Acid Sulfate Soils of Bowen North Queensland

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Acid sulfate soils of Bowen, North Queensland

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Summary

This study, funded by the Natural Heritage Trust, involves an area of some 3100 ha around Bowen, North Queensland, and is part of the statewide program to identify acid sulfate soil (ASS) hazard areas. This area is subject to urban expansion into previously horticultural land use areas and, as such, represents a higher level of disturbance of these sensitive coastal soils. The values obtained and mapped in this project constitute a current appraisal of the risks inherent in any change of land use as well as data useful to any determination of current release of oxidation products.

The survey area extends from the salt works to the south of Bowen to the mouth of the Don River to the north-west. ASS were mapped at a scale of 1:25 000 from 154 boreholes, which were located using free survey techniques at spacings of 200 to 400 metres (m) depending on landform, or at wider intervals in tidal areas where ASS were very consistent. Profiles were described in the field, and field peroxide oxidation tests were carried out at regular 0.25 m intervals down the profile, or from within horizons thinner than 0.25 m.

Soil samples for analysis were taken mainly at intervals of 0.5 m from each borehole. Actual acid sulfate soils (AASS) were analysed by the suspension peroxide oxidation combined acidity and sulfate method (SPOCAS), while potential acid sulfate soils (PASS) were analysed by the chromium reducible sulfur method (S_{CR}). Some 830 samples were analysed to determine the actual and potential acid sulfate soil layers. Map units were allocated an AASS code (**A**) and/or PASS code (**S**), and a depth code number indicating the depth to these soil layers, based on the laboratory data. Colouring on the acid sulfate soil map highlights the depth to an actual or potential acid sulfate soil layer and associated level of risk. Sediments with an acid neutralising capacity (ANC) from either shells or strong alkalinity are indicated on the map units by the N subscript, e.g. $S3_N$.

The study identified 1506 hectares (ha) of PASS, and 4.4 ha of AASS. Mapping shows that 626 ha (42%) of the ASS occur in the tidal areas up to the level of the highest astronomical tide (HAT). ASS are shallowest in the tidal zone and occur mainly in the upper metre of the profile. On other landforms such as floodplains, channel benches and dune fields, they are deeper, mainly at depths between 2 and 5 m.

Analysis of AASS layers indicate that they are fully oxidised, with oxidisable sulfur contents (%S) less than 0.02%. Existing acidity concentrations (actual and retained) are also less than the threshold level of 62 mol H^+/t. The %S content varies significantly between the sandy and clayey PASS sediments. Throughout the Bowen area, the mean value in the pyritic sands is 0.29%, while in the clay PASS sediments it is 0.79%, indicating that the mangrove muds pose the highest potential environmental risk. However fine shells in the sandy sediments, and the natural buffering capacity of the alkaline clay sediments provided effective acid neutralising capacities in some of the PASS layers.

There are two main disturbances of ASS at Bowen. The first is at the Bowen marina, which was first dredged in the 1960s and later extended in the 1990s. The second is the man-made lagoon at north Bowen, known as Mullers Lagoon. The very high neutralising capacity, provided by fine shells and coral fragments, of the sediments at the marina meant that the sulfuric acid produced was neutralised *in situ* and did not cause any off-site environmental impacts. The excavated PASS deposited around the sides of the lagoon, were found to be fully oxidised, with no obvious signs of off-site impacts. Urban development of lands underlain by ASS around Bowen has similarly not had any adverse impacts on these sediments.

The groundwater at six sites around Bowen is being monitored on a monthly basis for six months and then only after significant rainfall events to determine if any off-site effects from disturbance of ASS have or are occurring.

1. Introduction

A mapping project to identify the extent of acid sulfate soils (ASS) at six coastal locations in Central Queensland was initiated in 2004 by the Fitzroy Basin Association, Mackay Whitsunday Natural Resource Management Group and the Department of Natural Resources, Mines and Water (NRMW) with funding support from the Natural Heritage Trust. Priority areas of mapping are centered round the Mackay and Rockhampton districts. As well as providing substantial in-kind support, NRMW was contracted to identify areas for mapping, undertake field surveys and provide laboratory analyses of soil and water.

Acid sulfate soils are soils or sediments containing sulfides (primarily pyrite) or an acid-producing layer as a result of the oxidation of sulfides. They commonly occur in low-lying, very poorly drained, coastal land at elevations less than 5 m AHD (Australian Height Datum). Excavating soil or sediment, extracting groundwater or filling land may cause disturbance of ASS. When exposed to air, sulfides oxidise to produce sulfuric acid. Disturbed land can release acid, aluminum, iron and heavy metals into drainage waters, thus affecting aquatic plants and animals. Concrete and steel infrastructure including pipes, foundations and bridges are susceptible to acidic corrosion leading to accelerated structural failure (Ahern et al. 1998, Powell & Martens 2005). Other potential impacts include deoxygenation of waterways (Bush et al.2004) and the excess iron stimulating blooms of cyanobacteria such as *Lyngbya majuscula* (fireweed). More detailed information on ASS, its formation and effects can be found in Malcolm et al. (2002).

In recent times, coastal lowlands around Bowen have been subject to increased development pressure from urban expansion. Very little was known of the extent and distribution of ASS in the Bowen area, and more importantly, of the depths at which ASS occur. Additionally, little was known or understood about the level of disturbance of ASS in the area and the off-site effects of these disturbances on the local water quality. Bowen was therefore identified as a high priority area for ASS mapping, and is the first of three priority areas to be assessed in the northern section of the Central Queensland coast for this project.

The aims of the study were to map the extent of ASS at a scale of 1:25 000, and to monitor groundwater through a network of piezometers to gain an understanding of the quality of the shallow groundwater. This would indicate if ASS had been disturbed and if off-site effects were occurring. The information from this project will be used by state and local government authorities to manage ASS around Bowen, and as a guide to developers and consultants.

1.1 Survey area

The survey area includes all land from the southern end of the Bowen salt works, west to the Don River and north to Queens Bay. This includes the town of Bowen and outlying beach suburb of Queens Bay (Figure 1). The low-lying lands of the Don River delta to the west of the river were not included in this study as they are not at present subject to urban development.

The coastline around Bowen is dominated by the rises and low hills formed on the underlying bedrock of granite, granodiorite and intermediate volcanic rocks. The Don River, which drains a north-orientated valley, enters the Coral Sea between the headlands of Bowen and Abbot Point, which is some 15 km to the west. During the last ice age, which ended 10 000 years before the present (BP), the river carved out a large basin in this valley when the sea level was about 130 m lower than it is today (Chappell 1987). As the sea level rose, the basin was infilled with alluvial gravels, sand, silt, and clay sediments, and formed the Don River floodplain as it is today.

Estuarine sediments of sands, silts and clay also infilled the basin in coastal areas, and the ASS were formed during this time. Later floods buried these sediments as the delta continued to grow seawards. After the sea level stabilised at its current height some 6000 years BP (Chappell 1987), sand dune deposits were laid down at beach fronts with mangrove forests colonising the wetter intertidal areas behind these sand barriers. Continued alluvial and estuarine deposition has extended the Don River delta seawards by several kilometers, leaving a parallel series of former beach ridges stranded in the intertidal zone (Photograph 1).

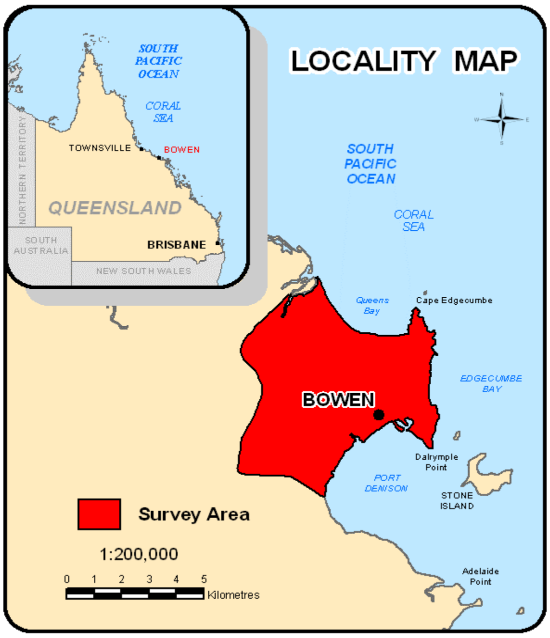

Figure 1. Location of the Bowen survey area

Bowen is a major horticultural centre of Queensland, and is known throughout Australia for its delicious Bowen, or Kensington Pride, mangoes. It is also a significant tomato producing area of Queensland, supplying local and southern markets over the winter and spring months. Fishing is another important recreational and commercial industry, with several processors exporting local reef fish to overseas and domestic markets. Disturbance of ASS could impact upon and adversely affect these primary industries.

Bowen also supports the nearby Collinsville coal mine, which provides coking quality coal to the Bowen coke works, and the Abbot Point coal loading terminal. Growth in the coalmining industry and upgrading of the Abbot Point terminal are driving the urban expansion of Bowen. In these circumstances, it is necessary to identify and manage any impacts on ASS from these urban developments, especially in areas where ASS are at shallow depths.

Photograph 1. Stranded sand dune (background) in the Kings Beach intertidal zone

2. Methods

Field sampling

The Ayr and Bowen 1:250 000 geological maps, and topographic information covering the study area were reviewed before field work began. Black and white aerial photographs from 1990, at a scale of approximately 1:25 000, were used for aerial photo interpretation of the landscape, location of borehole sites, and mapping of soil boundaries. Colour topographic image maps with a 2.5 m contour interval at a scale of 1:25 000 were were used to estimate the elevation of each site.

Free soil survey techniques were employed, with boreholes located at various spacings depending on the landform (Reid 1988). Boreholes were spaced at intervals of 200 to 400 m or more on landforms outside the tidal zone. Wider intervals were used in the tidal zone because the consistency of depth to ASS within the mangrove associations meant that intensive field sampling was not warranted. Time and budget constraints also meant it was more important to identify the areas underlain by ASS outside the tidal zone.

Starting on the lowest-lying land of the tidal flats, boreholes were located progressively up the catchment until ASS were no longer encountered, or a landform boundary identified that defined the inland limit of the Holocene ASS deposition. The soil profile was examined using various methods depending on the landform being sampled. A tapered gouge auger, 1.8 m long with an 83 mm diameter, was used to sample in mangrove areas and, occasionally, on supratidal flats (saltpans) that were wet and inaccessible to a four-wheel-drive-vehicle (Photograph 2).

A trailer-mounted, vacuum-vibro soil-coring rig was used to obtain intact 50 mm cores of saturated sediments to a maximum depth of 5.7 m (Photograph 3). Depending on the type of sediments present, the drier overlying soil materials were first removed with hand augers. This soil was laid out in half-metre sections on a vinyl tarpaulin. When the soil materials were moist and soft enough, the vibro-corer was inserted into the augered hole to sample the deeper, saturated Holocene sediments. The cores were extruded into 2 m x 100 mm PVC trays and cut in half for recording soil properties and for sampling. A Geoprobe® coring machine was used for inaccessible sites as it is track-propelled, and for deeper sampling beyond 5.7 m (Photograph 4). A total of 154 boreholes were examined, described and sampled for this project.

The properties of the soil materials such as texture, colour, mottles, structure, soil moisture status, coarse fragments and segregations were described according to McDonald et al. (1990) and recorded in code format for each horizon on NRMW field sheets. The soil was classified by the Australian Soil Classification (Isbell 1996), and other features of the land such as landform, slope and microrelief were also recorded. Mangrove and tree species were identified either from Lovelock (1993), Lear and Turner (1977), and Alcock and Champion (1989), or were sampled and identified by NRMW vegetation management officers.

Field pH (pH_F) and peroxide oxidised pH (pH_{FOX}) were measured with a portable pH meter (TPS Ionode WP84) at 0.25 m intervals down the profile, or within other soil horizons if these were less than 0.25 m thick. Soil samples were also taken at 0–0.1 m, 0.2–0.3 m, 0.5–0.6 m and 0.8–1.0 m intervals in the upper metre, and then at 0.5 m intervals throughout the remainder of the soil profile, with approximately 500 grams of soil placed in sealed plastic bags. Soil samples were refrigerated in the field and transferred to a freezer for longer-term storage. They were then sent frozen to the NRMW soil laboratory at Indooroopilly for analysis. Eight hundred and thirty-one soil samples were analysed by the methods described below.

Laboratory soil analysis

The method of analysis selected depended on whether the ASS layers were assessed as being AASS or PASS.

Photograph 2. Gouge auger, 1.8 m long, used for hand sampling in mangrove forests

Photograph 3. Trailer mounted vibro-coring soil rig used for sampling wet sediments

Photograph 4. Geoprobe® used for deep sediment sampling

Actual acid sulfate soil (AASS) samples containing *jarosite*, or with a pH of 4 or less, were analysed by the suspension peroxide oxidation combined acidity and sulfate method (SPOCAS) (Ahern et al. 2004).

Analytes from the SPOCAS methods include:

- total actual acidity (TAA)
- total potential acidity (TPA)
- peroxide sulfur (S_P)
- 1M potassium chloride (KCl) extractable sulfur (S_{KCl}).
- 4M HCl extractable sulfur
- 1M KCl and peroxide oxidised extracted calcium and magnesium.

Total sulfidic acidity (TSA) is calculated from the acid trail (TSA = TPA–TAA), while the peroxide oxidisable sulfur (S_{POS}) is determined by the sulfur trail ($S_{POS} = S_p – S_{KCl}$). An additional analyte of the SPOCAS method is the 4M HCl extractable sulfur (S_{HCl}), which enables net acid soluble sulfur (S_{NAS}), otherwise known as retained acidity ($S_{NAS} = [S_{HCl} – S_{KCl}] x\ 0.75$), to be calculated (Ahern et al. 2004).

The potential acid sulfate soil (PASS) samples were analysed by the chromium reducible sulfate (S_{CR}) method only (Sullivan et al. 2000). If fine shells or corals were present, the acid neutralising capacity (ANC) was determined by the back titration method (Ahern et al. 2004).

All field and laboratory data were entered into the NRMW Soil and Land Information (SALI) database and are available from NRMW upon request.

Interpretation of field and laboratory data

The determination of which horizons constitute an AASS or PASS is based on an assessment of field morphological properties (e.g. soil colour, mottles and coarse fragments such as shell), field pH test results, and laboratory results. The texture-based action criteria (Ahern et al. 1998) are used to identify ASS based on laboratory results. The action criteria are based on the sum of existing acidity plus potential acidity (i.e. net acidity), soil texture and the amount of soil being disturbed. For disturbances of 1 to 1000 tonnes of soil, the action criteria are 0.03 %S for sands, 0.06 %S for loams to light clays, and 0.1 %S for medium to heavy clays. If more than 1000 tonnes of soil are being disturbed, the action criterion is 0.03 %S regardless of texture. If these values are met or exceeded, the soil is an acid sulfate soil and will require treatment. For the purposes of this report, the identification of ASS is based on the action criteria where the volume of disturbance is 1 to 1000 tonnes.

Potential acidity was assessed using the S_{CR} method for PASS samples, or S_{POS} and TPA results for the AASS. If these values met or exceeded the texture-based ASS action criteria, the soil was identified as PASS. Existing acidity (i.e. AASS) was assessed using TAA laboratory results above the action criteria, the presence of jarosite and a field pH (pH_F) and/or laboratory value (pH_{KCl}) of 4 or less. Neutralising capacity was assessed using either the sum of reacted calcium and magnesium cations for the AASS, or the acid neutralising capacity back titration method (ANC_{BT}) for the PASS samples.

The results of selected laboratory analyses and field pH test results are reported in the Appendix.

Mapping unit categories

The presence and depth to ASS layers form the primary basis for defining the mapping units. The upper depth of the first horizon in which the action criteria have been exceeded has been assigned a 'depth to sulfide' code, as follows:

- **S0** indicates that the action criteria were exceeded between 0 and 0.5 m.
- **S1** indicates that the action criteria were exceeded in the 0.5 to 1 m interval.
- **S2** indicates that the action criteria were exceeded in the 1 to 2 m interval.

- **S3** indicates that the action criteria were exceeded in the 2 to 3 m interval.
- **S4** indicates that the action criteria were exceeded in the 3 to 4 m interval.
- **S5** indicates that the action criteria were exceeded in the 4 to 5 m interval.
- **S5**+ indicates that the action criteria were exceeded at depths greater than 5 m.

If AASS layers were present, the horizon was assigned an A code, as well as the depth code as shown above. For example, **'A0**' denotes a horizon with a pH of 4 or less, occurring between depths of 0.0 and 0.5 m. As it is not uncommon to find AASS overlying PASS, in these cases the 'A' code and the 'S' code are combined. For example **'A0S2'** denotes a soil layer with a pH of 4 or less, between depths of 0.0 and 0.5 m, overlying PASS at 1 to 2 m.

Many of the PASS layers were found to have significant quantities of fine shell, or were strongly alkaline, thus providing effective ANCs for these layers. The 'N' subscript at the end of a map unit code indicates the presence of neutralising agents in the ASS sediments, e.g. $\mathbf{S2_N}$.

Because of the wealth of pH data obtained during the project, and the importance of pH to agriculture, it was also decided to indicate areas where pH values between 4 and 5 were recorded. In these cases, the same depth codes have been used preceded by a lower case '**a**'. For example, **'a1'** denotes a profile registering a field pH between 4 and 5 at a depth of 0.5 to1.0 m**,** and **'a1S3'** denotes the same profile overlying PASS at 2 to 3 m.

Other map units used in the project are:

$\mathbf{S_{LA}}$—(limited assessment) indicates land that was inaccessible to field survey because of its topography or thick vegetation, but was in a landscape position that indicated it had a high probability of being underlain by ASS.

$\mathbf{S_{DL}}$—(disturbed lands) indicates various types of disturbed land that were likely to contain or be underlain by ASS.

LP—(low probability) indicates land at or below an elevation of 5 m AHD (Australian Height Datum), which field survey showed had little if any probability of being underlain by ASS.

LP5—indicates land above an elevation above 5 m AHD that had little if any probability of being underlain by ASS. It includes hills formed on bedrock and elevated areas of the Don River floodplain.

NA—(not assessed) indicates land not assessed by field survey, and therefore excluded from the defined ASS map units.

Soil mapping

The distribution of ASS was mapped onto the 1990 black and white aerial photographs, based on interpretation of the field data and landforms on the photographs. Quite often, a distinct landform change was used to identify the limit of ASS. When this was not available, such as on the Don River floodplain, the boundary was determined using additional boreholes. Once analytical data were available, ASS areas were subdivided into units of the previously mentioned categories showing the AASS and/or PASS codings. PASS depth categories were coloured in shades of red, pink, orange and brown, with red denoting the shallowest depth. Where AASS were present, a yellow dot overlay was also used to indicate this. Those map units that were found to have significant neutralising capacity, at least 1.5 times the level of oxidisable sulfur, are indicated on the map with green dots.

The location of each site is also shown on the map. Cartographers at NRMW Rockhampton transferred the linework from the aerial photographs to a base map to produce the 1:25 000 ASS map. The 5 m contour from the 1:25 000 topographic maps is also shown on the ASS map.

3. Results: Description of ASS map units and analytical data

The ASS mapping of Bowen found only 4.4 ha of AASS, in one map unit (A2S2), and 1502 ha of PASS. The main areas of PASS occur in the tidal zone (S0 and S1 map units—353 ha), and underlying the Don River floodplain and coastal sand dunes (S2 to S5+ map units— 842 ha).

There are also 275 ha of limited assessment lands (S_{LA}), which are the inaccessible sand dunes, Bowen golf course and salt works, and 32 ha of disturbed lands (S_{DL}) where PASS have been excavated and used as fill nearby. There are significant areas (752 ha) of land below 5 m AHD that are not underlain by ASS, which are the LP units, and similar areas of LP5 land (826 ha) on the Don River floodplain and surrounding low hills and rocky headlands.

All of these areas are described in more detail in the following sections. Table 1 below outlines the total areas for each of the map units in the Bowen survey area.

Table 1. Areas and proportions of the Bowen ASS survey map units

Map unit	Map unit area (ha)	Percentage of area assessed (%)
Actual acid sulfate soils		
A2S2	4.4	<1
Total	**4.4**	**<1**
Potential acid sulfate soils		
S0	286.4	9
S1	66.7	2
S2	54.7	2
S2/S3	10.1	<1
S3	216.9	7
S3/S4	32.6	1
S4	199.9	7
S5	188.9	6
S5+	138.4	5
Total	**1 194.6**	**39**
Acid sulfate soil on undisturbed land		
S_{LA}	275.4	9
Acid sulfate soil on disturbed land		
S_{DL}	31.6	1
Low probability land		
LP	752.0	24
LP5	825.8	27
Total	**1 577.8**	**51**
Total area	**3 083.8**	**100**

3.1 Actual acid sulfate soils on relatively undisturbed land

A2S2 (AASS layer and PASS layer 1 to 2 m depth)

This is the only area of AASS found in the Bowen survey area. This map unit occurs on a small area of a backplain on the Don River floodplain, and has an elevation of 4 m AHD. It is only 4.4 ha in area and has a remnant Queensland blue gum and narrow-leaved paperbark vegetation association

(Photograph 5). It is also one of the few areas on the Don River floodplain in this survey area that was found to have a black cracking clay soil.

As the estuarine sediments are covered by only one metre of alluvium, this area was most likely a tidal creek until the final development of the floodplain. This contrasts with the surrounding areas where the PASS are covered by 2.5 to 5.5 m of dune sand or alluvium. The clay AASS, which have only very few jarosite mottles, occur just below 1.0 m and are 0.6 m thick. They have a pH of 3.8 at 1.25 and 1.5 m, and an actual acidity of 44 mol H^+/t. The analytical data show that this layer is fully oxidized with an S_{POS} of <0.02% and TSA of <10 mol H^+/t. Retained acidity within the AASS layer is also negligible (<10 mol H^+/t) as there are only very few jarosite mottles present.

However, the underlying clay PASS layer has a very high oxidisable sulfur (%S) content of 2.3% at 2.0 m. This layer is then underlain by coarse sandy PASS which have moderate to high %S levels of 0.31 to 0.86%. This indicates that this area was a quiet backwater at the upper end of the creek where the conditions were conducive to the formation of pyrite.

The groundwater, which has a pH of 5.5, is being monitored on a monthly basis to determine whether the AASS have had any effect on the quality of the underlying water.

3.2 Potential acid sulfate soils on relatively undisturbed land

S0 and $S0_N$ (PASS layer 0 to 0.5 m depth)

The S0 map units are all within the tidal zone, predominantly in the mangrove forests, but also at times extending out onto the wetter saltpans. These landforms have elevations between 1 to 1.5 m AHD. The mangrove areas consist of dense forests of red mangrove with interwoven aerial roots, which surround the creek lines and channels (Photograph 6), and the lower, more open, fringing forests of grey mangrove (Photograph 7). The soils are mangrove muds to a depth of 0.5 to 1.4 m, which overlie sandy PASS layers. Pyrite is nearly always present in the surface of these muds, with contents of 0.16 to 1.2 %S. Overall, these clay sediments have levels of 0.12 to 2.1% (0.84% average). The underlying sandy layers have lower levels of 0.06 to 0.4% (0.29% average). Fine shells are only rarely present within the clay layers, while the sands are always shelly, and these provide acid neutralising capacities (ANCs) equivalent to 3.2 to 6 %S.

The S0 saltpans are mainly bare with occasional clumps of samphire (Photograph 8) and the soil profile is more developed than that in the mangrove forests. These soils have a dark grey subsoil with many brown mottles that overlie clay PASS sediments at depths of 0.3 to 0.45 m. These upper layers are non-pyritic, while the clay PASS layers are only quite thin, extending to depths of 0.6 to 1.2 m and have %S contents of 0.44 to 1.9% (0.98% average). These are then underlain by sandy PASS layers which have significantly lower %S levels of 0.05 to 0.54% (0.23% average). Fine shells are usually present in the sandy sediments providing equivalent ANCs of 1.4 to 25 %S.

S1 and $S1_N$ (PASS layer 0.5 to 1 m depth)

The S1 map units occur on the slightly more elevated and drier saltpans of the tidal zones with an elevation of about 2 m AHD. A former saltpan next to the marina that has been filled is also an S1 map unit. Again these saltpans are mainly bare with some clumps of samphires and occasionally with a few low grey mangrove trees (Photograph 9). The soil profiles are more variable in these map units with some profiles similar to those of the S0 saltpans, but with the PASS occurring between 0.55 to 0.95 m . These are then underlain by sandy PASS layers between depths of 0.9 to 1.1 m. The other profiles are multi-layered in the surface metre, with recent sand deposits being laid down over former mangrove muds and sands.

The clay PASS of the S1 map units have %S concentrations of 0.2 to 1.8% (0.72% average), while those in the pyritic sands are much lower at 0.05 to 0.71% (0.21% average). Shells are again usually present below 1.2 m in the sandy PASS sediments which have ANCs equivalent to 0.5 to 14.6 %S (6.2% average).

S2 and $S2_N$ (PASS layer 1 to 2 m depth)

The S2 map units occur on a variety of landforms that have elevations of 2 to 2.5 m AHD. They are found mainly on the saltpans and marine couch flats of the tidal zone, but occur also on the margins of the Don River floodplain that adjoin the tidal zone, and on the former beachfront area of the Bowen harbour. As a result, the soils overlying the PASS are highly variable. The floodplain soils have between 0.3 to 0.7 m of dark brown, silty clay or clay loam surface soils overlying sandy river sediments, which in turn overlie the estuarine, sandy PASS sediments. The beachfront soils have nearly two metres of aeolian sands overlying the sandy PASS, while the saltpan soils consist of multi-layered clay and sand lenses that overlie either clay or sandy PASS horizons.

The saltpans are predominantly bare with occasional small to large clumps of samphires, while the marine couch flats have thick grasslands of marine couch. The floodplain and frontal dune S2 units have been cleared for pastures or residential development.

The PASS of the S2 map units is predominantly coarse to fine sands, sometimes with small quantities of fine to medium-sized, rounded gravels. Few to many, fine to medium shells occasionally occur in some of these sandy PASS sediments. The %S content of these sands varies mainly from 0.04 to 0.51% (0.2% average), and the ANCs in the shell layers vary between the equivalent of 0.22 to 13.5 %S (4.7% average). This shows that some of these sandy PASS horizons have extremely high neutralising capacities.

The few clay PASS sediments found occurred on the saltpans, and have %S levels of 0.14 to 0.59% (0.3% average), which are similar to those of the sandy PASS.

$S2_N/S3_N$ (PASS layer 1 to 3 m depth)

The $S2_n/S3_n$ map unit occurs on a narrow frontal dune system at the southern end of the salt works, with an elevation of 2 to 3 m AHD (the two depth categories are used to indicate the difference in elevation between the dune crest and swale). This area consists of a series of three to four parallel, low sand dunes separated by swales, with up to one metre difference between their heights.

This frontal dune system is quite narrow, as the land rises sharply to low hills only 100 m or so behind the beachfront. The vegetation is typical coastal vegetation with a low, open forest of wattles, Burdekin plum, soap bush and other trees. The sandy PASS, which are overlain by 1.3 to 2.7 m of fine, white aeolian sands, have %S contents of 0.08 to 0.39% (0.24% average). The lower PASS layers have occasional to very many fine shells which provide effective ANCs equivalent to 0.35 and 1.6 %S (only 2 samples analysed).

S3 or $S3_N$ (PASS layer 2 to 3 m depth)

The S3 map units are very extensive and occur on the Don River floodplain (Photograph 10), the frontal dunes of Queens Bay, and some of the large stranded dunes or sand sheets in the Kings Beach and salt works tidal areas. As a result, the elevation of these landforms varies from 2.5 to 3.5 m AHD. Two smaller S3 areas on the outskirts of Bowen appear to have been former tidal lands that have been filled for urban development. Only the stranded dunes of Kings Beach and the salt works are still vegetated with an open forest of Moreton Bay ash with an understorey of wattle, Burdekin plum and soap bush.

The coastal dunes have between 0.7 to 1.8 m of fine, white aeolian sands overlying river or estuarine coarse sands. These, in turn, overlie the predominantly sandy PASS sediments. However, the floodplain soils consist of between 0.4 to 1.5 m of dark or dark brown, loamy or clay alluvial soils that overlie the gravelly, coarse, river sand layers before the PASS sediments occur below 2 m.

Photograph 5. Backplain of the Don River underlain by an actual acid sulfate soil at 1.1 m

Photograph 6. The red mangroves with interwoven aerial roots, S0 map units

Photograph 7. Fringing grey mangrove forest of the S0 map units

Photograph 8. Wetter areas of saltpans underlain by PASS at 0.45 m, S0 map units

Photograph 9. Drier saltpans with samphire and scattered grey mangroves, S1 map units

Photograph 10. Don River floodplain on the margins of the tidal zone, S3 map units

The PASS in these map units are mainly fine to coarse sandy sediments, with much fewer clay layers and the occasional loamy sediment. The %S levels of the sandy PASS are mainly less than 0.4%, with a low average of 0.24%. The levels in the clay sediments, however, are much higher—in the order of 0.16 to 1.4% with a significantly higher average of 0.69%. Levels in the few loamy sediments vary from 0.34 to 0.73% (0.57% average).

About half of the sandy and loamy PASS layers contain few to many, fine to medium-sized shell fragments that provide effective ANCs equivalent to 0.32 to 10.9 %S. This is based on the fine shell fragments less than 2 mm in size, and demonstrates the high neutralising capacities of some of these pyritic sediments. None of the clay PASS had shell layers.

$S3_N$/$S4_N$ (PASS layer 2 to 4 m depth)

The two $S3_n$/$S4_n$ areas occur on the rear section of frontal dunes at the eastern end of Queens Bay, and along the length of Kings Beach (Photograph 11). Elevations in both these areas vary from 2.5 to 3.5 m AHD. The Queens Bay map unit is an area of the original coastal dunefield that has not been developed for housing, and consists of a series of low dunes and swales. The Kings Beach map unit consists of the beach ridge directly above the high water level, and a low frontal dune and swale. The compound map unit is used to indicate the difference in elevation, and therefore the depth to PASS, between the dune crest and swale.

The vegetation of the Queens Bay dunefield again is an open forest of Moreton Bay ash with an understorey of coastal low trees and shrubs, while the Kings Beach frontal dune has largely been cleared with only a few coastal she-oaks remaining. The soils of these dunefields consist of 1.3 to 2.8 m of fine, aeolian sands overlying coarse, non-pyritic, river sands that often have few, small, rounded gravels. These layers overlie the fine to coarse sandy PASS sediments that, apart from the upper 0.4 to 0.9 m, contain many fine and medium shell fragments. These sandy layers again have only low to moderate %S levels of 0.03 to 0.44% (0.13% average), while the shell fragments provide ANCs equivalent to 0.22 to 1.9 %S (0.8% average).

S4 and $S4_N$ (PASS layer 3 to 4 m depth)

The S4 map units occur on the former frontal dunes of Queens Bay, at the Bowen harbour beachfront, on one of the larger stranded dunes in the Kings Beach tidal area, and on the Don River floodplain. These landforms have elevations of 3 to 4.5 m AHD. Only the stranded dune is still vegetated with a low forest of Burdekin plum, wattles and soap bush. The frontal dunes have between 0.4 to 2.3 m of fine, pale, aeolian sands that overlie coarse, gravelly river sands. These in turn overlie the dominant fine to coarse sandy PASS sediments. The soils of the S4 map units on the Don River floodplain consist of up to one metre of dark brown, loamy or clayey recent alluvium that overlies coarse, gravelly, former river sands. These layers then overlie the sandy or clay PASS sediments.

The sandy PASS have low to moderate %S concentrations, mainly between 0.03 to 0.5% (0.24% average), while the clay PASS layers have higher oxidisable sulfur contents, mainly between 0.4 to 1.0% (0.59% average). Some of the sand horizons in the long S4 map unit to the south of the golf course and the Kings Beach stranded dune contain few to many fine shell fragments which provide ANCs equivalent to 0.35 to 5.1 %S (1.9% average). Some of the clay PASS and one of the sandy PASS layers underlying the floodplain areas are alkaline, to strongly alkaline (pH 8.0 to 9.5), and this natural alkalinity provides sufficient buffering capacity to neutralise the potential quantity of sulfuric acid these sediments are capable of producing. These ANCs were measured as being equivalent to 0.22 to 0.93 %S, compared to the %S contents of 0.07 to 0.22%.

S5 and $S5_N$ (PASS layer 4 to 5 m depth)

The S5 map units occur mainly on the Don River floodplain (Photograph 12), with one extensive area just to the south of the golf course at Queens Bay. They also occur on two smaller areas on the former frontal dunes of Queens Bay. All of these areas have been cleared for either agriculture or housing, and have elevations that vary from 4 to 6.5 m.

The floodplain areas are the most significant, and the overlying sediments consist of 0.5 to 1.5 m of dark or dark brown, loamy or clay soils, which overlie another 2.5 to 3.5 m of either coarse, gravelly sands, or further layers of interbedded, alluvial, fine sand, silt or clay sediments. The PASS which underlie these latter layers consist of equal amounts of clay and sandy sediments, unlike those in the other map units where they are predominantly sands.

In the dune soils there are from one to nearly four metres of fine, pale, aeolian sands overlying less than one to three metres of coarse, gravelly river sands before the mainly fine sandy PASS sediments occur. The PASS of the S5 areas also have consistently higher %S concentrations than those of the previous map units. The %S of the clay layers varies from 0.3 to 1.8% with a high average of 1.1%, while in the sands it is mainly between 0.12 to 1.1 %S, with one very high content of 2.7%, and an overall average of 0.61%. The four loamy layers analysed have %S contents of 0.03 to 0.85% (0.53% average).

Fine shell fragments occur in only one of the sandy PASS layers underlying the coastal dunes, which resulted in an ANC equivalent to 1.5 %S. Some of the alkaline clay and loam sediments also have ANCs provided by the previously mentioned natural buffering capacity of these alkaline sediments. These layers have a pH of 7.0 to 9.1 and ANCs equivalent to 0.38 to 1.0 %S, which in most cases is only just sufficient to fully neutralise the potential quantity of sulfuric acid capable of being produced.

S5+ and $S5_N$+ (PASS layers >5 m depth)

The S5+ map units are found on the former frontal dunes of Queens Bay, the large Kings Beach foredune (Photograph 11) and the Don River floodplain. The Kings Beach sand dune is the highest in the Bowen and Queens Bay areas, as this part of the coastline is fully exposed to the prevailing south-easterly winds. It has an elevation of 10 m AHD which is more than twice as high of any of the other dunes. With the exception of the Kings Beach sand dune, all other S5+ areas have been cleared for agriculture or housing, and have lower elevations between 4 to 6 m AHD.

The soils of the floodplain areas consist of 0.6 to 2.1 m of dark or dark brown, clay alluvium which overlies a further three to four metres of either gravelly, coarse river sands or further layers of interbedded, alluvial fine sands, silts or clay sediments, which in turn overlie the PASS. The sand dune areas have 2 to 5.3 m of fine aeolian sands that overlie a further 1.7 to 4.8 m of gravelly, coarse river sands before the PASS are found. As a result, the PASS occur at depths of 5.3 to 7.7 m.

The PASS underlying the frontal dunes are always sandy sediments, while those of the alluvial areas are predominantly clay sediments. The sands have significantly higher levels of oxidisable sulfur than the S0 to S4 map units, which vary from 0.03 to 0.79% with an average of 0.46%. The clay sediments are similar to those of the sands, with %S contents between 0.15 to 1.0% and an average of 0.57%.

A few of the sandy PASS layers have few to many, fine shell fragments that provide ANCs equivalent to 0.6 to 11.3 %S. The clay sediments do not contain any shell fragments, but half of these layers are alkaline (pH 7.8 to 8.2). Due to their natural buffering capacity, they have ANCs equivalent to 0.26 to 0.32 %S, which is just sufficient to fully neutralise the potential quantity of sulfuric acid these layers are capable of producing.

3.3 Acid sulfate soils on relatively undisturbed land

S_{LA} (Limited field assessment on lands underlain by ASS)

The S_{LA} map units have a total area of 275 ha, and consist of the Bowen salt works to the south of Bowen, the golf course at Queens Bay and the stranded sand dunes in the tidal areas of Kings Beach and the salt works.

The salt works are situated almost entirely on former mangrove and saltpan tidal lands. Boreholes around the perimeter of the salt works show that ASS are present on its northern (S1 and S4 map units) and eastern sides (S0 and S3 map units), and only along a narrow former tidal creek on its western boundary (S2 and LP map units). PASS were most likely only disturbed where the bund walls were constructed on the former mangrove areas where the PASS are shallowest at less than half a metre deep. The only site in the mangroves on the eastern side of the salt works (site 734) has %S contents of 1.1 to 1.4% in the surface half metre of mud. As the salt works were constructed in 1923, it is most likely that any PASS disturbed at that time are now fully oxidised. It is also unlikely that PASS were disturbed on any of the former saltpan lands now covered by the salt works, as the PASS here are relatively deep at 0.9 to 1.5 m, and material excavated for the bund walls was taken from only the surface 0.3 m or so. Limited observations of the bund walls in these areas did not show any signs of AASS (Photograph 13).

The Bowen golf course is situated on the low frontal dune and swale of Queens Bay (Photograph 14). The six sites investigated around the perimeter of the golf course have PASS at depths of 2.5 to 2.75 m in the swale (S3 map unit), and at 3.4 to deeper than 5 m (S4 to S5+ map units) on the former dunes on the eastern and southern sides of the golf course. Therefore it was felt that the golf course would also be underlain by PASS where these landforms continue into it.

The inaccessible sand dunes in the Kings Beach tidal zone are surrounded by mangrove forests, with PASS at less than 0.5 m (S0 map unit). As the accessible, stranded sand dunes just to the north are underlain by PASS at depths of 3 to 4.5 m (S3 and S4 map units), it is reasonable to assume that these other dunes would also be underlain by PASS. They would have had similar land-forming processes, with sand being blown over the top of the former mangrove muds at a new beachfront as the delta grew seawards. As they are narrower and smaller than the other S3 and S4 dunes, the PASS would not be as deep as the PASS underlying those dunes.

3.4 Acid sulfate soils on disturbed land

S_{DL} (Disturbed lands likely to contain ASS)

A total of 32 ha of disturbed lands containing ASS occur at the marina and surrounding the lagoon (Mullers lagoon) constructed just to the north of Bowen.

The dredging for the marina occurred at two different times. The outer harbour was dredged in the 1960s, while the second harbour to the north was dredged more recently in the mid-1990s. The dredged sediments were used as fill to construct the outer break wall and surrounding lands for the marina facilities (Photograph 15). The outer wall from the 1960s dredging was examined at site 653, while the more recent dredging was investigated at site 672. These profiles showed that the dredged marina sediments contained significant amounts of shell and coral fragments, which were able to neutralise all the sulfuric acid produced from the oxidation of these sediments.

The outer break wall consists of about 3 m of former sandy PASS fill, and the data from site 653 shows that this is all fully oxidised (<0.02 %S at 3.0 m). The original sea bed occurs at 3.2 m, and the sandy sediments below this have %S levels of 0.12 and 0.18%, with ANCs equivalent to 7.5 to 14.2 %S, which is 40 to 80 times greater than the maximum oxidisable sulfur content. As the dredged sediments would have been similar to this, it is obvious that these sediments were self-neutralising, and that the acid produced would have been neutralised within the break wall and not have leached into the harbour.

The more recent dredging is a different story. As this part of the marina is formed on former mangrove lands, the dredged sediments are mainly clays with much higher levels of oxidisable sulfur (0.5 to 0.9%). Site 672 shows that these sediments are only partially oxidised, and still have between 0.3 and 0.6 %S remaining. However, the pH_F of the partially oxidised upper dredged layers is 7.3 to 8.9 due to the shells present and the natural buffering capacity of the clay sediments. The ANC of the dredge spoil varies from the equivalent of 3.2 to 7.3 %S, which is up to 10 times greater than the remaining oxidisable sulfur in the sediments. Again this shows the self-neutralising capacity of these sediments, and accounts for why there are no observable signs (iron staining and pitted concrete infrastructure) of the possible effects of this disturbance of PASS within the harbour.

The lagoon at North Bowen is 11 ha in area and several metres deep (Photograph 16). It was privately constructed over a twenty-year period in the late 1960s to late 1980s in a naturally occurring, low-lying wetland. Three sites around the lagoon were cored to depths of 3.2 to 4.1 m and into the underlying, undisturbed PASS sediments (sites 635, 638 and 763). These three sites showed that the PASS layers occur at a depth of about 2.5 m, and are from 0.5 m to more than 2.0 m thick.

However, only one of these three sites (638) showed evidence of PASS disturbance. From a depth of 0.3 to 1.25 m, this site has a pH_F of 4.2 to 4.5 with the occasional jarosite mottle still evident between 0.4 to 0.9 m. The SPOCAS data shows this layer to be fully oxidised, with only a small amount of existing acidity remaining (31 mol H^+/t). The TPA is <10 mol H^+/t and S_{POS} 0.028%, which indicates that all the pyrite has oxidised. The %S measured is most likely to be from organic sulfur rather than pyrite, as the acid trail and sulfur trail of the SPOCAS test do not agree (i.e. the equivalent TPA of 0.028 %S is 17.5 mol H^+/t). The other two sites showed that even though the upper 2.5 m of soil is fill, it appears to be the original, non-ASS, black alluvial clay soil.

Therefore, it is possible that excavation of the lagoon may not have been deep enough to disturb significant quantities of PASS, and what was disturbed is now fully oxidised after some 20 to 30 years. This time lapse also means it is unlikely that any indicators of acid leachate events would still remain. The groundwater just downstream of the lagoon is now being monitored by a piezometer installed at site 739 to investigate if there are any measurable changes in the chemistry of the groundwater as a result of this disturbance. The data from all the piezometers will be reported separately at the end of the project in 2007.

3.5 Land with a low probability of acid sulfate soil occurrence

LP (Land predominantly less than an elevation of 5 m AHD)

The LP lands consist of the footslopes of the low hills and rocky headlands around Bowen and the low-lying alluvial plains, as well as some of the tidal saltpan areas adjoining the salt works. The footslopes of the rises and hills have deep colluvial clay subsoil horizons that overlie bedrock at depths of up to 3 m. The floodplain soils to the south of Bells Gully are older Pleistocene (10 000 to 1.8 M years old) alluvial clay sediments with between three to over five metres of sediment deposited over the bedrock. During the last ice age (120 000 to 10 000 years BP), the river did not scour out this part of the Don River floodplain into deep basins. So, because there was no subsequent infilling with estuarine sediments as sea levels rose, these lands are not underlain by ASS.

To the north of Bells Gully is a former basin that has been infilled by either alluvial gravelly sands or estuarine sediments. A strip of land between the two ASS areas is underlain only by former river gravels and coarse sands to depths of up to 15 m. This is the large LP map unit to the north-west of Bowen, and some of the best irrigation water supplies around Bowen have been found in these gravel aquifers. It appears that these deposits represent former channels of the Don River that have been covered by up to one metre of alluvial loam and clay soils since the river has migrated to its present course.

Some of the saltpans investigated around the salt works consist of up to only 1.5 m of interbedded, non-ASS sand and clay sediments that overlie the former Pleistocene clay basement. As these areas have been infilled with alluvial sediments only, it appears they too have not been subject to estuarine conditions since the sea level rose to its present height.

LP5 (Land predominantly above an elevation of 5 m AHD)

The LP5 lands are made up of the hills and rocky headlands, and floodplain areas with elevations greater than 5 m AHD. The hills and headlands are formed from the upper Carboniferous granites, or the interbedded volcanic and sedimentary rocks of the Permian Carmilla Beds. When formed on the granites and acid volcanic rocks, the hills have shallow (<0.5 m deep), sandy-surfaced, sodic soils. They have shallow, red or brown clayey soils when formed on the intermediate volcanic rocks of the Carmilla Beds. The LP5 lands on the Don River floodplain are extensions of the two LP land types described in the previous section.

3.6 Potential acid sulfate soil analytical data summary

The PASS sediments at Bowen comprised the three ASS texture groups of sands, loams and clays. The PASS however are mainly sands (66%), with just under one-third being clay sediments (30%) and only a very small amount of loams (4%). The sandy PASS have, on average, significantly lower %S levels than the clay sediments, with an average of 0.29% compared to 0.77%. This is similar to the levels found in the Mackay ASS study (Muller & Coutts 2005), and the bar graph in the figure below demonstrates this relationship. The %S levels of the sands are mainly less than 0.5%, with only the occasional layer above 1%, including the highest level of 2.7% recorded for all the PASS analysed in the Bowen survey.

In comparison, the %S levels of the clay sediments are mainly higher than 0.5%, with nearly half being 0.75% or more, but with a slightly lower maximum of 2.3%. There are insufficient loamy PASS samples to make a comparison with the sand and clay sediments, but most are within the 0.5 to 0.75 %S range with an average of 0.55%.

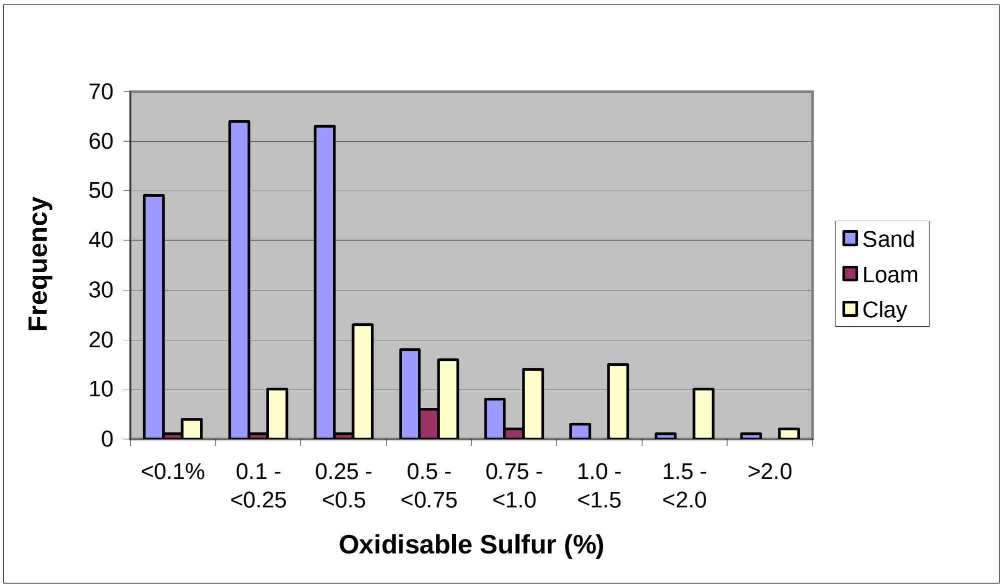

Figure 2. Frequency of PASS samples within oxidisable sulfur ranges for the three ASS texture groups

Photograph 11. Frontal dune and swale at Kings Beach, S3/S4 map unit, with the steeper inland dune, S5+ map unit on the left

Photograph 12. Tomato growing area of the Don River floodplain underlain by ASS, S5 map unit

Photograph 13. Bowen salt works mainly underlain by ASS, limited assessment land, S_{LA} map unit

Photograph 14. Low dune–swale landscape of the Bowen golf course, Queens Bay, S_{LA} map unit

Photograph 15. Bowen marina with the bare areas showing the dredged sediments around the inner harbour, S_{DL} map units

Photograph 16. Disturbed land around Mullers Lagoon, S_{DL} map unit

4. Discussion

This survey defines the extent of, and depths to, ASS around Bowen. The ASS map, at a scale of 1:25 000, uses unit codes and a colour scheme to indicate the depth to ASS—the darker the red colour, the shallower the ASS. The colour scheme indicates the risk of disturbance by excavating, or by lowering the watertable through deep drainage or dewatering. Therefore the S0 map units pose the highest risk and require the greatest levels of management as the ASS are very shallow.

The study identified 1502 ha of PASS and only 4.4 ha of AASS, with the PASS occurring mainly at shallow depths of less than one metre in the tidal lands, or underlying the Don River floodplain at significantly greater depths of 2 to 6 m. PASS have also been buried, at highly variable depths of 1.6 to 8.0 m depending upon the thickness of the overlying sands, on the coastal fringes of Bowen by recent sand dune deposits.

The ASS map shows also that only small areas of the Don River floodplain and the steep frontal dune at Kings Beach, that are underlain by PASS, are at elevations above 5 m AHD. Therefore, nearly all the ASS in the survey area occurs at elevations below 5 m, with the shallowest occurring in the tidal lands at an elevation of 1–2 m AHD. This demonstrates that the 5 m contour is a reliable indicator of where ASS are most likely to be found in the Bowen area. The maximum elevations at which ASS were found in this study are 6.5 m on the floodplain and 10 m on the frontal dune at Kings Beach.

Only one small area of AASS was found over the entire survey area. This occurs on a backplain of the Don River just to the south of the golf course. The watertable associated with this soil occurs in only the lower part of this AASS layer so that it is fully oxidised, with only a low level of actual acidity (44 mol H^+/t) remaining. This is below the action level of treatment for a clay soil (62 mol H^+/t for disturbances <1000m^3).

The PASS sediments are predominantly sandy, but on average, have only one-third of the oxidisable sulfur content of the clay sediments. Many of the sandy and some of the clay PASS layers in the eastern half of the survey area contain fine shell fragments which provide a natural acid neutralising capacity. Some of the alkaline clay and sandy PASS sediments also have a natural buffering capacity either equal to, or greater than, their oxidisable sulfur content, thus also providing an effective acid neutralising capacity. However, in most cases, not all of the PASS within a profile are self-neutralising, and need to be managed appropriately if they are disturbed, regardless of these other self-neutralising layers.

The two significant disturbances of ASS are at the Bowen marina and Mullers Lagoon. At the time of this survey, there were no off-site effects as a result of excavations of PASS during construction. The dredged sediments at the marina, which were found to be self-neutralising due to their shell and coral content had been able to neutralise all the acid produced from their oxidation. The pH of the partially oxidised sediments from the most recent dredging in the mid-1990s is between 7.4 and 8.9, which is also not significantly low as a result of acid that has been produced.

The PASS excavated at the lagoon and used as fill around it were also found to be fully oxidised. However it is not known whether the sulfuric acid produced in the past has had any detrimental effects on the water quality of the lagoon over time. Monitoring of the groundwater nearby may indicate if there have been any off-site impacts.

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6. Glossary

Acid sulfate soils (ASS): Soils or soil horizons which contain sulfides, or acid soil horizons affected by oxidation of sulfides. Acid sulfate soils is the common name given to naturally occurring sediments and soils containing iron sulfides (principally iron disulfide or their precursors). The exposure of the sulfide in these soils to oxygen by drainage or excavation leads to the generation of sulfuric acid. The term ‘acid sulfate soils’ includes both actual and potential acid sulfate soils. (See below).

Action criteria: The oxidisable sulfur (%S) values of soil samples which exceed the Queensland acid sulfate soils guidelines (Ahern et al. 1998). Soils that exceed these criteria are classed as ASS, and may require remedial treatment such as application of neutralising agents if disturbed or drained. The action criteria used as the determinant of PASS are:

- 0.03 %S or 18 mol H^+/t for sands
- 0.06 %S or 36 mol H^+/t for loams to light clays
- 0.1 %S or 62 mol H^+/t for light medium to heavy clays.

Note that when excavations exceed 1000 tonnes (or m^3), the action criterion of 0.03 %S or 18 mol H^+/t applies regardless of texture.

Actual acid sulfate soils (AASS): Soils containing highly acidic soil horizons or layers resulting from the aeration of soil materials that are rich in iron sulfides, primarily pyrite. This oxidation produces hydrogen ions in excess of the capacity of the sediment to neutralise the acidity, resulting in soils of pH of 4 or less, and often the formation of the iron mineral jarosite. These soils can usually be identified by the presence of yellow mottles and coatings of jarosite.

Anaerobic: Conditions where oxygen is excluded, usually by waterlogging.

Australian Height Datum (AHD): The datum used for determining elevations in Australia. Using a national network of benchmarks and tide gauges, a mean sea level has been set as zero elevation.

Borehole: The hole created when an auger or push tube is inserted into the soil body. The portion removed (the core) demonstrates the soil profile and is used for profile description and soil sampling.

Holocene: The period of time about 10 000 years before present. It is an epoch of the Quaternary period (the last 1.8 million years).

Jarosite: An acidic, pale yellow iron sulfate mineral, $KFe_3(OH)_6(SO_4)_2$. The most conclusive indicator of AASS, jarosite is a byproduct of the acid sulfate soil oxidation process, and forms at a pH less than 3.7. It is commonly found along root channels and other soil surfaces exposed to air.

Pleistocene: An epoch of the Quaternary period—the period of time from 1.8 million years ago to about 10 000 years ago (the start of the Holocene epoch).

Potential acid sulfate soils (PASS): Soils containing iron sulfides of sulfidic material, which have not been exposed to air or have oxidised. The field pH of these soils in the undisturbed state can be 4.1 or more, and may be neutral or slightly alkaline. However, they pose a considerable environmental risk when disturbed, as they will become very acidic from oxidation of the iron sulfides to sulfuric acid when exposed to air.

Pyrite: Pale bronze or brass yellow, isometric mineral (FeS_2). It is the most widespread and abundant of the sulfide minerals.

Quaternary: A geological period of time extending from 1.8 million years ago to the present. It incorporates both the Pleistocene and Holocene epochs.

Watertable: The portion of the ground saturated with water; often used specifically to refer to the upper limit of the saturated ground.

Chemical acronyms used for acid sulfate soil analytical procedures

POCAS: Peroxide oxidation, combined acidity and sulfate method

SPOCAS: Suspension peroxide oxidation, combined acidity and sulfate method

pH_F: Field pH

pH_{FOX}: Field oxidised pH of the soil sample by 30% hydrogen peroxide

pH_{KCl}: pH of a 1:5 solution of soil and 1 molar (M) potassium chloride (KCl)

S_{CR}: Chromium reducible sulfur method

S_{POS}: Oxidisable sulfur measured by the SPOCAS method

TAA: Titratable actual acidity

TPA: Titratable peroxide acidity

TSA: Titratable sulfidic acidity

ANC_{BT}: Acid neutralising capacity estimated by the back titration method

Notes for the appendix

Texture codes: The texture codes, such as ‘FS’ for fine sand, used in the Appendix are from McDonald et al. (1990)

s-ANC_{BT}: The ANC converted to %S units, i.e. % $CaCO_3$ x 3.121 = equivalent %S

s-ANC: Acid neutralising capacity estimated by the sum of the reacted calcium and magnesium cations from the SPOCAS method, expressed in equivalent %S units

To convert mol H^+/t to the equivalent %S, divide by 623.7

The dotted line between some samples indicates a change in soil horizon, due mainly to texture, but also because of changes in colour, mottles, gravels and shells, calcareous and/or manganese concretions and sediment type.

Not all the SPOCAS and field pH data is presented in the Appendix. Full data sets are available from NRMW upon request. The data shown is only for those horizons that were sampled and analysed.

Appendix

Selected profile pH and analytical data

Site	Depth	Texture	pH_F	pH_{FOX}	S_{CR}	ANC_{BT}	s-ANC_{BT}	TAA	TPA	TSA	S_{POS}	s-ANC
	(m)				%S	%$CaCO_3$	%S	mol H^+/t			%S	%S
613	1.9-2.0	FS	8.3	6.6	<0.02							
	2.4-2.5	FS	7.8	2.4	0.1	1.0	0.32					
	2.9-3.0	KS	7.5	1.6	0.24	1.5	0.48					
	2.45-2.55	ZLC	7.2	1.1	1.0							
	3.9-4.0	ZLC	7.1	0.9	0.48							
	4.2-4.3	MHC	7.1	2.2	0.31							
614	0-0.1	LMC	7.0	5.4	<0.02							
	0.5-0.6	KS	7.8	7.0	<0.02							
	0.9-1.0	KS	8.2	6.9	<0.02							
	1.4-1.5	KS	7.9	5.9	<0.02							
	1.9-2.0	KS	7.5	5.5	<0.02							
	2.4-2.5	KS	7.6	5.1	<0.02							
	2.9-3.0	KS	7.3	5.8	<0.02							
	3.45-3.55	KS	7.4	6.5	0.11	6.4	2.1					
	3.9-4.0	FS	7.8	6.1	0.44	9.3	3.0					
	4.4-4.5	FS	7.7	5.9	0.27	3.3	1.1					
615	4.9-5.0	KS	8.0	5.7	<0.02							
	5.9-6.0	KS	6.9	5.7	<0.02							
	6.9-7.0	KS	7.5	5.6	<0.02							
	7.9-7.8	KS	7.4	5.5	<0.02							
	8.9-9.0	KS	7.6	6.2	<0.02							
	9.9-10.0	KS	6.9	5.7	<0.02							
	10.9-11.0	FSL	6.6	5.9	<0.02							
	11.7-11.8	SLC	6.9	6.4	<0.02							
	11.9-12.0	SMC	7.6	6.2	<0.02							
616	0.9-1.0	CLS	6.8	6.0	<0.02							
	1.9-2.0	KS	7.6	6.4	<0.02							
	2.9-3.0	LC	8.2	6.5	<0.02							
617	2.4-2.5	KS	7.3	6.7	<0.02							
	2.9-3.0	KS	7.5	6.1	0.1	6.5	2.1					
	3.4-3.5	S	6.9	5.5	0.2	7.6	2.4					
	3.9-4.0	FS	6.9	5.9	0.36	9.1	2.9					
618	0-0.1	FSLC	6.2	1.5	0.28							
	0.2-0.3	FSLC	6.3	1.7	0.25							
	0.45-0.55	FSLC	6.4	1.6	0.42							
	0.55-0.65	FS	6.5	5.5	0.37	10.2	3.3					
	0.9-1.0	FS	6.5	6.0	0.4	23.7	7.6					
619	0-0.1	FSCL	7.0	6.8	<0.02							
	0.5-0.6	FS	6.9	5.2	0.22							
	0.8-0.9	FS	7.0	6.1	0.28	16.2	5.2					
620	2.4-2.5	KS	7.5	6.2	<0.02							
	2.9-3.0	KS	7.9	1.9	0.03	0.9	0.29					
	3.4-3.5	S	7.7	1.8	0.44	<0.5						
	3.9-4.0	FS	8.0	2.7	0.14	0.8	0.26					
	4.4-4.5	S	8.0	5.9	0.05	2.5	0.8					
	4.9-5.0	S	7.9	5.3	0.26	2.3	0.74					
621	2.4-2.5	KS	5.9	4.4	<0.02							
	2.9-3.0	KS	6.9	3.7	0.03							
	3.4-3.5	FS	7.2	2.1	0.14	0.7	0.22					
	3.9-4.0	FS	7.2	5.7	0.22	2.4	0.77					
	4.4-4.5	FS	7.4	5.8	0.09	1.6	0.51					

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
									mol H^+/t			
622	0-0.1	ZMC	7.0	6.6	<0.02							
	0.4-0.5	ZLC	6.1	1.7	1.25							
	0.9-1.0	KSLC	6.1	0.9	1.48							
623	0.9-1.0	KS	6.2	3.5	0.02							
	1.4-1.5	S	6.5	1.4	0.08							
	1.9-2.0	S	6.8	1.3	0.04							
	2.4-2.5	S	6.9	4.3	0.33	2.3	0.74					
	2.9-3.0	FS	6.8	3.4	0.11	1.5	0.48					
624	4.4-4.5	FS	7.4	3.9	<0.02							
	4.9-5.0	FS	7.7	1.7	0.14							
625	0.55-0.65	KS	7.0	1.0	0.26							
	0.9-1.0	KS	6.6	1.1	0.71							
626	2.9-3.0	FS	7.3	5.9	0.03	6.0	1.9					
	3.4-3.5	FS	7.2	6.4	0.05	5.5	1.8					
	3.9-4.0	KS	7.1	4.3	0.05	4.3	1.4					
	4.4-4.5	KS	7.4	4.7	0.16	2.9	0.9					
627	2.9-3.0	KS	7.5	5.3	<0.02							
	3.4-3.5	FS	7.8	1.6	0.81							
	3.9-4.0	FS	8.0	2.1	0.03							
	4.4-4.5	FS	7.4	1.3	0.09							
	4.9-5.0	FS	7.8	1.9	0.12							
628	0-0.1	FSCL	5.2	3.0	<0.02							
	0.5-0.6	S	5.9	4.3	<0.02							
	0.9-1.0	KS	6.9	4.4	<0.02							
	1.4-1.5	KS	7.0	6.0	<0.02							
	1.9-2.0	KS	7.5	5.9	<0.02							
	2.9-3.0	S	7.1	6.3	0.21	66.4	21.3					
	3.4-3.5	S	7.6	6.0	0.77	41.0	13.1					
629	1.45-1.55	KS	6.7	4.6	<0.02							
	1.9-2.0	KS	6.7	1.4	0.09							
	2.4-2.5	KS	7.3	0.9	0.08							
	2.9-3.0	FS	7.1	1.1	0.41							
630	1.9-2.0	KS	7.3	5.3	<0.02							
	2.4-2.5	FS	7.9	5.5	0.20	2.2	0.71					
	2.9-3.0	FS	7.4	5.9	0.15	19.2	6.2					
	3.4-3.5	FS	7.6	6.2	0.26	34.4	11.0					
	3.9-4.0	FS	7.8	6.1	0.32	21.0	6.7					
631	0.2-0.3	CLS	7.1	6.2	<0.02							
	0.55-0.65	SLC	6.9	0.9	0.7							
	0.9-1.0	SLC	6.9	0.6	1.0							
	1.4-1.5	KS	7.0	1.4	0.24							
	1.9-2.0	KS	7.1	2.9	0.07							
	2.4-2.5	ZLC	6.6	1.6	0.91							
	2.9-3.0	ZLC	6.5	0.7	1.8							
632	0-0.1	KSLC	5.2	0.9	0.16							
	0.4-0.5	LC	5.6	0.6	0.34							
	0.9-1.0	ZLC	5.8	0.3	2.1							
633	2.4-2.5	KS	7.2	5.3	<0.02							
	2.9-3.0	FS	7.1	5.9	0.13	20.8	6.7					
	3.4-3.5	FS	6.7	5.8	0.17	71.6	22.9					
634	2.4-2.5	KS	7.5	5.3	<0.02							
	2.9-3.0	KS	7.7	5.2	<0.02							
	3.4-3.5	KS	7.5	6.2	<0.02							
	3.9-4.0	FS	7.4	6.3	0.28	15.8	5.1					

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
								mol H^+/t				
635	2.45-2.55	FSLC	6.8	1.1	0.66							
	2.9-3.0	SCL	7.6	1.2	0.66							
	3.1-3.2	KS	7.5	1.0	0.50							
	3.4-3.5	KS	7.6	5.6	0.42	17.1	5.5					
636	0-0.1	LC	7.0	6.3	<0.02							
	0.4-0.5	ZLC	6.5	1.2	1.9							
	0.65-0.7	FS	6.5	1.3	0.54							
637	4.9-5.0	S	8.2	6.3	<0.02							
	5.9-6.0	S	7.3	6.1	<0.02							
	6.9-7.0	MC	7.5	7.7	<0.02							
638	0.2-0.3	SCL	4.5	3.7				<10	<10	<10		
	0.5-0.6	LC	4.3	3.5				<10	<10	<10		
	0.9-1.0	LC	4.2	3.6				31	<10	31		
	1.4-1.5	LC	5.7	5.6	<0.02							
	1.9-2.0	LC	5.6	4.9	<0.02							
	2.4-2.5	ZCL	5.9	4.1	0.18							
	2.9-3.0	FS	5.7	1.5	0.13							
	3.4-3.5	FS	5.7	1.1	0.12							
	3.9-4.0	S	6.5	1.2	0.54							
639	0-0.1	SLC	6.3	5.2	<0.02							
	0.2-0.3	SLC	6.2	1.0	0.49							
	0.5-0.6	SLC	6.5	1.1	0.84							
	0.8-0.85	SLC	6.2	1.1	1.5							
640	1.4-1.5	KS	7.8	5.7	<0.02							
	1.9-2.0	FS	7.6	6.3	0.09	28.5	9.1					
	2.4-2.5	FS	7.6	6.6	0.09	35.1	11.2					
	2.9-3.0	FS	7.8	6.4	0.18	42.2	13.5					
	3.4-3.5	FS	7.8	6.2	0.36	19.4	6.2					
641	0.5-0.6	CLS	6.7	5.7	<0.02							
	0.9-1.0	FS	7.6	1.5	0.14							
	1.4-1.5	KS	7.6	5.8	0.05	1.6	0.51					
	1.9-2.0	KS	7.6	6.2	0.12	10.2	3.3					
	2.4-25.	FS	7.7	6.0	0.21	45.5	14.6					
642	1.95-2.0	FS	7.0	5.0	0.04							
	2.4-2.5	FS	6.5	0.6	0.29							
	2.9-3.0	FS	6.8	0.6	0.27							
	3.2-3.3	KS	6.4	0.7	0.32							
643	4.4-4.5	KS	7.3	5.7	<0.02							
	4.9-5.0	ZLC	6.7	0.2	1.9							
	5.4-5.5	ZLC	6.8	0.3	1.5							
644	0.5-0.6	LMC	8.0	7.6	<0.02							
645	2.8-2.9	FSLC	7.4	6.9	<0.02							
652	1.9-2.0	SMC	6.5	7.2	<0.02							
653	2.9-3.0	FS	8.4	8.0	<0.02							
	3.4-3.5	FS	8.1	6.4	0.12	23.4	7.5					
	3.9-4.0	KS	8.2	6.6	<0.02	38.2	12.2					
	4.4-4.5	FS	8.0	6.5	0.18	44.3	14.2					
654	0.9-1.0	FS	6.9	6.0	0.09							
	1.4-1.5	FS	6.9	3.3	1.4							
	1.9-2.0	LC	7.1	3.8	1.3							
	2.4-2.5	LC	7.1	4.2	0.4							
	2.9-3.0	FS	7.7	5.7	0.22	3.3	1.1					
655	1.4-1.5	FS	7.8	6.5	<0.02	19.9	6.4					
	1.6-1.7	MC	7.5	7.1	<0.02							
	2.2-2.3	LC	6.2	3.6	<0.02							
	2.9-3.0	LMC	6.4	8.1	<0.02							

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
								mol H^+/t				
655 cont	3.4-3.5	MC	7.2	6.8	<0.02							
	3.9-4.0	MC	7.5	6.8	<0.02							
656	0-0.1	ZLC	6.5	4.8	0.90							
	0.4-0.5	LC	6.3	1.0	1.5							
	0.9-1.0	LC	6.4	0.6	1.6							
657	4.4-4.5	KS	7.3	6.1	<0.02							
	4.9-5.0	KS	6.6	1.9	0.13							
	5.5-5.6	FS	7.4	5.5	0.41	4.7	1.5					
658	1.9-2.0	KS	7.5	7.1	<0.02	0.8	0.26					
	2.4-2.5	KS	7.4	6.8	0.04	2.1	0.67					
	2.9-3.0	KS	7.6	6.9	<0.02	6.3	2.0					
	3.4-3.5	FS	7.5	6.6	0.30	11.4	3.7					
	3.9-4.0	FS	7.6	6.4	0.28	6.3	2.0					
659	1.4-1.5	S	8.5	7.7	<0.02	4.4	1.4					
	1.9-2.0	KS	7.9	7.1	<0.02	5.2	1.7					
	2.4-2.5	KS	8.4	6.3	0.13	3.7	1.2					
	2.9-3.0	FS	8.3	6.3	0.09	1.4	0.45					
660	1.9-2.0	KS	7.5	5.6	<0.02							
	2.4-2.5	KS	7.5	4.7	0.025	<0.5						
	2.9-3.0	S	7.6	6.2	<0.02	0.5	0.16					
	3.4-3.5	KS	7.6	6.1	<0.02	0.8	0.26					
	3.9-4.0	FS	7.3	5.8	0.06	2.2	0.71					
	4.4-4.5	KS	7.2	5.8	0.07	5.4	1.7					
	4.9-5.0	S	7.1	6.2	0.07	5.1	1.6					
661	0-0.1	ZLC	6.0	3.6	0.35							
	0.2-0.3	SLC	5.9	1.1	0.72							
	0.5-0.6	SLC	5.9	1.3	0.37							
662	1.4-1.5	SCL	7.5	6.9	<0.02							
663	0-0.1	ZLC	6.4	0.8	1.2							
	0.4-0.5	ZLC	6.2	1.1	1.8							
	0.9-1.0	ZLC	6.2	1.1	1.1							
	1.3-1.4	ZLC	6.3	4.3	0.72	18.6	6.0					
664	0.02-0.1	SLC	7.2	5.7	<0.02							
	0.2-0.3	SLC	6.6	5.5	<0.02							
	0.45-0.5	SLC	6.4	1.5	0.56							
	0.9-1.0	S	8.1	4.6	0.25	7.3	2.3					
	1.4-1.5	FS	7.8	4.9	0.34	34.1	10.9					
	1.9-2.0	FS	7.8	5.2	0.28	22.6	7.2					
	2.4-2.5	FS	8.0	5.7	0.11	57.8	18.5					
	2.9-3.0	FS	8.1	6.1	0.20	43.0	13.8					
	3.4-3.5	MHC	7.8	8.8	<0.02							
665	1.4-1.5	KS	7.1	5.2	<0.02							
	1.9-2.0	KS	7.3	1.0	0.33							
	2.4-2.5	S	7.4	1.5	0.51							
	2.9-3.0	KS	7.6	1.1	1.2							
666	1.9-2.0	FS	7.3	5.8	<0.02							
	2.9-3.0	KS	7.7	6.3	<0.02							
	3.9-4.0	KS	7.5	6.2	<0.02							
	4.9-5.0	KS	8.2	6.5	<0.02							
667	3.4-3.5	KS	7.8	5.7	<0.02							
	3.9-4.0	FS	7.4	5.8	<0.02							
	4.4-4.5	FS	7.2	5.7	<0.02							
	4.9-5.0	FS	7.1	5.7	<0.02							
	5.4-5.5	FS	6.9	6.3	0.25	1.8	0.58					
668	0.05-0.1	MC	6.0	5.4	<0.02							
	0.5-0.6	MC	6.1	5.7	<0.02							
	0.9-1.0	ZLC	6.1	5.7	<0.02							

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} %$CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
								mol H^+/t				
668 cont	1.4-1.5	ZLC	3.8	3.1				44	18	<10	<0.01	0.01
	1.9-2.0	ZLC	5.7	0.8	2.3							
	2.4-2.5	KS	6.3	1.0	0.86							
	2.9-3.0	KS	6.2	1.2	0.42							
	3.4-3.5	KS	6.3	1.2	0.77							
	3.9-4.0	KS	7.1	1.3	0.31							
669	4.9-5.0	FS	7.9	6.6	<0.02							
	5.4-5.5	FS	7.9	6.6	<0.02	4.4	1.4					
	5.9-6.0	FS	7.5	6.8	<0.02	4.3	1.4					
	6.4-6.5	FS	7.8	6.6	<0.02	4.2	1.3					
	6.9-7.0	FS	7.9	6.3	<0.02	4.2	1.3					
	7.1-7.2	KS	7.6	5.9	0.033							
670	5.4-5.5	KS	8.1	7.7	<0.02							
	5.9-6.0	FS	7.9	5.7	0.49	35.4	11.3					
	6.3-6.4	KS	8.1	5.6	0.51	22.3	7.1					
	6.45-6.55	MHC	8.3	6.7	0.34							
671	0-0.1	ZL	6.5	7.1	<0.02							
	0.45-0.5	LC	6.1	2.0	0.44							
	0.9-1.0	LC	6.1	1.3	0.61							
	1.4-1.5	KS	7.2	1.2	0.15							
	1.9-2.0	KS	7.6	3.8	0.05							
	2.4-2.5	KS	7.6	5.3	<0.02							
	2.9-3.0	FS	7.1	4.7	0.13	4.5	1.4					
	3.4-3.5	FS	7.2	4.8	0.18	4.5	1.4					
	3.9-4.0	LC	7.5	5.7	0.58	6.2	2.0					
	4.4-4.5	FS	7.5	6.1	0.26	61.4	19.7					
	4.9-5.0	FS	7.3	5.7	0.16	78.3	25.1					
672	0.5-0.6	SLC	6.9	2.6	<0.02							
	0.9-1.0	LC	7.9	6.2	0.57	10.6	3.4					
	1.4-1.5	LC	8.2	6.3	0.33	10.3	3.3					
	1.9-2.0	LC	8.2	6.6	0.32	11.3	3.6					
	2.4-2.5	LC	8.9	7.2	0.35	9.9	3.2					
	2.9-3.0	FS	7.9	6.9	0.05	22.9	7.3					
	3.4-3.5	SLC	7.9	4.7	0.89	3.3	1.1					
	3.9-4.0	SLC	7.5	4.6	0.52	2.6	0.83					
	4.4-4.5	KS	7.4	5.5	0.56	1.6	0.51					
673	1.9-2.0	KS	6.1	4.0	<0.02							
	2.4-2.5	KS	6.8	2.1	0.03	<0.5						
	2.9-3.0	KS	6.6	3.1	<0.02	<0.5						
	3.4-3.5	KS	7.3	3.2	<0.02	<0.5						
	3.9-4.0	KS	7.2	5.4	<0.02	<0.5						
	4.4-4.5	KS	7.2	5.6	<0.02	0.7	0.22					
	4.6-4.7	FS	7.3	5.8	0.08	7.8	2.5					
674	0-0.1	ZLC	5.7	4.9	<0.02							
	0.4-0.5	ZLC	7.1	6.0	<0.02							
	0.9-1.0	SLC	7.0	0.9	0.19							
	1.4-1.5	FS	7.2	1.2	0.29							
	1.9-2.0	KS	7.7	0.8	0.41							
	2.4-2.5	KS	7.9	1.6	0.09							
	2.9-3.0	FS	7.4	2.8	0.27	4.4	1.4					
	3.4-3.5	FS	7.2	3.5	0.24	18.9	6.1					
675	7.4-7.5	KS	6.6	5.9	<0.02							
	8.1-8.2	FSLC	6.9	6.6	<0.02							
676	2.4-2.5	KS	7.0	5.5	<0.02							
	2.9-3.0	KS	7.1	4.7	<0.02	<0.5						
	3.4-3.5	KS	6.9	4.7	<0.02	<0.5						
	3.9-4.0	KS	7.1	5.1	<0.02	<0.5						

Site	Depth	Texture	pH_F	pH_{FOX}	S_{CR}	ANC_{BT}	s-ANC_{BT}	TAA	TPA	TSA	S_{POS}	s-ANC
	(m)				%S	%$CaCO_3$	%S	mol H^+/t			%S	%S
676 cont	4.4-4.5	KS	7.1	3.7	<0.02	<0.5						
	4.9-5.0	KS	6.9	4.7	<0.02							
	5.4-5.5	KS	6.6	5.9	<0.02							
	5.9-6.0	ZLC	7.3	1.3	0.98							
677	3.4-3.5	KS	8.0	3.2	<0.02							
	3.9-4.0	KS	7.4	1.7	0.04							
	4.4-4.5	KS	7.5	1.7	0.13							
	4.9-5.0	S	7.6	1.5	0.09							
	5.4-5.5	FS	7.2	3.4	0.53	3.5	1.1					
	5.9-6.0	KS	7.1	1.7	0.45	1.1	0.35					
678	3.9-4.0	KS	7.7	4.2	<0.02							
	4.2-4.3	KS	7.3	2.2	<0.02							
	4.4-4.5	KS	7.6	3.9	<0.02							
	4.9-5.0	KS	7.5	5.5	<0.02							
	5.9-6.0	KS	7.8	5.6	<0.02							
	6.4-6.5	KS	6.8	1.5	0.38							
	6.9-7.0	MHC	7.8	4.6	0.25							
679	2.4-2.5	KS	7.6	4.9	<0.02							
	2.9-3.0	ZLC	6.8	1.4	0.45							
	3.4-3.5	ZLC	6.8	2.4	0.53							
	3.9-4.0	ZLC	7.1	0.7	0.39							
	4.4-4.5	S	7.3	1.6	0.15							
	4.9-5.0	S	7.3	1.1	0.15							
680	0.9-1.0	SL	7.4	4.6	<0.02							
	1.9-2.0	CFS	6.8	6.2	<0.02							
	2.9-3.0	CLFS	8.0	7.0	<0.02							
	3.9-4.0	LMC	8.1	7.3	<0.02							
	4.9-5.0	LMC	8.0	7.2	<0.02							
	5.9-6.0	MC	7.7	6.9	<0.02							
	6.9-7.0	HC	8.4	7.2	<0.02							
681	3.9-4.0	KS	8.0	6.0	<0.02							
	4.4-4.5	KS	8.0	5.9	<0.02	<0.5						
	4.9-5.0	FSLC	7.5	4.3	<0.02	<0.5						
	5.4-5.5	FSLC	7.5	5.6	<0.02	1.3	0.42					
	5.9-6.0	FSLC	7.5	6.5	0.024	1.3	0.42					
	6.4-6.5	FSLC	6.9	6.0	<0.02	1.4	0.45					
	6.9-7.0	FSLC	7.4	6.1	0.024	1.2	0.38					
682	0.9-1.0	CFS	6.7	6.7	<0.02							
	1.9-2.0	CS	7.4	7.3	<0.02							
	2.9-3.0	CFS	7.7	8.1	<0.02							
	3.9-4.0	FSLMC	7.3	7.9	<0.02							
	4.9-5.0	KS	8.0	6.4	<0.02							
	5.9-6.0	KS	7.5	6.1	<0.02							
	6.9-7.0	KS	7.1	5.8	<0.02							
	7.9-8.0	KS	7.1	6.1	<0.02							
	8.9-9.0	KS	7.1	5.7	<0.02							
	9.9-10.0	KS	7.1	6.2	<0.02							
	10.7-10.8	MC	7.6	7.9	<0.02							
686	0.8-0.9	MC	7.2	6.6	<0.02							
687	2.4-2.7	KS	7.4	5.4	<0.02							
	2.9-3.0	KS	8.0	5.3	<0.02	<0.5						
	3.4-3.5	KS	8.2	5.1	<0.02	<0.5						
	3.9-4.0	KS	8.0	5.5	<0.02	<0.5						
	4.4-4.5	KS	7.3	5.7	<0.02	0.5	0.16					
	4.9-5.0	KS	7.1	5.7	<0.02	0.5	0.16					
	5.4-5.5	LC	7.4	1.1	1.0							

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA mol H^+/t	TPA	TSA	S_{POS} %S	s-ANC %S
688	2.9-3.0	KS	6.7	5.5	<0.02							
	3.4-3.5	KS	7.4	1.9	<0.02							
	3.9-4.0	KS	6.5	1.5	0.07							
	4.4-4.5	FS	7.1	1.6	0.11							
	4.9-5.0	FS	7.9	4.7	0.22	2.9	0.93	<10	<10	<10	0.19	0.28
689	2.4-2.5	KS	7.7	3.8	<0.02							
	2.9-3.0	KS	7.4	1.3	0.77							
	3.4-3.5	KS	7.5	1.7	0.14							
	3.9-4.0	FS	7.2	1.7	0.05							
	4.4-4.5	FS	7.3	2.1	0.13	<0.5						
	4.9-5.0	FSL	7.1	5.6	0.35	2.6	0.83					
	5.4-5.5	FSL	7.2	6.1	0.54	6.0	1.9					
690	4.9-5.0	KS	7.4	5.7	<0.02							
	5.2-5.3	FS	7.1	5.6	<0.02							
	5.4-5.5	KS	7.3	1.9	0.18							
	5.6-5.7	FS	7.2	1.4	0.74							
691	3.9-4.0	KS	7.3	6.7	<0.02							
	4.4-4.5	KS	7.0	1.7	1.1							
	4.9-5.0	FS	6.6	1.9	0.98							
	5.4-5.5	FS	7.1	1.9	0.29							
692	3.9-4.0	FSLC	7.3	6.2	<0.02							
	4.4-4.5	S	7.0	5.4	<0.02							
	4.9-5.0	ZLC	6.7	1.0	1.3							
	5.4-5.5	SMC	7.5	1.6	0.82							
693	0-0.1	LMC	5.6	4.2	<0.02							
	0.4-0.5	MC	7.1	7.1	<0.02							
	0.9-1.0	LMC	7.0	6.9	<0.02							
	1.4-1.5	LMC	6.9	6.2	<0.02							
	1.9-2.0	LC	6.7	5.9	<0.02							
	2.4-2.5	LC	6.5	6.1	<0.02							
	2.9-3.0	FSLMC	6.7	5.8	<0.02							
694	1.9-2.0	MC	6.7	5.9	<0.02							
	2.9-3.0	SMC	7.3	6.8	<0.02							
	3.9-4.0	SMC	6.9	6.0	<0.02							
695	2.9-3.0	S	7.8	7.2	<0.02							
	3.05-3.15	ZLC	6.5	6.4	<0.02							
	3.4-3.5	ZLC	6.0	2.8	<0.02							
	3.9-4.0	KS	6.6	1.6	1.7							
	4.4-4.5	KS	7.0	2.1	0.30							
	4.9-5.0	KS	7.0	1.8	0.34							
696	3.9-4.0	KS	6.7	6.6	<0.02							
	4.4-4.5	KS	7.1	7.0	<0.02							
	4.9-5.0	KS	7.8	6.9	<0.02							
	5.9-6.0	KS	7.5	6.9	<0.02							
	6.9-7.0	KS	6.9	6.6	<0.02							
	7.9-8.0	KS	7.3	7.1	<0.02							
	8.9-9.0	KS	7.5	7.0	<0.02							
	9.9-1.0	KS	7.7	6.7	<0.02							
	10.9-11.0	KS	7.6	6.7	<0.02							
	11.4-11.5	FSMC	7.3	8.9	<0.02							
	11.9-12.0	FSMC	7.4	6.5	<0.02							
697	7.4-7.5	KS	7.4	6.7	<0.02							
	7.9-8.0	LC	6.8	1.2	0.69							
	8.4-8.5	FS	6.8	0.8	0.79							
	8.9-9.0	FSLC	7.5	8.0	0.02							
	9.4-9.5	LMC	7.5	7.3	0.02							

Site	Depth	Texture	pH_F	pH_{FOX}	S_{CR}	ANC_{BT}	s-ANC_{BT}	TAA	TPA	TSA	S_{POS}	s-ANC
	(m)				%S	$\%CaCO_3$	%S	mol H^+/t			%S	%S
698	3.9-4.0	FS	6.9	6.7	<0.02							
	4.4-4.5	KS	7.7	6.4	<0.02							
	4.9-5.0	KS	7.5	2.7	<0.02							
	5.4-5.5	KS	7.8	1.2	0.26							
699	3.4-3.5	KS	7.9	7.1	<0.02							
	3.9-4.0	KS	7.7	7.0	<0.02							
	4.1-4.2	KS	6.8	1.5	0.75							
	4.4-4.5	FSCL	7.0	1.3	0.85							
	4.9-5.0	FSCL	8.1	2.6	0.64	3.1	0.99	<10	<10	<10	0.57	0.49
700	3.4-3.5	KS	7.6	8.6	<0.02							
	3.9-4.0	S	8.5	7.3	<0.02							
	4.4-4.5	S	7.8	6.0	<0.02							
	4.7-4.8	S	7.1	1.5	0.43							
	4.9-5.0	LC	6.8	2.5	0.45	1.4	0.45	<10	191	191	0.40	0.02
	5.4-5.5	FSCL	7.6	7.7	0.03	1.4	0.45					
701	4.4-4.5	KS	7.3	7.1	<0.02							
	4.8-4.9	KS	7.3	7.0	<0.02							
	4.95-5.0	KS	7.7	1.9	0.15							
	5.1-5.15	FSCL	6.9	1.2	0.58							
702	1.4-1.5	KSL	8.7	7.9	<0.02							
703	3.7-3.8	LC	7.4	7.1	<0.02							
704	3.9-4.0	MC	7.8	6.9	<0.02							
705	1.72-1.75	LMC	6.5	2.7	<0.02							
	3.9-4.0	KS	8.0	6.4	<0.02							
	4.9-5.0	ZLC	7.7	6.4	<0.02							
	5.9-6.0	FSL	8.0	6.3	<0.02							
	6.9-7.0	FSLMC	7.6	6.7	<0.02							
	7.9-8.0	LMC	7.5	6.6	<0.02							
706	0.7-0.8	LC	6.2	5.8	<0.02							
707	5.4-5.5	FSLC	7.4	6.5	<0.02							
	5.7-5.8	ZLC	6.9	6.0	<0.02							
	5.9-6.0	LC	6.5	4.8	<0.02	1.0	0.32					
	6.4-6.5	LC	6.8	5.9	0.03	1.0	0.32					
	6.9-7.0	LC	7.4	7.4	<0.02	0.9	0.29					
708	3.9-4.0	KS	8.7	7.4	<0.02							
	4.9-5.0	KS	8.7	7.4	<0.02							
	5.7-5.8	KS	8.0	7.3	<0.02							
709	3.9-4.0	FS	7.4	6.9	<0.02							
	4.4-4.5	FS	7.5	6.9	<0.02							
	4.9-5.0	KS	7.9	6.8	<0.02							
710	2.4-2.5	ZMHC	8.3	8.5	<0.02							
	2.9-3.0	LC	8.3	9.0	<0.02							
	3.4-3.5	CFS	7.7	6.4	<0.02							
	3.9-4.0	CFS	7.5	6.5	<0.02							
	4.2-4.3	FS	7.5	5.8	<0.02							
	4.4-4.5	FS	7.6	1.6	0.43							
	4.9-5.0	FS	8.0	1.1	0.62							
	5.4-5.5	ZLC	6.9	0.5	1.8							
711	3.4-3.5	KS	8.1	6.7	<0.02							
	4.9-5.0	KS	8.2	6.2	<0.02							
712	0.9-1.0	LC	6.8	6.9	<0.02							
	2.8-2.9	CFS	6.8	7.7	<0.02							
	4.9-5.0	KS	7.3	6.8	<0.02							

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
								mol H^+/t				
713	0.9-1.0	S	7.2	7.1	<0.02							
	1.4-1.5	S	6.9	6.7	<0.02							
	1.7-1.8	SLMC	7.2	6.6	<0.02	<0.5						
	1.9-2.0	SLMC	7.6	7.3	<0.02	<0.5						
714	3.9-4.0	LMC	6.9	7.5	<0.02							
	5.7-5.8	KS	7.4	6.6	<0.02							
715	2.4-2.5	CFS	7.2	6.0	<0.02							
	2.7-2.8	LC	6.9	5.8	0.07	0.7	0.22					
	2.9-3.0	KS	7.4	6.2	<0.02							
	3.4-3.5	KS	8.1	1.4	0.13							
	3.9-4.0	KS	7.8	1.6	0.06							
	4.4-4.5	MHC	8.3	7.8	<0.02							
716	2.45-2.5	KS	7.8	6.6	<0.02							
	2.9-3.0	KS	7.6	5.7	<0.02							
	3.4-3.5	KS	7.7	1.8	0.07							
	3.9-4.0	KS	7.9	1.9	0.03							
	4.4-4.5	ZLC	7.4	1.6	0.86							
	4.7-4.8	FS	7.5	1.2	0.07							
717	2.9-3.0	ZLC	7.8	7.4	<0.02							
	3.4-3.5	FS	7.7	7.2	<0.02							
	3.9-4.0	FS	8.8	6.6	<0.02							
	4.2-4.25	ZLC	7.7	6.7	<0.02							
	4.4-4.5	KS	8.2	6.3	<0.02							
	4.9-5.0	ZLC	8.8	7.6	<0.02							
	5.4-5.5	LC	8.4	6.8	<0.02							
	5.5-5.6	FSLC	9.0	7.1	<0.02							
718	1.4-1.5	MC	7.6	7.1	<0.02							
	1.9-2.0	LMC	7.3	7.1	<0.02							
	2.4-2.5	LC	7.5	4.2	0.07	<0.5						
	2.9-3.0	S	7.3	3.4	0.58	0.5	0.16	<10	324	324	0.60	<0.02
	3.2-3.3	FS	7.9	1.9	0.95							
	3.4-3.5	KS	8.5	1.8	0.55							
	3.9-4.0	FS	8.0	1.4	0.31							
	4.4-4.5	LC	8.4	7.4	<0.02							
	4.9-5.0	LMC	8.5	8.1	0.02							
719	1.45-1.5	FSLC	8.4	8.3	<0.02							
	1.9-2.0	S	7.6	7.6	<0.02							
	2.4-2.5	KS	7.7	7.1	<0.02							
	2.9-3.0	KS	7.7	6.9	<0.02							
	3.4-3.5	KS	7.6	6.4	<0.02							
	3.9-4.0	KS	7.6	6.6	<0.02							
	4.4-4.5	KS	8.0	6.0	<0.02							
	4.9-5.0	KS	8.3	5.3	0.03	<0.5						
720	2.4-2.5	KS	7.5	6.4	<0.02							
	2.9-3.0	KS	7.0	6.3	<0.02							
	3.4-3.5	KS	7.3	1.4	0.28							
	3.9-4.0	FS	7.4	1.3	0.22							
	4.4-4.5	KS	7.2	1.1	0.29							
	4.6-4.65	LC	7.1	1.1	1.0							
721	2.4-2.5	LC	8.0	6.2	<0.02							
	2.9-3.0	LC	7.6	5.3	<0.02							
	3.4-3.5	SLC	6.2	3.4	<0.02							
	3.9-4.0	LC	7.5	0.6	0.96							
	4.4-4.5	LC	7.5	1.1	0.96							
	4.9-5.0	FS	7.4	1.3	0.59							
	5.4-5.5	FS	8.4	0.7	0.25							

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
								mol H^+/t				
722	2.9-3.0	LC	7.8	7.2	<0.02							
	3.4-3.5	LC	8.0	6.9	<0.02							
	3.9-4.0	LC	5.9	4.1	<0.02							
	4.4-4.5	FS	7.9	1.8	0.38							
	4.9-5.0	FS	7.9	1.2	0.50							
	5.4-5.5	KS	8.4	0.9	2.74							
	5.5-5.6	LMC	9.1	3.9	0.58	1.6	0.51	<10	171	171	0.57	0.13
723	3.4-3.5	FS	7.9	7.3	<0.02							
	3.9-4.0	FSCL	7.5	6.8	<0.02							
	4.4-4.5	FSCL	7.4	6.3	<0.02							
	4.9-5.0	FSLC	6.8	5.4	<0.02							
	5.5-5.6	CLFS	7.4	6.6	<0.02							
724	2.4-2.5	FSLC	8.7	8.0	<0.02							
	2.9-3.0	CFS	8.4	8.1	<0.02							
	3.4-3.5	CFS	8.9	6.4	0.20	<0.5		<10	50	50	0.14	<0.02
	3.7-3.8	CFS	8.7	7.0	0.21	0.9	0.29					
	3.9-4.0	LC	9.3	6.3	0.39	1.2	0.38	<10	161	161	0.40	0.05
	4.1-4.2	S	8.8	1.8	0.21							
	4.4-4.5	ZLC	8.7	6.5	0.09	0.9	0.29	<10	<10	<10	0.09	<0.02
	4.9-5.0	LMC	9.3	7.2	<0.02							
725	2.9-3.0	LC	8.5	8.2	<0.02							
	3.4-3.5	FSL	8.1	7.6	<0.02							
	3.9-4.0	KS	8.2	7.1	<0.02							
	4.4-4.5	ZCL	8.5	7.2	<0.02							
	4.9-5.0	LMC	8.6	7.6	0.28	1.2	0.38	<10	35	35	0.26	0.09
726	4.4-4.5	KS	8.0	7.1	<0.02							
	5.4-5.5	KS	7.6	5.9	<0.02							
	5.9-6.0	FSLC	7.7	0.8	0.73							
	6.5-6.5	CFS	7.0	1.1	0.73							
	6.9-7.0	FSLC	7.3	6.5	0.04							
727	3.9-4.0	SLC	8.0	7.8	<0.02							
	4.4-4.5	KS	7.7	7.0	<0.02							
	4.9-5.0	S	7.7	6.9	<0.02							
	5.4-5.5	ZLC	8.2	6.2	0.15	0.8	0.26	<10	17	17	0.14	0.01
	5.6-5.7	ZLC	8.2	6.1	0.31	1.0	0.32	<10	66	66	0.29	0.07
728	3.9-4.0	KS	8.1	6.4	<0.02							
	4.2-4.3	KS	7.8	6.7	<0.02							
	4.4-4.5	ZLC	7.3	0.3	1.6							
	4.9-5.0	FS	8.2	1.5	0.12							
729	0-0.1	FSLC	7.1	6.7	<0.02							
	0.9-1.0	CFS	7.2	6.6	<0.02							
	1.9-2.0	KS	7.8	7.0	<0.02							
	2.9-3.0	KS	7.8	7.3	<0.02							
	3.9-4.0	KS	8.1	9.3	<0.02							
	4.9-5.0	KS	7.5	6.6	<0.02							
	5.9-6.0	KS	7.2	6.6	<0.02							
	6.9-7.0	FSLC	7.5	6.3	<0.02							
	7.9-8.0	KS	8.1	6.3	<0.02							
	8.9-9.0	MC	7.4	6.5	<0.02							
	9.4-9.5	MC	7.6	6.8	<0.02							
730	0.9-1.0	FS	7.0	5.9	<0.02							
	1.9-2.0	FS	7.9	6.8	<0.02							
	2.9-3.0	KS	7.2	6.6	<0.02							
	3.4-3.5	KS	7.3	6.4	<0.02							
	3.9-4.0	KS	7.1	1.5	0.49							
	4.1-4.2	LC	5.8	0.8	0.91							

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
								mol H^+/t				
730 cont	4.4-4.5	SCL	7.8	5.7	0.10			<10	14	14	0.07	<0.02
	4.6-4.7	KS	7.3	1.5	0.41							
	4.75-4.85	KSLC	8.1	1.9	0.06							
	4.9-5.0	MHC	8.5	7.3	0.04							
731	0.1-0.2	CS	6.7	6.7	<0.02							
	0.9-1.0	FS	6.8	6.8	<0.02							
	1.9-2.0	S	7.0	6.6	<0.02							
	2.9-3.0	SLC	8.4	7.0	<0.02							
	3.4-3.5	SLC	8.6	7.3	<0.02							
732	0.4-0.5	LC	7.7	6.9	<0.02							
733	0.9-1.0	S	7.3	6.7	<0.02							
	1.9-2.0	S	8.0	7.1	<0.02							
	2.4-2.5	S	7.2	1.3	0.11							
	2.75-2.85	S/LC	7.7	4.3	0.38	<0.5						
	2.9-3.0	S	6.1	2.4	0.22	0.5	0.16					
	3.2-3.3	FSLC	9.3	1.8	0.3							
734	0-0.1	ZLC	6.3	1.1	1.1							
	0.2-0.3	ZLC	6.4	1.0	1.4							
	0.55-0.6	SLC	6.3	0.4	0.40							
	0.9-1.0	SLC	6.2	0.9	0.37							
	1.3-1.4	CKS	6.4	1.0	0.33							
735	0.7-0.8	SLC	5.2	5.4	<0.02							
736	0-0.1	FSLC	7.6	6.7	<0.02							
	0.2-0.3	FSLC	7.7	6.8	<0.02							
	0.5-0.6	FSLC	6.9	5.9	<0.02							
	0.8-0.9	FSLC	6.6	4.5	0.06							
	0.9-1.0	KS	6.9	3.2	0.05							
	1.4-1.5	KS	6.7	1.1	0.17							
	1.9-2.0	FS	6.5	4.7	0.18	0.8	0.26					
	2.4-2.5	KS	8.2	1.8	0.06							
	2.9-3.0	KS	7.4	1.9	0.10							
	3.4-3.5	KS	8.0	1.5	0.11							
737	0.9-1.0	CLFS	7.4	6.7	<0.02							
	1.9-2.0	FSLC	7.2	6.3	<0.02							
	2.9-3.0	SLMC	6.9	6.3	<0.02							
	3.4-3.5	SLMC	3.4-3.5	7.2	6.4							
738	0-0.1	LMC	6.6	6.5	<0.02							
	0.4-0.5	LMC	5.9	5.4	<0.02							
	0.9-0.95	LMC	5.4	4.9	<0.02							
	0.95-1.0	ZLC	5.1	4.9	<0.02							
	1.2-1.3	ZLC	6.0	4.9	0.02							
	1.4-1.5	FSLC	6.5	1.8	0.18							
739	0-0.1	ZLC	7.2	7.6	<0.02							
	0.2-0.3	ZLC	8.1	8.7	<0.02							
	0.5-0.6	FS	8.2	7.0	<0.02							
	0.82-0.9	FS	8.9	6.7	<0.02							
	1.1-1.2	FS	8.4	7.0	<0.02							
	1.4-1.5	S	8.2	6.7	<0.02							
	1.9-2.0	FS	8.2	6.4	<0.02							
	2.4-2.5	KS	7.8	2.0	0.02							
	2.9-3.0	KS	7.8	1.6	0.20							
	3.4-3.5	KS	7.3	5.2	0.02							
740	0-0.1	FSCL	6.4	5.8	<0.02							
	0.2-0.3	FSCL	6.1	5.7	<0.02							
	0.5-0.6	CLFS	6.3	5.9	<0.02							
	0.8-0.9	FSCL	6.3	5.8	<0.02							

Site	Depth (m)	Texture	pH$_F$	pH$_{FOX}$	S$_{CR}$ %S	ANC$_{BT}$ %CaCO$_3$	s-ANC$_{BT}$ %S	TAA (mol H$^+$/t)	TPA (mol H$^+$/t)	TSA (mol H$^+$/t)	S$_{POS}$ %S	s-ANC %S
740 cont	1.1-1.2	FS	6.5	6.4	<0.02							
	1.4-1.5	FS	6.9	6.3	<0.02							
	1.9-2.0	FS	6.5	6.2	<0.02							
	2.4-2.5	S	6.9	6.1	<0.02							
	2.9-3.0	S	7.0	6.4	<0.02							
	3.4-3.5	S	7.0	5.9	<0.02							
	3.9-4.0	KS	7.5	6.1	<0.02							
	4.4-4.5	KS	7.4	5.7	<0.02							
741	0-0.1	FSL	6.4	7.7	<0.02							
	0.2-0.3	ZLC	6.4	6.4	0.04							
	0.5-0.6	ZLC	6.9	7.1	<0.02							
	0.95-1.0	ZLC	6.5	1.4	0.86							
	1.4-1.5	ZLC	6.4	1.2	0.72							
	1.9-2.0	MHC	6.6	2.0	0.66							
742	0.9-1.0	MC	7.6	8.0	<0.02							
	1.9-2.0	CS	7.5	6.8	<0.02							
	2.3-2.4	FSLC	7.2	7.1	<0.02							
743	0-0.1	ZLC	7.5	7.6	<0.02							
	0.5-0.6	LC	7.6	6.5	<0.02							
	0.9-1.0	CFS	7.2	6.9	<0.02							
	1.3-1.4	ZLC	7.4	2.4	0.13							
	1.45-1.5	SLC	7.1	4.5	0.15	<0.5						
744	0.9-1.0	CKS	8.1	8.4	<0.02							
	1.9-2.0	MHC	7.7	7.6	<0.02							
	2.9-3.0	S	7.3	6.7	<0.02							
	3.4-3.5	S	7.2	6.4	<0.02							
745	0.9-1.0	FS	7.8	6.8	<0.02							
	1.4-1.5	S	7.6	6.6	0.02							
	1.9-2.0	FS	7.4	1.5	0.08							
	2.4-2.5	S	7.3	2.6	0.25	5.0	1.6					
	2.9-3.0	S	7.6	1.8	0.39	1.1	0.35					
746	0-0.1	ZLC	6.5	3.8	0.13	1.1	0.35					
	0.4-0.5	FS	6.7	1.6	0.06							
747	0.9-1.0	FSLMC	8.0	8.8	<0.02							
	1.9-2.0	MHC	8.0	8.8	<0.02							
	2.9-3.0	MHC	7.7	8.6	<0.02							
	3.9-4.0	MHC	7.7	8.6	<0.02							
	4.9-5.0	MHC	7.6	8.2	<0.02							
748	0-0.1	LMC	7.4	6.9	<0.02							
	0.5-0.6	FS	6.9	6.2	<0.02							
	0.9-1.0	S	7.0	6.2	<0.02	<0.5						
	1.4-1.5	FS	7.3	3.6	0.04	0.7	0.22					
	1.7-1.8	S	7.2	2.7	0.27	2.9	0.93					
	1.9-2.0	ZLC	7.0	1.2	0.59	0.6	0.19					
	2.4-2.5	MHC	6.8	1.4	0.33							
749	0.9-1.0	KS	7.6	6.8	<0.02	1.0	0.32					
	1.4-1.5	FS	7.0	6.6	<0.02							
	1.9-2.0	KS	7.5	6.8	<0.02	8.7	2.8					
	2.4-2.5	ZLC	6.5	1.0	0.73							
	2.9-3.0	ZLC	6.5	1.3	1.1							
	3.3-3.4	ZLC	6.9	1.4	0.96							
	3.7-3.8	LMC	7.0	2.5	0.34							
750	1.4-1.5	SLC	8.1	6.2	<0.02							
	1.9-2.0	KS	7.7	5.7	<0.02							
	2.4-2.5	KS	7.3	5.7	0.02							

Site	Depth (m)	Texture	pH_F	pH_{FOX}	S_{CR} %S	ANC_{BT} $\%CaCO_3$	s-ANC_{BT} %S	TAA	TPA	TSA	S_{POS} %S	s-ANC %S
								mol H^+/t				
750 cont	2.9-3.0	KS	7.6	1.7	0.51							
	3.4-3.5	KS	7.5	1.6	0.13							
	3.9-4.0	FS	7.4	1.6	0.08							
	4.4-4.5	FS	7.7	3.5	0.02							
	4.9-5.0	FS/LC	7.3	1.8	0.41							
	5.4-5.5	FS	7.3	5.5	0.26	4.1	1.3	<10	<10	<10	0.23	0.38
751	0.9-1.0	SMC	6.8	5.7	<0.02							
	1.9-2.0	SL	7.0	6.0	<0.02							
752	1.9-2.0	FSLC	7.7	6.0	<0.02							
	2.9-3.0	KS	7.3	5.6	<0.02							
	3.9-4.0	KS	7.3	5.8	<0.02							
	4.7-4.8	MHC	7.3	6.5	<0.02							
753	0.9-1.0	LC	7.5	7.0	<0.02							
	1.9-2.0	MHC	7.3	6.4	<0.02							
	2.9-3.0	KSLC	7.6	6.3	<0.02							
	3.9-4.0	MHC	7.6	6.3	<0.02							
754	0.9-1.0	CL	8.1	8.2	<0.02							
	1.9-2.0	LMC	7.7	7.3	<0.02							
	2.9-3.0	MHC	7.6	7.8	<0.02							
	3.9-4.0	MHC	7.8	6.4	<0.02							
755	0-0.1	ZLMC	7.0	5.3	<0.02							
	0.5-0.6	LMC	7.5	6.1	<0.02							
	0.9-1.0	LC	7.9	6.6	<0.02							
	1.4-1.5	LC	7.6	6.1	<0.02							
	1.9-2.0	LC	5.1	3.9	<0.02							
	2.4-2.5	ZLC	6.0	1.6	1.4							
	2.9-3.0	ZLC	6.0	1.6	1.1							
	3.4-3.5	CLFS	6.6	1.8	0.73							
	3.9-4.0	KS	6.5	1.7	0.28							
	4.4-4.5	ZLC	6.6	1.8	0.37							
	4.9-5.0	FS	7.2	1.8	0.13							
	5.4-5.5	ZLC	7.3	2.0	0.33							
756	0.9-1.0	ZMC	8.3	7.7	<0.02							
	1.9-2.0	FS	8.8	7.1	<0.02							
	2.9-3.0	FS	8.7	8.7	<0.02							
	3.9-4.0	FSLC	8.0	7.1	<0.02							
	4.9-5.0	MC	8.0	7.2	<0.02							
757	0.07-0.15	LC	7.6	7.7	<0.02							
	0.5-0.6	LC	7.3	6.6	<0.02							
	0.9-1.0	FSLC	6.9	5.7	<0.02							
	1.4-1.5	MHC	7.1	6.5	<0.02							
	1.9-2.0	MHC	7.1	6.2	<0.02							
758	2.4-2.5	FS	7.2	6.5	<0.02							
	2.9-3.0	KS	7.6	6.2	<0.02							
	3.2-3.3	CFS	6.6	1.2	0.15							
	3.4-3.5	ZLC	7.5	1.0	0.90							
	3.7-3.8	LC	6.9	5.9	0.2	1.7	0.54					
	3.9-4.0	MHC	7.1	7.0	<0.02							
759	0.9-1.0	KS	7.5	7.2	<0.02							
	1.4-1.5	KS	7.7	7.2	<0.02							
	1.9-2.0	KS	7.6	7.4	<0.02							
	2.4-2.5	KS	7.3	3.1	0.04	<0.5						
	2.9-3.0	KS	7.5	5.0	0.08	<0.5						
	3.2-3.3	MHC	7.9	7.3	<0.02							

Site	Depth	Texture	pH_F	pH_{FOX}	S_{CR}	ANC_{BT}	s-ANC_{BT}	TAA	TPA	TSA	S_{POS}	s-ANC
	(m)				%S	$\%CaCO_3$	%S	mol H^+/t			%S	%S
760	0.5-0.6	LC	7.1	6.8	<0.02							
	0.9-1.0	LC	6.9	6.7	<0.02							
	1.4-1.5	SMC	7.0	6.9	<0.02							
761	0.9-1.0	MC	7.4	6.6	<0.02							
	1.9-2.0	CLFS	7.1	7.5	<0.02							
	2.9-3.0	FSL	6.9	6.6	<0.02							
	3.4-3.5	SLC	6.5	3.0	<0.02	0.5	0.16					
	3.9-4.0	SLC	5.8	2.0	0.33	<0.5						
	4.4-4.5	SLC	6.3	1.2	0.7							
	4.9-5.0	S	6.6	1.7	0.36							
	5.4-5.5	S	6.5	1.1	0.30							
762	0.9-1.0	FSL	7.8	6.5	<0.02							
	1.9-2.0	KS	7.7	6.4	<0.02							
	2.9-3.0	KS	7.4	5.0	<0.02							
	3.4-3.5	KS	7.1	3.2	0.07	0.7	0.22					
	3.9-4.0	KS	6.5	3.4	0.04	0.6	0.19					
	4.65-4.7	FS	6.7	5.1	<0.02							
	4.9-5.0	FSL	7.1	4.4	0.9	3.3	1.1					
763	0.9-1.0	SLMC	7.1	6.0	<0.02							
	1.9-2.0	LC	6.7	5.4	<0.02							
	2.4-2.5	LC	5.7	3.7	<0.02	0.7	0.22					
	2.9-3.0	LC	4.6	1.9	0.16	<0.5		56				
764	0-0.1	FS	7.7	7.1	<0.02	3.6	1.2					
	0.4-0.5	S	7.4	7.7	<0.02	2.2	0.71					
	0.9-1.0	FS	7.5	7.0	<0.02	3.3	1.1					
765	0-0.1	MC	7.1	6.9	<0.02							
	0.5-0.6	KS	7.3	6.5	<0.02							
	0.9-1.0	S	5.6	4.3	<0.02							
766	0.5-0.6	SLC	7.4	6.4	<0.02							
	0.9-1.0	SLC	7.2	1.5	0.19	0.5	0.16					
	1.2-1.3	KS	7.0	1.5	0.37	<0.5						
	1.4-1.5	KS	7.4	6.0	0.27	17.1	5.5					
	1.9-2.0	KS	7.3	6.0	0.31	4.7	1.5					
	2.4-2.5	KS	7.3	4.4	0.13	4.5	1.4					
	2.9-3.0	FS	7.2	6.0	0.12	39.9	12.8					
	3.4-3.5	FS	7.5	6.3	0.13	45.7	14.6					
767	2.9-3.0	KS	7.7	7.2	<0.02							
	3.9-4.0	ZLMC	7.6	7.2	<0.02							
	4.9-5.0	FSLC	7.4	6.9	<0.02							
	5.4-5.5	ZLC	6.9	6.5	<0.02	1.2	0.38					
	5.7-5.8	ZLC	7.4	6.7	<0.02	1.4	0.45					
768	3.9-4.0	KS	7.6	6.8	<0.02							
	4.4-4.5	KS	7.5	6.7	<0.02							
	4.9-5.0	ZLMC	6.8	6.0	<0.02							
	5.4-5.5	LC	7.6	6.3	<0.02							
769	4.65-4.75	KS	7.7	6.3	<0.02							