REPORT ON

GEOTECHNICAL INVESTIGATION

FOR

PROPOSED 'ADDITIONAL FLOW PATH' WORKS AT 'BYRON BAY SEWERAGE TREATMENT PLANT', WALLUM PLACE, BYRON BAY

PREPARED FOR

PLANIT CONSULTING PTY LTD

PROJECT REF: GI 4982-A

12 FEBRUARY 2019

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1. INTRODUCTION

This report details the results of a geotechnical investigation for the proposed new concrete pits as part of the 'additional flow path' works at the 'Byron Bay Sewerage Treatment Plant' (BBSTP). The site is located to the south of Wallam Place, Byron Bay. Geotech Investigations Pty Ltd (GI) was commissioned by Planit Consulting Pty Ltd, the designer, to complete this investigation.

Details of the works are provided on the 'preliminary issue' drawings by Planit Consulting Pty Ltd, referenced Job No: J5908 Rev A dated 9th December 2019. The plans indicate the deevlopemnt will require the installation of 4 new concrete cast in-situ pits. The pits are between 0.81 m^2 and 2.2 m^2 in surface area and are all 1.2 m in depth.

2. OBJECTIVES AND AGREED SCOPE OF SERVICE

The geotechnical investigation was to determine information regarding the subsurface conditions and how this influences the design of the new pits etc. The investigation and report involved:-

- Drilling and sampling of borehole(s) / Dynamic Cone Penetrometer test(s) at three locations,
- Summarise the subsurface conditions, including any groundwater observations at the time;
- Typical constraints that these conditions may have on the project,
- Lateral earth pressure coefficients;
- Site Classification in accordance with AS2870-2011[1] to assist with footing and slab design; and
- Suggested design parameters for shallow footing and slab design.

3. SITE LOCATION AND DESCRIPTION

The proposed pits are located to the north of an existing vehicular track within the BBSTP precinct, refer Figure 1. The proposed building area was considered generally level to slightly undulating, well grassed and positioned adjacent to wetlands, refer Figure 2.

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[1] Australian Standard AS2870-2011 *'Residential footings and slabs - Construction'*, Standards Australia

Figure 1: View of vehicular track

Figure 2: View of grassed area and adjacent wetlands

4. GEOTECHNICAL CONDITIONS

4.1 Geotechnical Model

Reference to the Tweed Heads 1:100,000 Coastal Quaternary Geology Map Series by the Geological Survey of New South Wales indicates the site is underlain by Pleistocene aged beach ridge and associated strandplain comprising *'marine sand, indurated sand and gravel'*.

4.2 Field Work Methodology

Fieldwork was undertaken on the 4th of February 2020, and comprised the drilling and sampling of three boreholes, designated BH 1 to BH 3, using a vehicle mounted drill rig. The boreholes were undertaken at accessible locations employing spiral flight auguring techniques to the termination depths between 2.8 m and 3.8 m. Dynamic cone penetrometer test/s (DCPs) were carried out adjacent to the borehole/s to provide an estimate of the strength consistency or relative density of the subsurface soils. The approximate locations of the boreholes are shown on Site Plan S01 attached in Appendix A.

This investigation has been carried out generally in accordance with AS 1726 – 2017[2] in terms of soil description. The fieldwork was carried out by an experienced geo-technician who positioned and logged the materials encountered in the boreholes and completed the DCP testing. At the completion of drilling, the boreholes were backfilled loosely with drill spoil.

4.3 Field Work Results

The results of the fieldwork are detailed on the Engineering Log attached in Appendix B, along with explanatory notes. Table 1 below provides a summary of these conditions.

Table 1: Summary of Subsurface Conditions *(depth below existing surface level)*

Material Descriptions	BH 1 (m)	BH 2 (m)	BH 3 (m)
Fill "Uncontrolled"			
- Loose SAND	NE	0 to 1.4	NE
- Medium dense SAND	0 to 2.7	NE	0 to 0.3, 1.3 to 2.5
- Sandy GRAVEL	NE	1.4 to 2.2	NE
- Firm to very stiff CLAY	NE	NE	0.3 to 1.3
Alluvial (Natural)			
- Medium dense (or better) SAND	2.7 to 3.8	2.2 to 2.8	2.5 to 2.8
Groundwater	1.3	NM	NM

Note: NE – Not Encountered NM – Not Measured accurately due to hole collapse

Documentation regarding the placement and compaction of this fill material has not been provided for perusal and the fill material must be considered '**uncontrolled'** in accordance with AS 2870 – 2011. This is further confirmed with the DCP testing inferring poor and inconsistent compaction of the fill.

4.4 Groundwater

Groundwater seepage was observed at 1.3 m depth within borehole BH 1 during the investigation. The water table could not be accurately determined in borehole BH 2 and BH 3 due to hole collapse.

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[2] Australian Standard AS 1726-2017 *'Geotechnical site investigations'*, Standards Australia

It should be noted that groundwater is affected by climatic conditions, varying soil permeability, and tidal influences, and will therefore vary over time.

5. INTERPRETATION OF RESULTS

5.1 Possible Constraints of Subsurface Conditions to the Project

Based on the results of the fieldwork, the exposed subgrade at the base of the proposed pit excavations (1.2 mm deep) is likely to comprise medium dense sand fill and medium dense sandy gravel fill. A summary of the key geotechnical constraints outlined within this report are detailed below:-

- The presence of 'uncontrolled' fill to depths of up to 2.5 m and variability in strength and soil type indicate there remains a risk of differential settlements and varying bearing strengths. The presence of the shallow water table also reduces the bearing pressures, refer Section 5.3.
- The groundwater was encountered at 1.3 m depth during the fieldwork at BH 1, and given the surrounding wetlands the groundwater will rise and fluctuate depending on rain events. It is expected that the groundwater could rise to surface level at times of flooding, which needs to be considered in both the detailed design and construction phase of the project. If the concrete pit needs to be designed for hydrostatic pressure the design engineer should assume the water table is at the surface.
- As excavations are likely to extend near the water table depth (at the time of the investigation), and suitable methods of excavation and possible localised dewatering techniques will need to be considered. Excavations in dry sands may be battered back at 1V:2H for short term conditions at a maximum height of 1.5 m. Alternatively, temporary retention options, such as a 'shore box' will need to be employed. Consideration to precast concrete boxes may be given, if he design allows for this.

5.2 Shrink-Swell Movements and Site Classification

The conditions encountered must be classified as **'Class P'** in accordance with the provisions of AS 2870 due to the existing fill ground and inadequate bearing strength (less than 100 kPa) if inundated by flooding. This indicates that engineering principles must be adopted in the design for new footings and slabs.

The results of the fieldwork indicate that the encountered subsurface conditions in the upper 1.5 m (depth of design soil suction change) predominately comprised inert materials (i.e. sands and gravels) with borehole BH 3 encountering clay fill layers. Therefore, GI suggests a reactivity similar to 'Class M' (moderately reactive) in accordance with AS 2870 may be considered, provided settlements can be tolerated. Suggested design information is provided in Section 5.3 below.

This classification is relevant to sites subject to seasonal moisture changes only. Abnormal moisture conditions, such as from the removal or planting of trees (including on adjacent sites), poor site drainage, and development of gardens adjacent to the footings, may cause higher movements to occur, probably resulting in damage, which may or may not be within acceptable ranges.

5.3 Footing Recommendations

Proposed Concrete Pits

The base of the concrete pits may be founded into medium dense (or better) filled sand / sandy gravel, where an allowable bearing pressure of 75 kPa may be adopted. Settlements of approximately 1 to 2 % of footing width may be allowed for, however settlements may be variable as a result of the existing uncontrolled fill.

Where this bearing pressure is considered too low for economical footing design, settlements are not tolerable or the loads are high, then the loads will need to be founded into the underlying competent natural soils. This will require the use of piles, and the most suitable for these conditions will be steel screw piles. The provision of pile design information is beyond the scope of this investigation, and further geotechnical investigations will be required to deeper depths to provide pile design parameters.

General

Footing excavations must be clear of loose, disturbed, or water softened materials, and should be inspected by a geotechnical engineer from GI to confirm the above parameters.

5.4 Lateral Earth Pressure Parameters

Excavations of 1.2 m in depth will be required for the works, and lateral earth pressure coefficients will be required for the design, which are provided in Table 2 below. The values provided in Table 2 are ultimate values, and appropriate safety factor or strength reduction factor should be included.

Table: 2 Earth Pressure Design Parameters (non-sloping crest)

Material Description	Unit weight (kN/m^3)	Internal Angle of Friction (ϕ’)	K_O	K_A	K_P
Existing ‘uncontrolled’ loose to medium dense filled SAND FILL	7$^{(1)}$	31	0.48	0.32	3.12
Existing ‘uncontrolled’ firm to stiff filled CLAY	7$^{(1)}$	24	0.59	0.42	2.37

Notes:
ϕ' – effective friction angle
k_o – coefficient of lateral earth pressure at rest
k_a – coefficient of active lateral earth pressure
k_p – coefficient of passive lateral earth pressure
(1) Unit weights assume inundation by water.

The design of all retaining walls will need to take into account any sloping ground surface behind the walls, as well as the usual design constraints and issues. The lateral earth pressure coefficients provided in Table 2 have not made allowances for surcharge loadings from future structures and these should be taken into consideration when designing the retaining wall system. Any backfill placed behind the wall should be loose granular material.

5.5 General Comments

The above information and calculations are based on existing site soils and assumes moisture conditions within site soils vary due to seasonal effects only. If abnormal moisture conditions occur (due to drying by tree root action, or wetting by leaking pipes, water ponding, etc.), significantly greater movements are considered possible, and the Site Classification should be reconsidered.

It is recommended that good engineering practices be adopted in the design of all structures and foundations and in particular, the following should be considered for movement in sensitive areas underlain with reactive materials:-

- Trees and shrubs should not be planted or be allowed to remain closer than their mature height to movement sensitive structures / features. Where trees exist within this distance, deeper foundations may be required and GI should be notified immediately to provide such recommendations;
- Soil moisture should be controlled to limit moisture content change during or following construction;
- The site should be graded to allow surface water to easily flow into a suitable stormwater system, and prevent ponding, particularly adjacent to the footings; and
- Underground services should be made flexible where possible.

6. LIMITS OF INVESTIGATION

Recommendations given in this report are based on the information supplied regarding the proposed building construction in conjunction with the findings of the investigation. Any change in the construction type or building location may require additional testing and/or make recommendations invalid.

Every reasonable effort has been made to locate the test sites so that the borehole/s are representative of the soil conditions within the area to be investigated. The client should be made aware, however, that this assessment has been based on limited site data using small diameter borehole/s, and that subsurface conditions may vary across the area.

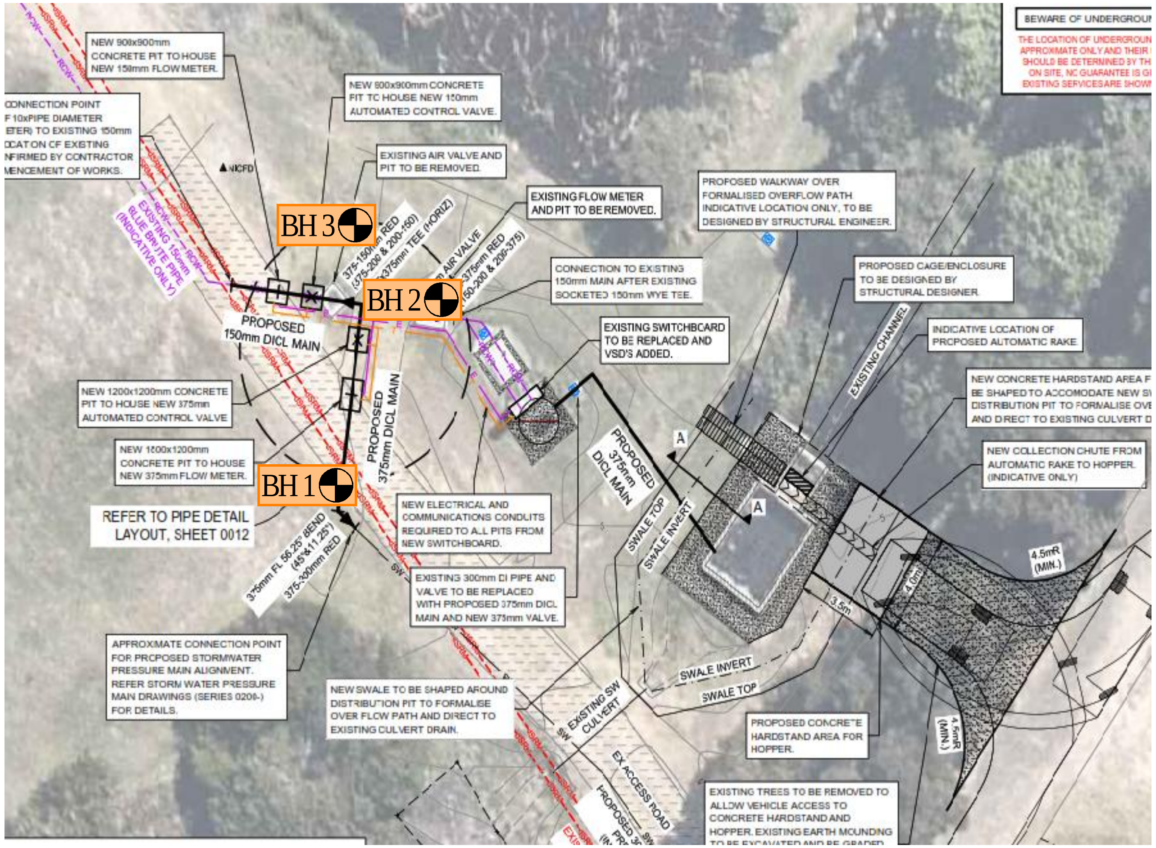
If you should require any further information or clarification, please do not hesitate to contact this office.

Yours faithfully
For and on behalf of
Geotech Investigations Pty Ltd

Andrew O'Carroll *BEng (Civil),*	**James Walle** *RPEQ (15701), RPEng (Civil), BEng (Civil)*
Geotechnical Engineer	Senior Geotechnical Engineer

APPENDIX A

SITE PLAN S01



LOCALITY IMAGE

Locality Image courtesy of
Google Earth & NSW Globe

NORTH

Geotech INVESTIGATIONS PTY LTD

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EMAIL: admin@geotechinvestigations.com
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CLIENT:
PLANIT CONSULTING PTY LTD

PROJECT:
PROPOSED 4 x CONCRETE PITS (1.2m Deep) AT
BBSTP, WALLUM PLACE
BYRON BAY

DRAWING REF:
S01: SITE PLAN

LEGEND:

⊕	Borehole and Dynamic Cone Penetrometer Location

Site Plan provided by PLANIT CONSULTING

APPROXIMATE NORTH

NORTH

DATE:
04.02.2020

OUR REF / JOB No.:
GI 4982-a sp

DRAWN BY:
DC

Drawing not to scale.
Printed dimensions only.

APPENDIX B

ENGINEERING LOG – BOREHOLE PROFILES BH 1 TO BH 3
GEOTECHNICAL REPORT STANDARD NOTES

GEOTECH INVESTIGATIONS PTY LTD

Unit 3/42 Machinery Drive, Tweed Heads South NSW 2486
Ph: 0755 233 979 Fax: 0755 233 981

ENGINEERING LOG – BOREHOLE PROFILE

GPS: **N:** **E:**

CLIENT: PLANIT CONSULTING PTY LTD	**BOREHOLE I.D. :** BH 1
PROJECT: BBSTP, WALLUM PLACE, BYRON BAY	**JOB No.:** GI 4982-a
EQUIPMENT TYPE: GT-10 **HOLE DIAMETER:** 110mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
AD		0.5 1.0	▨	(SM) Silty SAND: Fine sand, Trace of clay, Moist, Pale grey	L / MD		1 2 3 2 2 1 8 4 5 4 4 3	FILL
	▼	1.5 2.0 2.5	▨	(SM) Silty SAND: Fine sand, Trace of fine to medium gravel, Moist to wet, Dark grey	MD		3 3 3 3 3 2 3 20	Possible DCP refusal on cobble?
		3.0 3.5	▨	(SM) Silty SAND: Fine sand, Moist, Dark brown	MD			ALLUVIUM
		4.0 4.5						

BH 1 TERMINATED AT 3.8m – LIMIT OF INVESTIGATION

METHOD	
AD	Auger Drilling
C	Casing
MS	Mud Support
NMLC	Rock Coring
RR	Rock Roller
TC	Tri Cone
WB	Wash Bore

WATER	
▼	Water Level
►	Water Seepage

WEATHERING	
EW	Extremely
HW	Highly
DW	Distinctly
MW	Moderately
SW	Slightly
F	Fresh

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
VL	Very Loose	M	Medium
L	Loose	H	High
MD	Medium Dense	VH	Very High

SAMPLES / TESTS	
U( )	Undisturbed (size in mm)
D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By: DAW	**Date:** 04/02/20	**Checked By:** AOC	**Date:** 12/02/20

GEOTECH INVESTIGATIONS PTY LTD

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ENGINEERING LOG – BOREHOLE PROFILE

GPS:	**N:**		**E:**

CLIENT: PLANIT CONSULTING PTY LTD	**BOREHOLE I.D. :** BH 2
PROJECT: BBSTP, WALLUM PLACE, BYRON BAY	**JOB No.:** GI 4982-a
EQUIPMENT TYPE: GT-10 **HOLE DIAMETER:** 110mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
AD		0.5 1.0	▒	(SM) Silty SAND: Fine sand, Trace of clay, Moist, Pale grey	L		1 1 2 2 2 1 1 1 1 3 4 2 20	FILL
		1.5 2.0	▓	(GP) Silty Sandy GRAVEL: Fine to coarse sand and gravel, Moist, Orange/brown	MD?			
		2.5	░	(SP) SAND: Fine sand, Moist, Pale orange and brown mottling	MD			ALLUVIUM
			▒	(SM) Silty SAND: Fine sand, Trace of clay, Moist, Dark grey and black mottling	MD/ D			
		3.0 3.5 4.0 4.5						

BH 2 TERMINATED AT 2.8m – LIMIT OF INVESTIGATION

METHOD		WEATHERING		CONSISTENCY / DENSITY / ROCK STRENGTH				SAMPLES / TESTS	
AD	Auger Drilling	EW	Extremely	VS	Very Soft	D	Dense	U( )	Undisturbed (size in mm)
C	Casing	HW	Highly	S	Soft	VD	Very Dense	D	Disturbed
MS	Mud Support	DW	Distinctly	F	Firm	Fb	Friable	BS	Bulk Sample
NMLC	Rock Coring	MW	Moderately	St	Stiff	ELw	Extremely Low	DCP	Dynamic Cone Penetrometer
RR	Rock Roller	SW	Slightly	VSt	Very Stiff	VLw	Very Low	SPT	Standard Penetrometer Test
TC	Tri Cone	F	Fresh	Hd	Hard	Lw	Low	N	Number of blows for SPT / 300mm
WB	Wash Bore			VL	Very Loose	M	Medium	VS	Vane Shear
WATER				L	Loose	H	High	A	Acid Sulfate Sample
▼	Water Level			MD	Medium Dense	VH	Very High	PP	Pocket Penetrometer (kPa)
►	Water Seepage								

Logged By: DAW	**Date:** 04/02/20	**Checked By:** AOC	**Date:** 12/02/20

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ENGINEERING LOG – BOREHOLE PROFILE

GPS:	**N:**		**E:**

CLIENT: PLANIT CONSULTING PTY LTD		**BOREHOLE I.D. :** BH 3
PROJECT: BBSTP, WALLUM PLACE, BYRON BAY		**JOB No.:** GI 4982-a
EQUIPMENT TYPE: GT-10	**HOLE DIAMETER:** 110mm	**PAGE:** 1 of 1

Method	Water	Depth (m)	Graphic Log	Material Description	Consistency / Rel. Density	Sample / Test	DCP Blows / 100mm	Structure and additional observation
AD			▓	(SM) Silty SAND: Fine sand, Moist, Grey	MD		1 2 2	FILL
		0.5	▥	(CI) Silty CLAY: Medium plasticity, Fine sand, Trace of fine to medium gravel, Moist (w<wp), Pale grey with red and orange mottling	F / St		4 1 2	
		1.0	▥	(CI) Sandy CLAY: Medium plasticity, Fine to coarse sand, Trace of fine to medium gravel, Moist (w<wp) Dark grey with orange and red mottling	VSt		8 12 12 20	
		1.5 2.0 2.5	▓	(SM) Silty SAND: Fine sand, Moist, Grey	MD			
			▓	(SM) Silty SAND: Fine sand, Moist, Dark grey	MD/ D			ALLUVIUM
		3.0 3.5 4.0 4.5						

BH 3 TERMINATED AT 2.8m – LIMIT OF INVESTIGATION

METHOD	
AD	Auger Drilling
C	Casing
MS	Mud Support
NMLC	Rock Coring
RR	Rock Roller
TC	Tri Cone
WB	Wash Bore

WATER	
▼	Water Level
►	Water Seepage

WEATHERING	
EW	Extremely
HW	Highly
DW	Distinctly
MW	Moderately
SW	Slightly
F	Fresh

CONSISTENCY / DENSITY / ROCK STRENGTH			
VS	Very Soft	D	Dense
S	Soft	VD	Very Dense
F	Firm	Fb	Friable
St	Stiff	ELw	Extremely Low
VSt	Very Stiff	VLw	Very Low
Hd	Hard	Lw	Low
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L	Loose	H	High
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D	Disturbed
BS	Bulk Sample
DCP	Dynamic Cone Penetrometer
SPT	Standard Penetrometer Test
N	Number of blows for SPT / 300mm
VS	Vane Shear
A	Acid Sulfate Sample
PP	Pocket Penetrometer (kPa)

Logged By: DAW	**Date:** 04/02/20	**Checked By:** AOC	**Date:** 12/02/20

SCOPE These standard notes may be of assistance when understanding terms and recommendations given in this report. These notes are for general conditions and not all terms given may be of concern to the report attached. The descriptive terms adopted by Geotech Investigations Pty Ltd are given below and are largely consistent with Australian Standards AS1726-1993 'Geotechnical Site Investigations'.

CLIENT can be described and is limited to the financier of this geotechnical investigation.

LEGALITY and privacy of this document is based on communication between Geotech Investigations Pty Ltd and the client. Unless indicated otherwise the report was prepared specifically for the client involved and for the purposes indicated by the client. Use by any other party for any purpose, or by the client for a different purpose, will result in recommendations becoming invalid and Geotech Investigations Pty Ltd will hold no responsibility for problems which may arise.

GEOTECHNICAL REPORTS are predominantly derived using professional estimates determined from the results of fieldwork, in-situ and laboratory testing and experience from previous investigations in the area, from which geotechnical engineers then formulate an opinion about overall subsurface conditions. The client must be made aware that the investigations are undertaken to ensure minimal site impact using test-pits or small diameter boreholes and soil conditions on-site may vary from those encountered during the investigation.

CLIENTS RESPONSIBILITY to notify this office should there be adjustments in proposed structure/location or inconsistencies with material descriptions given in this report and those encountered on site. Geotech Investigations Pty Ltd is able to provide a range of services from on-site inspections to full project supervision to confirm recommendations given in the report.

CSIRO Publication BTF 18 'Foundation Maintenance and Footing Performance: A Homeowner's Guide' explains how to adequately maintain drainage during and post construction which lies as the responsibility of the client. Suitable drainage ensures recommendations given in this report remain valid.

INVESTIGATION METHODS adopted by Geotech Investigations Pty Ltd are designed to incorporate individual project-specific factors to obtain information on the physical properties of soil and rock around a site to design earthworks and foundations for proposed structures. The following methods of investigation currently adopted by this company are summarised below:-

HAND AUGER – investigations enable field work to be undertaken where access is limited. The materials must have sufficient cohesion to stand unsupported in an unlined borehole and there must be no large cobbles boulders or other obstructions which would prevent rotation of the auger.

TEST-PITS – investigations are carried out with an excavator or backhoe, allowing a visual inspection of sub-surface material in-situ and from samples removed. The limit of investigation is restricted by the reach of the excavator or backhoe.

CONTINUOUS SPIRAL FLIGHT AUGERING TECHNIQUES – investigations are advanced by pushing a 100mm diameter spiral into the sub-surface and withdrawing it at regular intervals to allow sampling or testing as it emerges.

WASH BORING – investigations are advanced by removing the loosened soil from the borehole by a stream of water or drilling mud issuing from the lower end of the wash pipe which is worked up and down or rotated by hand in the borehole. The water or mud carries the soil up the borehole where it overflows at ground level where the soil in suspension is allowed to settle in a pond or tank and the fluid is re-circulated or discharged to waste as required.

NON-CORE ROTARY DRILLING – investigations are advanced using a rotary bit with water being pumped down the drill rods 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 feel and rate of penetration.

ROTARY MUD DRILLING – is carried out as above using mud as support and circulating fluid for the borehole drilling. The mud tends to mask the cuttings and reliable identification is again only possible from separate intact sampling.

CONTINUOUS CORE DRILLING – investigations are carried out in rock material, specimens of rock in the form of cylindrical cores are recovered from the drill holes by the means of core barrel. The core barrel is provided at its lower end with a detachable core bit which carries industrial diamond chips in a matrix of metal. Rotation of the barrel by means of the drill rods causes the core bit to cut an annulus in the rock, the cuttings being washed to the surface by a stream of pumped down the hollow drill rods.

TESTING METHODS adopted by Geotech Investigations Pty Ltd to determine soil properties include but not limited to the following:-

U50 – Undisturbed samples are obtained by inserting a 50mm diameter thin-walled steel tube into the material and withdrawing with a sample of the soil in a moderately undisturbed condition.

PP – Pocket Penetrometer tests are commonly used on thin walled tube samples of cohesive soils to evaluate consistency and approximate unconfined compressive strength of saturated cohesive soils. They may also be used for the same purpose in freshly excavated trenches.

VS – Vane Shear test are commonly used in-situ or on thin walled tube samples of cohesive soils by introducing the vane into the material where the measurement of the undrained shear strength is required. Then the vane is rotated and the torsional force required to cause shearing is calculated.

DCP – Dynamic Cone Penetrometer tests are commonly used in-situ to measure the strength attributes of penetrability and compaction of sub-surface materials.

SPT – Standard Penetration Tests are commonly uses to determine the density of granular deposits but are occasionally used in cohesive material as a means of determining strength and also of obtaining a relatively undisturbed sample. Samples and results are obtained by driving a 50mm diameter split tube through blows from a slide hammer with a weight of 63.5kg falling through a distance of 760mm. Blow counts are recorded for 150mm intervals with the sum of the number of blows required for the second and third 150mm of penetration is termed the "standard penetration resistance" or the "N-value".

GEOLOGICAL ORIGINS of sub-surface material plays a considerable role in the development of engineering parameters and have been summarised as follows:-

FILL – materials are man made deposits, which may be significantly more variable between test locations than naturally occurring soils.

RESIDUAL – soils are present in a region as a result of weathering over the geological time scale.

COLLUVIAL – soils have been deposited recently, on the geological time scale, as soils being transported slowly down slope due to gravitational creep.

ALLUVIAL – soils have been deposited recently, on the geological time scale, as water borne materials.

AEOLIAN – soils have been deposited recently, on the geological time scale, as wind borne materials.

SOIL DESCRIPTION is based on an assessment of disturbed samples, as recovered from boreholes and excavations, and from undisturbed materials. Soil descriptions adopted by Geotech Investigations Pty Ltd are largely consistent with AS 1726-1993 '*Geotechnical Site Investigation'.* Soil types are described according to the predominating particle size, qualified by the grading of other particles present on the following bases detailed in Table 1.

COHESIVE SOILS ability to hold moisture known as its liquid limit is the state of a soil when it goes from a solid state to a liquid state described in Table 2

TABLE 1

Soil Classification	Particle Size
Clay	< 0.002 mm
Silt	0.002 – 0.06 mm
Sand	0.06 – 2.00 mm
Gravel	2.00 – 60.0 mm

TABLE 2

Descriptive Type	Range of Liquid Limit %
Of low plasticity	≤ 35
Of medium plasticity	> 35 ≤ 50
Of high plasticity	> 50

Furthermore to soil description cohesive soils are described on their strength (assessed in conjunction with penetration tests) and liquid limit. Non-cohesive soil strengths are described by their density index. With descriptions for cohesive and non-cohesive soils summarised in Table 3.

TABLE 3

COHESIVE SOILS		NON-COHESIVE SOILS	
Term	**Undrained Shear Strength kPa**	**Term**	**Density Index %**
Very soft	≤ 12	Very Loose	≤15
Soft	> 12 ≤25	Loose	> 15 ≤35
Firm	> 25 ≤50	Medium Dense	> 35 ≤65
Stiff	> 50 ≤100	Dense	> 65 ≤85
Very Stiff	> 100 ≤200	Very Dense	> 85
Hard	> 200		

Description of terms used to describe material portion are summarised in Table 4.

TABLE 4

COARSE GRAINIED SOILS		**FINE GRAINED SOILS**	
% Fines	**Modifier**	**% Coarse**	**Modifier**
≤ 5	Omit or 'trace'	≤ 15	Omit or 'trace'
> 5 ≤12	Describe as 'with'	> 15 ≤30	Describe as 'with'
> 12	Prefix soil as 'silty/clayey'	> 30	Prefix soil as 'sandy/gravelly'

ROCK DESCRIPTIONS are determined from disturbed samples or specimens collected during field investigations. A rocks presence of defects and the effects of weathering are likely to have a great influence on engineering behaviour.

Rock Material Weathering Classification is summarised in Table 5.

TABLE 5

Term	**Symbol**	**Definition**
Residual Soils	-	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported
Extremely Weathered Rock	XW	Rock is weathered to such an extent that it has 'soil' properties, i.e. it either disintegrates or can be remoulded, in water
Distinctly Weathered Rock	DW	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to decomposition of weathering products in pores
Slightly Weathered Rock	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock
Fresh rock	FR	Rock shows no signs of decomposition or staining

Rock Material Strength Classification is summarised in Table 6.

TABLE 6

Term	**Symbol**	**Point load index (MPa) I_s50**	**Field guide to strength**
Extremely Low	EL	≤0.03	Easily remoulded by hand to a material with soil properties
Very Low	VL	>0.03 ≤0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 3cm thick can be broken by finger pressure
Low	L	>0.1 ≤0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling
Medium	M	>0.3 ≤1.0	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty
High	H	>1.0 ≤3.0	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer
Very High	VH	>3.0 ≤10	Hand specimen breaks with pick after more than one blow; rock rings under hammer
Extremely High	EH	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer

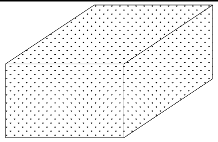
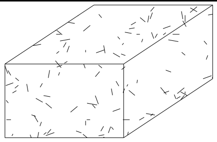
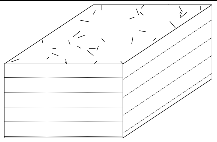
Rock Material Defect Shapes are summarised in Table 7.

TABLE 7

Term	Description
Planar	The defect does not vary in orientation.
Curved	The defect has a gradual change in orientation
Undulating	The defect has a wavy surface
Stepped	The defect has one or more well defined steps.
Irregular	The defect has many sharp changes of orientation
Smooth	The defect has a flat even finish
Rough	The defect has a irregular disoriented finish

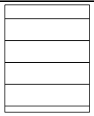
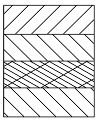
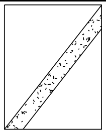
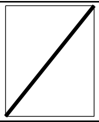
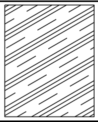
Rock Material Texture and Fabric are summarised in Table 8.

TABLE 8

Geological Description	Massive		Layered (Bedded foliate cleaved)
Diagram			
Fabric Type	Effectively homogenous and isotropic. Bulky or equi-dimensional grains uniformly distributed	Effectively homogeneous and isotropic. Elongated	Effective homogeneous with planar anisotropy. Elongated or tabular grains or pores in a layered arrangement

Rock Material Defect Type is summarised in Table 9

TABLE 9

Term	Definition	Diagram
Bedding	Signifying existence of beds or laminate. Planes dividing sedimentary rocks of the same or different lithology. Structure occurring in granite and similar rocks evident in a tendency to split more or less horizontally to the land surface	
Cross Bedding	Also called cross-lamination or false bedding. The structure commonly present in granular sedimentary rocks, which consists of tabular, irregularly lenticular or wedge-shaped bodies lying essentially parallel to the general stratification and which them selves show pronounced lamination structure in which the laminae are steeply inclined to the general bedding.	
Crushed Seam	A fracture at a more or less acute angle to applied force generally with some pulverized material along its surface	
Joint	A fracture in rock, generally more or less vertical or transverse to bedding, along which no appreciable movement has occurred.	
Parting	A small joint in rock or a layered rock where the tendency of crystals to separate along certain planes that are not true cleavage planes.	
Sheared Zone	A fracture that results from stresses which tend to shear one part of a specimen past the adjacent part