GEOTECHNIQUE®
PTY LTD
ABN 64 002 841 063

Job No: 11201/1
Our Ref: 112011-AC
17 May 2021

Beach Property Group
c/- Bonus & Associates
Level 1, 597 Darling Street
ROZELLE NSW 2039
Email: geoff.bonus@bonusarch.com

Attention: Mr G Bonus

Dear Sir

re: **Proposed Mixed-Use Development**
1184-1186 Pittwater Road, corner of Clarke Street, Narrabeen
Geotechnical Investigation and Acid Sulphate Soil Assessment Report

This report details the results of a geotechnical investigation and acid sulphate soil assessment carried out for a proposed mixed use development at 1184-1186 Pittwater Road, Narrabeen, hereafter referred to as the site.

Proposed development is understood to include demolition of the existing residence and construction of two to three storey high buildings with a single basement car park with base at RL3.3m AHD. The basement excavation is anticipated to be up to about 3.6m deep from existing ground surface. Designs of proposed buildings are detailed in the following design drawings prepared by Bonus & Associates Architects.

Job No 0314 Drawing No DA01 Issue O
Job No 0314 Drawing No DA02 Issue R
Job No 0314 Drawing No DA03 Issue S
Job No 0314 Drawing No DA04 Issue L
Job No 0314 Drawing No DA05 Issue K
Job No 0314 Drawing No DA06 Issue N
Job No 0314 Drawing No DA07 Issue S
Job No 0314 Drawing No DA08 Issue O

This report is prepared in support of proposed development detailed in above design drawings and is based on results of geotechnical investigation and acid sulphate soil assessment carried out in 2006 and presented in Report No 11201/1-AA dated 18 September 2006 and Report No 11201/1-AB dated 22 September 2006 respectively. Relevant information in the above reports is reproduced in this report so that it can be read independently. In brief this report provides the following:

- Assessment of subsurface conditions across the site and geotechnical recommendations on design of basement excavation, retaining structures, floors slabs and footings of the building.
- Assessment if soils likely to be disturbed and/or excavated during proposed development works are acid sulphate or potential acid sulphate soils and, if so, recommendation of an “Acid Sulphate Soil Management Plan” to be implemented during proposed development works.

Review of Available Information

Reference to the Geological Map of Sydney (scale 1:100,000) indicates that the site is underlain by Quaternary deposit comprising medium to fine grained marine sand with minor shell and silt, belonging to a beach ridge system.

Geotechnique Pty Ltd has completed a few projects in the local area, which included borehole drilling and insitu testing. Information from these investigations indicated that the marine sands extend to depths exceeding 10m from existing ground surface.

Reference to the Newport Group, which is characterised by gently undulating plains, to rolling rises of Holocene sands, mantling other soil materials or bedrock, with local relief of less than 10m and ground surface slope less than 10% on lower slopes and up to 35% against obstacle facing prevailing winds. The sub-surface soils are usually shallow to moderately deep (0.5-1.5m), non-cohesive and susceptible to high erosion hazard.

Reference to the Acid Sulphate Soil Risk Map (Edition 2, 1:25,000) of Hornsby/Mona Vale prepared by Department of Land and Water Conservation indicates that there is "Low Probability" of occurrence of acid sulphate soil materials within the soil profiles at depths exceeding 3.0m.

Field Work

Field work for the geotechnical investigation was carried out on 6 September 2006 and included the following:

- Carrying out a walk over survey to assess existing site conditions.
- Reviewing services plans obtained from "Dial Before You Dig" to determine locations of services across the site.
- Scanning proposed borehole locations for underground services to ensure that services were not damaged during field work.
- Drilling three boreholes (BH1, BH2 and BH3) using a utility mounted drilling rig fully equipped for geotechnical investigation. Boreholes were uniformly distributed in accessible portions of the site, close to locations suggested by Woolacotts in an email dated 4 September 2006. Boreholes were terminated in sandy soils at depth of about 8.0m to 8.5m from existing ground surface. The approximate borehole locations are indicated on the attached Drawing No 11201/1-AA1. Engineering borehole logs are also attached.
- Conducting Standard Penetration Test (SPT) in the boreholes to assess strength of sub-surface soils. Test results are included in appropriate borehole logs.
- Installing standpipes in boreholes BH1 and BH2 for future groundwater level monitoring.
- Recovering representative soil samples for visual assessment and laboratory tests.
- Measuring depths to groundwater level or seepage in the boreholes, where encountered.

Field work was supervised by an Engineering Geologist from this company who was responsible for the conducting OH&S, nominating the borehole locations, supervision of drilling and SPT, sampling and preparation of field logs.

Site Description

The proposed development site is of trapezoidal shape and bound by Clarke Street, Narrabeen, to the north, a double storey unit block to the south, ocean frontage to the east and Pittwater Road to the west. The site measures about 30.0m along Pittwater Road and 55.0m along Clarke Street.

There is a double storey residence in the western portion of the site and remainder portions of the site are relatively flat and partially grass-covered with scattered mature trees.

Sub-surface profiles encountered in the boreholes are detailed in the attached logs, and summarised below in Table 1.

Table 1 – Sub-surface Profiles encountered in Boreholes

Borehole No	Termination Depth (m)	Depth Range for Topsoil/Fill (m)	Depth to Marine Deposit (m)
BH1	8.0	0.0-0.3	0.3
BH2	8.45	0.0-0.3	0.3
BH3	8.45	0.0-0.2	0.2

Table 1 indicates that the sub-surface profile across the site comprises a sequence of topsoil/fill underlain by marine deposit to depths exceeding 8.5m from existing ground surface. The subsurface materials may in general be described as follows.

Topsoil/Fill Sand, fine grained, brown, with root and root fibres.

Marine Deposit Sand, fine to coarse grained, pale brown, brown, pale yellow, loose to depth of about 3.0m to 3.5m and medium dense to dense at greater depths, with some shell fragments

Groundwater

Depth to groundwater levels encountered in boreholes were measured on drilling date and presented below in Table 2. Standpipes were installed in two boreholes BH1 and BH2 for future groundwater level monitoring and groundwater levels measured in standpipes about a week after their installation are also presented below in Table 2.

Table 2 – Depth to Groundwater Levels in Boreholes/Standpipes

Borehole No	Drilling Date	Depth to Groundwater Level on 6 Sept 2006	Depth to Groundwater Level on 14 Sept 2006
BH1	6 Sept 2006	6.0	5.75
BH2	6 Sept 2006	5.4	6.0
BH3	6 Sept 2006	6.0	No Standpipe

Table 2 indicates that the depth to groundwater level across the site is likely to vary from about 5.4m to 6.0m from existing ground surface under normal climatic conditions. However, it should be noted that the fluctuations in the level of groundwater and/seepage might occur due to variationsin rainfall and/or other factors not evident during field works.

Strength of Subsurface Soils

SPT results are used to assess strength of subsurface soils. Results of SPT and assessed relative densities and estimates of strength parameters in terms of unit weights and friction angle for subsurface soils encountered in boreholes are presented below in Table 3.

Table 3 – Results of SPT and estimates of Strength Parameters

Depth (m)	Blow Count (N) for SPT			Estimates Relative Density	Estimated Unit Weight (kN/m^3)	Estimated Friction Angle (deg)
	Borehole BH1	Borehole BH2	Borehole BH2			
0.5	6	5	4	Very Loose	18.0	32.0
2.0	8	7	9	Loose	18.0	32.0
3.5	9	28*	6	Medium Dense	18.0	32.0
5.0	15	46*	25	Medium Dense	18.0	32.0
6.5	28	37*	25	Dense	19.0	36.0
8.0	32	31	31	Dense	19.0	36.0

Note * BH2 encountered a layer of very dense sand between about 3m and 7m

Although, there are some variations in strength of subsurface soils across the site, based Table 3 and borehole logs, the following assessments may be made.

- The subsurface soils up to depth of about 3.0m to 3.5m is loose sand
- The subsurface soils in depth range of about 3.0m to 6.5m is medium dense sand
- The subsurface soils at depths exceeding 6.5m is dense

Laboratory Testing

Representative soil samples recovered from boreholes were tested in the NATA accredited laboratory of SGS Environmental Services, in accordance with Suspension Peroxide Oxidation Combined Acidity and Sulphate (SPOCAS) method. Test results are attached and summary is presented below in Table 4.

Table 4 – Results of Laboratory Test Results

Borehole No	Depth (m)	%S Oxidisable	pH_{KCl}	pH_{ox}	TPA (pH 6.5)	TAA (pH 6.5)	TSA (pH 6.5)
BH1	0.5-0.95	<0.005*	9.5	9.3	<5.0	<5.0	<5.0
BH2	2.0-2.45	<0.005*	9.8	10.0	<5.0	<5.0	<5.0
BH3	3.5-3.95	0.020	9.9	10.7	<5.0	<5.0	<5.0

Note % S Oxidisable = Oxidisable Sulphur (%)
pH_{KCl} = pH of filtered 1:20, 1M K_{Cl} extract, overnight shake
pH_{ox} = pH of filtered 1:20, 1M K_{Cl} after peroxide digestion TPA
= Total Potential Acidity (mol H^+/tonne)
TAA = Total Actual Acidity (mol H^+/tonne)
TSA = Total Sulphidic Acidity (mol H^+/tonne)
Limit of Reporting for TAA, TPA and TSA is 5 moles H^+/tonne, and for S_{POS} is 0.005% w/w

DISCUSSION AND RECOMMENDATIONS

Excavation Conditions

Three boreholes drilled to depth of 8.0m to 8.5m encountered sandy soils indicating that the materials to be excavated during proposed basement excavation include sandy topsoil/fill and sandy marine deposit. Therefore, it is our assessment that the proposed basement excavation can readily be achieved using conventional earthmoving equipment such as an excavator or dozer.

Table 2 indicates that the depth to groundwater level across the site is likely to vary from about 5.4m to 6.0m from existing ground surface under normal climatic conditions. That means RL of groundwater level varies from RL0.4m to 1.5m AHD. Therefore, it is unlikely that the proposed basement excavation will encounter significant groundwater inflow. Minor groundwater inflow or seepage, if any, would be adequately handled by a conventional sump and pump system.

Trafficability problems might arise locally during wet weather, or if water is allowed to pond on these materials. Under such situation, we recommend foundation preparation at the base of basement excavation by replacing upper 300mm of marine sand with compacted crushed granular material,such as crushed sandstone or recycled concrete, is recommended.

Fill Placement

It is likely that some fill placement may be required as part of site preparation for construction of proposed buildings. We recommend the following procedures for placement of controlled fill, where required.

- Strip topsoil and stockpile separately for possible use in landscaping or dispose off the site.
- Strip existing fill and stockpile separately for possible use in controlled fill or dispose off the site.
- Undertake proof rolling (using an 8 to 10 tonnes roller) of the exposed marine deposit to detect potentially weak spots (ground heave). Excavate areas of localised heaving to a depth of about 300mm and replace with crushed sandstone or recycled concrete, compacted as described below.
- Undertake proof rolling of soft spots backfilled with crushed sandstone or recycled concrete, as described above. If the backfilled area shows further movement during proof rolling, this office should be contacted for further recommendations.
- Place suitable fill materials on proof rolled surface of marine deposit. Controlled fill should preferably comprise non-reactive materials such as crushed sandstone or recycled concrete with a maximum particle size not exceeding 75mm or low plasticity clay. The marine deposit obtained from excavation within the site is assessed to be suitable for use in controlled fill after removal of deleterious materials. The fill should be placed in horizontal layers of 200mm to 250mm maximum loose thickness (depending on the size of equipment) and compacted to a Minimum Dry Density Ratio (MDDR) of 98% Standard, at moisture content within 2% of Optimum Moisture Content (OMC), for cohesive materials (clayey soils) and density index of 70% for cohesionless materials (sandy and gravelly soils).
- Fill placement should be supervised to ensure that material quality, layer thickness, testing frequency and compaction criteria conform to the specifications. We recommend "Level 2" or better supervision, in accordance with AS3798-2007 (Reference 1). It should be noted that a Geotechnical Inspection and Testing Authority will generally provide certification on the quality of compacted fill only if Level 1 supervision and testing is carried out.

Batter Slopes and Earth Pressures
All cut and fill slopes for the proposed development should be battered for stability or retained with engineered retaining structures. We anticipate cut and fill slopes for proposed development will be retained with engineered retaining structure. Therefore, do not anticipate proposed development to include any better slope for long term stability.

However, if battered slopes are required we recommend the following battered slopes n marine deposit and controlled fill.

- For short term stability = 1 vertical to 1.6 horizontal
- For short term stability = 1 vertical to 3.0 horizontal

However, surface of cut and fill slopes should be protected by providing a layer of shotcrete. Alternatively, batter slope may be protected using plastic sheeting, providing an Engineering Geologist/Geotechnical Engineer inspects for stability of batter slopes at regular time interval especially during and after inclement weather conditions.

If the recommended batter slope are not feasible due to space limitations or vertical slopes are required for whatever reason, the batter slopes should be retained with an engineered retaining structures. An appropriate retaining structure for the proposed excavation couldcomprise a grout injected contiguous pile wall, designed as a cantilever wall or anchored wall. The piles should be drilled prior to excavation and taken to below bulk excavation level. Ground anchors might have to be used to reduce the load on the piles. The earth pressure distribution on such walls is assumed to be triangular and estimated as follows:

$$p_h = \gamma kH$$

If the retaining walls are anchored or strutted, the earth pressure distribution on such retaining structures is assumed to be rectangular and estimated as follows:

$$p_h = 0.65\gamma kH$$

Where,

p_h	= Horizontal active pressure (kN/m^2)
γ	= Total density of materials to be retained (kN/m^3)
k	= Coefficient of earth pressure (k_a or k_o)
H	= Retained height (m)

Distribution of passive pressure, if retaining walls are embedded below the base of excavation, may also be assumed triangular and estimated as follows:

$$p_p = \gamma_1 \, k_p \, h$$

Where,

p_p	= Horizontal passive pressure (kN/m^2)
γ_1	= Wet density of materials below base of excavation (kN/m^3)
k_p	= Coefficient of passive earth pressure
h	= Wall embedment depth below base of excavation (m)

For design of flexible retaining structures, where some lateral movement is acceptable, an active earth pressure coefficient (k_a) is recommended. If it is critical to limit the horizontal deformation of a retaining structure, use of an earth pressure coefficient at rest (k_0) should be considered.

Recommended earth pressure coefficients for design of retaining walls are presented below.

- Unit weight of retained soil (γ) =1.8 t/m^3
- Unit weight of soil below base of excavation (γ_1) =1.9 t/m^3
- Coefficient of Active earth pressure (k_a) = 0.32
- Coefficient of At Rest earth pressure (k_o) = 0.47
- Coefficient of Passive earth pressure (k_p) = 3.25

The above coefficients are based on the assumption that ground level behind the retaining structure is horizontal and the retained material is effectively drained. If materials are subjected to groundwater pressure and other surcharge loads (structures and traffic in the vicinity of the site), additional earth pressures resulting from groundwater and surcharge loads should also be allowed for in the design of retaining structures. We do not anticipate the retaining structures to be subjected to groundwater pressure under normal climatic conditions.

The design of retaining structure should also be checked for bearing capacity, overturning, sliding and overall stability of the slope.

Soil Anchor
It is possible that the retaining structures for the basement excavation will require anchorage or tie-back in order to resist lateral pressure. We recommend an allowable bond stress of 25.0kPa for design of anchorage. It should be noted that permission should be sought from adjacent property owners if anchors extend beneath their properties.

Floor Slabs and Footings
We anticipate that the foundation materials at the base of about 3.6m deep basement excavations will be medium dense sandy marine deposits. Therefore, floor slabs for the proposed buildings may be designed as ground bearing slabs or suspended slabs supported by footings. For design of floor slabs bearing on medium dense sandy marine deposit, we recommend a Modulus of Subgrade Reaction Value of 25.0kPa/mm. We do not anticipate the floor slabs to be subjected to uplift groundwater pressure under normal climatic conditions.

Exact loadings from the proposed structures are not known at this stage. However, we consider that appropriate footings would comprise shallow (pad or strip) footings founded on medium dense sandy anticipated at the base of basement excavation. The recommended allowable bearing pressures for design of different types of shallow footings founded at the base of basement excavation and anticipated are presented in Table 5.

Table 5 – Recommended Earth Pressure Parameters

Shallow Footing Type	Recommended Allowable End Bearing Pressure (kPa)	Anticipated Total Settlement (mm)
Rigid Square Pad of 1.0mx1.0m	200.0	5.0-15.0
Rigid Strip footing of 0.5m width	200.0	3.0-10.0

Design of footings should be based on allowable bearing pressures for the foundation materials and acceptable settlements. Table 5 provides estimate of total settlements for specific types and sizes of shallow footings and differential settlements may be considered to be halves of total settlements. The settlement of footing under recommended allowable bearing pressure will vary depending on minimum dimension (width) of footing. Larger footings will result in greater settlements.

Shallow footings may be appropriate in areas where the depth to footing excavation is 1.5m or less. In areas where the founding depth is in excess of 1.5m, excavation of shallow footings would be difficult and therefore, deep footings would be appropriate. Under such situation, grout injected piles founded at depths of about 6.0m from base of basement excavation may be used. A grout injected pile of 500mm diameter founded at depth of 6.0m is estimated to have an overall capacity of about 50 tonnes, with estimated total settlement in the range of 5mm to 10mm.

Acid Sulphate Soil Assessment

The Acid Sulphate Management Advisory Committee, New South Wales (Reference 2), recommends that the assessment of acid sulphate soils and/or potentially acid sulphate soils at a site is carried out in stages, as detailed below in Table 6.

Table 6 – Steps in Assessment of Acid Sulphate and Potential Acid Sulphate Soils

Steps	Recommended Assessment Procedure	Results of Assessment
Step 1	Check the Acid Sulphate Soils Map	Low probability of occurrence below 3m
Step 2	Check if the site area meets the geomorphic or site criteria	Base of proposed excavation at RL3.3m AHD will be below RL5.0m AHD, indicating possible occurrence of acid sulphate soils and/or potentially acid sulphate soils. However, there were no visual indicators of presence of acid sulphate and/or potentially acid sulphate soils
Step 3	Analyse soil indicators (pH)	Negative result
Step 4	Chemical analysis to confirm Acid Sulphate Soil and action level	Refer to laboratory test results presented in Table 4

Geomorphic or site feature in Step 2 in Table 6 indicates possibility that basement excavation to RL 3.3mAHD may encounter acid sulphate and/or potentially acid sulphate soils. Therefore, results of laboratory tests on representative soil samples presented in Table 4 were analysed in accordance with Step 4 in Table 6 to ascertain if proposed basement excavation are likely to encounter acid sulphate and/or potentially acid sulphate soils.

Acid sulphate soils are of problem because they produce significant acid (sulphuric acid) by oxidation when exposed to oxygen, which might occur during excavation or disturbance of soils containing iron sulphides/oxidisable sulphur. Lowering the groundwater level might also encourage oxidation. The New South Wales Acid Sulphate Soils Management Advisory Committee (Reference 2) recommends "Action Criteria" presented below in Table 7 based on results of acid sulphate soils analysis for three broad texture categories.

Works in soils that exceed these "Action Criteria" presented in Table 7 must be carried out in accordance with an approved Acid Sulphate Soils Management Plan.

Table 7 – Action Criteria to ascertain if Excavation and Disturbance of Soil during proposed Development Works should be carried out in accordance with An Acid Sulphate Soils Management Plan

Type of Material		**Action Criteria 1-1000 tonnes of soil is disturbed**		**Action Criteria More than 1000 tonnes of soil is disturbed**	
Texture Range	**Approximate Clay Content <0.002mm** (%)	**Sulphur Trail** % S oxidisable (S_{TOS} or S_{POS})	**Acid Trail** mol H^+/tonne (TPA or TSA)	**Sulphur Trail** % S oxidisable (S_{TOS} or S_{POS})	**Acid Trail** mol H^+/tonne (TPA or TSA)
Coarse Texture Sands to loamy sands	≤5	0.03	18	0.03	18
Medium Texture Sandy loams to light clays	5-40	0.06	36	0.03	18
Fine Texture Medium to heavy clays and silty clays	≥40	0.10	62	0.03	18

The borehole logs indicate that soils likely to be disturbed or excavated during proposed development are sand (medium to coarse texture). It is anticipated that the volume of soils to be disturbed during footing excavations is more than 1000 tonnes.

Therefore, based on laboratory test results presented in Table 4 and both Acid and Sulphur Trails indicated in Action Criteria presented in Table 7, it is our assessments that soils likely to be disturbed or excavated during proposed development do not exceed "Action Criteria". Therefore, it is our assessments that the excavations and disturbance of soils during construction of proposed development can be carried out without an approved "Acid Sulphate Soils Management Plan".

General

The sub-surface profiles presented in this report are based on information obtained from three boreholes drilled at accessible portions of the site. Likewise, strength parameters for the foundation soils are based on Standard Penetration Tests (SPT) conducted in boreholes. Although we believe that the sub-surface profile presented in this report is indicative of the general profile across the site, it is possible that the sub-surface profile including depth to groundwater level could differ from that encountered in the boreholes. Therefore, we recommend that this company is contacted for further advice if soils or groundwater level encountered during the construction stage differ from those presented in this report in order to ascertain that the geotechnical assessments and recommendations provided in this report are appropriate or provide alternate appropriate recommendations. Possibility of groundwater level at level higher than basement level should also be considered in designing retaining structure and floor slab to address likely groundwater condition under extreme and rare weather conditions.

If you have any questions, please do not hesitate to contact the undersigned.

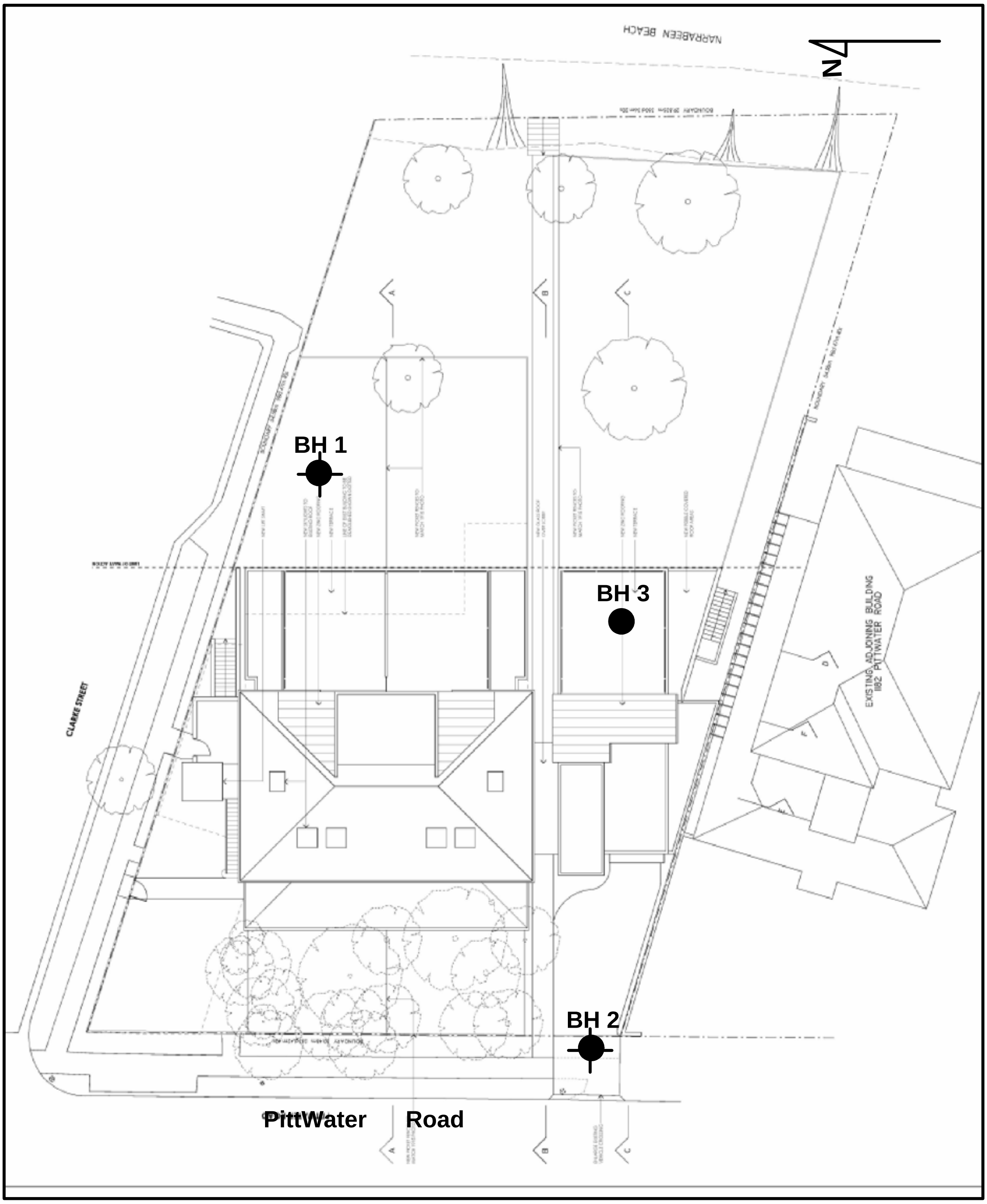
Yours faithfully
GEOTECHNIQUE PTY LTD

INDRA JWORCHAN
Principal Geotechnical Engineer

Attached	Drawing No 11201/1-AA1 Borehole Location Plan
Engineering Borehole Logs
Laboratory Test Results

References

1. Australian Standard AS3798-2007, Guidelines on Earthworks for Commercial and Residential Developments, 2007.
2. New South Wales, Acid sulphate Soil Management Advisory Committee, 1988 – Acid sulphate Soil Manual.



LEGEND

- Boreholes With Groundwater Monitoring Well
- Borehole

PREPARED BY:

GEOTECHNIQUE PTY LTD
CONSULTING ENGINEERS

PO Box 880
Penrith NSW 2750
ABN 64 002 841 063
Tel: 02 4722 2700
Fax: 02 4722 2777
Email:info@geotech.com.au
www.geotech.com.au

Bonus & Associates Architects
Proposed Mixed Development
1184-1186 Pittwater Road,
Narrabeen

Borehole & Monitoring Well Location Plan

Drawing No: 11201/1-1
Job No: 11201/1
Drawn By: ZM
Scale: 1: 350
Date: 08/09/2006
Checked By: ZM

GEOTECHNIQUE PTY LTD

engineering log - borehole

Client : Bonus & Associates Architects
Project : Proposed Mixed Development
Location : 1184-1186 Pittwater Road, Narrabeen

Job No. : 11201/1
Borehole No. : 1
Date : 6 September 2006
Logged/Typed/Checked by: ZM/ac/

drill model and mounting : XP60 **slope :** 90° **deg.** **R.L. surface :** -
hole diameter : 125 **mm** **bearing :** - **deg.** **datum :** -

method	groundwater	samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
TC-Bit				0			FILL: Sand, fine grained, brown, with glass and ceramic fragments	D			Fill appears loosely compacted
		DS	N=6 2,2,4			SP	SAND: Fine to medium grained, pale brown	D	L		
				1		SP	SAND: Fine to medium grained, pale yellow, brown	D	L		
		DS	N=8 2.3,5	2							
				3		SW	SAND: Fine to coarse grained, pale yellow, brown, some shell fragments	M W	MD D		
		DS	N=9 3,4,5	4							
		DS	N=15 3,5,10	5							
	▼			6							More shell fragments from 6.0m Stand pipe installed to 6.2m
		DS	N=28 3,7,21	7							
		DS	N=32 5,8,23	8			Borehole No 1 terminated at 8.0m				
				9							

GEOTECHNIQUE PTY LTD

engineering log - borehole

Client : Bonus & Associates Architects
Project : Proposed Mixed Development
Location : 1184-1186 Pittwater Road, Narrabeen

Job No. : 11201/1
Borehole No. : 2
Date : 6 September 2006
Logged/Typed/Checked by: ZM/ac/

drill model and mounting : XP60 **slope :** 90° **deg.** **R.L. surface :** -
hole diameter : 125 **mm** **bearing :** - **deg.** **datum :** -

method	groundwater	samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
TC-Bit				0			TOPSOIL: Sand, fine grained, brown, roots and root fibres	D			
						SW	SAND: Fine to medium grained, pale yellow, brown	D	L		
		DS	N=5 2,2,3								
				1							
		DS	N=7 2,3,4	2							
				3							
						SW	SAND: Fine to medium grained, pale yellow, with shell fragments	M	MD		
		DS	N=28 9,15,13					W	D		
				4							
		DS	N=46 13,16,30	5							
	▼										
				6							Stand pipe installed to 6.4m
		DS	N=37 9,15,22	7							
				8							
		DS	N=31 10,15,16				Borehole No 2 terminated at 8.45m				
				9							

form no. 002 version 02 - 11/04

GEOTECHNIQUE PTY LTD

engineering log - borehole

Client : Bonus & Associates Architects
Project : Proposed Mixed Development
Location : 1184-1186 Pittwater Road, Narrabeen

Job No. : 11201/1
Borehole No. : 3
Date : 6 September 2006
Logged/Typed/Checked by: ZM/ac/

drill model and mounting : XP60 **slope :** 90° **deg.** **R.L. surface :** -
hole diameter : 125 **mm** **bearing :** - **deg.** **datum :** -

method	groundwater	samples	field test	depth or R.L. in meters	graphic log	classification symbol	MATERIAL DESCRIPTION soil type, plasticity or particle characteristic, colour, secondary and minor components.	moisture condition	consistency density index	hand penetrometer kPa	Remarks and additional observations
TC-Bit				0			TOPSOIL: Sand, fine grained, brown				
						SP	SAND: Fine to medium grained, pale brown	D	L		
		DS	N=4 2,1,3								
						SP	SAND: Fine to medium grained, pale yellow, brown	D	L		
				1							
		DS	N=9 3,4,5	2							
				3		SW	SAND: Fine to coarse grained, pale yellow, brown, with some shell fragments	M	MD		
								W	D		
		DS	N=6 1,2,4	4							
		DS	N=25 5,11,14	5							
	▼			6							
		DS	N=25 4,10,15	7							
		DS	N=31 6,15,16	8							
							Borehole No 3 terminated at 8.45m				
				9							

KEY TO SYMBOLS

Symbol Description

Strata symbols

Fill

Sand

Topsoil

Misc. Symbols

Groundwater encountered during drilling

Notes:

1. Exploratory borings were drilled on 6 September 2006 using a 125mm diameter continuous flight power auger.

2. Boring locations were taped from existing features and elevations extrapolated from the final design schematic plan.

3. These logs are subject to the limitations, conclusions, and recommendations in this report.

4. Results of tests conducted on samples recovered are reported on the logs.

EXPLANATORY NOTES

Introduction
These notes have been provided to simplify the geotechnical report with regard to investigation procedures, classification methods and certain matters relating to the Discussion and Comments section. Not all notes are necessarily relevant to all reports.

Geotechnical reports are based on information gained from finite sub-surface probing, excavation, boring, sampling or other means of investigation, supplemented by experience and knowledge of local geology. For this reason they must be regarded as interpretative rather than factual documents, limited to some extent by the scope of information on which they rely.

Description and Classification Methods
The methods of description and classification of soils and rocks used in this report are based on AS1726 - 1993 "Geotechnical Site Investigations". In general, descriptions cover the following properties; strength or density, colour, structure, soil or rock type, and inclusions. Identification and classification of soil and rock involves, to a large extent, judgement within the acceptable level commonly adopted by current geotechnical practices.

Soil types are described according to the predominating particle size, qualified by the grading or other particles present (e.g. sandy clay) on the following basis:

Soil Classification	Particle Size
Clay	Less than 0.002mm
Silt	0.002 to 0.06mm
Sand	0.06 to 2.00mm
Gravel	2.00mm to 60.00mm

Cohesive soils are classified on the basis of strength, either by laboratory testing or engineering examination. The strength terms are defined as follows:

Classification	Undrained Shear Strength kPa
Very Soft	Less than 12
Soft	12 – 25
Firm	25 – 50
Stiff	50 – 100
Very Stiff	100 – 200
Hard	Greater than 200

Non-cohesive soils are classified on the basis of relative density, generally from the results of standard penetration tests (SPT) or Dutch cone penetrometer tests (CPT), as below:

Relative Density	SPT 'N' Value (blows/300mm)	CPT Cone Value (q_c-MPQ)
Very Loose	Less than 5	Less than 2
Loose	5 – 10	2 – 5
Medium Dense	10 – 30	5 – 15
Dense	30 – 50	15 – 25
Very Dense	>50	>25

Rock types are classified by their geological names, together with descriptive terms on degrees of weathering, strength, defects and other minor components. Where relevant, further information regarding rock classification is given on the following sheet.

Sampling
Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of the soil or rock.

Disturbed samples taken during drilling provide information on plasticity, grain size, colour, type, moisture content, inclusions and depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin walled sample tube (normally known as U_{50}) into the soil and withdrawing a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils. Details of the type and method of sampling are given in the report.

Field Investigation Methods
The following is a brief summary of investigation methods currently carried out by this Company and comments on their use and application.

Hand Auger Drilling
The borehole is advanced by manually operated equipment. The diameter of the borehole ranges from 50mm to 100mm. Penetration depth of hand augered boreholes may be limited by premature refusal on a variety of materials, such as hard clay, gravels or ironstone.

Test Pits
These are excavated with a tractor-mounted backhoe or a tracked excavator, allowing close examination of the insitu soils if it is safe to descend into the pit. The depth of penetration is limited to about 3.0m for a backhoe and up to 6.0m for an excavator. A potential disadvantage is the disturbance caused by the excavation.

Care must be taken if construction is to be carried out near, or within the test pit locations, to either adequately recompact the backfill during construction, or to design the structure to accommodate the poorly compacted backfill.

Large Diameter Auger (e.g. Pengo)
The hole is advanced by a rotating plate or short spiral auger, generally 300mm or larger in diameter. The cuttings are returned to the surface at intervals (generally of not more than 0.5m) and are disturbed, but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers and is usually supplemented by occasional undisturbed tube sampling.

Continuous Spiral Flight Augers
The hole is advanced by using 90mm-115mm diameter continuous spiral flight augers, which are withdrawn at intervals to allow sampling or insitu testing. This is a relatively economical means of drilling in clays and in sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are very disturbed and may be highly mixed with soil of other stratum.

Information from the drilling (as distinct from specific sampling by SPT or undisturbed samples) is of relatively lower reliability due to remoulding, mixing or softening of samples by groundwater, resulting in uncertainties of the original sample depth.

The spiral augers are usually advanced by using a V-bit through the soil profile to refusal, followed by Tungsten Carbide (TC) bit, to penetrate into bedrock. The quality and continuity of the bedrock may be assessed by examination of recovered rock fragments and through observation of the drilling penetration resistance.

Non-core Rotary Drilling (Wash Boring)
The hole is advanced by a rotary bit, with water being pumped down the drill rod and returned up the annulus carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the feel and rate of penetration.

Rotary Mud Stabilised Drilling
This is similar to rotary drilling, but uses drilling mud as a circulating fluid, which may consist of a range of products from bentonite to polymers such as Revert or Biogel. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling (e.g. SPT and U_{50}) samples).

Continuous Core Drilling
A continuous core sample is obtained using a diamond tipped core barrel. Providing full core recovery is achieved (which is not always possible in very low strength rocks and granular soils), this technique provides a very reliable (but relatively expensive) method of investigation. In rocks, an NMLC triple tube core barrel, which gives a core of about 50mm diameter, is usually used with water flush.

Portable Proline Drilling
This is manually operated equipment and is only used in sites which require bedrock core sampling and there is restricted site access to truck mounted drill rigs. The boreholes are usually advanced initially using a tricone roller bit and water circulation to penetrate the upper soil profile. In some instances, a hand auger may be used to penetrate the soil profile. Subsequent drilling into bedrock involves the use of NMLC triple tube equipment, using water as a lubricant.

Standard Penetration Tests
Standard penetration tests are used mainly in non-cohesive soils, but occasionally also in cohesive soils, as a means of determining density or strength and of obtaining a relatively undisturbed sample. The test procedure is described in AS1289 6.3.1.

The test is carried out in a borehole by driving a 50mm diameter split sample tube under the impact of a 63kg hammer with a free fall of 769mm. It is normal for the tube to be driven in three successive 150mm increments and the 'N' value is taken as the number of blows for the last 300mm. In dense sands, very hard clays or weak rock, the full 450mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form:

- In a case where full penetration is obtained with successive blow counts for each 150mm of, say 4, 6 and 7 blows as;

N = 13
4,6,7

- In a case where the test is discontinued short of full penetration, say after 15 blows for the first 150mm and 30 blows for the next 40mm as;

15, 30/40mm

The results of the tests can be related empirically to the engineering properties of the soil. Occasionally the test method is used to obtain samples in 50mm diameter thin walled sample tubes in clays. In these circumstances, the test results are shown on the bore logs in brackets.

Cone Penetrometer Testing and Interpretation
Cone penetrometer testing (sometimes referred to as Dutch Cone-CPT) described in this report, has been carried out using an electrical friction cone penetrometer and the test is described in AS1289 6.5.1.

In the test, a 35mm diameter rod with cone tipped end is pushed continuously into the soil, the reaction being provided by a specially designed truck or rig, which is fitted with a hydraulic ram system. Measurements are made of the end bearing resistance on the cone and the friction resistance on a separate 130mm long sleeve, immediately behind the cone. Transducers in the tip of the assembly are connected by electrical wires passing through the centre of the push rods to an amplifier and recorder unit mounted on the control truck.

As penetration occurs (at a rate of approximately 20mm per second) the information is output on continuous chart recorders. The plotted results given in this report have been traced from the original records. The information provided on the charts comprises:

- Cone resistance - the actual end bearing force divided by the cross sectional area of the cone, expressed in MPa *
- Sleeve friction - the frictional force on the sleeve divided by the surface area, expressed in kPa

The ratios of the sleeve resistance to cone resistance will vary with the type of soil encountered, with higher relative friction in clays than in sands. Friction ratios of 1% to 2% are commonly encountered in sands and very soft clays, rising to 4% to 10% in stiff clays.

In sands, the relationship between cone resistance and SPT value is commonly in the range:

$$q_c \text{ (MPa)} = (0.4 \text{ to } 0.6) \text{ N (blows per 300mm)}$$

In clays, the relationship between undrained shear strength and cone resistance is commonly in the range:

$$q_c = (12 \text{ to } 18) C_u$$

Interpretation of CPT values can also be made to allow estimate of modulus or compressibility values, to allow calculation of foundation settlements. Inferred stratification, as shown on the attached report, is assessed from the cone and friction traces, from experience and information from nearby boreholes etc.

This information is presented for general guidance, but must be regarded as being to some extent interpretive. The test method provides a continuous profile of engineering properties and where precise information or soil classification is required, direct drilling and sampling may be preferable.

Portable Dynamic Cone Penetrometer (DCP)
Portable Dynamic Cone Penetrometer tests are carried out by driving a rod into the ground with a falling weight hammer and measuring the blows per successive 100mm increment of penetration.

There are two similar tests, Cone Penetrometer (commonly known as Scala Penetrometer) AS1289 6.3.2 and the Perth Sand Penetrometer AS1289 6.3.3. Scala Penetrometer is commonly adopted by this company and consists of a 16mm rod with a 20mm diameter cone end, driven with a 9kg hammer, dropping 510mm (AS1289 Test P3.2).

Laboratory Testing
Laboratory testing is carried out in accordance with Australian Standard 1289 "Methods of Testing Soil for Engineering Purposes". Details of the test procedures are given on the individual report forms.

Engineering Logs
The engineering logs presented herein are an engineering and/or geological interpretation of the sub-surface conditions and their reliability will depend to some extent on frequency of sampling and the method of drilling. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, however, this is not always practicable or possible to justify economically. As it is, the boreholes represent only a small sample of the total sub-surface profile. Interpretation of the information and its application to design and construction should take into account the spacing of boreholes, frequency of sampling and the possibility of other than 'straight line' variations between the boreholes.

Groundwater
Where groundwater levels are measured in boreholes, there are several potential problems:

- in low permeability soils groundwater, although present, may enter the hole slowly or perhaps not at all during the investigation period
- a localised perched water table may lead to an erroneous indication of the true water table
- water table levels will vary from time to time due to the seasons or recent weather changes. They may not be the same at the time of construction as indicated in the report
- the use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must be washed out of the hole if water observations are to be made

More reliable measurements can be achieved by installing standpipes that are read at intervals over several days, or weeks for low permeability soils. Piezometers sealed in a particular stratum may be advisable in low permeability soils, or where there may be interference from a perched water table or surface water.

Engineering Reports
Engineering reports are prepared by qualified personnel and are based on the information obtained and on current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, perhaps a three-storey building, the information and interpretation may not be relevant if the design proposal is changed, say to a twenty-storey building. If this occurs, the Company will be pleased to review the report and sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of sub-surface conditions, discussions of geotechnical aspects and recommendations or suggestions for design and construction. However, the Company cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on bore spacing and sampling frequency.

- Changes in policy or interpretation of policy by statutory authorities.

- The actions of contractors responding to commercial pressures.

If these occur, the Company will be pleased to assist with investigation or advice to resolve the matter.

Site Anomalies
In the event that conditions encountered on-site during construction appear to vary from those that were expected from the information contained in the report, the Company requests immediate notification. Most problems are much more easily resolved when conditions are exposed rather than at some later stage, well after the event.

Reproduction of Information for Contractual Purposes
Attention is drawn to the document "Guidelines for the Provision of Geotechnical Information in Tender Documents", published by the Institute of Engineers Australia. Where information obtained from this Investigation is provided for tendering purposes; it is recommended that all information, including the written report and discussion, be made available.

In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. The Company would be pleased to assist in this regard and/or make additional copies of the report available for contract purposes, at a nominal charge.

Site Inspection
The Company will always be pleased to provide engineering inspection services for geotechnical aspects of work to which this report is related. This could range from a site visit to confirm that the conditions exposed are as expected, to full time engineering presence on site.

Review of Design
Where major civil or structural developments are proposed, or where only a limited investigation has been completed, or where the geotechnical conditions are complex, it is prudent to have the design reviewed by a Senior Geotechnical Engineer.

LABORATORY REPORT COVERSHEET

Date: 18 September 2006

To: Geotechnique Pty Ltd
PO Box 880
PENRITH NSW 2751

Attention: Thawng Zo Mung

Your Reference:	11201/1 Narrabeen (Syd. Ref.47646)
Laboratory Report No:	53379
Samples Received:	13/09/2006
Samples / Quantity:	3 Soils

The above samples were received intact and analysed according to your written instructions. Unless otherwise stated, solid samples are reported on a dry weight basis and liquid samples as received.

Lauren Conroy
Administration Manager
CAIRNS

Jon Dicker
Operations Manager
CAIRNS

SGS Australia Pty Ltd ABN 44 000 964 278 | Environmental Services Unit 2, 58 Comport Street, Portsmith 4870 QLD Australia www.au.sgs.com
t +61 (0)7 4035 5111 f +61 (0)7 4035 5122

CLIENT: Geotechnique Pty Ltd **Laboratory Report No:** 53379

PROJECT: 11201/1 Narrabeen (Syd. Ref.47646)

LABORATORY REPORT

SPOCAS Our Reference Your Reference	Units	53379-1 BH1 0.5-0.95	53379-2 BH2 2.0-2.45	53379-3 BH3 3.5-3.95
Moisture *	% w/w	5	16	14
pH $_{KCl}$	pH Units	9.5	9.8	9.9
TAA pH 6.5	moles H^+/tonne	<5	<5	<5
s-TAA pH 6.5	% w/w S	<0.01	<0.01	<0.01
pH $_{Ox}$	pH Units	9.3	10.0	10.7
TPA pH 6.5	moles H^+/tonne	<5	<5	<5
s-TPA pH 6.5	% w/w S	<0.01	<0.01	<0.01
TSA pH 6.5	moles H^+/tonne	<5	<5	<5
s-TSA pH 6.5	% w/w S	<0.01	<0.01	<0.01
ANC_E	% $CaCO_3$	4.9	7.1	11
a-ANC_E	moles H^+/tonne	980	1,400	2,100
s-ANC_E	% w/w S	1.6	2.3	3.4
S $_{KCl}$ *	% w/w	0.036	0.008	<0.005
S $_P$ *	% w/w	0.020	0.012	0.024
S $_{POS}$ *	% w/w	<0.005	<0.005	0.020
a-S $_{POS}$ *	moles H^+/tonne	<5	<5	12
Ca $_{KCl}$ *	% w/w	0.54	0.49	0.62
Ca $_P$ *	% w/w	1.8	2.8	4.2
Ca $_A$ *	% w/w	1.3	2.3	3.6
Mg $_{KCl}$ *	% w/w	0.024	0.028	0.036
Mg $_P$ *	% w/w	0.056	0.056	0.032
Mg $_A$ *	% w/w	0.032	0.028	<0.005
S_{HCl} *	% w/w	NA	NA	NA
S $_{NAS}$ *	% w/w	NA	NA	NA
a-S $_{NAS}$ *	moles H^+/tonne	NA	NA	NA
s-S $_{NAS}$ *	% w/w S	NA	NA	NA
s-Net Acidity	% w/w S	<0.02	<0.02	<0.02
a-Net Acidity	moles H^+/tonne	<10	<10	<10
Liming Rate	kg $CaCO_3$/tonne	NA	NA	NA
Verification s-Net Acidity	% w/w S	NA	NA	NA
a-Net Acidity without ANCE	moles H^+/tonne	<10	<10	12
Liming Rate without ANCE	kg $CaCO_3$/tonne	NA	NA	0.9

CLIENT: Geotechnique Pty Ltd **Laboratory Report No:** 53379
PROJECT: 11201/1 Narrabeen (Syd. Ref.47646)

LABORATORY REPORT

TEST PARAMETERS	UNITS	LOR	METHOD
SPOCAS			
Moisture *	% w/w	1	CEP-003
pH KCl	pH Units	0.1	ASSMAC_23A / CEI-401
TAA pH 6.5	moles H^+/tonne	5	ASSMAC_23F / CEI-401
s-TAA pH 6.5	% w/w S	0.01	ASSMAC_S_23F/CEI-401
pH ox	pH Units	0.1	ASSMAC_23B / CEI-406
TPA pH 6.5	moles H^+/tonne	5	ASSMAC_23G / CEI-406
s-TPA pH 6.5	% w/w S	0.01	ASSMAC_S_23G/CEI-406
TSA pH 6.5	moles H^+/tonne	5	ASSMAC_23H
s-TSA pH 6.5	% w/w S	0.01	ASSMAC_S_23H
ANCE	% $CaCO_3$	0.05	ASSMAC_23Q
a-ANCE	moles H^+/tonne	5	ASSMAC_A_23Q
s-ANCE	% w/w S	0.05	ASSMAC_S_23Q
S KCl *	% w/w	0.005	ASSMAC_23Ce
S P *	% w/w	0.005	ASSMAC_23De
S POS *	% w/w	0.005	ASSMAC_23Ee
a-S POS *	moles H^+/tonne	5	ASSMAC_A_23Ee
Ca KCl *	% w/w	0.005	ASSMAC_23Vh
Ca P *	% w/w	0.005	ASSMAC_23Wh
Ca A *	% w/w	0.005	ASSMAC_23Xh
Mg KCl *	% w/w	0.005	ASSMAC_23Sm
Mg P *	% w/w	0.005	ASSMAC_23Tm
Mg A *	% w/w	0.005	ASSMAC_23Um
SHCl *	% w/w	0.005	ASSMAC_20B
S NAS *	% w/w	0.005	ASSMAC_20J
a-S NAS *	moles H^+/tonne	5	ASSMAC_A_20J
s-S NAS *	% w/w S	0.01	ASSMAC_S_20J
s-Net Acidity	% w/w S	0.02	Calculation
a-Net Acidity	moles H^+/tonne	10	Calculation
Liming Rate	kg $CaCO_3$/tonne	0.1	ASSMAC_23H
Verification s-Net Acidity	% w/w S		Calculation
a-Net Acidity without ANCE	moles H^+/tonne	10	Calculation
Liming Rate without ANCE	kg $CaCO_3$/tonne	0.1	ASSMAC_23H

CLIENT: Geotechnique Pty Ltd **Laboratory Report No:** 53379
PROJECT: 11201/1 Narrabeen (Syd. Ref.47646)

LABORATORY REPORT

NOTES:
LOR - Limit of Reporting.
* This test is not covered by our current NATA accreditation.

Liming rate calculated using a Fineness factor of 1.5 (which is equivalent to finely divided Ag Lime <0.5mm)
and Neutralising Value (NV) of 100%
If using Liming Material <100% NV, then Liming Rate can be adusted as follows:
Actual Liming Rate equals Calculated Liming Rate times 100 divided by NV of actual Liming Material

Bulk Density of Material of 1g/cm3 assumed.
If Bulk Density differs from 1g/cm3 then Liming rate can be adjusted as follows:
Actual Liming Rate equals Calculated Liming Rate times Actual Bulk Density

Analysis Date: **Between** 13/09/06 **and** 18/09/06

SGS Environmental Services
Unit 16, 33 Maddox St. Alexandria NSW 2015
Telephone Number : (+61 2) 8594 0400
Fax Number : (+61 2) 8594 0499

SAMPLE RECEIPT CONFIRMATION

COMPANY	:	Geotechnique	FAX NO.	:	02 4722 6161
ATTENTION	:	Thawng Zo Mung	PAGES	:	1
FROM	:	Sample Receipt	DATE	:	11/09/06

This is to confirm that samples for Project **11201/1, Narrabeen** were received on **11/09/06** the results are expected to be ready on **18/09/06** . Please quote SGS Reference: **47646** when making enquiries regarding this project. Please refer to below which details information about the integrity of the samples and other useful information.

Samples will be held for 1 month for water samples and 2 months for soil samples from date of receipt of samples, unless otherwise instructed.

Samples received in good order:	YES
Samples received in correct containers:	YES
Samples received without headspace:	N/A
Sufficient quantity supplied:	YES
Upon receipt sample temperature:	Cool
Cooling Method:	Ice Pack
Sample containers provided by:	Customer
Samples Clearly Labelled:	YES
Turnaround time requested:	Standard
Completed documentation received:	YES

Comments:

Terms and conditions are available from www.au.sgs.com

The signed chain of custody will be returned to you with the original report.