Acid Sulfate Soil Investigation
Nebraska Estate,
Park Road, St Georges Basin,
New South Wales

Report No 101045

Report to Shoalhaven City Council

May 2001

Environmental & Earth Sciences Pty Ltd

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7 May 2001

Shoalhaven City Council
PO Box 42
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Attention: **Alan Stasiukynas**

Dear Alan

Re: Acid Sulfate Soil Investigation Nebraska Estate, Park Road, St Georges Basin, New South Wales

Please find enclosed four copies of Environmental & Earth Sciences Pty Ltd report No. 101045 entitled, *Acid sulfate soil investigation Nebraska Estate, Park Road, St Georges Basin, New South Wales.*

The study found that only the location of bore BH6 (in the creek alignment) requires any management for acid sulfate soil. Bores BH1 and BH5, on either side of bore BH6, require no management for acid sulfate soil.

The soil along the creek alignment, which includes the location of bore BH6 is classified as "no risk – non-reactive", while all other locations are "no risk – no sulfur" or "not acid sulfate soil (NASS)". Hence, the acid sulfate soil risk in the area assessed is very minor to negligible and management requirements are limited to the immediate creek alignment.

Thank you for the opportunity to carry out this study. Should you have any further queries please do not hesitate to call us on (02) 9922 1777. We look forward to being of service to you again in the future.

Yours sincerely
Environmental & Earth Sciences Pty Ltd

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Rep01/101045.doc

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1.0 INTRODUCTION

Environmental & Earth Sciences Pty Ltd were requested by Alan Stasiukynas of Shoalhaven City Council to conduct a limited soil investigation and devise a management plan for excavation of potential sulfidic sediments from a proposed sewer line for the planned Nebraska Estate development. This report outlines the results of soil analysis and recommendations for handling excavated materials along this sewer path.

A potential exists for low lying areas of the St Georges Basin region to contain sediments laid down in colluvium during the Holocene geological period (up to 10 000 years ago) when sea levels rose. Sulfate in sea water when mixed with iron oxides and organic matter forms pyrite (FeS_2) and other iron sulfides under anoxic (oxygen depleted) conditions. Exposure of this material to air can produce sulfuric acid (H_2SO_4) by oxidation.

As sea levels fell alluvial deposition occurred over the Holocene colluvium sediments.

A site inspection and field monitoring and sampling of groundwater was undertaken as part of this assessment. Professional judgement was used to extrapolate between inspected areas, however, even under ideal circumstances, actual conditions may vary from those inferred to exist. The actual interface between materials and variation in soil and groundwater quality may be more abrupt or gradual than the report indicates.

Results for this investigation are reviewed in accordance with the NSW EPA *Environmental guidelines: assessing and managing acid sulfate soils* (1995) and the Acid Sulfate Soil Management Advisory Committee (ASSMAC) *Acid sulfate soil manual* (1998).

The work has been undertaken in accordance with Environmental & Earth Sciences proposal, number PO101064 dated 22 March 2001 and written approval by Shoalhaven City Council received on 29 March 2001.

2.0 OBJECTIVES

The objectives of this study were to :

— assess the potential for acid sulfate soil in the area to be excavated; and

— devise simple, easily understood management procedures to minimise acid generation from site activities associated with the sewer line installation.

The work undertaken to achieve these objectives is reported and discussed in the following sections.

3.0 SITE CHARACTERISTICS

3.1 Location

The site being investigated is the proposed Nebraska Estate, located on The Wool Road, St Georges Basin, New South Wales (see Figure 1). The area of sediment excavation for the pipeline is shown on Figure 2.

3.2 Geology, topography and soil

The local geology of the site has been described in reference 6 as being Permian aged (about 250 million years old) sediments of the Shoalhaven Group which consist of lithic sandstone, felspathic sandstone sandy mudstone, shale, quartz sandstone, conglomerate, pebbly siltstone and latite flows.

Local topography is of low-lying alluvial flats along streamlines rising to undulating hills on Permian sandstone. Crests are broad and rock outcrops are rare. Slopes are generally less than 10 percent and up to 100 metres long.

The soil of this region is described in reference 8 as predominantly comprising soloth soils. Soloths are characterised by a strong textural contrast between the topsoil and the subsoil. Topsoils are typically loamy sands to sandy clays with bleached horizons and manganese nodulation. The pH of topsoil is generally acidic in the range pH 4.5 to 5.5. Subsoils are dominated by clay to sandy clay material of block structure and mottled colours such as brownish-grey, yellow-grey and redish-brown. Subsoils are characteristically acidic with pH ranges between 4 and 7 (reference 7).

The soil in low lying areas of this region is formed from alluvial, colluvial or aeolian deposition of sediments. The soil for the region is described in reference 2 as comprising alluvial levee sediments. Low lying areas of the region have the potential to have had sulfidic marine sediments deposited on them during sea level fluctuations. Hence according to reference 2, the acid sulfate potential of the site is described as high within one metre of the ground surface.

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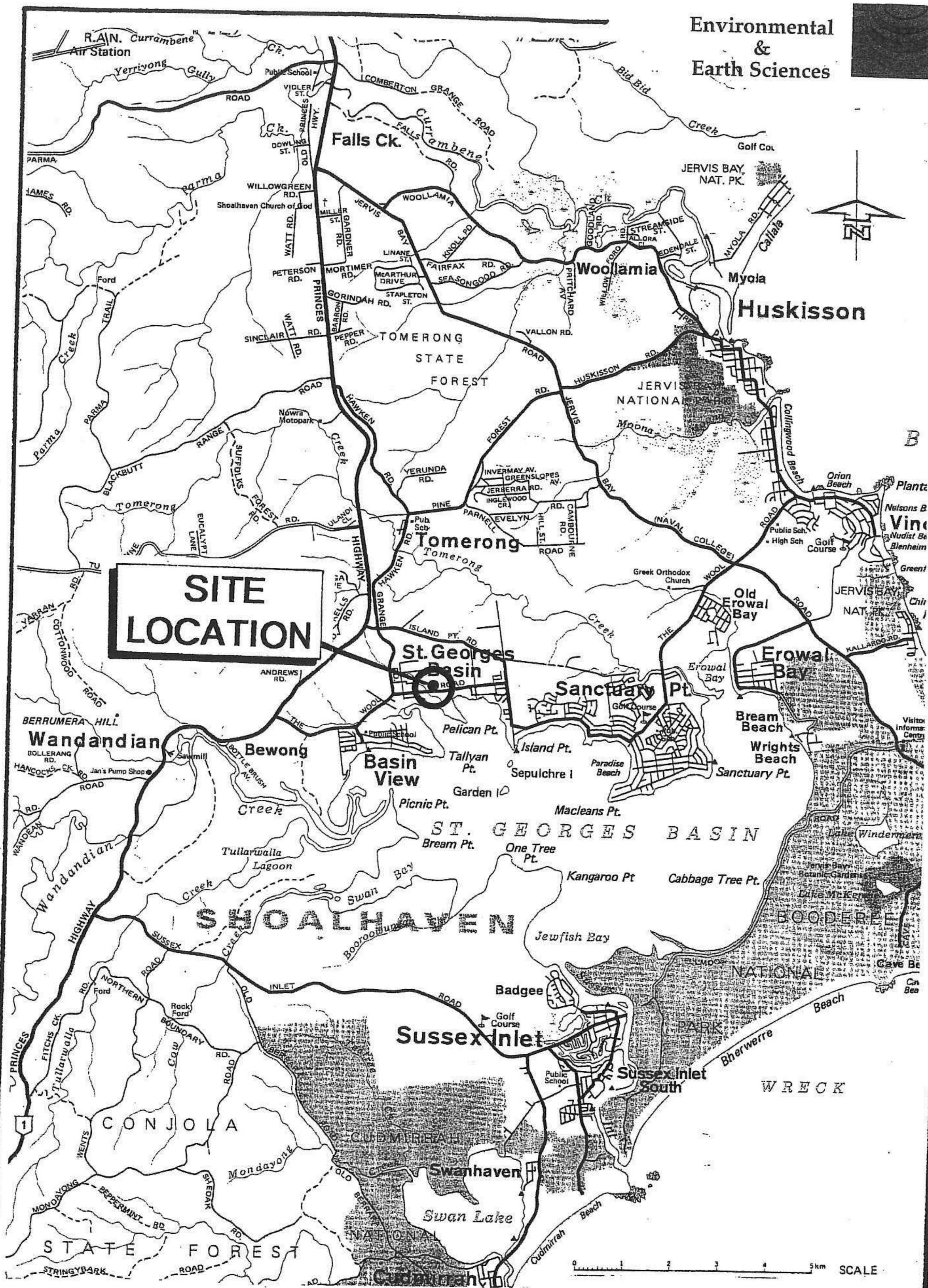


Ref. Craigies Shoalhaven Street Directory

Client: SHOALHAVEN CITY COUNCIL

Title: Locality Plan

Location: Nebraska Estate, The Wool Road, St.Georges Basin

Drawn: TJ

Project Manager: CM

Approved: MS

Fig. 1

Date: Apr.01

Job No. 10/045 Date 12/4/01 TJ

4.0 FIELD INVESTIGATION

The field investigation was undertaken on 3 April 2001 and consisted of a site inspection and soil and water sampling.

4.1 Site inspection

At the time of the inspection the site and surrounds were generally well timbered native bushland on natural soil. The site included creek flats to the west across which most of the soil sampling was undertaken. These creek flats rose to a low ridge in the east of the site.

Within the creek the native vegetation was dominated by casuarinas and melaleucas, elsewhere the vegetation was dominated by eucalypts.

Sampling points for soil analysis were concentrated on areas classified as potential acid sulfate soil (PASS) in reference 2. Hence a transect of 4 boreholes (locations BH1, BH2, BH5 and BH6) were sunk on the western portion of the site along the line of the planned sewer line. One borehole (location BH3) was cored on the northern boundary of the site over the proposed sewer line. One background borehole was placed on soil classified as not being PASS (location BH4).

4.2 Piezometer locations and installation

Piezometers were constructed in three of the locations (bores BH1, BH5 and BH6) as these locations had the potential to generate water. Details of the piezometer construction can be seen on the geological borelogs in Appendix A. Following soil testing works these piezometers were purged and sampled. Borehole BH1 did not generate any water during the day and hence was not sampled. Field measurements of pH, Eh, EC and temperature were taken at the time of sampling. These results are presented in Table 1.

4.3 Sampling protocol

Details of the protocol used by Environmental & Earth Sciences in soil and groundwater investigations is set out in Environmental & Earth Sciences (1999) *Soil, gas and groundwater sampling manual* (reference 3). Protocols undertaken specifically for this site comply with the methodologies stated in the above-mentioned manual.

4.4 Field measurements and observations

Details of the field measurements and observations of individual soil horizons can be seen in the geological borelogs presented in Appendix A. A general site stratigraphy is described in section 4.5.

Field measurements and observations for the water analysis are presented in Table 1.

TABLE 1

FIELD MEASUREMENTS

Location	SWL	pH	Eh	EC	Temp	Comments
Units	m		mV	µS/cm	°C	
BH1	3.3	-	-	-	-	Dry
BH5	1.4	5.54	49.1	1672	20.3	Brown, cloudy, faint sulfide odour, pumped dry, very slow recovery.
BH6	1.3	4.37	115.7	3020	18.7	Brown, cloudy, faint sulfide odour, pumped dry, very slow recovery.

Notes: 1. - = not measured
2. SWL = Standing Water Level, measured to top of bore casing, adjusted to ground level

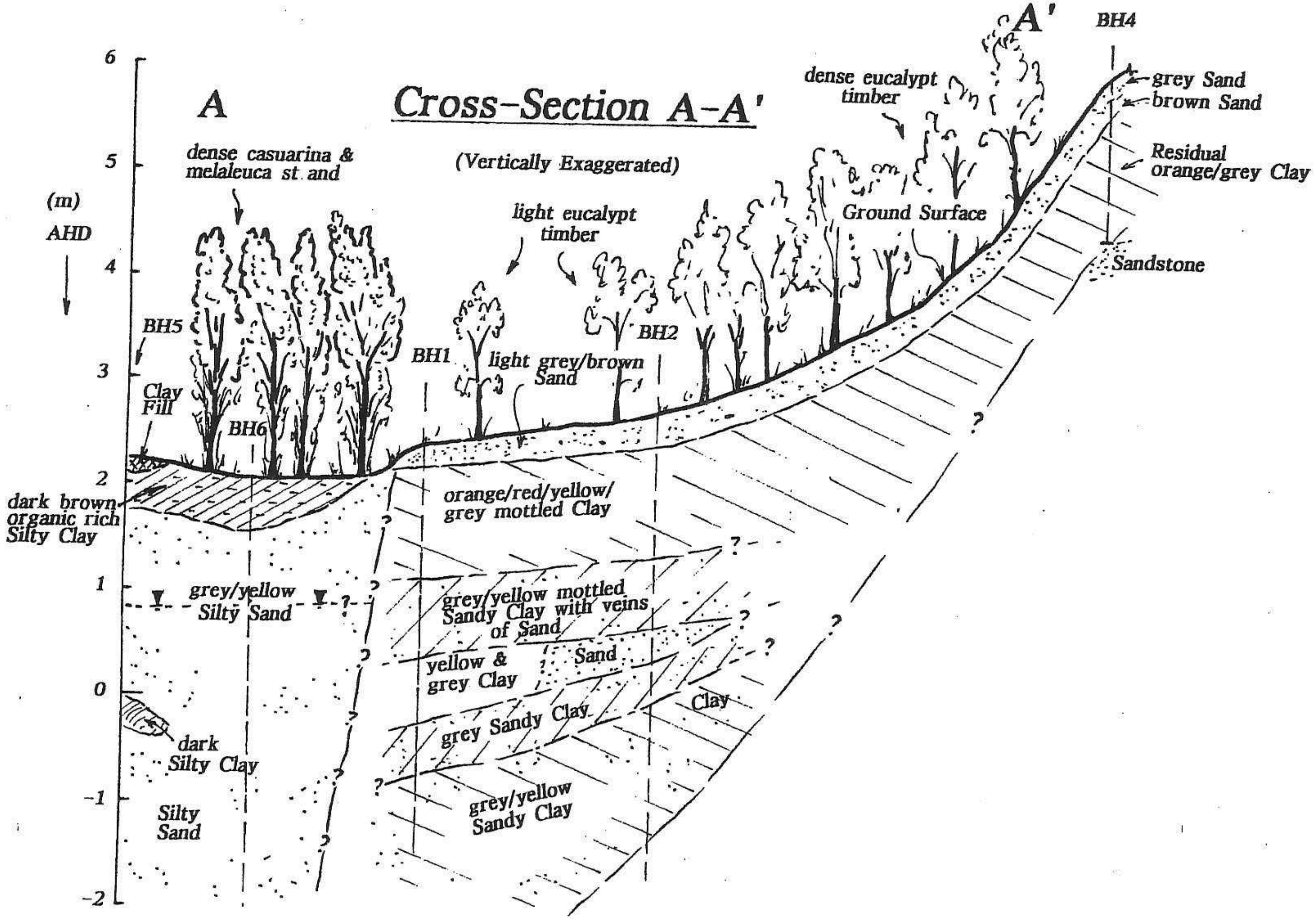
4.5 Stratigraphy

The soil on the site can be described as a catena, or toposequence, whereby the soil's development has been strongly influenced by it's topographic location.

The eastern portion of the site (borehole BH4) and the northern investigation point (borehole BH3) are located at relatively high elevation and are characterised by residual soils formed on the underlying sandstone predominantly from weathering of this sandstone. This has resulted in a grey/brown sand overlying an orange grey clay to sandy clay. Due to an inherently acid parent material and a highly weathering environment the resulting soil has an acidic pH profile.

On the lower slopes of the hill at locations, such as boreholes BH1 and BH2, the soil has formed from both weathering of underlying sandstone in conjunction with colluvial and alluvial deposition. These colluvial and alluvial deposits on the site have resulted in a variety of soil horizons characterised by varying textures, colours and pHs. In general the uppermost layer on the lower slopes is a grey or brown sand which overlies the various clay, sandy clay and sand horizons. The profile is also naturally acidic due to the parent materials.

Job No. 10/045 Date 19/4/01



Client:	SHOALHAVEN CITY COUNCIL		
Title:	Cross-Section A-A'	Drawn: TJ	Fig. 3
		Project Manager: CM	
Location:	Nebraska Estate, The Wool Road, St.Georges Basin	Approved:	Date: Apr.01

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Boreholes BH5 and BH6 are located on the lowest point in the landscape, BH6 is within an ephemeral creek. The formation of the soil on this portion of the site has been strongly influenced by alluvial and possibly estuarine deposits kept in an anoxia state. These deposits have resulted in a predominantly silty sand, mottled yellow and grey, with some inclusion of dark silty clay.

Due to the anoxic conditions of the soil and possible soil sulfides present within the soil, some hydrogen sulfide odours were encountered. The topsoil of this lowlying area contains a 0.5 metres thick humus layer. The pH of the soil from this portion of the site typically ranges between 4.5 and 6. Groundwater was encountered in this lowlying area at approximately one metre below the site surface.

A minor quantity of fill was observed on the surface of location borehole BH5. This fill is likely to be sourced onsite in the formation of the sewer pumping station to the south. The fill consisted of mottled brown, grey and orange clay.

A cross-sectional stratigraphy of the soil profile across the site is presented in Figure 3, the location of which is given on Figure 2.

4.6 Soil and water sampling

Soil samples were collected from the six borehole locations on the site as shown in figure 2 while water samples were extracted from the boreholes BH5 and BH6.

5.0 LABORATORY ANALYSIS

5.1 Laboratory procedures

Analyses for potential acid generation of the soil were based on calculating the amount of total oxidisable sulfides (TOS) present in the sample, and taking into account the acid neutralising capacity (ANC) and total actual acidity (TAA) of the soil.

Total oxidisable sulfides were analysed in a furnace after a hot water wash. This process removes inorganic oxidised forms of sulfur (usually sulfates), allowing TOS to be determined. Filtrate from this procedure can then be used to quantify sulfate sulfur by ion chromatography, allowing determination of total sulfides (total S - sulfate). Interference from organic sulfur compounds in high organic matter samples may effect the accuracy of these calculations.

One method frequently used in acid sulfate soil studies is the total potential acidity (TPA) test. This test indicates the potential acidity from hydrogen peroxide (H_2O_2) oxidation, less the amount of acid already in the system (TAA). This method is prone to over-estimation of potential acidity as oxidation is rapid and buffering capacity, and effects of organic matter oxidation are not fully considered. For this reason an alternative test was undertaken to assess the potential for acid generation, namely the net acid generation potential (NAGP) test.

Net acid generating potential (NAGP) was used to assess the amount of acidity reproduced by the oxidation of pyrite in the soil, less the buffering capacity of the soil (reference 4). If the potential acidity of the soil is greater than the inherent buffering capacity, acid leachate will be produced. An estimate of the amount of neutralising agent required to treat the net acid generated can be calculated once the NAGP is established. The use of NAGP is recommended by the NSW EPA (reference 5) for assessing acid sulfate soils.

The acid neutralisation capacity (ANC) measures the ability of the sample to neutralise acid generated from sulfide oxidation. It is generally determined by reacting a sample with a known amount of standardised hydrochloric acid and back titrating to determine the amount of acid consumed. The NAGP is then calculated by the following equation:

$$\text{NAGP (kg } H_2SO_4\text{/t soil)} = \%\ S \times 30.6 - \%\ ANC \times 9.8$$

It is important to note that the detection limit for ANC is approximately 5 times greater than that of percent sulfide. Therefore, at low levels % sulfide can give erroneously high NAGP values.

Total actual acidity (TAA) determines the amount of acid present in the soil prior to oxidising remaining sulfides. The method determines the moles of titratable protons per unit mass of soil displaced by an unbuffered KCl solution. The TAA is otherwise known as the salt-replaceable acidity.

Selected soil samples were also tested for the cation exchange capacity (CEC) and concentrations of major cations both on the exchange surfaces and within the soil solution.

5.2 Laboratory results

Laboratory results are presented in Tables 2, 3 and 4 and Appendix A. The analytical suites were conducted by Sydney Analytical Laboratories.

TABLE 2

SOIL ANALYSIS RESULTS — ACID SULFATE TESTS

Sample	Depth	Sample	pH	EC	TOS	ANC	NAGP	TAA
Units	m	texture		μScm^{-1}		kg H_2SO_4/t soil		
BH1	1.6-1.9	Clay	4.3	390	0.83	<0.01	+0.8	1.23
BH1	2.8-3.0	Sandy clay	6.3	180	0.24	0.39	-0.1	-
BH2	0.3-0.4	Sandy clay	5.0	140	0.37	<0.01	+0.4	-
BH2	1.6-1.7	Sandy clay	5.4	220	0.12	<0.01	+0.1	0.25
BH2	2.8-2.9	Sand	5.9	70	0.21	<0.01	+0.2	-
BH3	0.7-0.9	Clay	4.8	50	-	-	-	-
BH3	1.4-1.6	Clay	4.3	60	0.15	<0.01	+0.2	4.36
BH5	0.2-0.4	Silt	4.8	130	-	-	-	-
BH5	0.8-1.0	Sand	4.8	75	<0.002	<0.01	0.0	0.74
BH5	1.6-1.8	Sand	4.9	75	0.24	<0.01	+0.3	-
BH5	2.4-2.6	Silty clay	4.9	115	0.95	<0.01	+1.0	-
BH6	0-0.2	Clay	4.6	650	1.59	<0.01	+1.6	0.74
BH6	1.8-2.0	Silty sand	4.3	160	2.30	<0.01	+2.3	0.74
BH6	2.8-3.0	Silty Sand	4.4	160	1.74	<0.01	+1.8	-

Note: - = not analysed

TABLE 3

SOIL ANALYSIS RESULTS — CEC AND EXCHANGABLES

Sample	Depth	CEC	Ex Na	Ex Ca	Ex Mg	Ex K	Ex Mn	Ex Al
Units	m	meq%			%CEC			
BH1	1.6-1.8	7.7	9.2	3.8	53.9	4.7	<0.2	36.4
BH2	1.6-1.7	4.8	17.1	2.5	71.9	1.9	<0.2	8.3
BH3	0.7-0.9	4.4	3.2	3.6	55.7	2.7	<0.2	43.2
BH5	0.2-0.4	4.7	1.3	18.1	37.2	2.1	<0.2	46.8
BH5	1.6-1.8	2.7	1.1	8.9	21.1	1.1	<0.2	63.0
BH5	2.4-2.6	3.6	1.7	12.5	37.5	1.4	<0.2	52.8

Sample	Depth	SAR	Sol Na	Sol Ca	Sol Mg	Sol K	Sol Mn	Sol Al
Units	m				meq%			
BH1	1.6-1.8	9.02	2.55	<0.01	0.08	0.02	<0.01	<0.01
BH2	1.6-1.7	8.84	1.25	<0.01	0.02	0.03	<0.01	<0.01
BH3	0.7-0.9	0.98	0.17	<0.01	0.03	<0.01	<0.01	<0.01
BH5	0.2-0.4	1.02	0.52	0.04	0.22	0.02	<0.01	<0.01
BH5	1.6-1.8	0.98	0.47	0.03	0.2	0.15	<0.01	<0.01
BH5	2.4-2.6	0.98	0.51	0.02	0.25	0.14	<0.01	<0.01

Notes:

1. CEC = cation exchange capacity
2. SAR = sodium absorption ratio
3. Ex Na ≡ ESP (exchangeable sodium percentage)

TABLE 4

WATER ANALYSIS RESULTS

Sample	pH	TDS	Na	Ca	K	Mg	Cl	F	NO_3	SO_4	HCO_3	PO_4	NH_4	Cl/SO_4
BH5	5.6	960	305	23	17	22	520	<0.1	0.13	71	2	<0.1	<0.1	7.3
BH6	4.4	1750	500	52	16	44	830	<0.1	<0.1	280	<1	<0.1	3.0	2.96

Note: results in mg/L

6.0 INTERPRETATION OF RESULTS

6.1 Soil hazard classes

Soil hazard classes are a management tool for defining material based on impact to the environment, and are derived from TOS and NAGP values. Classes normally used are no risk (no-sulfur, non-reactive), moderate risk and high risk. An explanation of these classes is presented in the following sections, and definitions are presented in Table 5.

TABLE 5

SOIL SULFIDE HAZARD CLASSES

	No risk				Risk			
Texture Group	**'No-sulfur'**		**'Non-reactive'**		**'Moderate Risk'**		**'High Risk'**	
	TOS	**NAGP**	**TOS**	**NAGP**	**TOS**	**NAGP**	**TOS**	**NAGP**
1 — Sands	<1	N/A	>1	<3	>1	>3	>10	>5
2 — Sandy silts and Silts	<2	N/A	>2	<6	>2	>6	>20	>10
3 — Clays	<3	N/A	>3	<9	>3	>9	>30	>15

Notes:
1. with the exception of 'no-sulfur', all samples need both TOS and NAGP to define the hazard class
2. all units in kg of H_2SO_4 generated per tonne of soil

6.1.1 No risk - no-sulfur

Acid sulfate soils (ASS) are defined in the *Acid sulfate soil manual* (reference 1) as including both actual and potential acid sulfate soils (AASS and PASS). AASS are defined as soil "containing highly acidic soil horizons"…producing…"hydrogen ions in excess of the sediments capacity to neutralise the acidity, resulting in soil of pH of 4 or less when measured in dry season conditions". PASS are defined as soil "that contains sulfidic material that has not been oxidised…and…poses a considerable environmental risk, as they will become extremely acid when exposed to air and oxidised".

Apart from this semi-quantitative definition the manual also defines what are not acid sulfate soils. Sediments and soil that fall in this class are no risk – no-sulfur or not acid sulfate soils (NASS).

The no risk – no-sulfur classification is based solely on the presence of sulfides measured by TOS. No risk – no-sulfur is defined as soil below the TOS threshold values given in Table 4.4 of reference 1, which are: for sand, TOS <1 kg H_2SO_4/t soil; for sandy silts and silts, TOS <2 kg H_2SO_4/t soil; and for sandy clays, silty clays and clays, TOS <3 kg H_2SO_4/t soil.

6.1.2 No risk - non-reactive

Non-reactive is based on NAGP and is defined as having TOS values greater than the no-sulfur threshold, but NAGP values below 3 times that of the no-sulfur values. Thus: for sand, NAGP <3 kg H_2SO_4/t soil; for sandy silts and silts, NAGP <6 kg H_2SO_4/t soil; and for sandy clays, silty clays and clays, NAGP <9 kg H_2SO_4/t soil.

These levels are based on Environmental & Earth Sciences Pty Ltd experience with ASS and require calibration using accelerated weathering trials to define the exact value, as soil variation can cause deviation by up to 30% from the anticipated value.

6.1.3 Moderate risk and high risk

Moderate and high risk sediment and soil is likely to cause a significant adverse risk to the environment. Essentially, moderate risk will generate a small amount of acid slowly while high risk will either generate acid quickly, in large volumes, or both. Values for moderate or high risk sediments have to be derived by either field trials or accelerated weathering experiments, but broad class groups are presented in Table 5. According to the definition in reference 1, these are the only two classes that are considered to be ASS from a management point of view. High risk material should not be disturbed or, if disturbance cannot be avoided, should be kept in an anoxic state.

6.2 Acid generation potential from excavating activities

Classification of the soil according to the above-mentioned hazard classes reveals that all soil samples analysed for acid generating potential fall into the "no risk" category. Most of the samples contain negligible sulfur and hence are classified as "no risk – no sulfur". The only location found to contain appreciable quantities of sulfur is borehole BH6 however these concentrations are still considered non reactive and are unlikely to result in significant acid generation upon oxidation, hence these samples were classified as "no risk – non reactive".

The small about of potential acidity which could be produced from soil within borehole BH6 could be neutralised by the addition of 4 kg of lime per tonne of soil.

The soils of the site are considered to have low cation exchange capacities however the dominance of calcium and magnesium on the exchange surfaces should provide some buffering to pH changes. Within the soil solution, the lack of soluble manganese and aluminium indicates that inherent acidity of the soil is currently being buffered by exchangeable magnesium, calcium and sodium ions.

Laboratory analysis of the groundwater at boreholes BH5 and BH6 confirm the findings of the soil study. The high chloride to sulfate ratio found in borehole BH5 indicates that soil sulfides in this location are either absent or have never oxidised whilst the lower chloride to sulfate ratio in borehole BH6 indicates the presence of some soil sulfides and little buffering capacity. No excessive concentrations of any major ionic species were found and results were characteristic of fresh water. The pH of the water is considered low however this is to be expected given the inherent acidity of the local soil and parent rock. The TDS of the groundwater water is typical of freshwater to slightly brackish.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Environmental & Earth Sciences Pty Ltd undertook an acid sulfate soil investigation along the path of the planned sewage line for the Nebraska Estate, St Georges Basin, New South Wales, on behalf of the Shoalhaven City Council.

The findings of this investigation are that the majority of the site contains negligible potential acid sulfate soil (PASS) and hence requires no particular management for acid sulfate soil. The soil within the locality of borehole BH6 contains low concentrations of soil sulfides but is considered non reactive. Oxidation of the sulfides can be neutralised by addition of approximately 2.5 kg of lime per tonne of soil. However, to allow for incomplete mixing of the lime it is advised that excavated soil from the creek alignment be treated by mixing well with 3.5 to 4 kg of lime per tonne of soil.

It is also recommended that dewatering of excavations within the creek alignment be minimised if possible to ensure the surrounding soil does not oxidise. If dewatering of the excavation within the creek alignment is undertaken for more than a one week period, ongoing monitoring of the groundwater in this vicinity would be required.

Any concrete or metallic structure placed in the sewer alignment between boreholes BH1 and BH5 (see Figure 2) should have a buffer of al least 150 mm of sand mixed with lime at a rate of 0.5% (5 kg/tonne sand), protecting them from direct contact with soil sulfides.

8.0 GLOSSARY OF TERMS

The following descriptions are of terms used in reports of this kind.

Acid neutralising capacity (ANC) – the soils natural resistance to acid generation. It is the number of moles of protons per unit mass of soil required to raise the pH of the soil by one pH unit. ANC is measured as percentage $CaCO_3$.

Acid Sulfate Soil (ASS) – Soil containing iron sulfides deposited during either the Pleistocene or Holocene periods as sea levels rose.

Actual Acid Sulfate Soil (AASS) – Soil in which soil sulfides are undergoing oxidation and producing more acid than the soils ANC, leading to a net acid generation.

Aeolian – deposits of soil material transported and/or arranged by wind.

Alluvial – describes material deposited by, or in transit in, flowing water.

Cation exchange capacity (CEC) – The sum of exchangeable cations that a soil, soil constituent or other material can adsorb at a specific pH. It is usually expressed in centimoles of charge per kilogram of exchanger.

Colluvial – unconsolidated soil and rock material moved downslope by gravity.

Discrete sample – samples collected from different locations and depths that will not be composited but analysed individually.

Ephemeral – of short duration eg ephemeral creek which only has sporadic flows of water.

Net acid generation potential (NAGP) – The difference between the TOS and ANC reported on a kilogram H_2SO_4 production per tonne of soil.

pH – negative log of hydrogen ion activity, measurement of the acidity or alkalinity of the soil or water.

Piezometer – a bore used for sampling groundwater.

Potential Acid Sulfate Soil (PASS) – Soil that contains sulfidic material that has not been oxidised but poses a considerable environmental risk should oxidation occur.

Profile – the solum. This includes the soil A and B horizons and is basically the depth of soil to weathered rock.

Soloth – Soils which are acidic throughout the solum and have a strong textural boundary between the topsoil and the subsoil

Texture – is the size of particles in the soil. Texture is divided into six groups, depending on the amount of coarse sand, fine sand, silt and clay in the soil.

Total Acidity (TA) – the difference between the soil CEC and ANC.

Total Actual Acidity (TAA) – the moles of titratable protons per unit mass of soil displaced by an unbuffered KCl solution, otherwise known as the salt-replaceable acidity.

Total oxidisable sulfur (TOS) – the maximum oxidisable sulfur present and represents the maximum production of acid possible from sulfide oxidation.

9.0 REFERENCES

1. Acid Sulfate Soils Management Advisory Committee (1998) — *Acid sulfate soil manual.*
2. Department of Land and Water Conservation (1997) — *Huskisson 1:25 000 Acid sulfate soil risk map.*
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8. Wright, D.A. (1998) — *A soil map of Australia* in Stace, H.C.T., Hubble, G.D., Brewer, R., Northcote, K.H., Sleeman, J.R., Mulcahy, M.J., and Hallsworth, E.G. (1968) *A handbook of Australian Soils*. Rellim Technical Publications, Glenside, South Australia.

APPENDIX A

GEOLOGICAL BORELOGS

LOCATION See Figure 2 Sampling Plan
SURFACE ELEVATION (RL) JOB No. 101045
GROUNDWATER As shown DATUM
DRILL TYPE/METHOD Push Tube DATE 3/4/01

BOREHOLE LOG BH1 LOGGED BY CM
Project Manager CM
Approved -

PROJECT Shoalhaven City Council
Nebraska Estate, St.Georges Basin

# No.	STRATIGRAPHY	GRAPHIC LOG	Depth metres	SAMPLE TYPE	SAMPLE undisturbed disturbed lost	Moisture Content %	FID Background	FID Reading ppm	CHEMICAL DATA pH - Soil	CHEMICAL DATA pH - H2O	CHEMICAL DATA pe - H2O	CHEMICAL DATA EC uS/cm	CONSTRUCTION DETAILS COMMENTS
BH1	NATURAL - Fine Sand, bleached grey with minor inclusions of yellow Sandy Clay		0		▨	M			4.5-5				No odours throughout
	NATURAL - Fine Sandy Clay, yellow/grey mottled with root channels		0.2										
			0.4										Piezo
			0.6						4.5-6				
	NATURAL - Fine Sandy Clay, orange/red/yellow & grey mottled with minor root channels & ironstone		0.8										
			1.0		▨				4.5-6				
			1.2										
			1.4										
	NATURAL - Clay, grey/yellow/red mottled with veins of alluvial sand - grey/brown		1.6		▨	M-W							Slotted
			1.8										
	NATURAL - Clay, grey		2.0						6				
	- grading to		2.2		▨								
	NATURAL - Clay, yellow/grey mottled		2.4										
	NATURAL - Sandy Clay, grey		2.6						6.5				
			2.8		▨								NGWE
	NAT. - Sandy Clay, grey/yellow mottled		3.0						6.5				
	E.O.H. @ 3.2m on Natural Sandy Clay.		3.2										
			3.4										
			3.6										
			3.8										
			4.0										

ACN 002 347 971
Environmental & Earth Sciences
Pty Ltd

LOCATION See Figure 2 Sampling Plan
SURFACE ELEVATION (RL) JOB No. 101045
GROUNDWATER As shown DATUM
DRILL TYPE/METHOD Push Tube DATE 3/4/01

BOREHOLE LOG BH2 LOGGED BY CM

Project Manager CM
Approved -

PROJECT Shoalhaven City Council
Nebraska Estate, St.Georges Basin

# No.	STRATIGRAPHY	Depth metres	SAMPLE TYPE	SAMPLE undisturbed disturbed lost	Moisture Content %	FID Background	FID Reading ppm	CHEMICAL DATA pH - Soil	CHEMICAL DATA pH - H2O	CHEMICAL DATA pe - H2O	CHEMICAL DATA EC uS/cm	CONSTRUCTION DETAILS COMMENTS
BH2	NATURAL - Fine Sand, grey/brown with roots & organic matter	0			M-D			6				No odours throughout
	NATURAL - Fine Sand, lt.grey bleached with minor inclusions of Sandy Clay	0.2										
	NATURAL - Sandy Clay, yellow/brown mottled with manganese nodules	0.4 0.6		▨	M			5.5				
	NATURAL - Sandy Clay, yellow/grey mottled	0.8 1.0 1.2 1.4		▨	M-W			5				
	NATURAL - Sandy Clay, grey/yellow mottled with some cream Sand (possibly jarosite)	1.6 1.8		▨	M-W			5				
	NATURAL - Sand, white	2.0			M			6				
	NATURAL - Sand, orange	2.2			M			5				
	NATURAL - Sandy Clay, grey	2.4 2.6		▨								NGWE
	NATURAL - Sandy Clay, grey/yellow/orange mottled	2.8		▨	W			6				
	E.O.H. @ 2.9m on Natural Clay.	3.0 3.2 3.4 3.6 3.8 4.0										

ACN 002 347 971

Environmental & Earth Sciences
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LOCATION See Figure 2 Sampling Plan
SURFACE ELEVATION (RL) JOB No. 101045
GROUNDWATER As shown DATUM
DRILL TYPE/METHOD Push Tube DATE 3/4/01

BOREHOLE LOG BH3

LOGGED BY CM
Project Manager CM
Approved -

PROJECT Shoalhaven City Council
Nebraska Estate, St.Georges Basin

# No.	STRATIGRAPHY	GRAPHIC LOG	Depth metres	SAMPLE TYPE	SAMPLE undisturbed disturbed lost	Moisture Content %	FID Background	FID Reading ppm	CHEMICAL DATA pH - Soil	CHEMICAL DATA pH - H2O	CHEMICAL DATA pe - H2O	CHEMICAL DATA EC uS/cm	CONSTRUCTION DETAILS COMMENTS
BH3	NATURAL - Fine Sand, lt.grey/brown with fine roots & gravel		0		▨	M-D			4.5				No odours
	NATURAL - Fine Sand, lt.brown with quartz fragments		0.2										
	NATURAL - Clay, orange/red/ yellow mottled		0.4										
			0.6										
			0.8		▨				4.5				
			1.0										
	NATURAL - Clay, yellow/grey mottled with smooth faced peds & minor quartz fragments		1.2										
			1.4		▨				4.5				
			1.6										
			1.8										NGWE
	NAT. - Weathered Sandstone, red/grey		2.0			↓							
	E.O.H. @ 2.1m - Refusal on Weathered Sandstone.		2.2										
			2.4										
			2.6										
			2.8										
			3.0										
			3.2										
			3.4										
			3.6										
			3.8										
			4.0										

LOCATION See Figure 2 Sampling Plan
SURFACE ELEVATION (RL) JOB No. 101045
GROUNDWATER As shown DATUM
DRILL TYPE/METHOD Push Tube DATE 3/4/01

BOREHOLE LOG BH4

LOGGED BY CM
Project Manager CM
Approved -

PROJECT Shoalhaven City Council
Nebraska Estate, St.Georges Basin

# No.	STRATIGRAPHY	GRAPHIC LOG	Depth metres	SAMPLE TYPE	SAMPLE undisturbed	SAMPLE disturbed	SAMPLE lost	Moisture Content %	FID Background	FID Reading ppm	CHEMICAL DATA pH - Soil	CHEMICAL DATA pH - H2O	CHEMICAL DATA pe - H2O	CHEMICAL DATA EC uS/cm	CONSTRUCTION DETAILS COMMENTS
BH4	NATURAL – Fine Sand, light grey/ brown		0								6				
	NATURAL – Fine Sand, brown		0.2		▨			M-D ↓			5				No odours
	NATURAL – Sandy Clay, orange/ grey mottled		0.4												
			0.6								4.5				
			0.8												
	– grading to .... grey/red mottled		1.0		▨										
			1.2								4.5				
			1.4												NGWE
	E.O.H. @ 1.5m – Refusal on Weathered Sandstone.		1.6												
			1.8												
			2.0												
			2.2												
			2.4												
			2.6												
			2.8												
			3.0												
			3.2												
			3.4												
			3.6												
			3.8												
			4.0												

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LOCATION See Figure 2 Sampling Plan
SURFACE ELEVATION (RL) JOB No. 101045
GROUNDWATER As shown DATUM
DRILL TYPE/METHOD Push Tube DATE 3/4/01

BOREHOLE LOG BH5 LOGGED BY CM
Project Manager CM
Approved –

PROJECT Shoalhaven City Council
Nebraska Estate, St.Georges Basin

# No.	STRATIGRAPHY	GRAPHIC LOG	Depth metres	SAMPLE TYPE	SAMPLE undisturbed disturbed lost	Moisture Content %	FID Background	FID Reading ppm	CHEMICAL DATA pH - Soil	pH - H2O	pe - H2O	EC uS/cm	CONSTRUCTION DETAILS COMMENTS
BH5	FILL – Clay, brown with minor grey & yellow flecks		0			M			6				No odour
	NATURAL – Silt, dark brown, organic rich with roots throughout & minor iron coatings on root channels		0.2		▨				6				Piezo
			0.4										
	NATURAL – Silty Fine Sand, grey with minor mottles of yellow/brown		0.6										
			0.8		▨	M-W			5.5				Faint H_2S odour
			1.0										
			1.2										
	NATURAL – as above with fragments of dark organic matter		1.4			WL			5.5				
			1.6		▨								Medium-strong H_2S odour
			1.8										
			2.0						5.5				slotted
	NATURAL – Silty Clay, dark brown with flecks of black organic matter		2.2										
			2.4		▨				6				Strong H_2S odour
			2.6										
	NATURAL – Silty Sand, grey/brown		2.8						6				Medium H_2S odour
			3.0										
	E.O.H. @ 3.0m on Silty Sand Sample slipage.		3.2										
			3.4										
			3.6										
			3.8										
			4.0										

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Pty Ltd

LOCATION See Figure 2 Sampling Plan		BOREHOLE LOG BH6 LOGGED BY CM	Project Manager CM
SURFACE ELEVATION (RL)	JOB No. 101045		
GROUNDWATER As shown	DATUM	PROJECT Shoalhaven City Council Nebraska Estate, St.Georges Basin	Approved -
DRILL TYPE/METHOD H/A	DATE 3/4/01		

# No.	STRATIGRAPHY	GRAPHIC LOG	Depth metres	SAMPLE TYPE	undisturbed disturbed lost	Moisture Content %	FID Background	FID Reading ppm	CHEMICAL DATA pH - Soil	pH - H2O	pe - H2O	EC uS/cm	CONSTRUCTION DETAILS COMMENTS
BH6	NATURAL - Clay, brown with minor grey & orange flecks		0		▨	M			4.5				
			0.2										
			0.4										Piezo
	NATURAL - Silty Sand, grey/yellow mottled		0.6										
			0.8						5				
			1.0	▨		M-W							
			1.2			WL							
			1.4										slotted
			1.6										
			1.8	▨				4.5-6					
			2.0										
			2.2										
			2.4										
			2.6										
			2.8	▨				6					H_2 S
	E.O.H. @ 3.0m Sample slip from Hand Auger		3.0										
			3.2										
			3.4										
			3.6										
			3.8										
			4.0										

ACN 002 347 971

Environmental & Earth Sciences Pty Ltd

APPENDIX B

LABORATORY RESULTS

**SYDNEY
ANALYTICAL
LABORATORIES**

Office:
PO BOX 48
ERMINGTON NSW 2115

Laboratory:
1/4 ABBOTT ROAD
SEVEN HILLS NSW 2147
Telephone: (02) 9838 8903
Fax: (02) 9838 8919
A.C.N. 003 614 695
A.B.N. 81 829 182 852

ANALYTICAL REPORT for:

ENVIRONMENTAL & EARTH SCIENCES

PO BOX 380
NORTH SYDNEY 2059

ATTN: COLIN McKAY

JOB NO: SAL9942

CLIENT ORDER: 101045

DATE RECEIVED: 05/04/01

DATE COMPLETED: 12/04/01

TYPE OF SAMPLES: SOILS

NO OF SAMPLES: 14

NATA
National Association of Testing Authorities, Australia
NATA Endorsed Test Report
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....
Issued on 19/04/01
Lance Smith
(Chief Chemist)

ANALYTICAL REPORT

JOB NO: SAL9942
CLIENT ORDER: 101045

	SAMPLES	pH 1:5	COND. uS/cm	*TOS %	*ANC %CaCO3	*NAGP KgH2SO4/T	TAA mol/T
1	BH1/1.6-1.9	4.3	390	0.027	<0.01	+0.8	25
2	BH1/2.8-3.0	6.3	180	0.008	0.04	-0.1	
3	BH2/0.3-0.4	5.0	140	0.012	<0.01	+0.4	
4	BH2/1.6-1.7	5.4	220	0.004	<0.01	+0.1	5
5	BH2/2.8-2.9	5.9	70	0.007	<0.01	+0.2	
6	BH3/0.7-0.9	4.8	50				
7	BH3/1.4-1.6	4.3	60	0.005	<0.01	+0.2	9
8	BH5/0.2-0.4	4.8	130				
9	BH5/0.8-1.0	4.8	75	<0.002	<0.01	0.0	15
10	BH5/1.6-1.8	4.9	75	0.008	<0.01	+0.3	
11	BH5/2.4-2.6	4.9	115	0.031	<0.01	+1.0	
12	BH6/0-0.2	4.6	350	0.052	<0.01	+1.6	15
13	BH6/1.8-2.0	4.3	160	0.075	<0.01	+2.3	15
14	BH6/2.8-3.0	4.4	160	0.057	<0.01	+1.8	
DUPLICATES:							
10	BH5/1.6-1.8	5.0	80	0.010	<0.01	+0.3	
MDL		0.1	0.1	0.002	0.01	0.1	5
Method Code		WA1	WA2	HT1	C15	CALC	C31
Preparation		P5	P5	P12	P12	P12	P12

ANALYTICAL REPORT

JOB NO: SAL9942
CLIENT ORDER: 101045

		EXCHANGEABLE					
	SAMPLES	Na MEQ%	K MEQ%	Ca MEQ%	Mg MEQ%	Mn MEQ%	Al MEQ%
1	BH1/1.6-1.9	0.71	0.36	0.29	4.15	<0.01	2.8
4	BH2/1.6-1.7	0.82	0.09	0.12	3.45	<0.01	0.4
6	BH3/0.7-0.9	0.14	0.12	0.16	2.45	<0.01	1.9
8	BH5/0.2-0.4	0.06	0.10	0.85	1.75	<0.01	2.2
10	BH5/1.6-1.8	0.03	0.03	0.24	0.57	<0.01	1.7
11	BH5/2.4-2.6	0.06	0.05	0.45	1.35	<0.01	1.9
MDL		0.01	0.01	0.01	0.01	0.01	0.1
Method Code		S7	S7	S7	S7	S7	S7
Preparation		P5	P5	P5	P5	P5	P5

ANALYTICAL REPORT

JOB NO: SAL9942
CLIENT ORDER: 101045

		SOLUBLES					
	SAMPLES	Na MEQ%	K MEQ%	Ca MEQ%	Mg MEQ%	Mn MEQ%	Al MEQ%
1	BH1/1.6-1.9	2.55	0.02	<0.01	0.08	<0.01	<0.01
4	BH2/1.6-1.7	1.25	0.03	<0.01	0.02	<0.01	<0.01
6	BH3/0.7-0.9	0.17	<0.01	<0.01	0.03	<0.01	<0.01
8	BH5/0.2-0.4	0.52	0.02	0.04	0.22	<0.01	<0.01
10	BH5/1.6-1.8	0.47	0.15	0.03	0.20	<0.01	<[illegible]1
11	BH5/2.4-2.6	0.51	0.14	0.02	0.25	<0.01	<0.[illegible]1
MDL		0.01	0.01	0.01	0.01	0.01	0.01
Method Code		S7	S7	S7	S7	S7	S7
Preparation		P5	P5	P5	P5	P5	P5

SYDNEY
ANALYTICAL
LABORATORIES

ANALYTICAL REPORT

JOB NO: SAL9942
CLIENT ORDER: 101045

	SAMPLES	CEC MEQ%
1	BH1/1.6-1.9	7.7
4	BH2/1.6-1.7	4.8
6	BH3/0.7-0.9	4.4
8	BH5/0.2-0.4	4.7
10	BH5/1.6-1.8	2.7
11	BH5/2.4-2.6	3.6

MDL	0.1
Method Code	S7
Preparation	P5

RESULTS ON DRY BASIS

LABORATORY DUPLICATE REPORT

JOB NO: SAL9942
CLIENT ORDER: 101045

Sample Number	Analyte	Units	MDL	Sample Result	Duplicate Result	%RPD
BH5/1.6-1.8	pH		0.1	4.9	5.0	2
BH5/1.6-1.8	Conductivity	uS/cm	0.1	75	80	6
BH5/1.6-1.8	*TOS	%	0.002	0.008	0.010	22
BH5/1.6-1.8	*ANC	%CaCO3	0.01	<0.01	<0.01	0
BH5/1.6-1.8	*NAGP	KgH2SO4/T	0.1	+0.3	+0.3	0

Acceptance criteria:

RPD <50% for low level (<20xMDL)
RPD <30% for medium level (20-100xMDL)
RPD <15% for high level (>100xMDL)
No limit applies at <2xMDL

MDL = Method Detection Limit

All results are within the acceptance criteria

ANALYTICAL REPORT

JOB NO: SAL9942
CLIENT ORDER: 101045

METHODS OF PREPARATION AND ANALYSIS

The tests contained in this report have been carried out on the samples as received by the laboratory.

P5	Sample dried, split and crushed to -150um
P12	Sample dried, jaw crushed and sieved at 2mm Visible shell removed prior to crushing
WA1	pH - 1:5 soil/water extract Determined by APHA 4500B
WA2	Conductivity - 1:5 soil/water extract Determined by APHA 2510B
*HT1	Total Oxidisable Sulphur Determined by High Temperature Furnace
*C15	Acid Neutralising Capacity - USEPA 600/2-78-054 SOBECK
*CALC	Nett Acid Generating Potential - P.Mulvey 1993 Determined by Calculation
C31	Total Actual Acidity - RTA T1030
S7	Cation Exchange Capacity & Exchangeable/Soluble Cations Determined by Silver Thiourea Method

*The laboratory's NATA registration does not cover performance of this service

A preliminary report was faxed on 12/04/01

**SYDNEY
ANALYTICAL
LABORATORIES**

Office:
PO BOX 48
ERMINGTON NSW 2115

Laboratory:
1/4 ABBOTT ROAD
SEVEN HILLS NSW 2147
Telephone: (02) 9838 8903
Fax: (02) 9838 8919
A.C.N. 003 614 695
A.B.N. 81 829 182 852

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10 MAY 2001

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0 MAY 2001

BY:..................

ANALYTICAL REPORT for:

ENVIRONMENTAL & EARTH SCIENCES

PO BOX 380
NORTH SYDNEY 2059

ATTN: COLIN McKAY

JOB NO: SA9942B

CLIENT ORDER: 101045

DATE RECEIVED: 05/04/01

DATE COMPLETED: 19/04/01

TYPE OF SAMPLES: WATERS

NO OF SAMPLES: 2

National Association of Testing Authorities, Australia
NATA Endorsed Test Report
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....
Issued on 26/04/01
Lance Smith
(Chief Chemist)

ANALYTICAL REPORT

JOB NO: SA9942B
CLIENT ORDER: 101045

DATE OF COLLECTION			05/04/01		05/04/01
SAMPLES			BH5		BH6
pH			5.6		4.4
Total Dissolved Solids	mg/L		960		1750
		mg/L	meq/L	mg/L	meq/L
Sodium Na+		305	13.268	500	21.750
Calcium Ca++		23	1.148	52	2.595
Potassium K+		17	0.435	16	0.410
Magnesium Mg++		22	1.811	44	3.621
Ammonia NH4-N		<0.1		2.0	0.143
TOTAL CATIONS			16.662		28.519
Chloride Cl-		520	14.664	830	23.406
Fluoride F-		<0.1		<0.1	
Nitrate NO3-		0.13	0.002	<0.1	
Sulphate SO4--		71	1.477	280	5.824
Bicarbonate HCO3-		2	0.033	<1	
Phosphate PO4---		<0.1		<0.1	
TOTAL ANIONS			16.176		29.230

SYDNEY ANALYTICAL LABORATORIES

ANALYTICAL REPORT

JOB NO: SA9942B
CLIENT ORDER: 101045

METHODS OF PREPARATION AND ANALYSIS

The tests contained in this report have been carried out on the samples as received by the laboratory, in accordance with APHA Standard Methods of Water and Wastewater 20th Edition, or other approved methods listed below:

4500B	pH
2540C	Total Dissolved Solids
3500B	Sodium Na+
3111B	Calcium Ca++
3500B	Potassium K+
3111B	Magnesium Mg++
4500D	Chloride Cl-
4500C	Fluoride F-
4500F	Nitrate NO3-
2320B	Bicarbonate HCO3-
4500F	Phosphate PO4---
4500D	Ammonia NH4-N

Sulphate: Dept Mineral Resources - BaCrO4 Method

A preliminary report was faxed on 19/04/01

CHAIN OF CUSTODY - INORGANIC ANALYSIS REQUEST FORM

Sheet 1 of 1

Job No: 101045

Site Location: St Georges Basin

Sampler: CM

Date: 5/4/01

Lab: SAC

Report To: ~~[illegible]~~ Colin McKa

SAMPLE ID	pH	Sample Description			Analysis Required											ANTICIPATED RESULTS/ TURNAROUND TIME
		SOIL	WATER	SEDIMENT	HEAVY METALS	IONIC BALANCE	PHENOLS	CEC AND EXCHANGEABLES	LEACH PROCEDURE	CYANIDE TOTAL/FREE	MAGP	TAA	pH/EC			
BH1(1·6-1·8)		✓						✓			✓	✓	✓			
BH1(2·8-3·0)		✓									✓		✓			
BH2 (0·3-0·4)		✓									✓		✓			
BH2 (1·6-1·7)		✓						✓			✓	✓	✓			
BH2 (2·8-2·9)		✓									✓		✓			
BH3 (0·7-0·9)		✓						✓					✓			
[illegible] (1·4-1·6)		✓									✓	✓	✓			
BH~~4~~5(0·2-0·4)		✓						✓					✓			
BH5(0·8-1·0)		✓									✓	✓	✓			
BH5(1·6-1·8)		✓						✓			✓		✓			
BH5 (2·4-2·6)		✓						✓			✓		✓			
BH6(0-0·2)		✓									✓	✓	✓			
BH6 (1·8-2·0)		✓									✓	✓	✓			
BH6 (2·8-3·0)		✓									✓		✓			
BH5			✓			✓										
BH6			✓			✓										
TOTAL		14	2			2		6			12	6	14			

TURN AROUND: [✓ NORMAL] / 3 DAYS / 48 HRS / 24 HRS

COMMENTS: Could we please have interim results by Thursday 12/

	Time	Date
Left E&ES Site:		5/4/01
Transported By:		Courier
Received Lab:	P. Mego (SAC)	5/4/01
Fax Results Rec'd		
Typed Results Rec'd		

LAB SUPERVISOR:

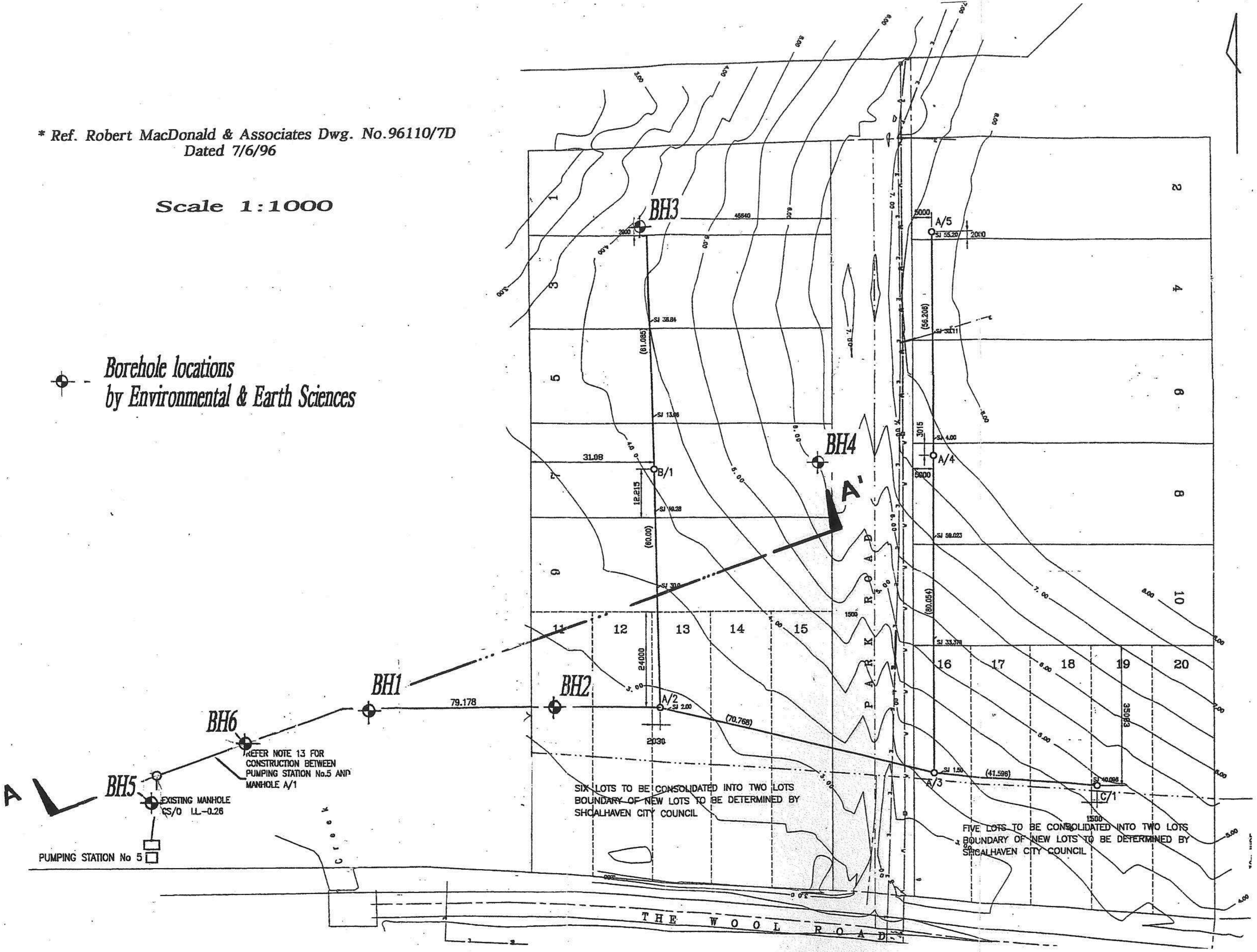
Environmental & Earth Sciences

ph: (02) 9922 1777 fax: (02) 9922 1010

n:\admin\forms\cocinorg.xls

* Ref. Robert MacDonald & Associates Dwg. No.96110/7D
Dated 7/6/96

Scale 1:1000



Job No. 10045 by T.J. 12/4/01

Client:	SHOALHAVEN CITY COUNCIL		
Title:	Borehole Locations	Drawn: TJ	Fig. 2
		Project Manager: CM	
Location:	Nebraska Estate, The Wool Road, St.Georges Basin	Approved: MS	Date: Apr.01

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