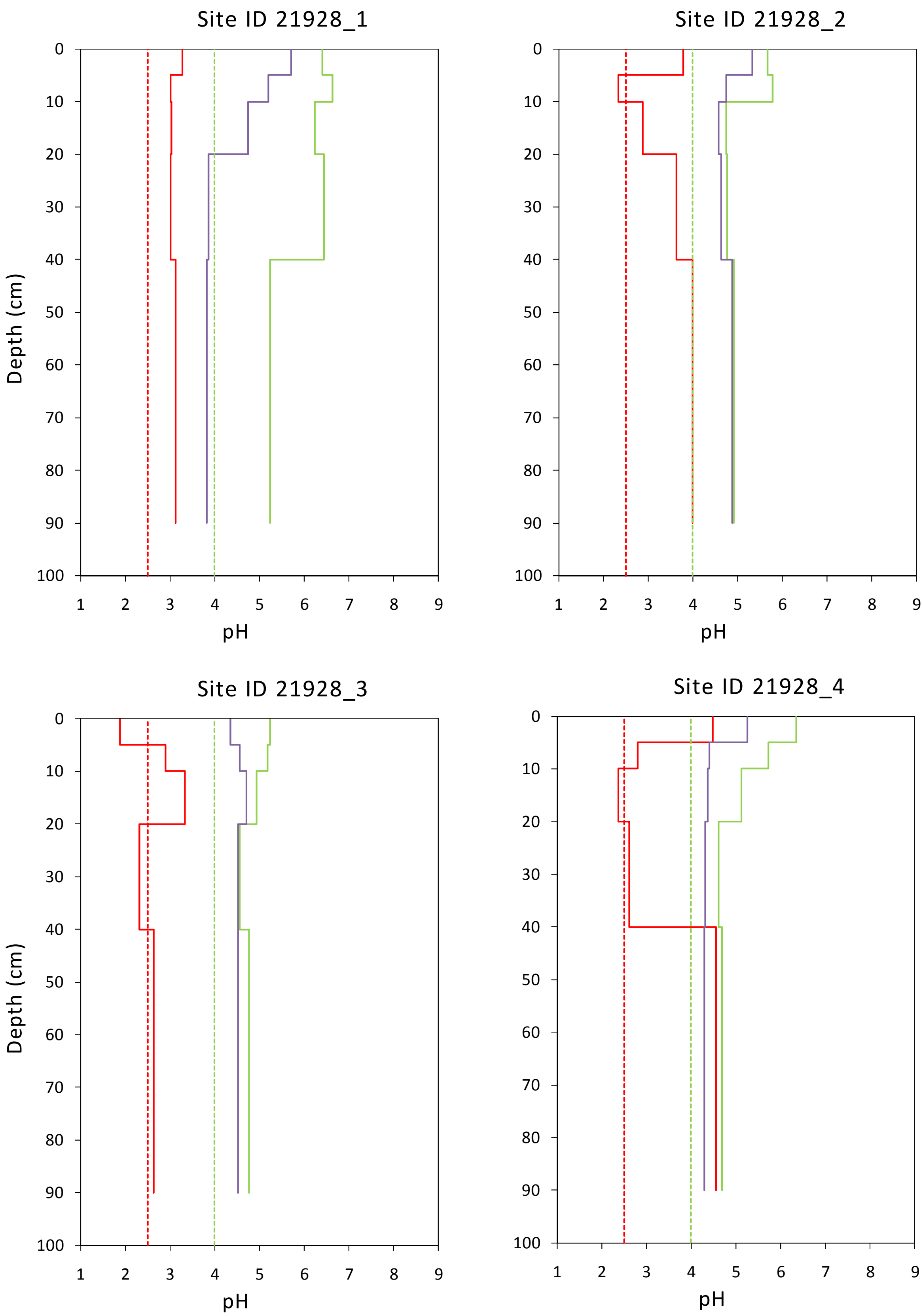

Figure 8-23. Depth profiles of soil pH for Croppers Lagoon (21928_1 – 21928_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

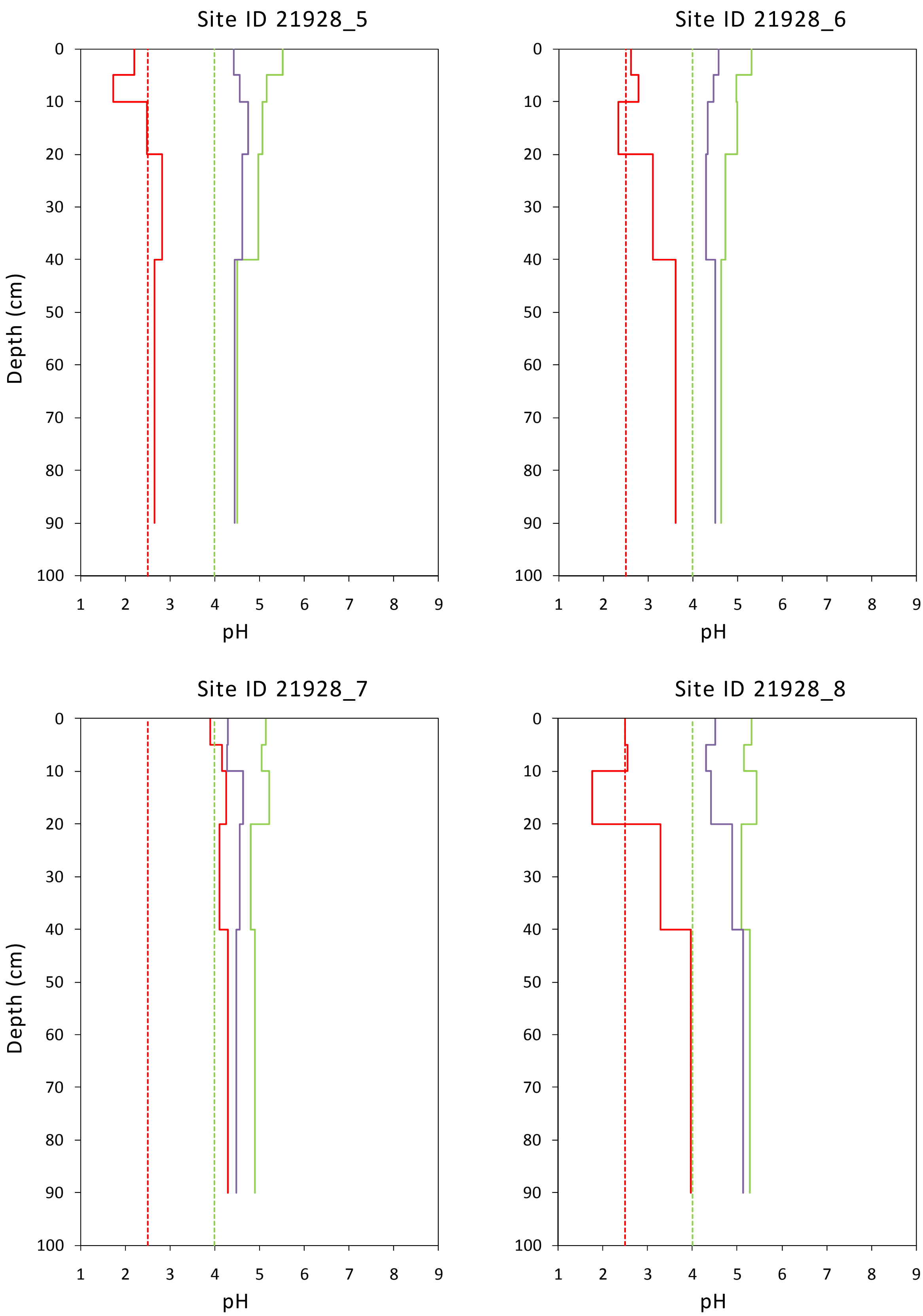

Figure 8-24. Depth profiles of soil pH for Croppers Lagoon (21928_5 – 21928_8), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) 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 Figures 8-25 and 8-26.

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 4 and 80 mole H^+/tonne. An increase in the TAA with depth was often observed.

Retained acidity

The retained acidity ranged between zero and 6 mole H^+/tonne, with all except two materials having no retained acidity.

Net acidity

Net acidity ranged between 4 and 86 mole H^+/tonne. An increase in net acidity with depth was often observed.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 39 and 299 mg/kg. Five of the eight 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 8-9 and 8-10, respectively. The field pH of the surface waters collected was 7.0. The water data indicates that the surface water has not been affected by acidification. The surface water sulfate concentration was 7.3 mg/L. Some nutrient (i.e. NH_4, PO_4) and metal (i.e. Al, Cd, Cr, Cu, Fe, Zn) values were found to exceed the most relevant ANZECC/ARMCANZ (2000) guideline value. The field pH of the groundwater ranged between 5.6 and 5.7. The groundwater had a sulfate concentration of 28.3 mg/L.

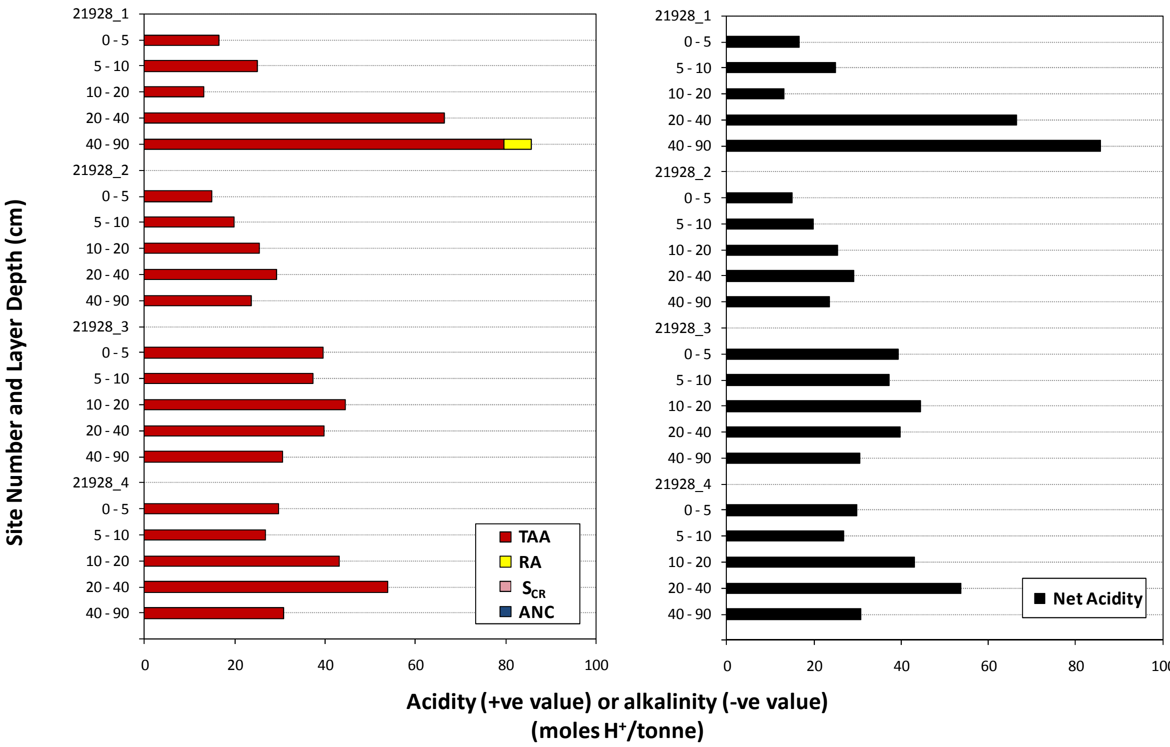

Figure 8-25. Acid-base accounting depth profiles for Croppers Lagoon (21928_1 – 21928_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

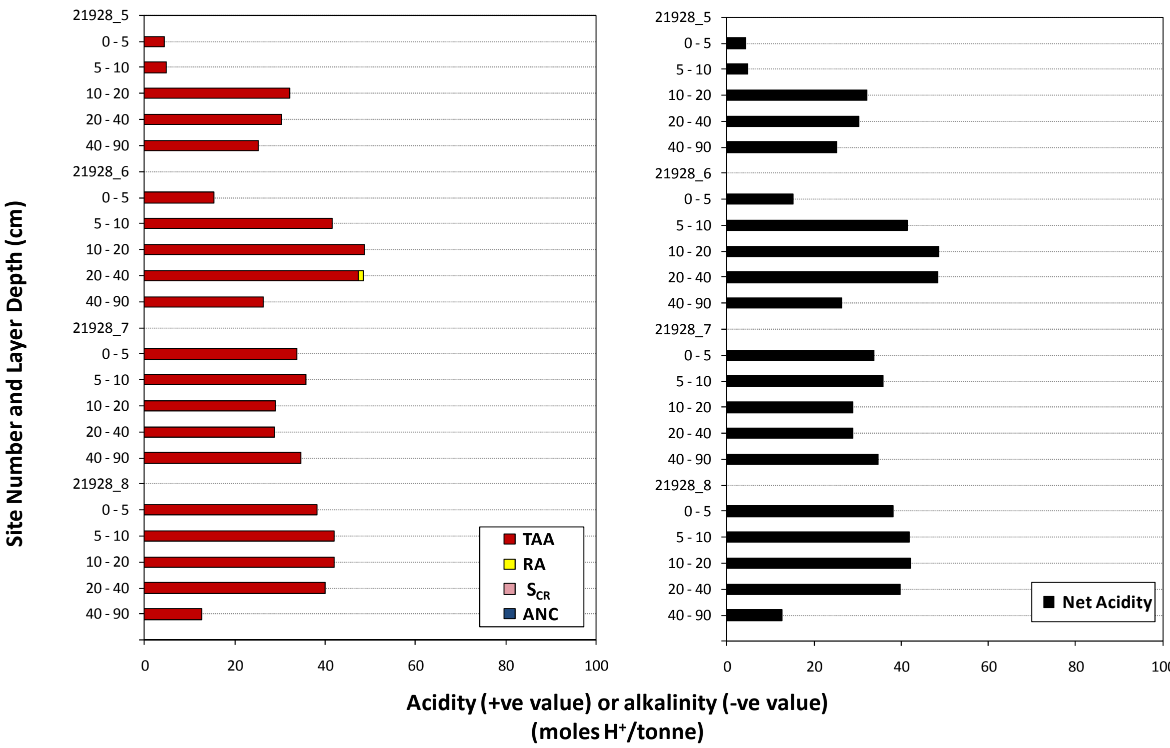

Figure 8-26. Acid-base accounting depth profiles for Croppers Lagoon (21928_5 – 21928_8). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.2.4. Discussion

Acid sulfate soils materials were not found at Croppers Lagoon. Soil materials were largely classified as other acidic soils. Other soil materials were also present in two soil materials.

A total of five 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, five 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 Croppers Lagoon wetland 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 surface soil materials at five 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 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 Croppers Lagoon:

Soil materials:	Sulfuric and sulfidic materials were not observed within this wetland. Other acidic soil materials observed at all 8 sites. Moderate net acidities dominant within wetland.
Acid sulfate soil identification:	• Other acid soils present at all sites.
Hazard assessment	• 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 Croppers Lagoon (Wetland ID 21928).
(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	fine	6.41	3.28	5.71	125	5.50	16.52	< 0.01	0	0.00	16.52	< 0.01	other soil materials
1.2	5-10	fine	6.63	3.01	5.19		5.21	25.07	< 0.01	0	0.00	25.07	< 0.01	other acidic
1.3	10-20	fine	6.24	3.03	4.74		5.93	13.18	< 0.01	0	0.00	13.18	< 0.01	other acidic
1.4	20-40	medium	6.44	3.01	3.86*		4.54	66.39	< 0.01	0	0.00	66.39	< 0.01	other acidic
1.5	40-90	medium	5.24	3.12	3.82		4.47	79.69	< 0.01	6	0.00	85.69	< 0.01	other acidic
2.1	0-5	medium	5.67	3.79	5.34	65.1	5.40	14.91	< 0.01	0	0.00	14.91	< 0.01	other soil materials
2.2	5-10	medium	5.78	2.34	4.74		5.23	19.89	< 0.01	0	0.00	19.89	< 0.01	other acidic
2.3	10-20	fine	4.74	2.89	4.58		4.92	25.40	< 0.01	0	0.00	25.40	< 0.01	other acidic
2.4	20-40	fine	4.77	3.64	4.64		4.73	29.26	< 0.01	0	0.00	29.26	< 0.01	other acidic
2.5	40-90	fine	4.91	4.00	4.88		4.85	23.66	< 0.01	0	0.00	23.66	< 0.01	other acidic
3.1	0-5	medium	5.24	1.88	4.35*	116	4.91	39.43	< 0.01	0	0.00	39.43	< 0.01	other acidic
3.2	5-10	medium	5.18	2.90	4.56		4.83	37.18	< 0.01	0	0.00	37.18	< 0.01	other acidic
3.3	10-20	fine	4.94	3.33	4.70		4.67	44.51	< 0.01	0	0.00	44.51	< 0.01	other acidic
3.4	20-40	fine	4.55	2.32	4.52		4.59	39.80	< 0.01	0	0.00	39.80	< 0.01	other acidic
3.5	40-90	fine	4.77	2.63	4.52		4.70	30.48	< 0.01	0	0.00	30.48	< 0.01	other acidic
4.1	0-5	medium	6.35	4.48	5.25	100	5.04	29.77	< 0.01	0	0.00	29.77	< 0.01	other acidic
4.2	5-10	medium	5.73	2.80	4.40		5.10	26.80	< 0.01	0	0.00	26.80	< 0.01	other acidic
4.3	10-20	fine	5.13	2.38	4.37		4.76	43.13	< 0.01	0	0.00	43.13	< 0.01	other acidic
4.4	20-40	fine	4.61	2.62	4.32		4.62	53.78	< 0.01	0	0.00	53.78	< 0.01	other acidic
4.5	40-90	fine	4.68	4.56	4.29		4.76	30.70	< 0.01	0	0.00	30.70	< 0.01	other acidic
5.1	0-5	coarse	5.51	2.20	4.42*	39.0	5.80	4.29	< 0.01	0	0.00	4.29	< 0.01	other acidic
5.2	5-10	coarse	5.16	1.73	4.55		5.31	4.87	< 0.01	0	0.00	4.87	< 0.01	other acidic
5.3	10-20	medium	5.06	2.48	4.74		4.93	32.12	< 0.01	0	0.00	32.12	< 0.01	other acidic
5.4	20-40	medium	4.98	2.83	4.61		4.89	30.28	< 0.01	0	0.00	30.28	< 0.01	other acidic
5.5	40-90	fine	4.51	2.66	4.45		4.85	25.16	< 0.01	0	0.00	25.16	< 0.01	other acidic
6.1	0-5	medium	5.31	2.62	4.58	299	5.37	15.25	< 0.01	0	0.00	15.25	< 0.01	other acidic
6.2	5-10	medium	4.98	2.78	4.46		4.67	41.53	< 0.01	0	0.00	41.53	< 0.01	other acidic
6.3	10-20	fine	4.99	2.34	4.34		4.60	48.72	< 0.01	0	0.00	48.72	< 0.01	other acidic
6.4	20-40	fine	4.72	3.10	4.29		4.38	47.46	< 0.01	1	0.00	48.46	< 0.01	other acidic
6.5	40-90	fine	4.63	3.62	4.50		4.72	26.42	< 0.01	0	0.00	26.42	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 11 weeks).

Table 8-8 (continued). Laboratory analytical data for acid sulfate soil assessment of Croppers Lagoon (Wetland ID 21928).
(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
7.1	0-5	medium	5.15	3.90	4.30	195	4.88	33.81	< 0.01	0	0.00	33.81	< 0.01	other acidic
7.2	5-10	medium	5.04	4.16	4.27		4.78	35.82	< 0.01	0	0.00	35.82	< 0.01	other acidic
7.3	10-20	fine	5.22	4.25	4.63		4.86	29.00	< 0.01	0	0.00	29.00	< 0.01	other acidic
7.4	20-40	fine	4.80	4.10	4.56		4.80	28.87	< 0.01	0	0.00	28.87	< 0.01	other acidic
7.5	40-90	fine	4.90	4.29	4.48		4.57	34.63	< 0.01	0	0.00	34.63	< 0.01	other acidic
8.1	0-5	medium	5.33	2.49	4.51	94.4	4.68	38.18	< 0.01	0	0.00	38.18	< 0.01	other acidic
8.2	5-10	medium	5.16	2.55	4.31		4.78	41.99	< 0.01	0	0.00	41.99	< 0.01	other acidic
8.3	10-20	fine	5.43	1.77	4.42		4.33	42.10	< 0.01	0	0.00	42.10	< 0.01	other acidic
8.4	20-40	fine	5.09	3.29	4.89		4.49	39.87	< 0.01	0	0.00	39.87	< 0.01	other acidic
8.5	40-90	fine	5.28	3.96	5.14		4.96	12.76	< 0.01	0	0.00	12.76	< 0.01	other acidic

Table 8-9. Field hydrochemistry data for acid sulfate soil assessment of Croppers Lagoon (Wetland ID 21928).

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
*Lowland River**		*125-2200*	*85-110*		*6.5-8.0*			*6-50*		
*Freshwater Lakes**		*20-30*	*90-110*		*6.5-8.0*			*1-20*		
21928_1 (SW)	16.4	142.4	85.2	7.78	6.96	344.8		18	56	Lots of aquatic life (bugs, tortoises)
21928_2 (PW)	17.6	112.2	28.1	2.69	5.60	398.2			24	Too muddy to get turbidity reading
21928_4 (PW)	15.9	294	4.0	0.40	5.68	271.4				No sample collected - too muddy

* 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 Croppers Lagoon (Wetland ID 21928).

Parameter	units	ANZECC Guidelines	Site 1 (SW)	Site 2 (PW)
depth	cm			
Na	mg l^{-1}		15.79	10.29
K	mg l^{-1}		3.16	1.10
Ca	mg l^{-1}		13.03	22.20
Mg	mg l^{-1}		5.85	3.60
Si	mg l^{-1}		0.22	0.46
Br	mg l^{-1}		0.103	0.032
Cl	mg l^{-1}		103	331
NO_3	mg l^{-1}	0.7	0.042	0.005
NH_4-N	mg l^{-1}	0.01	0.237	0.213
PO_4-P[E]	mg l^{-1}	0.005	0.032	0.014
SO_4	mg l^{-1}		7.30	28.29
Ag	µg l^{-1}	0.05	<1	<1
Al[A]	µg l^{-1}	55	58	86
As[B]	µg l^{-1}	13	2	1
Cd	µg l^{-1}	0.2	47	127
Co	µg l^{-1}	2.8	1	2
Cr[C]	µg l^{-1}	1	2	1
Cu[H]	µg l^{-1}	1.4	3	4
Fe	µg l^{-1}	300	659	110
Mn	µg l^{-1}	1700	236	173
Ni[H]	µg l^{-1}	11	5	4
Pb[H]	µg l^{-1}	3.4	1	2
Se	µg l^{-1}	11	<1	<1
Zn[H]	µg l^{-1}	8	55	59
DOC	mg l^{-1}		19.44	11.87

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 NH_4 and PO_4, 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 Croppers Lagoon (Wetland ID 21928).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-35	Underwater; firm cracked clay surface below water	water	Low, sample taken from within water body in main part of the wetland	Main water body in wetland	other acidic	very firm underfoot, not much muddy material
2	30	Shallow water and water weed sitting on ground surface	common	Low, sample taken at edge of current water body	close to margin between current water body vegetation and more established vegetation	other acidic	abundant water weed present on surface
3		damp surface, vegetated with mainly weeds	common	Mid slope, on small rise with in wetland between main water body and old flood runner	high point within main part of the wetland	other acidic	
4	10	wet and boggy surface with vegetation cover	water/common	Low, sample taken in old flood runner	additional flow path through wetland in floods	other acidic	
5		densely vegetated sandy surface	common	upper slope, edge of wetland boundary, adjacent to bank	characterise conditions at the edge of the wetland	other acidic	
6		damp vegetated surface, depressions from cattle hooves	common	Low, eastern end of wetland upstream of dam and constriction	low point in this part of the wetland, above influence from dam downslope	other acidic	Actively farmed, evidence of cropping in the past
7		damp vegetated surface, depressions from cattle hooves	common	Mid-slope, eastern end of wetland upstream of dam and constriction, at edge of wetland	characterise conditions at edge of wetland in this part of the wetland, above influence from dam downslope	other acidic	Actively farmed, evidence of cropping in the past
8		damp vegetated surface, depressions from cattle hooves	common	Low, eastern end of wetland upstream of dam and constriction	low point in this part of the wetland, above influence from dam downslope, but closer to constriction point	other acidic	Actively farmed, evidence of cropping in the past

Table 8-12. Profile description data for acid sulfate soil assessment of Croppers Lagoon (Wetland ID 21928).

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 3/1	C	light-medium	W	2	FM			SB	1	mod-firm	6.58	
1.2	5-10	2.5Y3/1	C	light-medium	W	2	FM			SB	1	mod-firm	6.67	
1.3	10-20	2.5Y 4/1	C	light-medium	W	1	FM			SB	2	mod-weak	6.62	
1.4	20-40	10Y 3/1	ZC	light	W	1	FM			SB	2	mod-weak	6.54	
1.5	40-90	2.5Y 3/2	ZC	light	W	2	FM			SB	2	mod-firm	6.05	
2.1	0-5	2.5Y 3/1	SCL		W					PO	1	very weak	5.82	
2.2	5-10	2.5Y3/2	SCL		W	1	FM			PO	1	very weak	6.33	quartz fragments
2.3	10-20	2.5Y 3/2	SC	medium	W	2	FM			SB	2	mod weak	6.35	quartz fragments
2.4	20-40	2.5Y 3/3	C	medium	W	3	FM			SB	2	mod firm	6.21	quartz fragments
2.5	40-90	2.5Y 3/3	C	medium	W	3	FM			SB	1	mod firm	6.06	quartz fragments
3.1	0-5	10YR 3/1	C	light	T					SB	3	mod weak	5.58	shells
3.2	5-10	10YR 3/1	C	light	T					SB	3	mod weak	5.61	shells
3.3	10-20	10YR 3/1	C	medium	T	1	FM			SB	3	mod firm	5.37	
3.4	20-40	10YR 3/1	C	medium	T	1	FM			SB	3	mod firm	5.06	
3.5	40-90	10YR 3/1	C	medium	M	1	FM			SB	3	mod firm	5.19	
4.1	0-5	10YR 3/2	ZC	light	W	1	FM			SB	3	very weak	6.57	
4.2	5-10	10YR 3/2	ZC	light	W	1	FM			SB	3	mod weak	6.62	
4.3	10-20	10YR 3/2	C	medium	W	1	FM			SB	3	mod weak	6.31	
4.4	20-40	10YR 3/2	C	medium	W	1	FM			SB	3	mod weak	5.34	
4.5	40-90	10YR 3/2	C	medium	W	1	FM			SB	3	mod weak	5.17	

Table 8-12 (continued). Profile description data for acid sulfate soil assessment of Croppers Lagoon (Wetland ID 21928).

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 3/2	LS		T					SG	0	loose	5.86	quartz fragments
5.2	5-10	10YR 3/2	LS		T					SG	0	loose	5.70	quartz fragments
5.3	10-20	10YR 3/1	C	light-medium	M	1	FM			SB	3	mod firm	5.57	
5.4	20-40	10YR 3/1	C	light-medium	M	1	FM			SB	3	mod firm	5.49	
5.5	40-90	10YR 4/2	C	medium	M	1	FM			SB	3	mod firm	5.16	ferromanganiferous nodules
6.1	0-5	10YR 3/2	C	light	M					SB	3	very weak	5.89	
6.2	5-10	10YR 3/2	C	light	M					SB	3	very weak	5.37	
6.3	10-20	10YR 4/2	C	medium	M	1	FM			SB	3	mod weak	5.29	charcoal
6.4	20-40	10YR 4/2	C	medium	M	1	FM			SB	3	mod weak	5.50	charcoal
6.5	40-90	10YR 4/2	C	medium	M	1	FM			SB	3	mod weak	5.79	charcoal
7.1	0-5	10YR 3/2	C	light	T					SB	3	mod weak	5.89	
7.2	5-10	10YR 3/2	C	light	T					SB	3	mod weak	5.73	
7.3	10-20	10YR 4/2	C	medium	T	1	FM			SB	3	mod firm	5.82	charcoal
7.4	20-40	10YR 4/2	C	medium	T	1	FM			SB	3	mod firm	5.79	charcoal
7.5	40-90	10YR 4/2	C	medium	T	1	FM			SB	3	mod firm	5.99	charcoal, quartz fragments
8.1	0-5	10YR 3/2	C	light	M					SB	3	very weak	5.55	
8.2	5-10	10YR 3/2	C	light	M					SB	3	very weak	5.43	
8.3	10-20	10YR 4/2	C	light-medium	M	1	FM			SB	3	mod weak	5.41	charcoal
8.4	20-40	10YR 4/2	C	medium	M	1	FM			SB	3	mod weak	6.04	charcoal
8.5	40-90	2.5Y 4/1	C	medium	M	1	FM			SB	3	mod firm	6.69	charcoal

8.3. Dairy Lagoon (Wetland ID 21942)

8.3.1. Location and setting description

Dairy Lagoon is a horseshoe-shaped body with a northerly extension on the western side (Figure 8-27). It abuts the southwest side of Corowa and is about 5 km in length, about 200 m wide and 21 ha. The wetland occurs on the north side of the Murray River and is the outermost scroll of a system of meander scrolls in this location. Part of the wetland includes a section of an adjoining scroll that forms an elevated surface. At the time of the soil survey in May 2010 the wetland was dry (at least in the areas visited). The surface was prominently cracked and groundwater was visible within the cracks at about 30 cm depth. Red gum sucker communities were present throughout the channel and on the fringing surfaces.

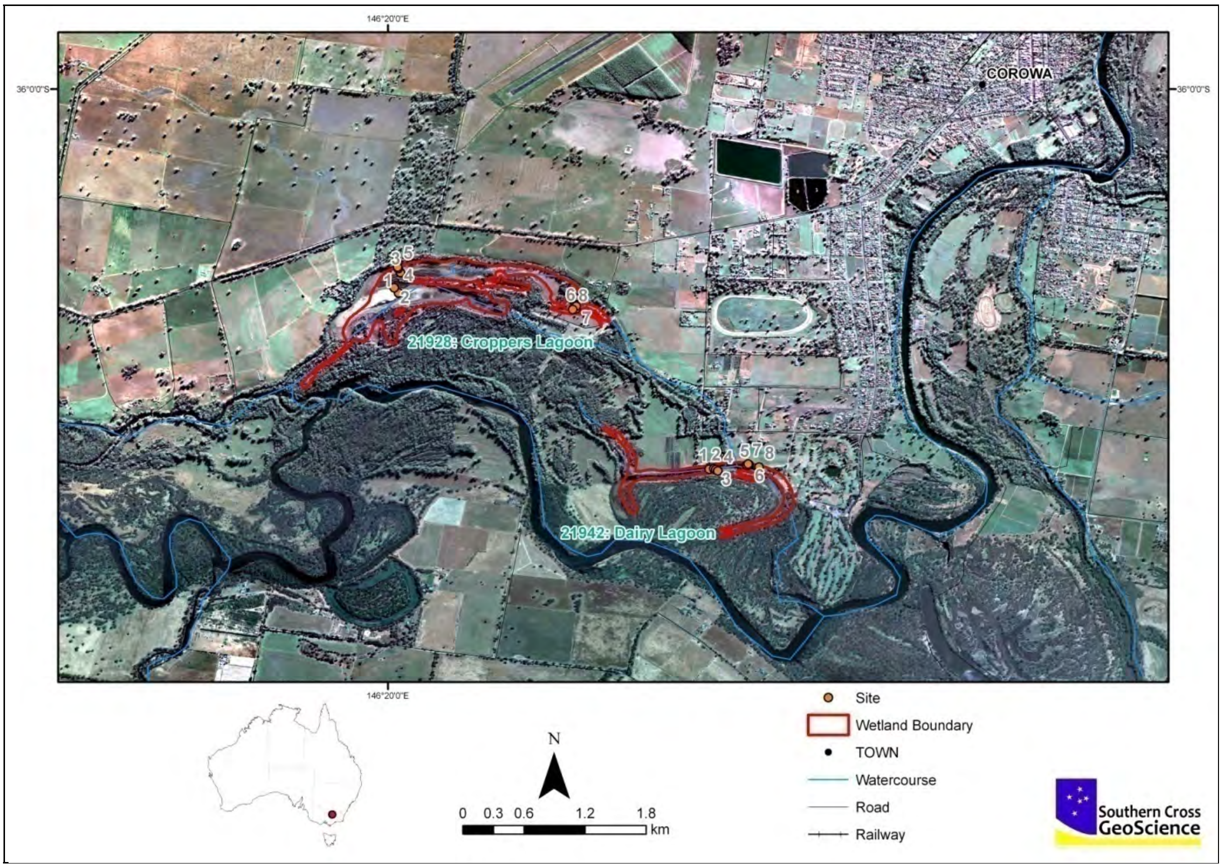

Figure 8-27. Dairy Lagoon and sample site locations.

8.3.2. Soil profile description and distribution

Eight sites were sampled within 2 transects, 4 sites within each transect. Sites were distributed across the wetland based on elevation and surface features. A transect approach was used, 2 transects being completed (Profiles 1, 2, 3 and 4; Profiles 5, 6, 7 and 8). The soil subtype and general location description are presented in Table 8-13.

The profile 21942_1 (Figure 8-29) occurred within the lowest part of the cracked channel surface, the soil consisted of dark grey mottled clay over wet grey sand. The profile 21942_2 (Figure 8-30) occurred on the slightly more elevated dry cracked channel surface, the soil consisted of dark grey mottled light medium clay over dark grey sand. The profile 21942_3 (Figure 8-31) occurred on the elevated fringing sedgeland, the soil consisted of dark sandy clay loam topsoil over dark grey mottled light medium silty clay; gravelly dark grey loamy sand was present at depth. The profile 21942_4 (Figure 8-32) occurred within an elevated meander scroll surface, the soil consisted of dark loamy sand over grey mottled and tough light medium silty clay. The profile 21942_5 (Figure 8-33) occurred within the lowest part of the cracked channel section, the soil consisted of dark clay loam over grey mottled medium clay; sandy loam sedimentary layer occurred at 50 cm. The profile 21942_6 occurred on the dry cracked channel surface, the soil consisted of grey mottled clay to 60 cm over gravelly loamy sand to 76 cm over silty clay (Figure 8-34). The profile 21942_7 (Figure 8-35) occurred on the margin of the wetland vegetation, the soil consisted of grey mottled clayey sand over sandy clay loam. The profile 21942_8 (Figure 8-36) consisted of clay loam over very gravelly loamy sand. 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 Dairy Lagoon.

Site ID	Easting UTM zone 55H	Northing UTM zone 55H	Acid sulfate soil subtype class	General location description
21942_1	442495	6012142	hypersulfidic cracking clay	cracked channel surface
21942_2	442533	6012148	hypersulfidic cracking clay	slightly elevated cracked channel
21942_3	442548	6012140	hydrosol	elevated fringing sedgeland
21942_4	442564	6012127	hydrosol	elevated meander scroll surface
21942_5	442795	6012186	cracking clay soil	lowest part of the cracked channel section
21942_6	442812	6012188	hypersulfidic cracking clay	cracked channel surface
21942_7	442805	6012196	hydrosol	margin of the wetland vegetation
21942_8	442892	6012165	cracking clay soil	cracked channel surface

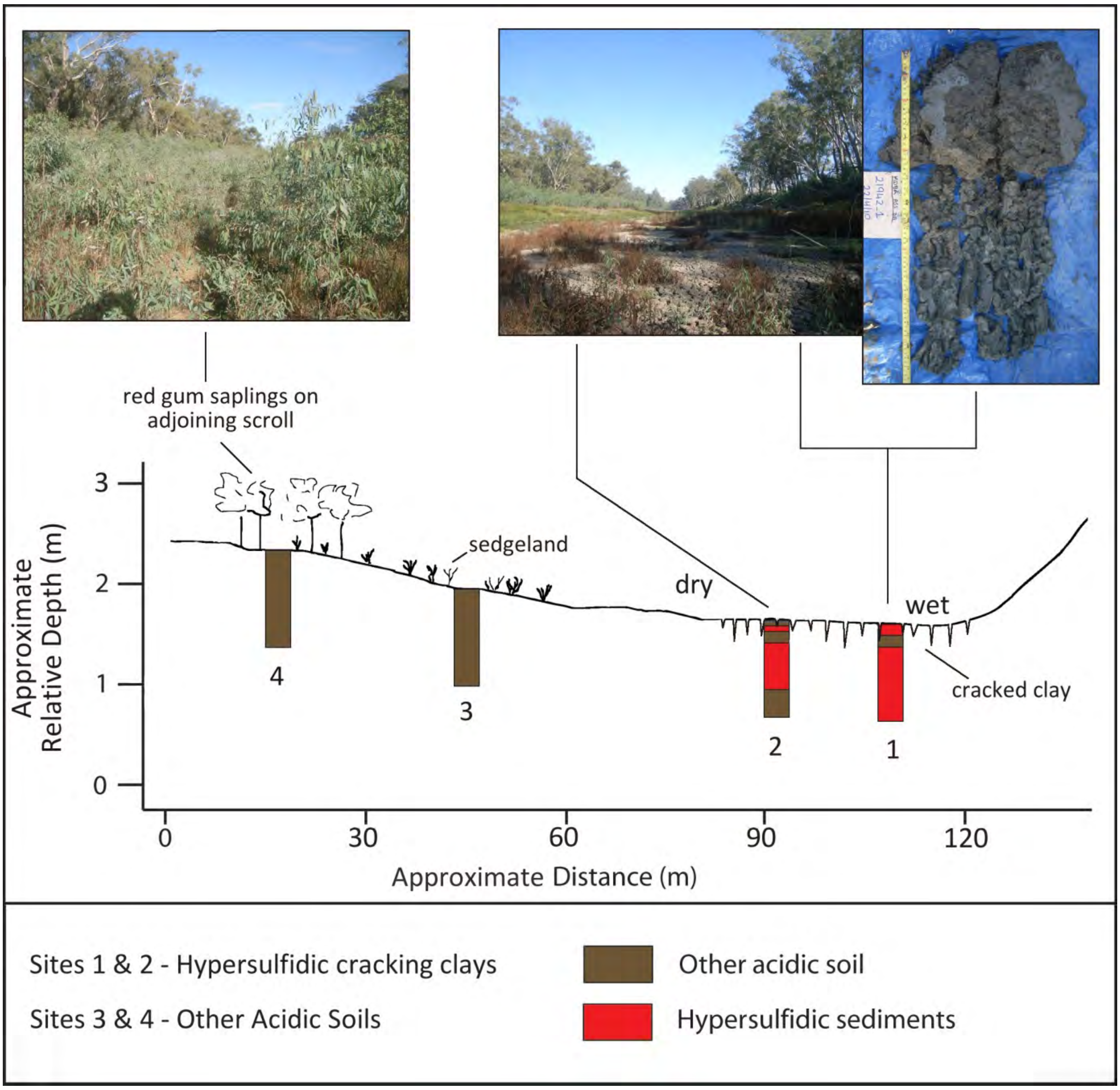

Figure 8-28. Conceptual cross section diagram showing the toposequence relationship of the Dairy Lagoon sediments/soil materials for sites 21942_1 to 21942_4.

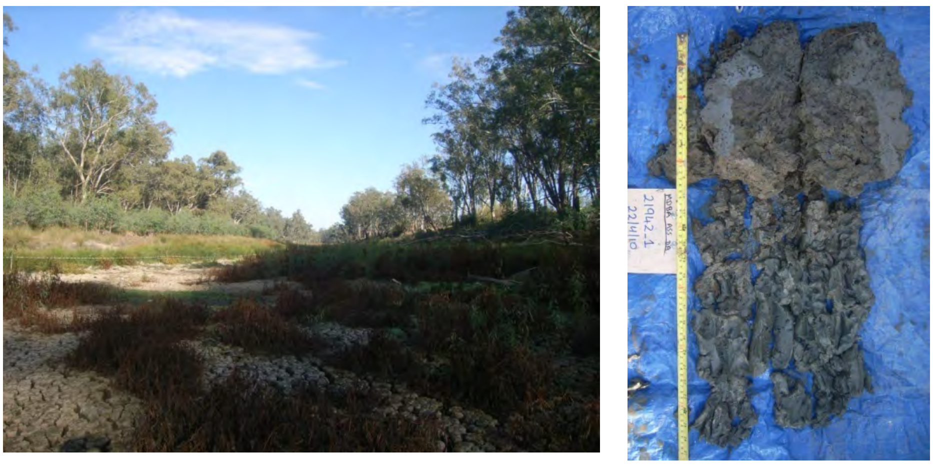

Figure 8-29. Photographs of site 21942_1, showing the situation of the site in a wet depression in the centre of the channel, and the soil core.

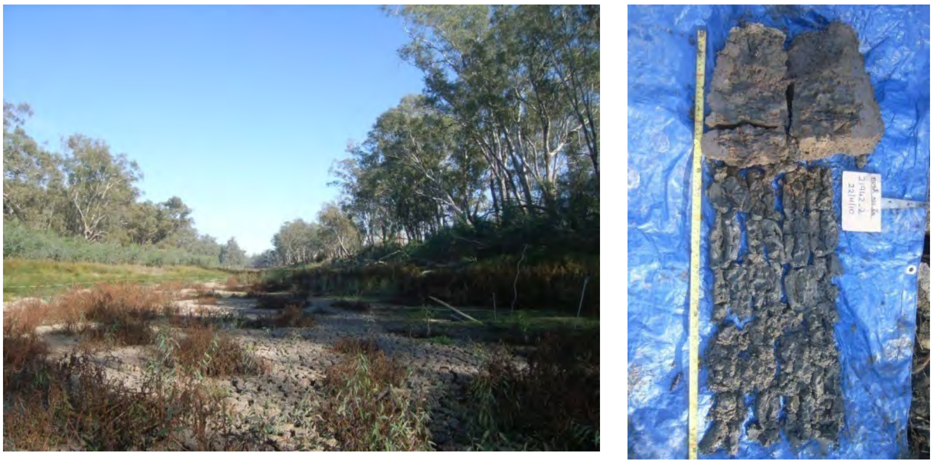

Figure 8-30. Photographs of site 21942_2, showing the dry, cracked surface in the centre of the channel, and the soil core.

Figure 8-31. Photographs of site 21942_3, showing the fringing sedgeland, and the soil core.

Figure 8-32. Photographs of site 21942_4, showing the elevated, subsidiary scroll supporting Red Gum saplings and sedges, and the blocky structure of the soil profile.

Figure 8-33. Photographs of site 21942_5, showing the bare cracking clay surface in the centre of the channel, and the soil profile.

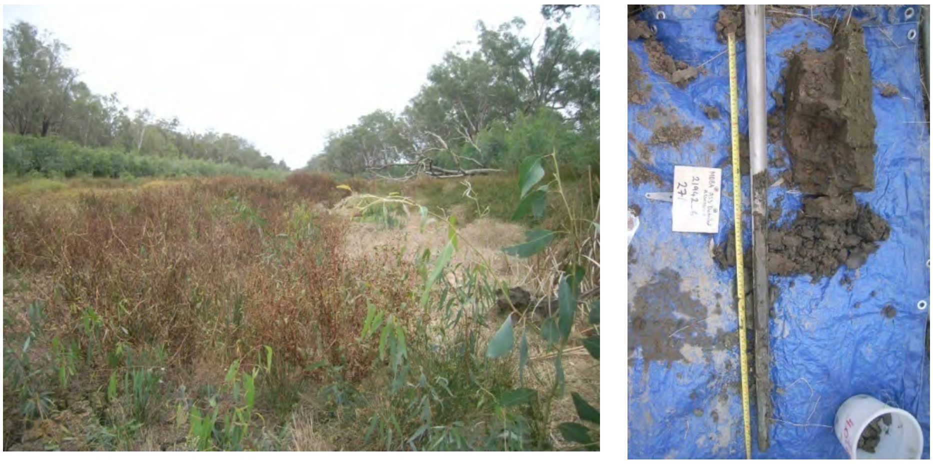

Figure 8-34. Photographs of site 21942_6, showing sedgeland on cracking clay, and the soil core.

Figure 8-35. Photographs of site 21942_7, showing elevated sedgeland and the soil profile.

Figure 8-36. Photographs of site 21942_8, showing the bare cracking clay surface in the centre of the channel, and the soil profile.

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 Figures 8-37 and 8-38. The pH_W values ranged between 4.00 and 6.61. Sulfuric materials (i.e. pH_W < 4) were not present. The pH_{FOX} values ranged between 1.94 and 4.90. The pH_{FOX} results indicate that 34 of the 42 surface soils examined may have the potential to acidify to pH < 4 as a result of sulfide oxidation. However, the S_{CR} data shows only five of these layers contained detectable sulfide (i.e. S_{CR} ≥ 0.01% S). Eight soil materials had a pH_{FOX} < 2.5, although none of these materials contained detectable sulfide. One of the sulfidic soil materials acidified to pH < 4 after at least 8 weeks of incubation. Other acidic soil materials were identified at all eight sites, indicating acidity in the soil profile at levels where aluminium may mobilise. Four other acidic soil materials acidified to a pH < 4 after at least 8 weeks of incubation.

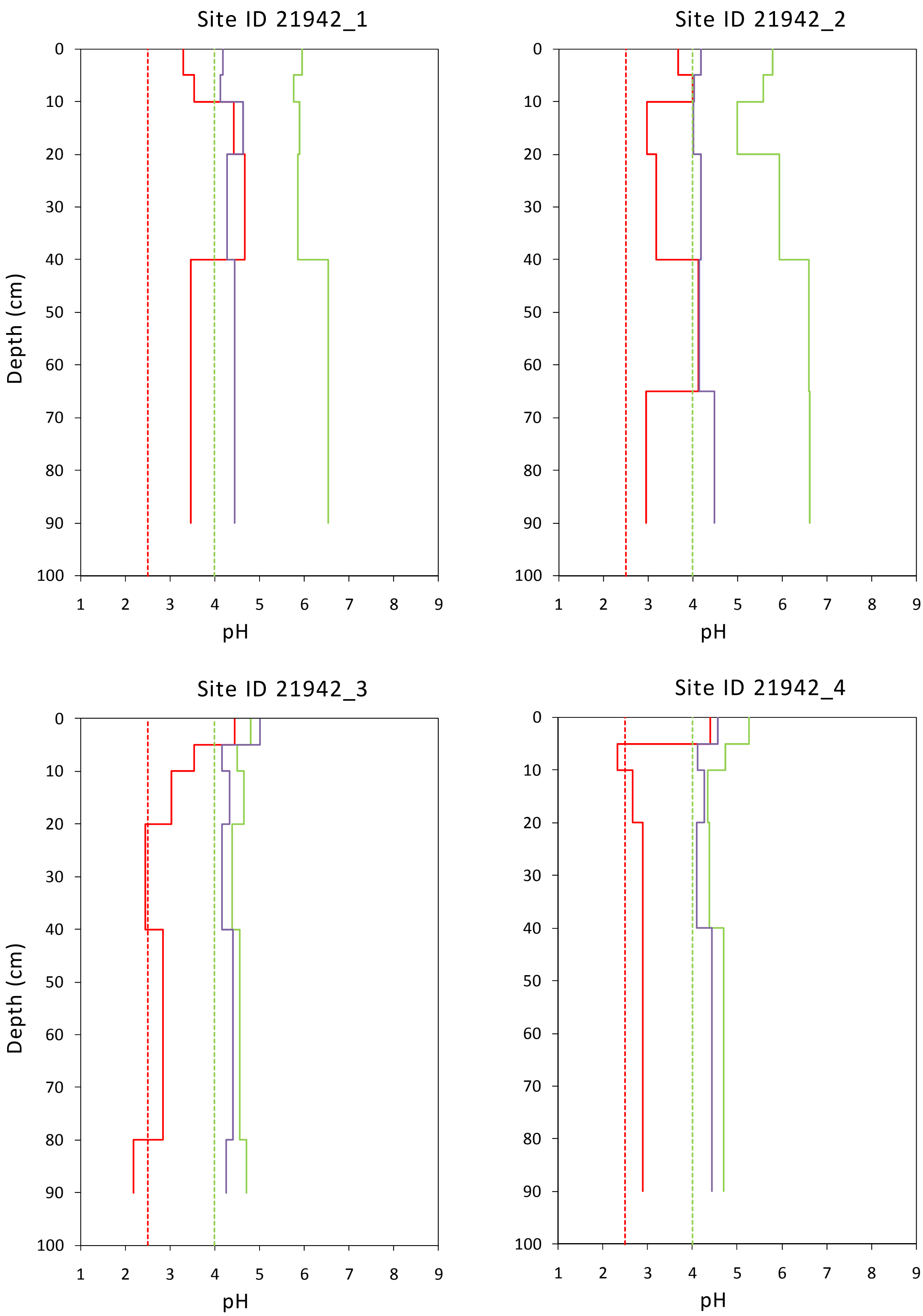

Figure 8-37. Depth profiles of soil pH for Dairy Lagoon (21942_1 – 21942_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

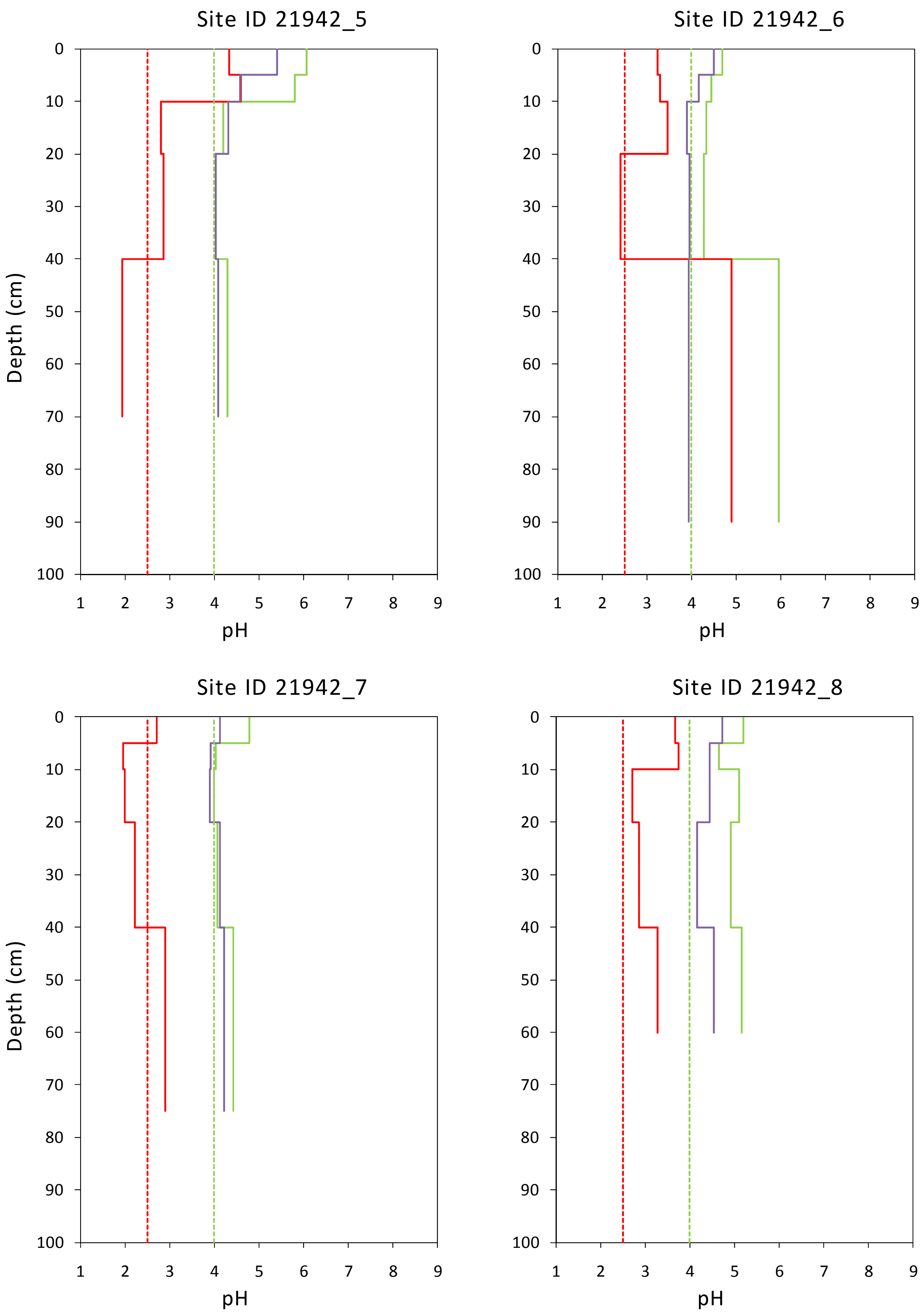

Figure 8-38. Depth profiles of soil pH for Dairy Lagoon (21942_5 – 21942_8), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and 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 Figures 8-39 and 8-40.

Chromium reducible sulfur

Chromium reducible sulfur (S_{CR}) values ranged between < 0.01 and 0.02% S. Sulfidic soil materials (i.e. S_{CR} ≥ 0.01% S) were identified at three sampling sites (sites 21942_1, 21942_2 and 21942_6), with 8 materials of the 42 samples collected equal to or greater than the sulfidic criterion.

Acid volatile sulfide

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

Acid neutralising capacity

The acid neutralising capacity (ANC) ranged between zero and 0.4 % $CaCO_3$, with all except one soil material having no ANC.

Titratable actual acidity

The titratable actual acidity (TAA) ranged between zero and 69 mole H^+/tonne. An increase in the TAA with depth was usually observed.

Retained acidity

Retained acidity was not present in any of the soil layers.

Net acidity

Net acidity ranged between -46 and 69 mole H^+/tonne, with all except one sample having positive net acidities. Eight hypersulfidic soil materials had moderate net acidities ranging between 26 and 52 H^+/tonne.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 83 and 617 mg/kg. Seven of the eight 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 8-15 and 8-16, respectively. The field pH of the surface water collected at site 21942_1 was 5.4, and was below the most relevant ANZECC/ARMCANZ (2000) trigger value for aquatic ecosystems of 6.5. The water data indicates that the surface water at this sulfidic site has been affected by acidification. The surface water sulfate concentration was 184 mg/L. Some nutrient (i.e. NH_4, PO_4), metal (i.e. Cd, Cu, Mn, Pb, Zn), turbidity and dissolved oxygen values were found to be outside the most relevant ANZECC/ARMCANZ (2000) guideline value. No groundwater data was collected from within this wetland.

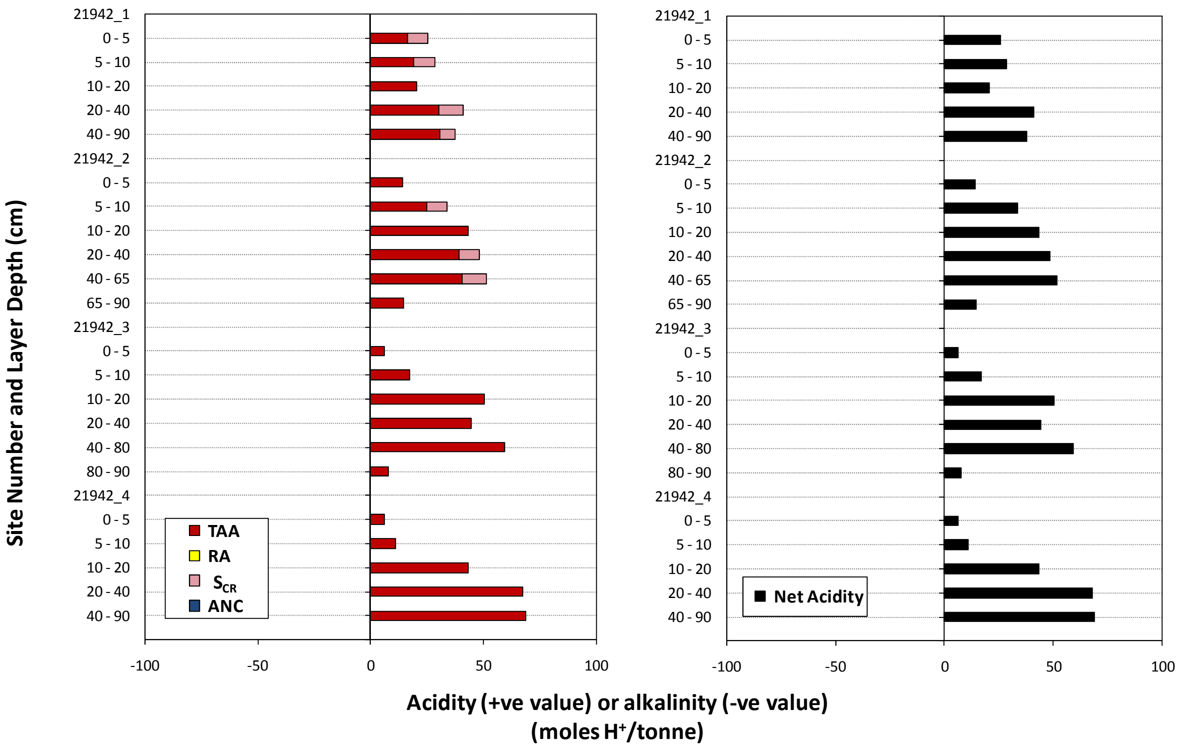

Figure 8-39. Acid-base accounting depth profiles for Dairy Lagoon (21942_1 – 21942_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

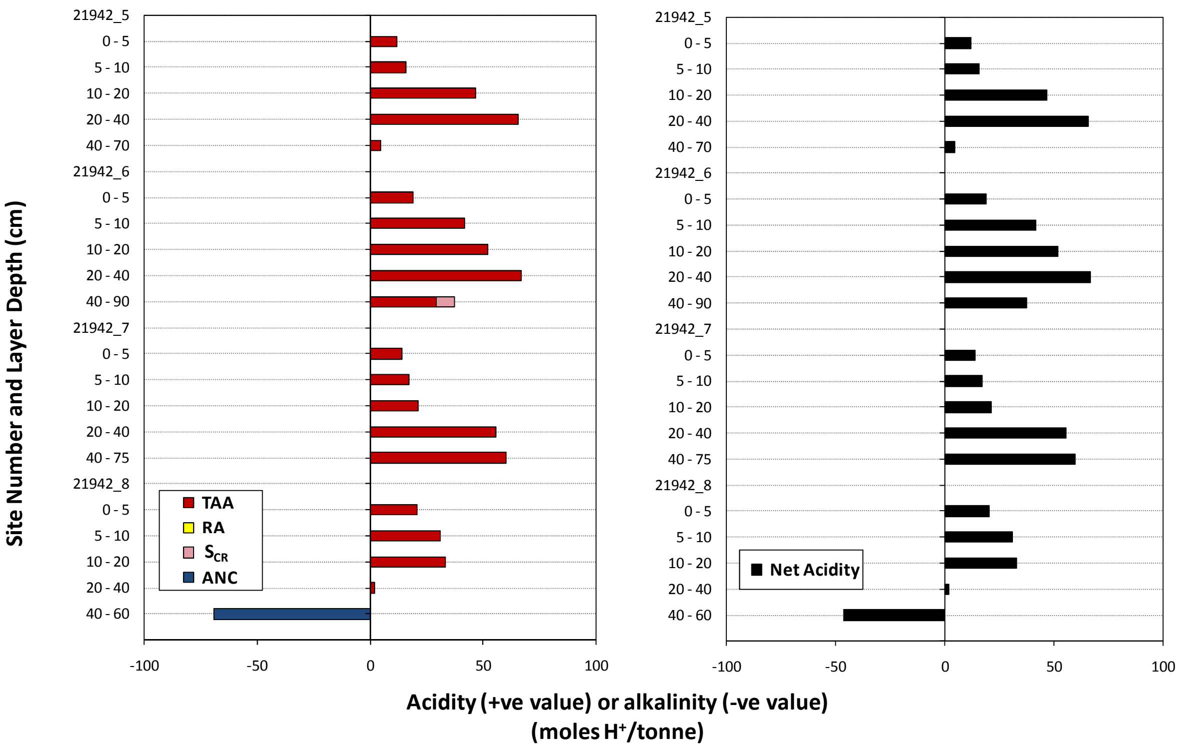

Figure 8-40. Acid-base accounting depth profiles for Dairy Lagoon (21942_5 – 21942_8). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.3.4. Discussion

Acid sulfate soils materials were found at three sites at Dairy Lagoon (i.e. sites 21942_1, 21942_2 and 21942_6). The remaining five sites were classified as other acidic soils.

Sulfuric materials were not observed. The reduced inorganic sulfur content of the sulfidic samples was low (i.e. S_{CR}. ≤ 0.02% S). These results indicate that minimal acidity would be produced upon oxidation of sulfides in these materials. Hypersulfidic soil materials with moderate net acidities were present in three soil profiles. A total of seven 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 were three high priority sites based on hypersulfidic material, and seven 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 Dairy Lagoon wetland are:

- Acidification hazard: The data indicate that with the presence of eight hypersulfidic soils with moderate net acidities that the degree of acidification hazard is moderate.

- Deoxygenation hazard: The soluble sulfate content of surface soil materials at seven 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 some sites.

Summary of key findings for the Dairy Lagoon:

Soil materials:	Sulfuric materials were not present. Sulfidic soil materials identified included: hypersulfidic (3 sites). Other acidic soil materials observed at the remaining 5 sites. Moderate net acidities dominant within wetland.
Acid sulfate soil identification:	• Sulfidic sites 1, 2 and 6 were hypersulfidic cracking clays. • Remaining sites were other acidic soil materials.
Hazard assessment	• Acidification hazard – moderate 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 Dairy Lagoon (Wetland ID 21942).
(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	fine	5.95	3.30	4.19	339	5.32	16.56	0.01	0.00	0.00	25.55	< 0.01	hypersulfidic#
1.2	5-10	fine	5.76	3.55	4.13		5.28	19.00	0.02	0.00	0.00	28.55	< 0.01	hypersulfidic#
1.3	10-20	fine	5.90	4.43	4.63*		5.20	20.66	< 0.01	0.00	0.00	20.66	< 0.01	other acidic
1.4	20-40	fine	5.85	4.68	4.27*		4.97	30.55	0.02	0.00	0.00	40.86	< 0.01	hypersulfidic#
1.5	40-90	fine	6.54	3.47	4.45*		5.01	30.72	0.01	0.00	0.00	37.68	< 0.01	hypersulfidic#
2.1	0-5	fine	5.78	3.67	4.19	614	5.35	14.02	< 0.01	0.00	0.00	14.02	< 0.01	other acidic
2.2	5-10	fine	5.57	3.99	4.04		5.01	24.84	0.01	0.00	0.00	33.70	< 0.01	hypersulfidic#
2.3	10-20	fine	5.00	2.98	4.02		4.72	43.49	< 0.01	0.00	0.00	43.49	< 0.01	other acidic
2.4	20-40	fine	5.93	3.18	4.18		4.68	39.14	0.01	0.00	0.00	48.41	< 0.01	hypersulfidic#
2.5	40-65	fine	6.60	4.12	4.14*		4.83	40.53	0.02	0.00	0.00	51.53	< 0.01	hypersulfidic#
2.6	65-90	fine	6.61	2.96	4.49*		5.18	14.68	< 0.01	0.00	0.00	14.68	< 0.01	other acidic
3.1	0-5	coarse	4.80	4.44	5.01	123	5.68	6.26	< 0.01	0.00	0.00	6.26	< 0.01	other acidic
3.2	5-10	medium	4.50	3.54	4.17		5.04	17.15	< 0.01	0.00	0.00	17.15	< 0.01	other acidic
3.3	10-20	medium	4.65	3.04	4.34		4.59	50.31	< 0.01	0.00	0.00	50.31	< 0.01	other acidic
3.4	20-40	fine	4.38	2.45	4.16		4.38	44.44	< 0.01	0.00	0.00	44.44	< 0.01	other acidic
3.5	40-80	fine	4.55	2.84	4.41		4.50	59.29	< 0.01	0.00	0.00	59.29	< 0.01	other acidic
3.6	80-90	fine	4.71	2.19	4.25		5.36	7.77	< 0.01	0.00	0.00	7.77	< 0.01	other acidic
4.1	0-5	coarse	5.27	4.40	4.56	82.8	5.61	6.06	< 0.01	0.00	0.00	6.06	< 0.01	other acidic
4.2	5-10	coarse	4.74	2.33	4.11		5.21	10.85	< 0.01	0.00	0.00	10.85	< 0.01	other acidic
4.3	10-20	medium	4.35	2.67	4.27*		4.59	43.12	< 0.01	0.00	0.00	43.12	< 0.01	other acidic
4.4	20-40	fine	4.38	2.89	4.10		4.46	67.70	< 0.01	0.00	0.00	67.70	< 0.01	other acidic
4.5	40-90	fine	4.70	2.90	4.43		4.59	69.04	< 0.01	0.00	0.00	69.04	< 0.01	other acidic
5.1	0-5	fine	6.07	4.33	5.40*	136	5.56	11.85	< 0.01	0.00	0.00	11.85	< 0.01	other acidic
5.2	5-10	medium	5.81	4.59	4.57*		5.24	15.74	< 0.01	0.00	0.00	15.74	< 0.01	other acidic
5.3	10-20	medium	4.20	2.80	4.31		4.56	46.73	< 0.01	0.00	0.00	46.73	< 0.01	other acidic
5.4	20-40	fine	4.03	2.86	4.03		4.39	65.62	< 0.01	0.00	0.00	65.62	< 0.01	other acidic
5.5	40-70	fine	4.29	1.94	4.08*		5.78	4.70	< 0.01	0.00	0.00	4.70	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 12 weeks). # Classified as hypersulfidic based on positive net acidity.

Table 8-14 (continued). Laboratory analytical data for acid sulfate soil assessment of Dairy Lagoon (Wetland ID 21942).
(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
6.1	0-5	medium	4.69	3.25	4.50	570	5.17	19.04	< 0.01	0.00	0.00	19.04	< 0.01	other acidic
6.2	5-10	medium	4.44	3.29	4.17*		4.53	41.67	< 0.01	0.00	0.00	41.67	< 0.01	other acidic
6.3	10-20	fine	4.34	3.46	3.90*		4.40	52.10	< 0.01	0.00	0.00	52.10	< 0.01	other acidic
6.4	20-40	fine	4.28	2.42	3.95		4.33	66.83	< 0.01	0.00	0.00	66.83	< 0.01	other acidic
6.5	40-90	fine	5.96	4.90	3.93		5.00	29.29	0.01	0.00	0.00	37.35	< 0.01	hypersulfidic
7.1	0-5	fine	4.78	2.72	4.13	116	4.36	13.94	< 0.01	0.00	0.00	13.94	< 0.01	other acidic
7.2	5-10	medium	4.03	1.96	3.92		4.91	17.24	< 0.01	0.00	0.00	17.24	< 0.01	other acidic
7.3	10-20	coarse	4.00	2.00	3.89		4.79	21.15	< 0.01	0.00	0.00	21.15	< 0.01	other acidic
7.4	20-40	fine	4.06	2.23	4.12		4.37	55.72	< 0.01	0.00	0.00	55.72	< 0.01	other acidic
7.5	40-75	coarse	4.43	2.90	4.22		4.36	59.91	< 0.01	0.00	0.00	59.91	< 0.01	other acidic
8.1	0-5	coarse	5.19	3.68	4.72*	617	5.00	20.63	< 0.01	0.00	0.00	20.63	< 0.01	other acidic
8.2	5-10	coarse	4.66	3.74	4.45		4.68	30.86	< 0.01	0.00	0.00	30.86	< 0.01	other acidic
8.3	10-20	medium	5.11	2.71	4.45		4.67	33.10	< 0.01	0.00	0.00	33.10	< 0.01	other acidic
8.4	20-40	medium	4.92	2.86	4.17*		6.32	1.91	< 0.01	0.00	0.00	1.91	< 0.01	other acidic
8.5	40-60	medium	5.16	3.28	4.54*		6.57	0.00	< 0.01	0.00	0.35	-46.13	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 12 weeks).

Table 8-15. Field hydrochemistry data for acid sulfate soil assessment of Dairy Lagoon (Wetland ID 21942).

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
*Lowland River**		*125-2200*	*85-110*		*6.5-8.0*			*6-50*		
*Freshwater Lakes**		*20-30*	*90-110*		*6.5-8.0*			*1-20*		
21942_1 (SW)	21.8	9.89	23.6	2.1	5.39	374.8		250	8	Probably rainwater ponded in cracks

* 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 8-16. Laboratory hydrochemistry data for acid sulfate soil assessment of Dairy Lagoon (Wetland ID 21942).

Parameter	units	ANZECC Guidelines	Site 1 (SW)
depth	cm		
Na	mg l^{-1}		74.36
K	mg l^{-1}		9.42
Ca	mg l^{-1}		49.34
Mg	mg l^{-1}		17.85
Si	mg l^{-1}		1.84
Br	mg l^{-1}		0.725
Cl	mg l^{-1}		20.
NO_3	mg l^{-1}	0.7	0.522
NH_4-N	mg l^{-1}	0.01	34.015
PO_4-P[E]	mg l^{-1}	0.005	0.007
SO_4	mg l^{-1}		184.49
Ag	µg l^{-1}	0.05	<1
Al[A]	µg l^{-1}	55	164
As[B]	µg l^{-1}	13	2
Cd	µg l^{-1}	0.2	61
Co	µg l^{-1}	2.8	13
Cr[C]	µg l^{-1}	1	1
Cu[H]	µg l^{-1}	1.4	9
Fe	µg l^{-1}	300	132
Mn	µg l^{-1}	1700	3,251
Ni[H]	µg l^{-1}	11	8
Pb[H]	µg l^{-1}	3.4	4
Se	µg l^{-1}	11	3
Zn[H]	µg l^{-1}	8	123
DOC	mg l^{-1}		13.48

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 NH_4 and PO_4, 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 Dairy Lagoon (Wetland ID 21942).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	30	grey, cracking clay, large and deep cracks	bare	base of wetland channel, damp	low point of wetland, some water	hypersulfidic	cracking clay produces large but fragile clay columns, probable connection to river during floods
2	35	grey, cracking clay, large and deep cracks	partial cover	base of wetland channel, dry	low point of wetland, dry	hypersulfidic	cracking clay produces large but fragile clay columns, probable connection to river during floods
3	dry	firm	common	fringing sedgeland	elevated margin of wetland channel	other acidic	
4	dry	firm	common	upper level of wetland, red gum suckers common	elevated surface beyond channel margin	other acidic	surface of adjoining flood chute
5	60	grey, cracking clay, large and deep cracks, no vegetation	bare	low, base of depression	low point in this part of the wetland	other acidic	cracking clay produces large but fragile clay columns, probable connection to river during floods
6	80	grey, cracking clay, large and deep cracks, vegetated	common	mid slope, where grassy vegetation begins to appear	slightly upslope from site 5, where vegetation appears	hypersulfidic	cracking clay produces large but fragile clay columns, probable connection to river during floods
7		sandy with dense vegetation cover	common	upper slope, where grassy vegetation gives way to woody sapling growth	upslope from site 6, at old high water mark	other acidic	
8		grey cracking clay, moderate and shallow cracks	bare	low, margin of depression adjacent to sites 5-7.	testing lateral changes between depressions in wetland	other acidic	cracking clay produces large but fragile clay columns, probable connection to river during floods

Table 8-18. Profile description data for acid sulfate soil assessment of Dairy Lagoon (Wetland ID 21942).

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		M	1	FM			AB	2		6.50	
1.2	5-10	10YR 3/1	C		M	1	FM			AB	2		6.50	
1.3	10-20	10YR 3/2	C		W	1	FM			MA	0		6.00	
1.4	20-40	10YR 4/2	C		W	2	FM			MA	0		5.70	
1.5	40-90	10YR 4/1	C		W					MA	0		6.80	
2.1	0-5		S		W					MA	0			
2.2	5-10	10YR 4/1	C	light medium	M	1	FM			AB	2		5.50	
2.3	10-20	10YR 4/1	C	light medium	M	1	FM			AB	2		6.30	
2.4	20-40	10YR 3/1	C	light medium	M	2	FM			AB	2		5.00	some fine sand at base of layer
2.5	40-65	10YR 31	C	light medium	W	3	FM			MA	0		4.50	
2.6	65-90	10Y 4/1	C	light medium	W					MA	0		6.60	
3.1	0-5	10Y 4/1	S		W					MA	0		6.50	
3.2	5-10	10YR 3/2	SL		D	1	FM			GR	2		5.92	
3.3	10-20	10YR 3/2	SCL		D	1	FM			PO	2		5.30	
3.4	20-40	10YR 2/1	ZC	light medium	D	1	FM			AB	2		4.57	
3.5	40-80	10YR 2/1	ZC	light medium	D	1	FM			PO	3		4.41	
3.6	80-90	10YR 3/1	ZC	light medium	D	1	FM			PO	3		4.69	
4.1	0-5	10YR 4/3	LS		T					SG	0		4.82	quartz fragments; mica flecks
4.2	5-10	10YR 3/3	LS		D					SG	0		5.75	thin organic cover
4.3	10-20	10YR 3/4	SL		D	2	FM			SG	0		5.52	
4.4	20-40	10YR 4/2	ZC	light medium	D	3	FM			AB	2		4.66	
4.5	40-90	10YR 4/1	ZC	light medium	D	3	FM			AB	2		4.83	

Table 8-18 (continued). Profile description data for acid sulfate soil assessment of Dairy Lagoon (Wetland ID 21942).

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 4/1	ZC	light medium	D	3	FM			AB	2		4.74	
5.2	5-10	10YR 3/2	CL		D					MA	0	very weak	7.60	
5.3	10-20	10YR 3/1	C	light	M					n/r	3	very firm	5.55	
5.4	20-40	10YR 4/2	C	medium	M	2	FM			n/r	3	mod firm	4.56	
5.5	40-70	10YR 4/2	C	medium heavy	M	2	FM			n/r	3	mod firm	5.00	
6.1	0-5	10YR 4/2	SL		W	2	FM					very weak	4.74	quartz fragments
6.2	5-10	10YR 3/2	C	light	D					MA	0		0.24	
6.3	10-20	10YR 4/2	C	medium	T	2	FM			n/r	3	very firm	4.94	
6.4	20-40	10YR 4/2	C	medium	T	2	FM			n/r	3	mod firm	4.26	
6.5	40-90	10YR 4/2	C	medium	M	2	FM			n/r	3	mod firm	4.47	
7.1	0-5	2.5G 5/1	C	medium	W	2	FM			n/r	3	mod weak	6.39	Several layers between 40 and 90 cm, grey plastic clay layer most dominant (75-90 cm)
7.2	5-10	10YR 3/1	C	light	W					n/r			6.40	
7.3	10-20	2.5Y 4/1	LS		W					n/r			6.50	quartz fragments
7.4	20-40	5G 5/1	C	S	W					n/r			7.00	
7.5	40-75	2.5Y 5/2	LS		D	2	FM			SG	0	loose	4.89	
8.1	0-5	2.5Y 5/2	LS		D	2	FM			SG	0	loose	4.32	
8.2	5-10	2.5Y 5/2	CS		D	2	FM			SG	0	loose	4.12	
8.3	10-20	2.5Y 3/3	SCL		T	2	FM			SB	2	mod firm	4.21	quartz fragments
8.4	20-40	2.5Y 5/2	CL		T					SB	2	mod firm	4.47	quartz fragments
8.5	40-60	10YR 3/2	CL		M					n/r	3	very firm	5.21	quartz fragments

8.4. Wetland ID 40205 – Ovens River (Vic)

8.4.1. Location and setting description

The wetland is part of a meander scroll system on the western side of the Ovens River (Figure 8-41). It is arcuate and about 2 km long and 17 ha. The wetland is bound by the north-south flowing Ovens River to the east and low hills and rises to the west. At the time when the soil survey was conducted in April 2010 it had a mixed surface of bare, crusty/cracked clay interspersed with grass and sedgeland. Clumps of *Phragmites* sp. were present but no ponded water was observed. Discontinuous gypsic precipitate was present throughout the crusty/cracked surface. Sedgeland mixed with woodland occurred on the elevated fringes of the wetland.

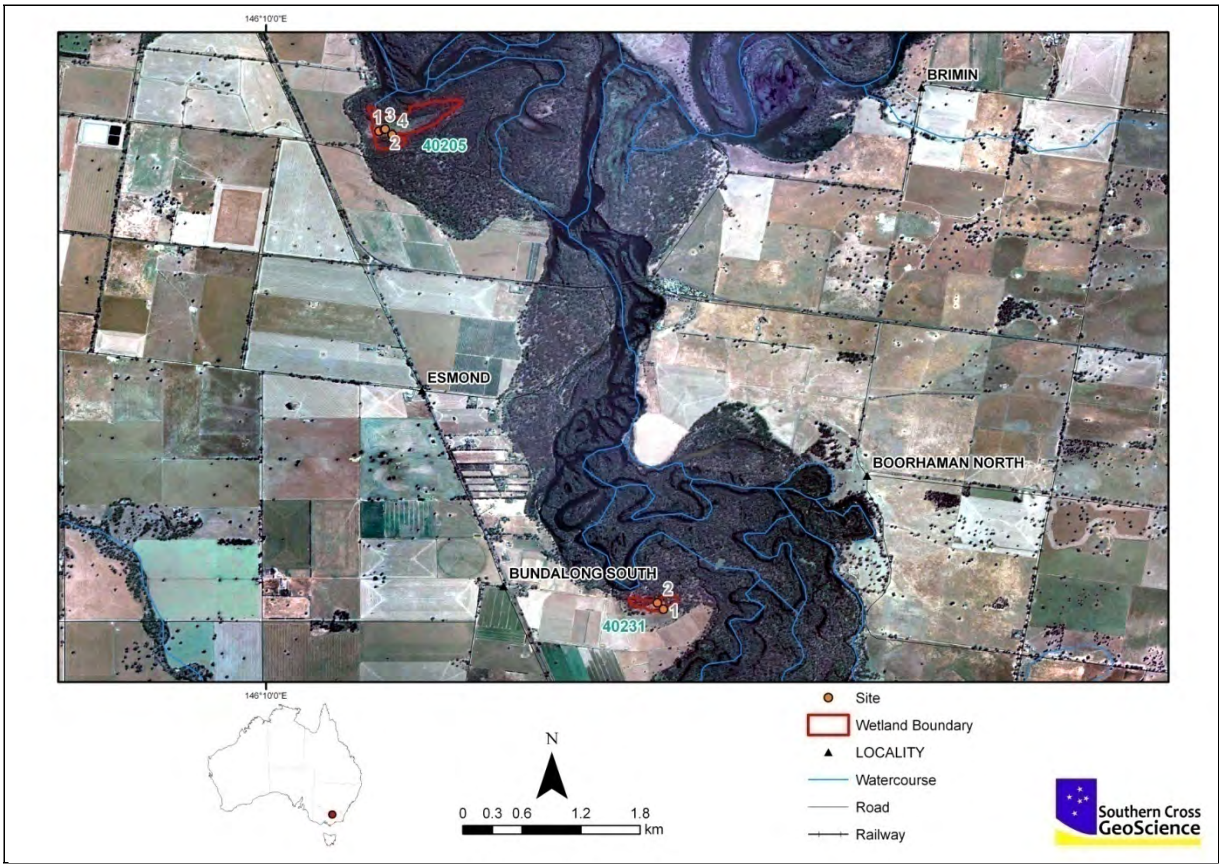

Figure 8-41. Wetland ID 40205 and sample site locations.

8.4.2. Soil profile description and distribution

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

The profile 40205_1 (Figure 8-43) occurred on a bare, self-mulched/crusty surface, the soil consisted of a grey mottled cracking medium clay. The profile 40205_2 (Figure 8-44) occurred on a grass/sedgeland, the soil consisted of a grey mottled medium clay. The profile 40205_3 (Figure 8-45) occurred within a cluster of *Phragmites* sp., the soil consisted of a grey mottled medium clay. The profile 40205_4 (Figure 8-46) occurred on the elevated fringing sedgeland/woodland, the soil consisted of grey mottled and blocky light medium clay, very tough at depth. Additional site and profile description data are presented in Tables 8-22 and 8-23, respectively.

Table 8-19. Soil identification, subtype and general location description for Wetland ID 40205.

Site ID	Easting UTM zone 55H	Northing UTM zone 55H	Acid sulfate soil subtype class	General location description
40205_1	425874	6009634	cracking clay soil	bare, crusty, cracked clay surface
40205_2	425918	6009653	hydrosol	grass/sedgeland
40205_3	425925	6009657	hydrosol	within cluster of *Phragmites* spp.
40205_4	425982	6009601	hydrosol	elevated fringing sedgeland/woodland

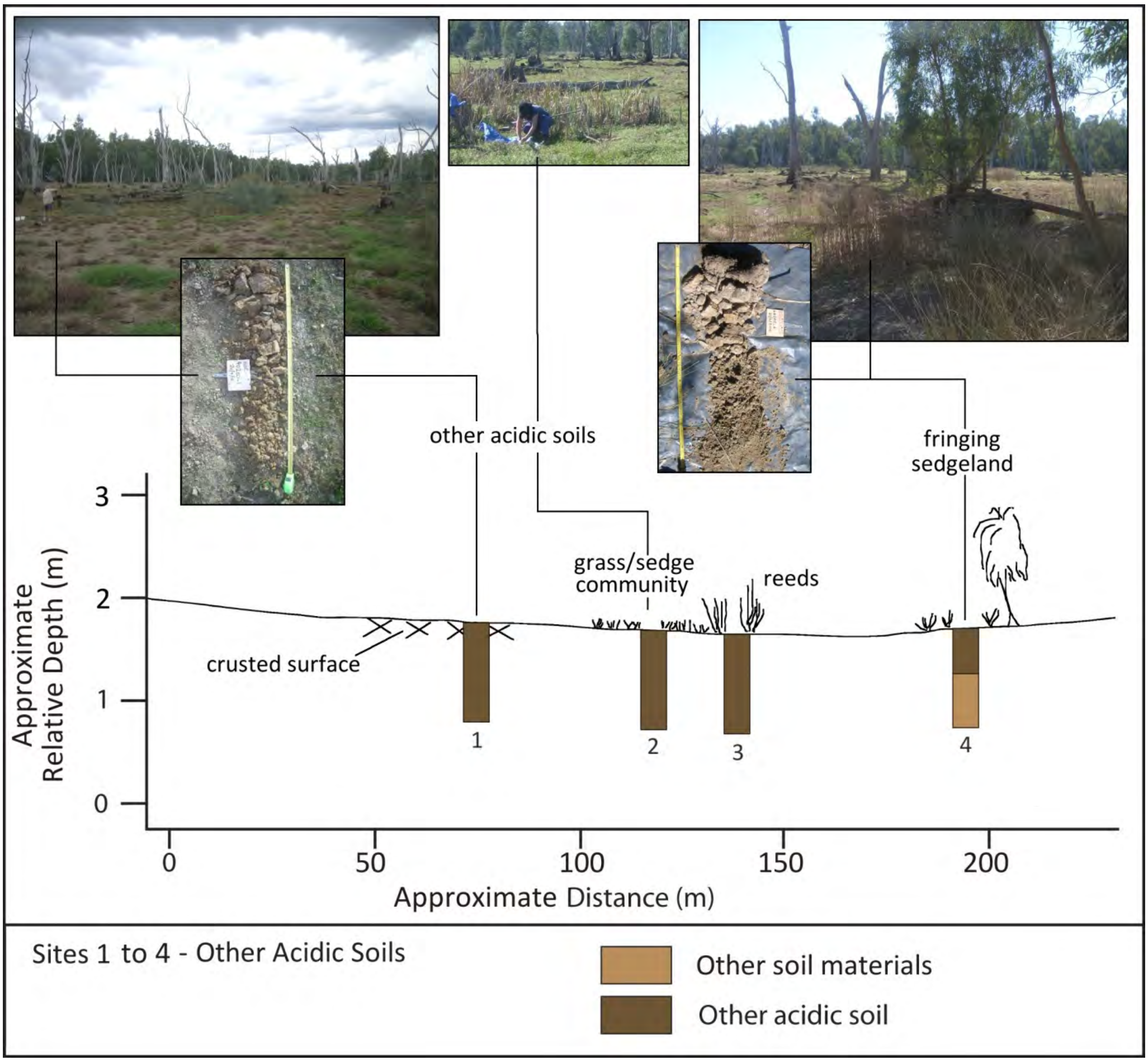

Figure 8-42. Conceptual cross section diagram showing the toposequence relationship of the Wetland ID 40205 sediments/soil materials throughout the wetland.

Figure 8-43. Photographs of site 40205_1, showing the low elevation site bordered by dead trees, and the soil profile

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Figure 8-44. Photographs of site 40205_2, showing the location of the site adjacent to reed vegetation, and the soil profile.

Figure 8-45. Photographs of site 40205_3, showing the sedgeland, and the soil profile.

Figure 8-46. Photographs of site 40205_4, showing the slightly elevated site at the margin of the wetland, 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 8-47. The pH_W values ranged between 4.28 and 5.89. Sulfuric materials (i.e. $pH_W < 4$) were not present. The pH_{FOX} values ranged between 1.83 and 5.72. The pH_{FOX} results indicate that 14 of the 20 surface soils examined may have the potential to acidify to pH < 4 as a result of sulfide oxidation. However, the S_{CR} data shows these layers contained no detectable sulfide (i.e. S_{CR} < 0.01% S). Three soil materials had a pH_{FOX} < 2.5. Other acidic soil materials were identified at all four sites, indicating acidity in the soil profile at levels where aluminium may mobilise. Three of the other acidic soils acidified to pH < 4 after at least 8 weeks of incubation.

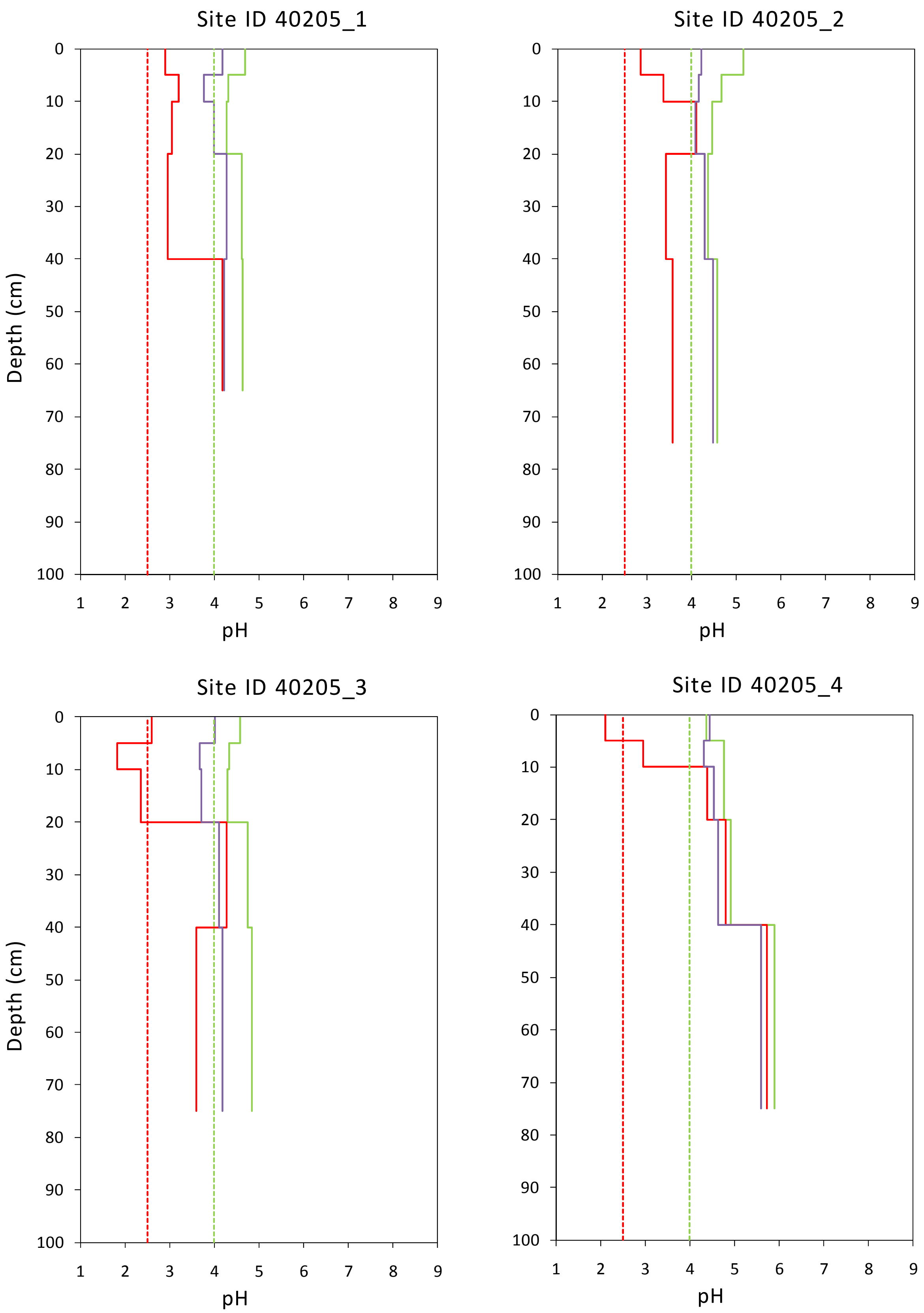

Figure 8-47. Depth profiles of soil pH for Wetland ID 40205 (40205_1 – 40205_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) 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 8-48.

Chromium reducible sulfur

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

Acid volatile sulfide

Monosulfidic soil materials (i.e. S_{AV} ≥ 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 91 mole H^+/tonne. A decrease in the TAA with depth was observed.

Retained acidity

The retained acidity ranged between zero and 6 mole H^+/tonne, and was only present in five of the soil materials.

Net acidity

Net acidity ranged between 10 and 94 mole H^+/tonne. A decrease in net acidity with depth was observed.

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 162 and 255 mg/kg. All four of the surface soil layers examined 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.

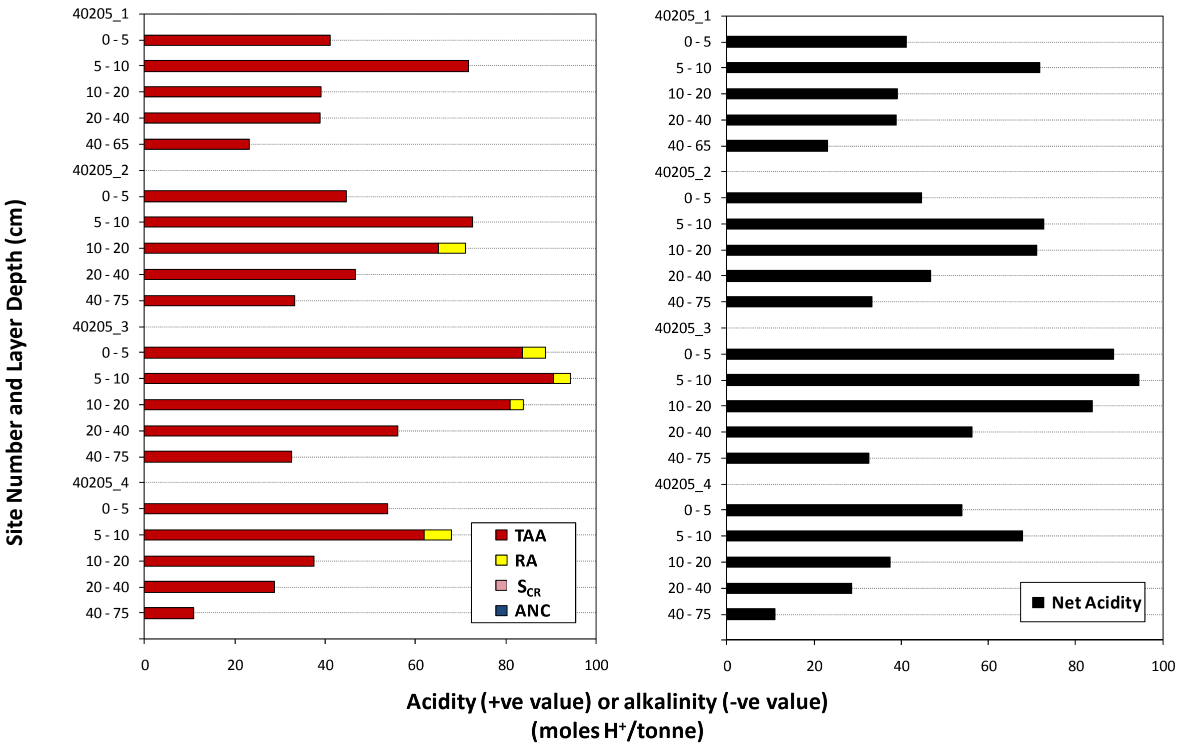

Figure 8-48. Acid-base accounting depth profiles for Wetland ID 40205 (40205_1 – 40205_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.4.4. Discussion

Acid sulfate soils materials were not found at Wetland ID 40205. The four sites were classified as other acidic soils. 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, 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 Wetland ID 40205 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 surface soil materials at 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 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 40205:

Soil materials:	Sulfuric and sulfidic materials were not observed within this wetland. Other acidic soil materials observed at 4 sites. Moderate net acidities dominant within wetland.
Acid sulfate soil identification:	• Other acidic soils present at all sites.
Hazard assessment	• Acidification hazard - low level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – low to moderate level of concern

Table 8-20. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 40205.
(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	4.69	2.91	4.19	255	4.86	41.19	< 0.01	0.00	0.00	41.19	< 0.01	other acidic
1.2	5-10	medium	4.31	3.20	3.76		4.52	71.85	< 0.01	0.00	0.00	71.85	< 0.01	other acidic
1.3	10-20	fine	4.28	3.05	4.00		4.55	39.10	< 0.01	0.00	0.00	39.10	< 0.01	other acidic
1.4	20-40	fine	4.62	2.96	4.28		4.57	38.97	< 0.01	0.00	0.00	38.97	< 0.01	other acidic
1.5	40-65	fine	4.64	4.18	4.22		4.80	23.11	< 0.01	0.00	0.00	23.11	< 0.01	other acidic
2.1	0-5	medium	5.16	2.86	4.22*	219	4.81	44.70	< 0.01	0.00	0.00	44.70	< 0.01	other acidic
2.2	5-10	medium	4.68	3.37	4.16		4.50	72.63	< 0.01	0.00	0.00	72.63	< 0.01	other acidic
2.3	10-20	fine	4.46	4.10	4.08		4.46	65.11	< 0.01	6.00	0.00	71.11	< 0.01	other acidic
2.4	20-40	fine	4.37	3.43	4.30		4.53	46.66	< 0.01	0.00	0.00	46.66	< 0.01	other acidic
2.5	40-75	fine	4.57	3.58	4.49		4.66	33.26	< 0.01	0.00	0.00	33.26	< 0.01	other acidic
3.1	0-5	medium	4.58	2.60	4.02	162	4.49	83.72	< 0.01	5.00	0.00	88.72	< 0.01	other acidic
3.2	5-10	medium	4.34	1.83	3.68		4.35	90.51	< 0.01	4.00	0.00	94.51	< 0.01	other acidic
3.3	10-20	fine	4.29	2.35	3.71		4.45	80.85	< 0.01	3.00	0.00	83.85	< 0.01	other acidic
3.4	20-40	fine	4.75	4.28	4.11		4.45	56.19	< 0.01	0.00	0.00	56.19	< 0.01	other acidic
3.5	40-75	fine	4.85	3.60	4.19*		4.71	32.60	< 0.01	0.00	0.00	32.60	< 0.01	other acidic
4.1	0-5	medium	4.36	2.10	4.45	165	4.69	53.93	< 0.01	0.00	0.00	53.93	< 0.01	other acidic
4.2	5-10	medium	4.76	2.96	4.31		4.48	61.94	< 0.01	6.00	0.00	67.94	< 0.01	other acidic
4.3	10-20	medium	4.76	4.38	4.54		4.57	37.60	< 0.01	0.00	0.00	37.60	< 0.01	other acidic
4.4	20-40	fine	4.92	4.81	4.64		4.72	28.74	< 0.01	0.00	0.00	28.74	< 0.01	other acidic
4.5	40-75	fine	5.89	5.72	5.59		5.45	10.97	< 0.01	0.00	0.00	10.97	< 0.01	other soil materials

* Indicates that a stable pH has not yet been reached for this sample (after 12 weeks).

Table 8-21. Site description data for acid sulfate soil assessment of Wetland ID 40205.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1		crusty, cracks	mostly bare	Bare area	distinctive surface/veg community feature	other acidic	Transect based on surface features and veg community
2		firm	complete veg cover	Sedge/grass community	distinctive veg community, slightly elevated	other acidic	Transect based on surface features and veg community
3		soft	near complete veg cover	Reed community	distinctive veg community, slightly depressed	other acidic	Transect based on surface features and veg community
4		firm	complete cover (litter)	Elevated fringe of wetland; sedge within woodland	distinctive veg community, elevated	other acidic	Transect based on surface features and veg community

Table 8-22. Profile description data for acid sulfate soil assessment of Wetland ID 40205.

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 2.5/2	C	light	D					PO	3		4.90	discontinuous gypsic precipitate on surface
1.2	5-10	7.5YR 2.5/2	C	light	D					PO	3		4.60	
1.3	10-20	10YR 7/2	C	light medium	T	4	FM		RPO	AB	2		4.60	
1.4	20-40	10YR 7/1	C	light medium	M	4	FM		MAT	MA	0		5.00	
1.5	40-65	10YR 7/1	C	light medium	M	3	FM		MAT	MA	0		5.30	
2.1	0-5	10YR 3/4	CL		T	3	FM			PO	2		5.73	
2.2	5-10	10YR 3/3	CL		M	2	FM			PO	2		5.10	
2.3	10-20	10YR 5/1	C	medium	M	2	FM			PO	2		4.78	
2.4	20-40	7.5YR 5/2	C	medium	M	3	FM			PO	2		5.05	
2.5	40-75	10YR 6/1	C	medium	M	3	FM			PO	1		5.15	
3.1	0-5	10YR 2/1	CL		T	1	FM			PO	2		4.93	
3.2	5-10	10YR 5/1	CL		T	2	FM			PO	2		4.58	
3.3	10-20	10YR 5/1	C	medium	M	2	FM			AB	2		4.70	
3.4	20-40	10YR 5/1	C	medium	M	3	FM			PO	2		5.48	
3.5	40-75	10YR 5/1	C	medium	M	4	FM			PO	2		5.51	
4.1	0-5	10YR 4/2	CL		D					GR	3		5.54	
4.2	5-10	10YR 6/2	C	light	D	3	FM			MA	0		5.36	
4.3	10-20	10YR 6/3	C	light	D	3	FM			MA	0		5.74	
4.4	20-40	10YR 6/3	C	medium	D	3	FM		SPO	PO	2		5.79	black streaks - charcoal?
4.5	40-75	10YR 6/3	C	medium	D	3	FM			PO	2		6.42	

8.5. Wetland ID 40231 – Ovens River (Vic)

8.5.1. Location and setting description

This is a small arcuate dry ox-bow on the western side of the Ovens River (Figure 8-49). It is about 1.5 km long, 700 m wide and 4 ha. It is also relatively shallow, being about 1-1.5 m below the alluvial plain surface. The wetland is an overflow chute on the outermost area subject to alluvial activity. It bounded to the west and south by rises and low hills. At the time of the soil survey in May 2010 the wetland was dry, with many bare areas. Sandy and gravelly sediment was common. A red gum sucker community was present in some of the lower parts of the wetland.

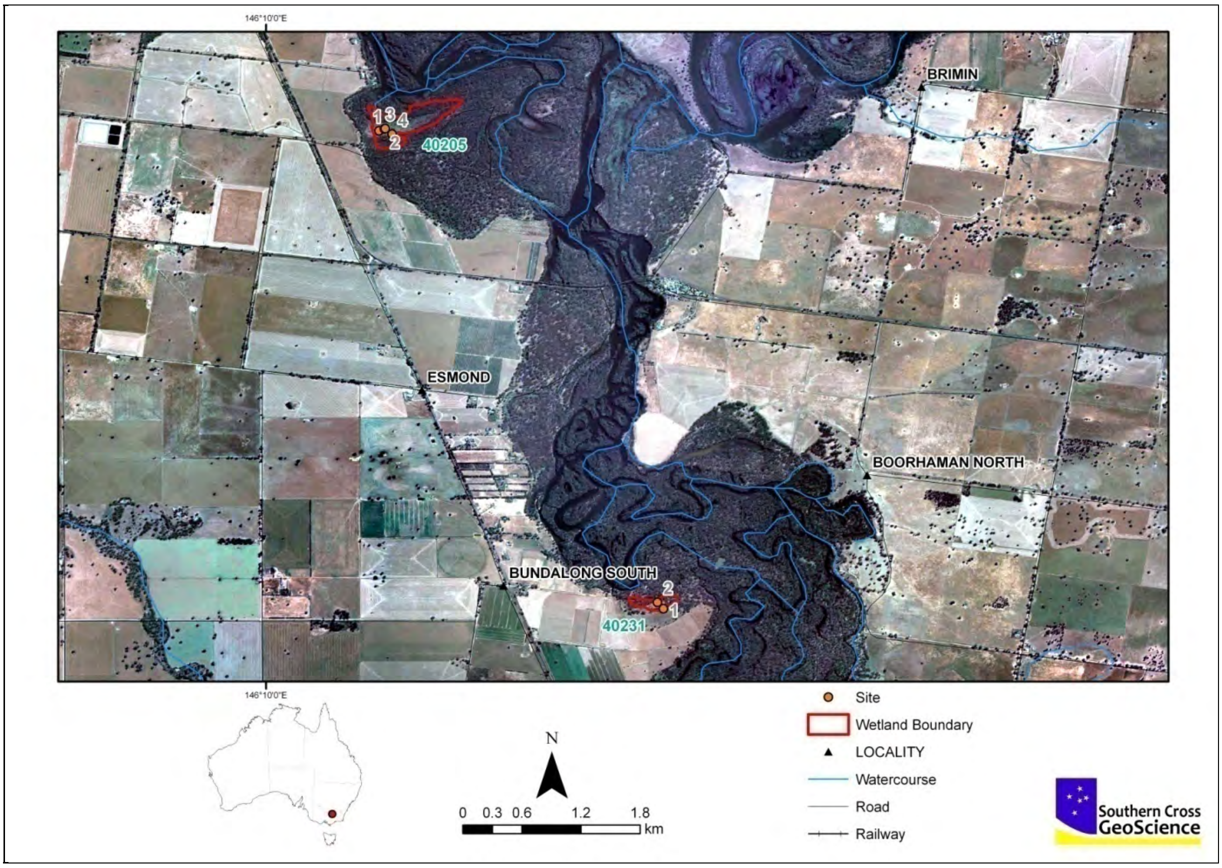

Figure 8-49. Wetland ID 40231 and sample site locations.

8.5.2. Soil profile description and distribution

Two sites were described and sampled. Sites were based on elevation differences. The soil subtype and general location description are presented in Table 8-23.

The profile 40231_1 (Figure 8-51) occurred on a bare and firm surface at the lowest part of the wetland, the soil consisted of brown clay loam over mottled grey silty clay loam and brown gravelly sand below 40 cm. The profile 40231_2 (Figure 8-52) occurred on a partially bare surface, the soil consisted of brown medium clay over grey light medium clay and sandy clay, gravelly sand occurred at 50 cm and continued to base of observation. Additional site and profile description data are presented in Tables 8-25 and 8-26, respectively.

Table 8-23. Soil identification, subtype and general location description for Wetland ID 40231.

Site ID	Easting UTM zone 55H	Northing UTM zone 55H	Acid sulfate soil subtype class	General location description
40231_1	428255	6004815	sulfuric soil	bare surface at lowest point of wetland
40231_2	428204	6004879	hydrosol	partly bare area

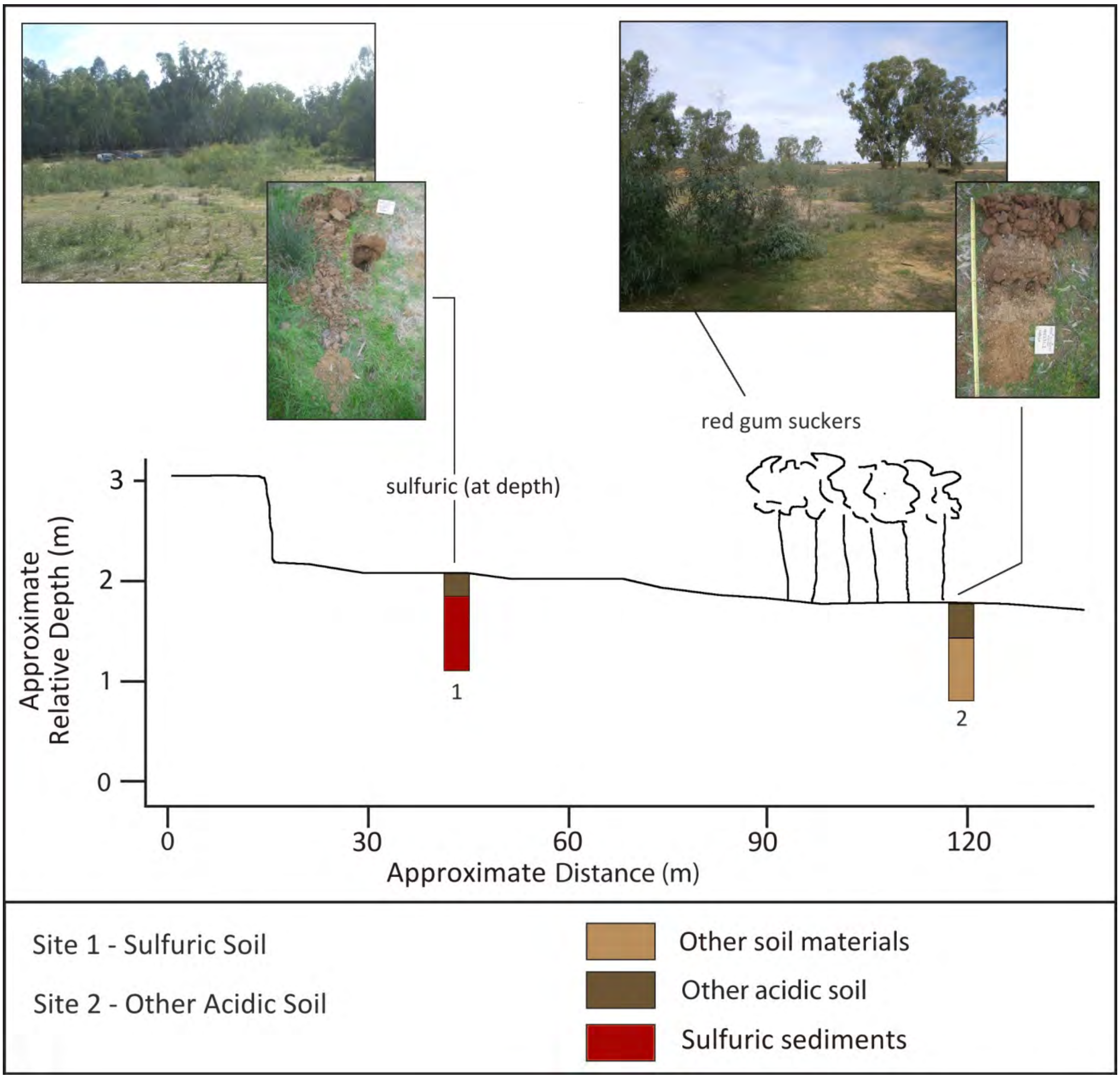

Figure 8-50. Conceptual cross section diagram showing the toposequence relationship of the Wetland ID 40231 sediments/soil materials.

Figure 8-51. Photographs of site 40231_1, showing the location of the wetland transect, and the soil profile.

Figure 8-52. Photographs of site 40231_2, showing the slightly elevated sampling site, and the soil profile.

8.5.3. Laboratory data assessment

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

The pH data is provided in Table 8-24 and profiles for all the sites sampled are presented in Figure 8-53. The pH_W values ranged between 3.23 and 6.15. Three sulfuric materials (i.e. $pH_W < 4$) were identified at site 40231_1 (20-90 cm). The pH_{FOX} values ranged between 1.54 and 6.42. The pH_{FOX} results indicate that eight of the 12 surface soils examined may have the potential to acidify to pH < 4 as a result of sulfide oxidation. However, the S_{CR} data shows only one of these layers contained detectable sulfide (i.e. $S_{CR} \geq 0.01\%$ S). Two of the sulfuric soil materials had a $pH_{FOX} < 2.5$. Other acidic soil materials were identified at both sites, indicating acidity in the soil profile at levels where aluminium may mobilise. Two of the other acidic soil materials acidified to a pH < 4 after at least 8 weeks of incubation.

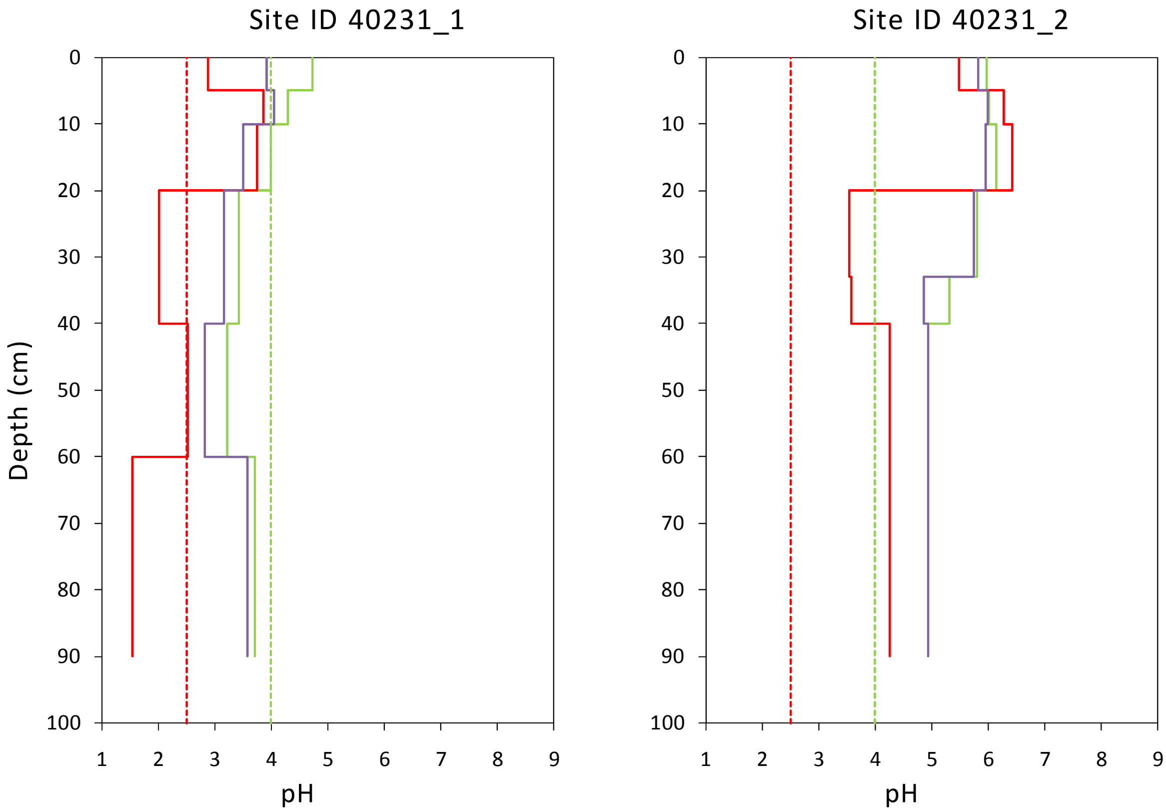

Figure 8-53. Depth profiles of soil pH for Wetland ID 40231 (40231_1 – 40231_2), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-24 and summarised in Figure 8-54.

Chromium reducible sulfur

Chromium reducible sulfur (S_{CR}) values ranged between < 0.01 and 0.02% S. A sulfidic soil material (i.e. S_{CR} ≥ 0.01% S) was only identified at site 40231_1 (40-60 cm).

Acid volatile sulfide

Monosulfidic soil materials (i.e. S_{AV} ≥ 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 3 and 144 mole H^+/tonne. An increase in the TAA with depth was observed at site 40231_1.

Retained acidity

The retained acidity ranged between zero and 22 mole H^+/tonne, with all except two of the sulfuric soil materials having no retained acidity

Net acidity

Net acidity ranged between 3 and 164 mole H^+/tonne. The three sulfuric materials had net acidities of between 4 and 164 mole H^+/tonne. Two of the sulfuric materials had high net acidities (i.e. > 100 mole H^+/tonne).

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) were 566 and 6,180 mg/kg. Both surface soil layers examined 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.

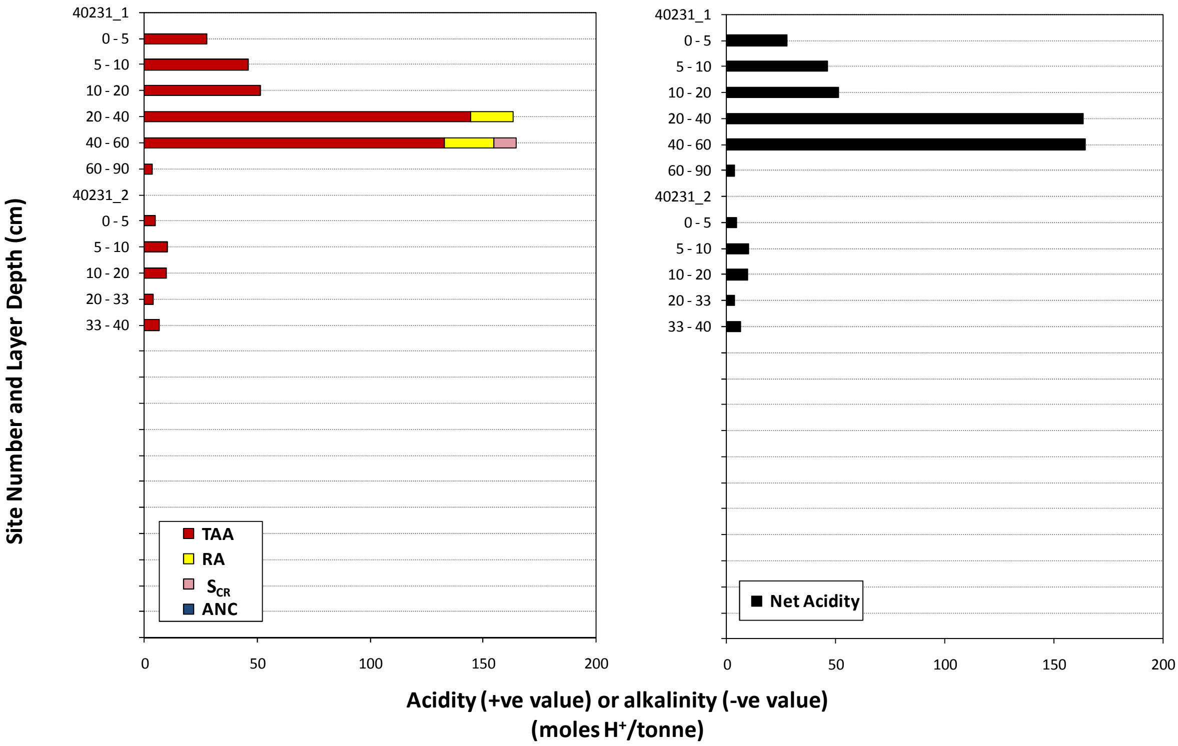

Figure 8-54. Acid-base accounting depth profiles for Wetland ID 40231 (40231_1 – 40231_2). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.5.4. Discussion

Acid sulfate soils materials were found at one site in Wetland ID 40231 (i.e. site 40231_1). The remaining site was classified as an other acidic soil. Three sulfuric materials were observed at one of the sites within this wetland. Two of the sulfuric subsoils had high net acidities (i.e. > 100 mole H^+/tonne). The reduced inorganic sulfur content of the single sulfidic sample was low (i.e. S_{CR}. = 0.02% S). These results indicate that acidity would be produced upon oxidation of sulfides in these materials. Both 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. Two sampling sites also 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 40231 are:

- Acidification hazard: The data indicate that with predominantly low to moderate net acidities, and only one sulfidic material where the S_{CR} was only 0.02% S, that the overall degree of acidification hazard is moderate. A high acidification hazard was only identified in two sulfuric subsoils that had high net acidities.

- Deoxygenation hazard: The soluble sulfate content of surface soil materials at two 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 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 Wetland ID 40231:

Soil materials:	Sulfuric materials were observed at 1 site within this wetland. And one of these materials was sulfidic. Other acidic soil materials observed at 1 site. Low to moderate net acidities dominant within wetland, although 2 sulfuric subsoil layers had high net acidities.
Acid sulfate soil identification:	• One site had a sulfuric soil • One site had an other acidic soil.
Hazard assessment	• Acidification hazard – moderate level of concern • Deoxygenation hazard - high level of concern • Metal mobilisation hazard – high level of concern

Table 8-24. Laboratory analytical data for acid sulfate soil assessment of Wetland ID 40231.
(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	4.73	2.88	3.91	6180	4.95	27.53	< 0.01	0	0.00	27.53	< 0.01	other acidic
1.2	5-10	medium	4.29	3.86	4.05		4.60	46.07	< 0.01	0	0.00	46.07	< 0.01	other acidic
1.3	10-20	medium	4.00	3.74	3.51		4.65	51.51	< 0.01	0	0.00	51.51	< 0.01	other acidic
1.4	20-40	medium	3.42	2.02	3.16		4.24	144.33	< 0.01	19	0.00	163.33	< 0.01	sulfuric
1.5	40-60	medium	3.23	2.52	2.83		4.28	132.81	0.02	22	0.00	164.39	< 0.01	sulfuric
1.6	60-90	medium	3.72	1.54	3.57		6.28	3.54	< 0.01	0	0.00	3.54	< 0.01	sulfuric
2.1	0-5	fine	5.98	5.48	5.82	566	5.97	4.62	< 0.01	0	0.00	4.62	< 0.01	other soil materials
2.2	5-10	fine	6.01	6.27	6.00		5.71	9.98	< 0.01	0	0.00	9.98	< 0.01	other soil materials
2.3	10-20	fine	6.15	6.42	5.96		5.59	9.48	< 0.01	0	0.00	9.48	< 0.01	other soil materials
2.4	20-33	n.r.	5.81	3.54	5.75		6.23	3.64	< 0.01	0	0.00	3.64	< 0.01	other soil materials
2.5	33-40	coarse	5.32	3.58	4.87		5.72	6.33	< 0.01	0	0.00	6.33	< 0.01	other acidic
2.6	40-90	fine	4.94	4.26	4.93		6.18	3.34	< 0.01	0	0.00	3.34	< 0.01	other acidic

Table 8-25. Site description data for acid sulfate soil assessment of Wetland ID 40231.

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1		firm	partly bare	Base of wetland, within sucker community	low point of wetland	sulfuric soil	
2		firm	partly bare	Margin of wetland depression	slightly elevated fringe of wetland	other acidic	

Table 8-26. Profile description data for acid sulfate soil assessment of Wetland ID 40231.

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 4/4	CL		M	2	FM			PO	2		4.65	
1.2	5-10	7.5YR 4/4	CL		M	3	FM			PO	2		4.21	
1.3	10-20	7.5YR 4/4	CL		W	3	FM			PO	1		4.16	
1.4	20-40	10YR 6/2	ZCL		W	3	FM			PO	1		3.54	
1.5	40-60	10YR 5/2	ZCL		W	3	FM			MA	0		3.78	
1.6	60-90	7.5YR 5/8	S		W					SG	0		3.93	
2.1	0-5	5YR 4/6	C	light medium	T	3	FM			PO	2		6.10	some tabular peds
2.2	5-10	5YR 4/6	C	light medium	T	4	FM			PO	2		6.08	
2.3	10-20	5YR 5/3	C	light medium	T	4	FM			PO	2		6.31	
2.4	20-33	n/r	n/r		T					n/r			n/r	distinct grey layer
2.5	33-40	5YR 4/3	S		T					SG	0		6.69	pan-like, possibly old surface; quartz fragments
2.6	40-90	5YR 4/3	C	S	T					MA	0		5.52	quartz fragments

8.6. Travellers Creek (Wetland ID 40790)

8.6.1. Location and setting description

Travellers Creek is a long sinuous wetland on the southern side of the Murray River (Figure 8-55), west of Wodonga. The wetland is about 6 km long and 27 ha, forming a distinct channel flanked on either side by the alluvial plain system. Streambanks are often steep and the channel is somewhat incised. A ferromanganese hardpan was observed generally outcropping at stream level. At the time of the soil survey in May 2010 the system was flowing and appeared to be acting as an anabranch of the Murray rather than an ox-bow. Gravels are very common throughout the wetland, often forming bars.

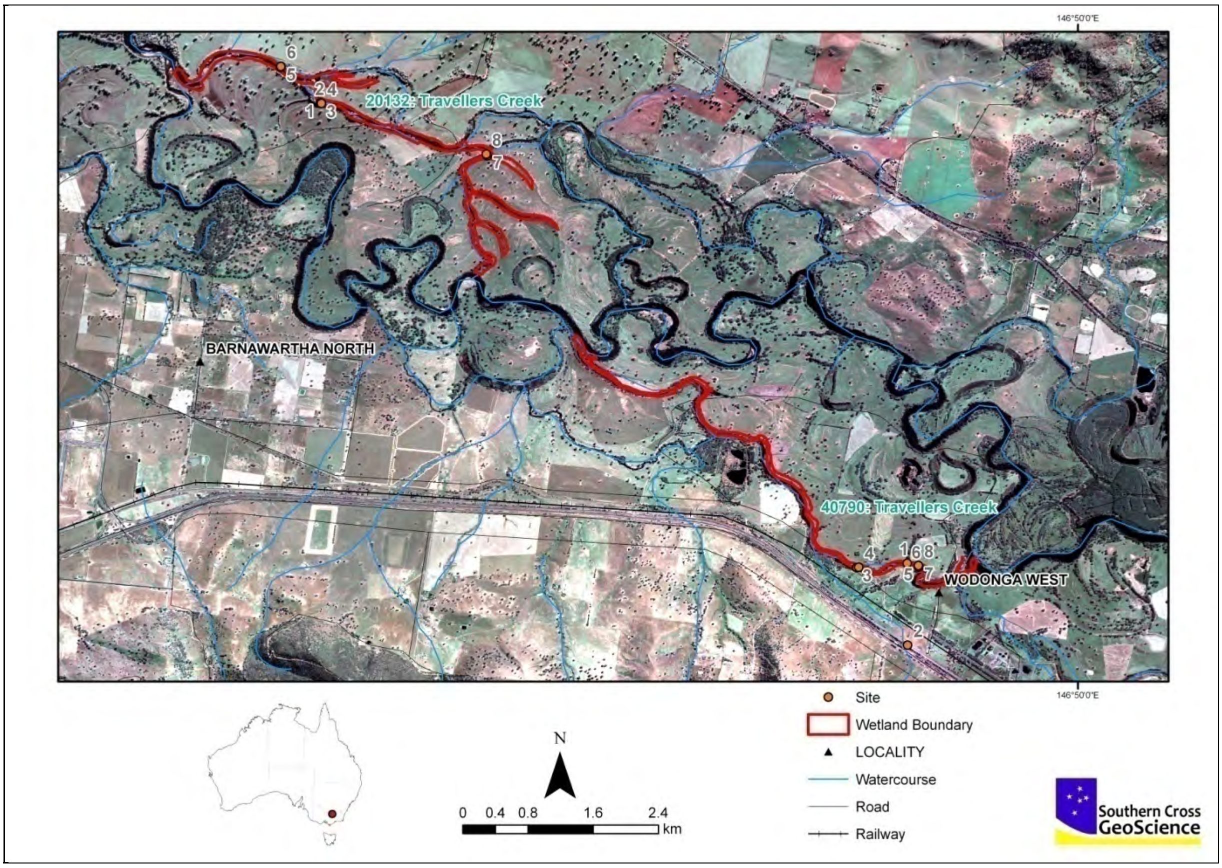

Figure 8-55. Travellers Creek and sample site locations.

8.6.2. Soil profile description and distribution

Eight sites were sampled in 3 transects, 4 sites in one transect and 2 each in the other transects. Sites were distributed across the wetland based on surface features. A transect approach was used, 3 transects being completed (Profiles 1 and 2; Profiles 3 and 4; Profiles 5, 6, 7 and 8).

The profile 40790_1 was subaqueous (45 cm water depth) and occurred within the main channel, the soil consisted of a thin veneer of dark grey silty loam over sand and gravels. The profile 40790_2 occurred on the crest of a bar, the soil consisted of dark grey gravelly sand. The soil subtype and general location description are presented in Table 8-27. The profile 40790_3 was subaqueous (25 cm water depth) and occurred within the main channel, the soil consisted of dark grey sand over very gravelly sandy clay. The profile 40790_4 occurred on a bar, the soil consisted of dark grey very gravelly sand. The profile 40790_5 was subaqueous (20 cm water depth) and occurred within the main channel, the soil consisted of dark grey gravelly sand over grey silty clay loam. The profile 40790_6 occurred on a bar, the soil consisted of brown gravelly sand over grey gravelly sand. The profile 40790_7 was subaqueous and occurred within a backwater section between the bar and streambank, the soil consisted of grey mottled gravelly sand over very compact gravels at 40 cm. The profile 40790_8 occurred in the slightly elevated area at the edge of the channel and below the streambank, the soil consisted of grey clayey sand over grey mottled medium sandy clay. Additional site and profile description data are presented in Tables 8-31 and 8-32, respectively.

Table 8-27. Soil identification, subtype and general location description for Travellers Creek.

Site ID	Easting UTM zone 55H	Northing UTM zone 55H	Acid sulfate soil subtype class	General location description
40790_1	483300	6006406	subaqueous soil	subaqueous, in main channel
40790_2	483305	6005405	hydrosol	on crest of bar
40790_3	482797	6006353	subaqueous soil	subaqueous, in main channel
40790_4	482818	6006357	hydrosol	on bar
40790_5	483415	6006363	subaqueous soil	subaqueous, in main channel
40790_6	483410	6006369	hydrosol	on bar
40790_7	483410	6006364	subaqueous soil	subaqueous backwater section
40790_8	483411	6006380	hydrosol	slightly elevated, edge of channel below streambank

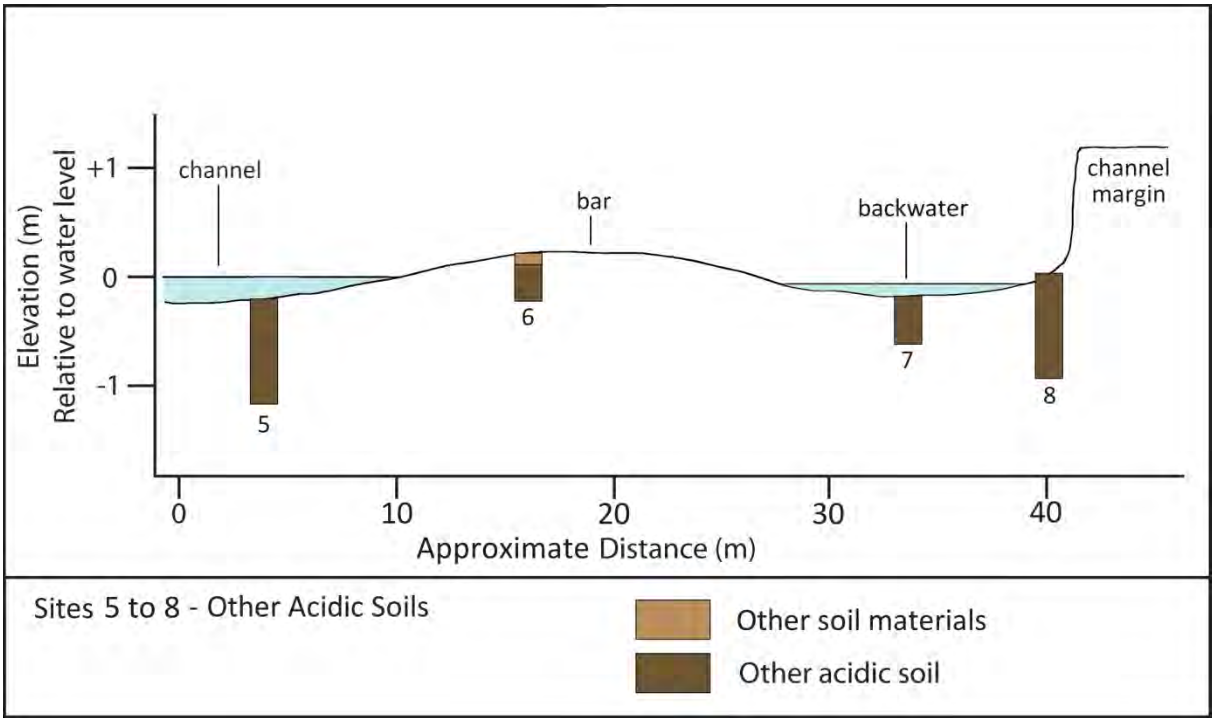

Figure 8-56. Conceptual cross section diagram showing the toposequence relationship of the Travellers Creek sediments/soil materials for sites 40790_5 to 40790_8.

8.6.3. Laboratory data assessment

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

The pH data is provided in Table 8-28 and profiles for all the sites sampled are presented in Figures 8-57 and 8-58. The pH_W values ranged between 4.84 and 7.40. Sulfuric materials (i.e. pH_W < 4) were not present. The pH_{FOX} values ranged between 1.63 and 7.04. The pH_{FOX} results indicate that 18 of the 35 surface soils examined may have the potential to acidify to pH < 4 as a result of sulfide oxidation. However, the S_{CR} data shows these layers contained no detectable sulfide (i.e. S_{CR} < 0.01% S). One soil material had a pH_{FOX} < 2.5. Other acidic soil materials were identified at all eight sites, indicating acidity in the soil profile at levels where aluminium may mobilise. None of the soil materials acidified to a pH < 4 after at least 8 weeks of incubation.

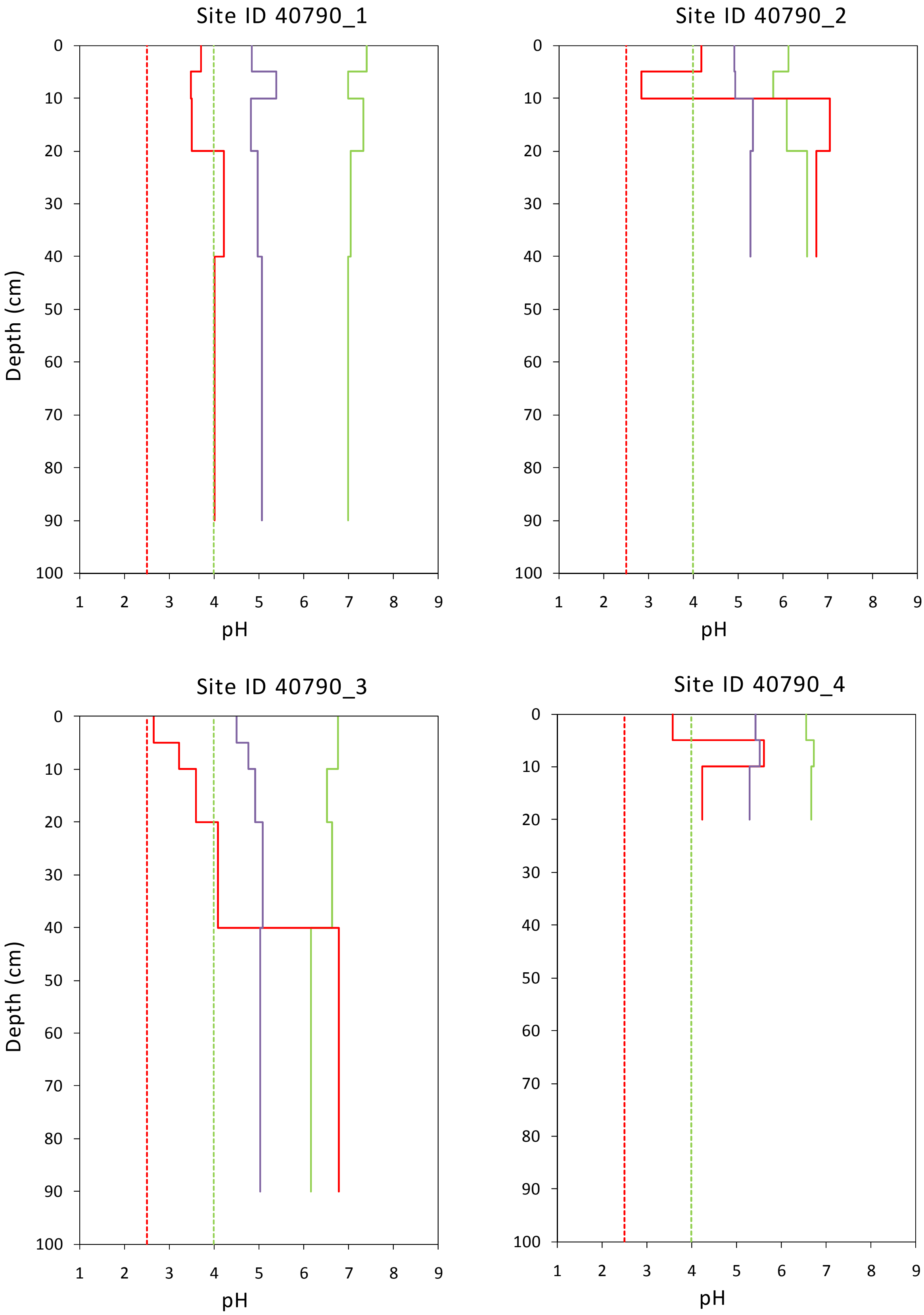

Figure 8-57. Depth profiles of soil pH for Travellers Creek (40790_1 – 40790_4), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

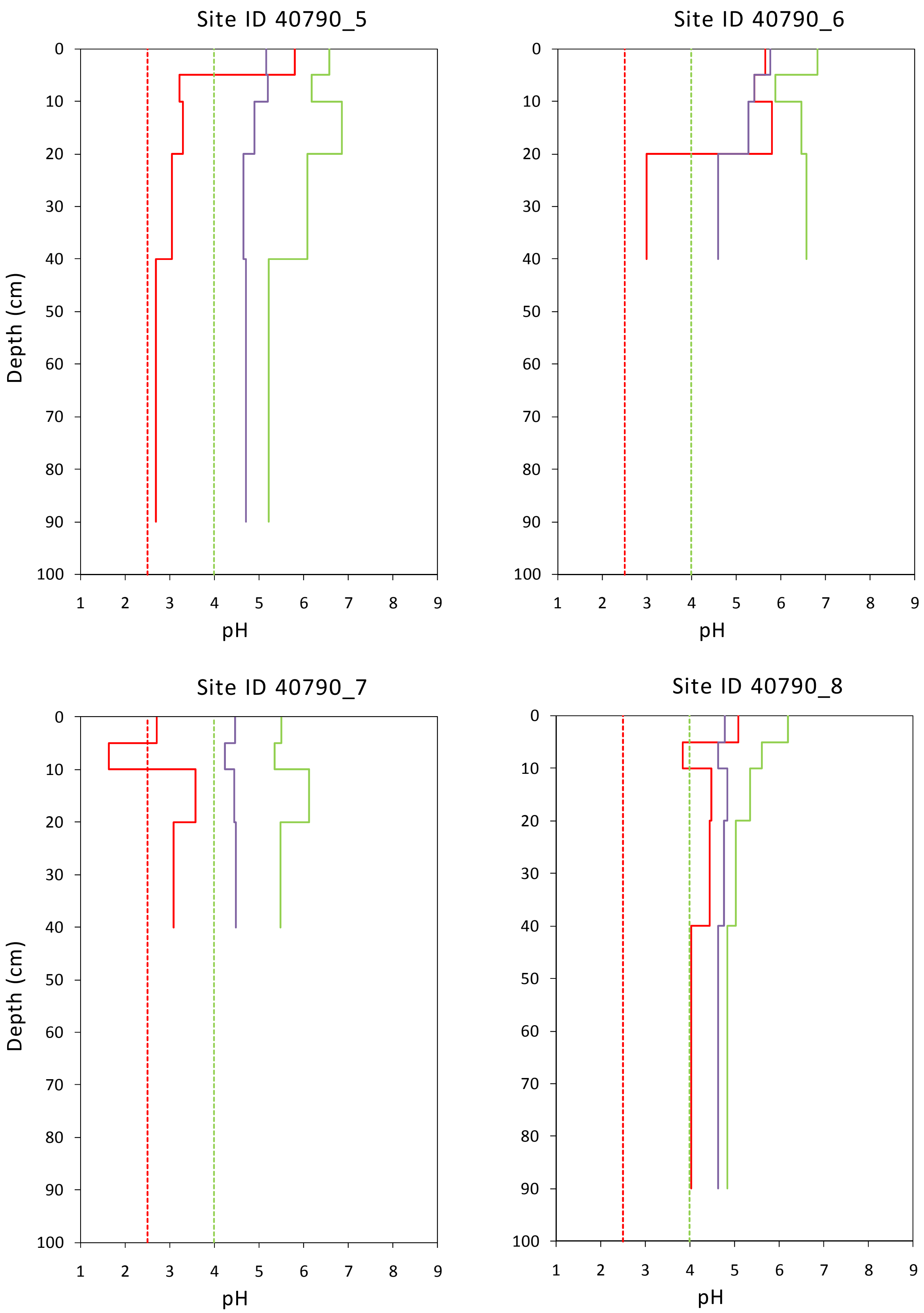

Figure 8-58. Depth profiles of soil pH for Travellers Creek (40790_5 – 40790_8), showing soil pH (pH_W as green line), peroxide treated pH (pH_{FOX} as red line) and ageing pH ($pH_{incubation}$ after at least 8 weeks as purple line). Critical pH_W and $pH_{incubation}$ value of 4 (green dashed line) and critical pH_{FOX} value of 2.5 (red dashed line).

Acid-base accounting

The acid-base accounting data is provided in Table 8-28 and summarised in Figures 8-59 and 8-60.

Chromium reducible sulfur

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

Acid volatile sulfide

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

Acid neutralising capacity

The acid neutralising capacity (ANC) ranged between zero and 0.4 %$CaCO_3$, with the majority of soil materials having no ANC.

Titratable actual acidity

The titratable actual acidity (TAA) ranged between zero and 29 mole H^+/tonne. An increase in the TAA with depth was sometimes observed.

Retained acidity

There was no retained acidity at any of the sites as all samples had a pH_{KCl} > 4.5.

Net acidity

Net acidity ranged between -55 and 29 mole H^+/tonne, with the majority of soil materials having a low net acidity (i.e. ≤ 18 mole H^+/tonne).

Water Soluble Sulfate

The water soluble sulfate in the surface soils (i.e. 0-5 cm) ranged between 18 and 31 mg/kg. None 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 8-29 and 8-30, respectively. The field pH of the three surface waters collected ranged between 6.8 and 8.4, with one site 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 concentrations ranged between 4.5 and 11.5 mg/L. Some nutrient (i.e. NH_4, PO_4), metal (i.e. Ag, Al, Cd, Co, Fe, Mn, Zn) and turbidity values were found to exceed the most relevant ANZECC/ARMCANZ (2000) guideline value. The field pH of the groundwater ranged between 6.5 and 7.2 indicating that the groundwater has not been affected by acidification. The groundwater had low sulfate concentrations of between 13.7 and 16.7 mg/L.

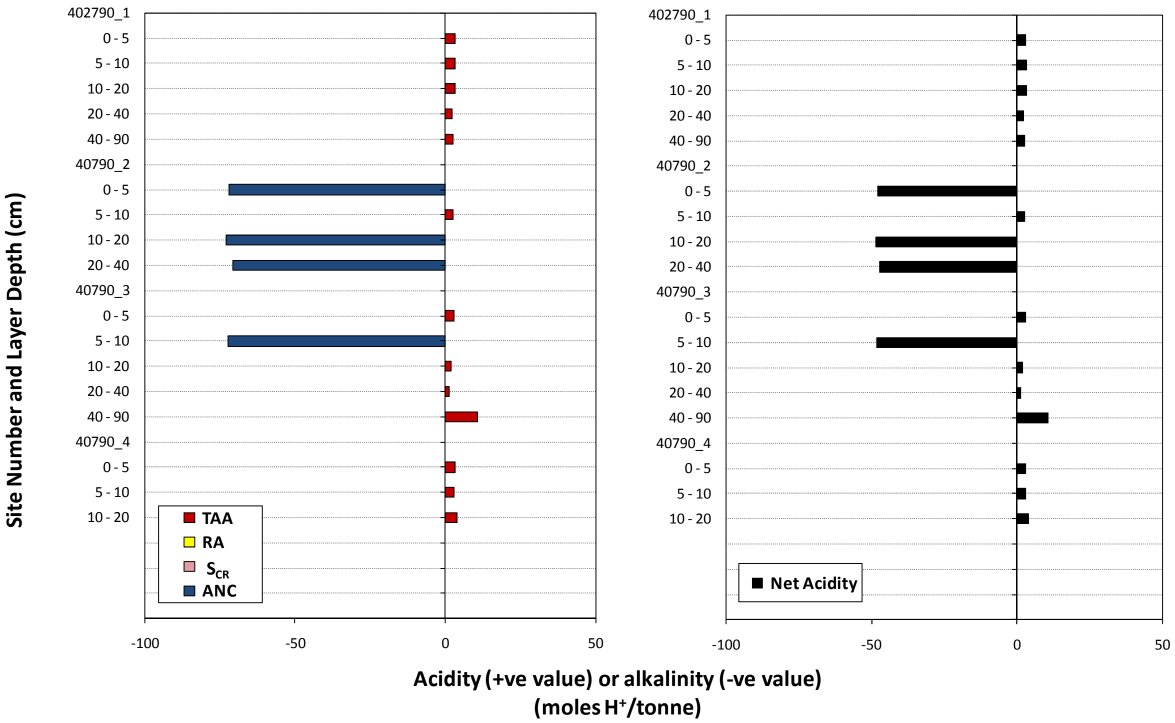

Figure 8-59. Acid-base accounting depth profiles for Travellers Creek (40790_1 – 40790_4). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

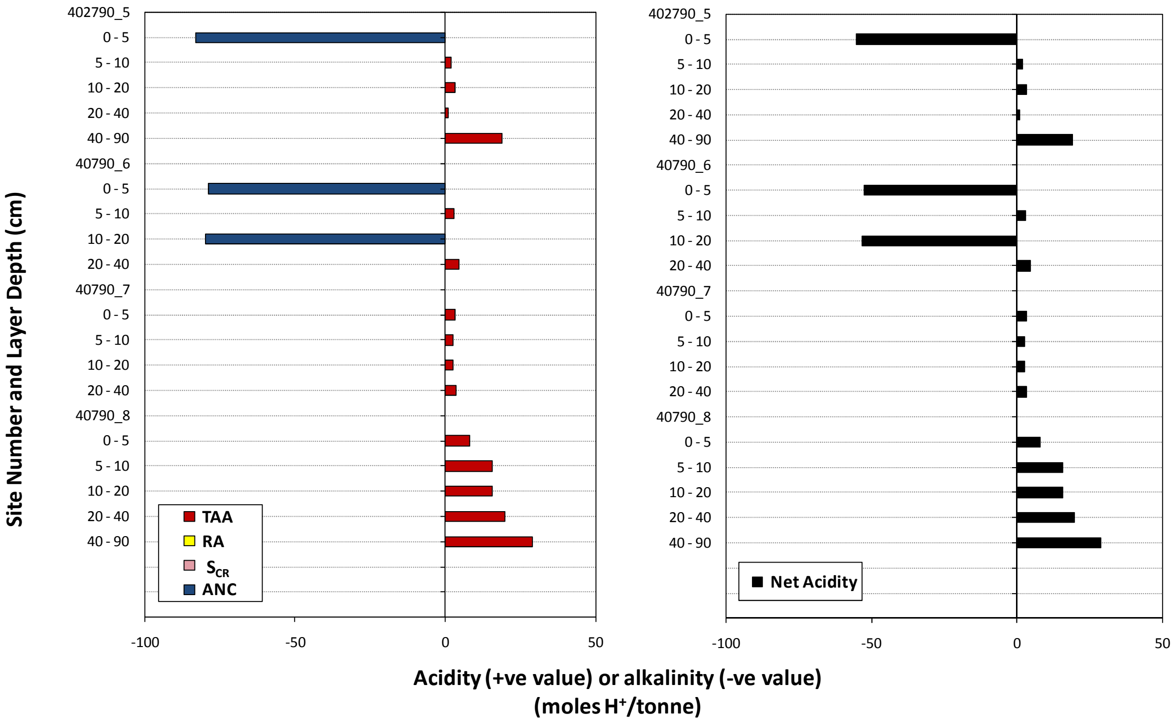

Figure 8-60. Acid-base accounting depth profiles for Travellers Creek (40790_5 – 40790_8). Left side shows the components: titratable actual acidity (TAA - red bar), acid generating potential (AGP as S_{CR} -pink bar), acid neutralising capacity (ANC - blue bar), retained acidity (RA - yellow bar), and right side shows net acidity.

8.6.4. Discussion

Acid sulfate soils materials were not found at Travellers Creek. All soil materials were classified as either other acidic soils or other soil materials.

None 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, all sites within this wetland require no further assessment.

Summary of key findings for the Travellers Creek:

Soil materials:	Sulfuric and sulfidic materials were not observed within this wetland. Other acidic soil materials observed at all 8 sites. Low net acidities dominant within wetland.
Acid sulfate soil identification:	• Other acidic soils present at all sites.
Hazard assessment	• Acidification hazard - low level of concern • Deoxygenation hazard - low level of concern • Metal mobilisation hazard – low level of concern

Table 8-28. Laboratory analytical data for acid sulfate soil assessment of Travellers Creek (Wetland ID 40790).
(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	7.40	3.72	4.85*	26.4	6.21	3.15	< 0.01	0	0.00	3.15	< 0.01	other acidic
1.2	5-10	medium	6.98	3.49	5.39*		6.23	3.34	< 0.01	0	0.00	3.34	< 0.01	other acidic
1.3	10-20	coarse	7.32	3.50	4.83*		5.92	3.34	< 0.01	0	0.00	3.34	< 0.01	other acidic
1.4	20-40	coarse	7.04	4.21	4.97*		5.87	2.43	< 0.01	0	0.00	2.43	< 0.01	other acidic
1.5	40-90	coarse	6.99	4.01	5.06*		6.13	2.53	< 0.01	0	0.00	2.53	< 0.01	other acidic
2.1	0-5	coarse	6.13	4.18	4.91	21.5	6.61	0.00	< 0.01	0	0.36	-47.99	< 0.01	other acidic
2.2	5-10	coarse	5.78	2.84	4.94		6.39	2.56	< 0.01	0	0.00	2.56	< 0.01	other acidic
2.3	10-20	coarse	6.08	7.04	5.34		7.04	0.00	< 0.01	0	0.36	-48.59	< 0.01	other acidic
2.4	20-40	coarse	6.54	6.75	5.27*		6.60	0.00	< 0.01	0	0.35	-47.16	< 0.01	other acidic
3.1	0-5	coarse	6.77	2.65	4.51*	30.9	6.41	3.06	< 0.01	0	0.00	3.06	< 0.01	other acidic
3.2	5-10	coarse	6.77	3.22	4.77		6.78	0.00	< 0.01	0	0.36	-48.14	< 0.01	other acidic
3.3	10-20	coarse	6.52	3.60	4.91		6.42	2.02	< 0.01	0	0.00	2.02	< 0.01	other acidic
3.4	20-40	fine	6.63	4.09	5.09*		6.47	1.44	< 0.01	0	0.00	1.44	< 0.01	other acidic
3.5	40-90	fine	6.16	6.79	5.02*		5.48	10.61	< 0.01	0	0.00	10.61	< 0.01	other acidic
4.1	0-5	coarse	6.55	3.58	5.43*	23.9	5.97	3.14	< 0.01	0	0.00	3.14	< 0.01	other acidic
4.2	5-10	coarse	6.73	5.61	5.51*		5.79	2.91	< 0.01	0	0.00	2.91	< 0.01	other soil materials
4.3	10-20	coarse	6.67	4.24	5.29		5.91	4.00	< 0.01	0	0.00	4.00	< 0.01	other acidic
5.1	0-5	coarse	6.57	5.81	5.16*	17.7	6.61	0.00	< 0.01	0	0.41	-55.25	< 0.01	other acidic
5.2	5-10	coarse	6.18	3.22	5.20		6.39	1.99	< 0.01	0	0.00	1.99	< 0.01	other acidic
5.3	10-20	medium	6.85	3.29	4.89*		6.24	3.28	< 0.01	0	0.00	3.28	< 0.01	other acidic
5.4	20-40	coarse	6.09	3.06	4.66*		6.43	1.02	< 0.01	0	0.00	1.02	< 0.01	other acidic
5.5	40-90	coarse	5.21	2.69	4.70*		5.24	19.01	< 0.01	0	0.00	19.01	< 0.01	other acidic
6.1	0-5	coarse	6.82	5.65	5.76*	17.6	6.53	0.00	< 0.01	0	0.39	-52.43	< 0.01	other soil materials
6.2	5-10	coarse	5.87	5.41	5.41*		6.22	2.89	< 0.01	0	0.00	2.89	< 0.01	other soil materials
6.3	10-20	coarse	6.46	5.81	5.28*		6.60	0.00	< 0.01	0	0.40	-53.07	< 0.01	other acidic
6.4	20-40	coarse	6.58	2.99	4.60*		5.73	4.56	< 0.01	0	0.00	4.56	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 10 weeks).

Table 8-28 (continued). Laboratory analytical data for acid sulfate soil assessment of Travellers Creek (Wetland ID 40790).
(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
7.1	0-5	coarse	5.50	2.71	4.47*	20.3	6.01	3.17	< 0.01	0	0.00	3.17	< 0.01	other acidic
7.2	5-10	coarse	5.35	1.63	4.23*		5.83	2.68	< 0.01	0	0.00	2.68	< 0.01	other acidic
7.3	10-20	fine	6.12	3.58	4.45		6.03	2.68	< 0.01	0	0.00	2.68	< 0.01	other acidic
7.4	20-40	fine	5.48	3.09	4.49		5.97	3.44	< 0.01	0	0.00	3.44	< 0.01	other acidic
8.1	0-5	medium	6.20	5.08	4.79*	29.1	5.52	8.03	< 0.01	0	0.00	8.03	< 0.01	other acidic
8.2	5-10	medium	5.62	3.84	4.63*		5.05	15.72	< 0.01	0	0.00	15.72	< 0.01	other acidic
8.3	10-20	medium	5.34	4.49	4.83		5.09	15.68	< 0.01	0	0.00	15.68	< 0.01	other acidic
8.4	20-40	coarse	5.03	4.45	4.77		4.98	19.90	< 0.01	0	0.00	19.90	< 0.01	other acidic
8.5	40-90	coarse	4.84	4.03	4.63		4.83	29.01	< 0.01	0	0.00	29.01	< 0.01	other acidic

* Indicates that a stable pH has not yet been reached for this sample (after 10 weeks).

Table 8-29. Field hydrochemistry data for acid sulfate soil assessment of Travellers Creek (Wetland ID 40790).

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
*Lowland River**		*125-2200*	*85-110*		*6.5-8.0*			*6-50*		
*Freshwater Lakes**		*20-30*	*90-110*		*6.5-8.0*			*1-20*		
40790_1 (SW)	15.7	46.5		9.43	8.40	310.6		9	16	
40790_2 (PW)	16	195		4.8	7.20	263		>1000	44	
40790_3 (PW)	13.8	84.9		2.63	6.96	280.3		>1000	24	
40790_4 (PW)	14.1	205.9		2.86	6.54	123		>1000	n.r.	
40790_5 (SW)	13.5	58.7		7.61	7.93	351.8		23	20	
40790_7 (SW)	14.1	203.1		0.25	6.83	-106.9		>1000	104	

* 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 8-30. Laboratory hydrochemistry data for acid sulfate soil assessment of Travellers Creek (Wetland ID 40790).

Parameter	units	ANZECC Guidelines	Site 1 (SW)	Site 2 (PW)	Site 3 (PW)	Site 5 (SW)	Site 7 (SW)
depth	cm						
Na	mg l^{-1}		4.72	3.47	4.73	4.70	5.00
K	mg l^{-1}		1.34	1.17	0.79	2.21	1.60
Ca	mg l^{-1}		2.84	6.80	2.19	5.89	9.12
Mg	mg l^{-1}		1.43	3.22	1.09	2.28	3.19
Si	mg l^{-1}		0.67	1.08	0.91	0.45	6.37
Br	mg l^{-1}		0.036	0.027	0.015	0.027	0.031
Cl	mg l^{-1}		571	227	209	77	356
NO_3	mg l^{-1}	0.7	0.121	0.092	0.011	0.062	<0.005
NH_4-N	mg l^{-1}	0.01	0.019	0.575	0.246	0.006	0.479
PO_4-P[E]	mg l^{-1}	0.005	0.005	0.006	0.009	0.003	0.013
SO_4	mg l^{-1}		4.45	13.67	16.70	10.59	11.47
Ag	µg l^{-1}	0.05	2	<1	<1	<1	<1
Al[A]	µg l^{-1}	55	10	36	20	151	12
As[B]	µg l^{-1}	13	1	<1	<1	1	4
Cd	µg l^{-1}	0.2	<1	95	64	110	112
Co	µg l^{-1}	2.8	<1	1	<1	<1	9
Cr[C]	µg l^{-1}	1	<1	1	1	1	1
Cu[H]	µg l^{-1}	1.4	1	1	1	1	<1
Fe	µg l^{-1}	300	21	59	32	171	26,574
Mn	µg l^{-1}	1700	20	1,878	65	94	5,981
Ni[H]	µg l^{-1}	11	<1	1	1	2	1
Pb[H]	µg l^{-1}	3.4	<1	1	1	1	<1
Se	µg l^{-1}	11	<1	<1	<1	<1	<1
Zn[H]	µg l^{-1}	8	10	51	43	54	66
DOC	mg l^{-1}		1.58	2.40	3.04	3.49	1.72

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 NH_4 and PO_4, 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 8-31. Site description data for acid sulfate soil assessment of Travellers Creek (Wetland ID 40790).

Site No.	Depth to Water Table (cm)	Surface Condition	Earth Cover (Vegetation)	Location Notes	Rationale for site selection	ASS Soil Classification	Comments
1	-45	subaqueous		Main channel	channel/bar transect	Other acidic	Flowing, acting as anabranch of the Murray
2	30	bare, sandy	bare	Bar	channel/bar transect	Other acidic	Flowing, acting as anabranch of the Murray
3	25	bare, sandy	bare	Bar	bar/backwater transect	Other acidic	Flowing, acting as anabranch of the Murray
4	30	bare, sandy	bare	Bar	bar/backwater transect	Other acidic	Flowing, acting as anabranch of the Murray
5	-20	subaqueous		Main channel	channel/bar/channel margin transect	Other acidic	Flowing, acting as anabranch of the Murray
6	30	bare, sandy	bare	Bar, main channel side	channel/bar/channel margin transect	Other acidic	Flowing, acting as anabranch of the Murray
7		bare, sandy	bare	Bar, streambank side	channel/bar/channel margin transect	Other acidic	Flowing, acting as anabranch of the Murray
8		soft, muddy	bare	Extreme edge of channel at base of vertical bank	channel/bar/channel margin transect	Other acidic	Flowing, acting as anabranch of the Murray

Table 8-32. Profile description data for acid sulfate soil assessment of Travellers Creek (Wetland ID 40790).

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	ZL		W					MA	0		7.02	some gravels
1.2	5-10	10YR 3/1	ZL		W					MA	0		6.98	some gravels
1.3	10-20	10YR 4/1	LS		W					SG	0		6.96	some gravels
1.4	20-40	10YR 4/1	S		W					SG	0		6.86	gravels common
1.5	40-90	not recorded	S		W					SG	0		6.65	predominantly gravels
2.1	0-5	10YR 4/2	S		M					SG	0		7.79	predominantly gravels
2.2	5-10	10YR 4/2	S		M					SG	0		7.62	predominantly gravels
2.3	10-20	10YR 5/3	S		M					SG	0		7.09	gravels common
2.4	20-40	10YR 5/3	S		W					SG	0		6.87	predominantly gravels; equipment refusal
3.1	0-5	10YR 4/2	S		W					SG	0		7.36	predominantly gravels
3.2	5-10	10YR 4/2	S		W					SG	0		7.30	predominantly gravels
3.3	10-20	10YR 5/3	S		W					SG	0		7.31	predominantly gravels
3.4	20-40	10YR 5/5	C	S	W	4	FM			MA	0		7.48	predominantly gravels
3.5	40-90	10YR 3/3	C	heavy	W	4	FM			MA	0		7.69	
4.1	0-5	10YR 5/2	S		W					SG	0		7.07	some gravels
4.2	5-10	10YR 5/2	S		W					SG	0		6.60	some gravels
4.3	10-20	10YR 4/2	S		W					SG	0		6.59	many gravels; equipment refusal
4.4	20-40	10YR 5/4	S		W					SG	0		6.40	gravels common
4.5	40-90	10YR 5/4	S		W					SG	0		6.55	predominantly gravels

Table 8-32 (continued). Profile description data for acid sulfate soil assessment of Travellers Creek (Wetland ID 40790).

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 5/4	S		W					SG	0		6.49	predominantly gravels
5.2	5-10	10YR 6/2	S		W					SG	0		6.63	predominantly gravels
5.3	10-20	10YR 5/1	ZCL		W					MA	0		7.10	some gravels
5.4	20-40	10YR 5/2	S		M					SG	0		7.04	many gravels
5.5	40-90	10YR 5/4	S		W					SG	0		7.04	many gravels
6.1	0-5	10YR 5/4	S		W					SG	0		6.94	many gravels
6.2	5-10	10YR 5/1	S		W					SG	0		6.64	many gravels; equipment refusal
6.3	10-20	10YR 6/2	S		T	4	FM		MAT	SG	0		5.37	some gravels
6.4	20-40	10YR 6/2	S		T	3	FM		MAT	SG	0		5.31	some gravels
6.5	40-90	10YR 6/2	S		T	3	FM		MAT	SG	0		5.90	some gravels
7.1	0-5	10YR 6/2	S		T	2	FM		MAT	SG	0		5.48	some gravels; equipment refusal (compact gravels)
7.2	5-10	10YR 5/1	CS		T	3	FM		MAT	MA	0		6.88	
7.3	10-20	10YR 5/1	C	S	T	2	FM		MAT	MA	0		6.54	
7.4	20-40	10YR 5/1	C	S	T	4	FM		MAT	MA	0		7.27	
7.5	40-90	10YR 5/1	C	S	T	4	FM		MAT	MA	0		5.64	
8.1	0-5	10YR 5/1	C	light	T	2	FM		MAT	MA	0		6.60	
8.2	5-10	10YR 3/1	ZL		W					MA	0		7.02	some gravels
8.3	10-20	10YR 3/1	ZL		W					MA	0		6.98	some gravels
8.4	20-40	10YR 4/1	LS		W					SG	0		6.96	some gravels
8.5	40-90	10YR 4/1	S		W					SG	0		6.86	gravels common

APPENDIX 2. ASSRAP screening criteria

Table 8-33: 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 µS/cm	Detailed assessment	High
	400 – 1000 µS/cm	Detailed assessment	Moderate
	<400 µS/cm	No further assessment	N/A
EC water	>5000 µS/cm	Detailed assessment	High
	1750 – 5000 µS/cm	Detailed assessment	Moderate
	<1750 µS/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.