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GEOTECHNICAL INVESTIGATION REPORT:
161 SUSSEX STREET REDEVELOPMENT, SYDNEY, NSW
PREPARED FOR GL INVESTMENT CO PTY LTD ATF GL NO1 TRUST
c/o CADENCE AUSTRALIA PTY LTD
CES DOCUMENT REFERENCE: CES111206-CA-AD
Revision 2

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Date: 29 May 2012

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Document Control

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Revision Number	Revision Date	Description
1	18/05/2012	Final Report
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1 INTRODUCTION

Consulting Earth Scientists Pty Ltd (CES) has been commissioned by Cadence Australia Pty Ltd (Cadence) on behalf of GL Investment Co Pty Ltd ATF GL No1 Trust (the Client), to undertake a geotechnical investigation for the 161 Sussex Street Redevelopment, Sydney, NSW (herein referred to as the Site). This geotechnical report was undertaken in general accordance with our proposal dated 15 December 2011 (CES document referenced: CES111206-CA-AA). The site location is shown on Figure 1.

It is understood by CES that the proposed hotel expansion involves the construction of a 25 storey tower over Slip Street in the south of the site.

The purpose of this investigation is to obtain geotechnical information regarding subsurface ground and groundwater conditions. This includes provision of recommendations regarding suitable footing systems and estimated bearing pressures, detail of groundwater instrumentation installed, and preliminary assessment of groundwater. Geotechnical constraints identified during the investigation are also discussed. The geotechnical investigation was completed concurrently with an Environmental Site Assessment (ESA) (Refer to CES document reference CES111206-CA-AE). The ESA is a requirement of the Director General's Requirements ((DGRs) Planning and Infrastructure reference 11/18985 dated 24 November 2011), Key Issue 1 - *Contamination.*

2 THE SITE

2.1 GENERAL LOCATION

The site is located at 161 Sussex Street, Sydney NSW which is approximately 50m east of the Sydney Aquarium, 500m north west of the Sydney CBD and 500m south west of Wynyard Railway Station. The site location is shown in Figure 1.

The site is generally rectangular in shape, aligned north to south, and is relatively flat throughout with a slight downward slope from the north to the south. It is bordered by the Western Distributor and Wheat Road to the west, and Sussex Street along the eastern boundary. The northern and southern site boundaries are defined by King Street and Market Street, respectively. Slip Street runs from the north to the south through the site, underneath the existing hotel. The Dundee Arms and Corn Exchange are also located along the site eastern boundary.

2.2 SITE DESCRIPTION

The following description of the site is based upon observations made during fieldwork that was completed between 26 April and 2 May 2012. At the time of the investigation, the site was occupied by the existing hotel buildings, which occupy more than approximately half of the area of the site. The remainder of the site is currently occupied by the Western Distributor and Slip Street and consist of asphalt and concrete pavements. Soft landscaped areas were also observed within Slip Street and include trees up to approximately 20m in height. Significant infrastructure owned and maintained by Ausgrid and Telstra was also located underneath Slip Street.

2.3 REGIONAL GEOLOGY

Review of the Sydney 1:100 000 Geological Series Sheet 9130 (Department of Mineral Resources, 1983) indicates that the site is underlain by the Hawkesbury Sandstone Formation of the Wianamatta Group. The Hawkesbury Sandstone Formation comprises medium to coarse grained quartz sandstone, with minor shale and laminite lenses.

3 METHOD OF INVESTIGATION

3.1 FIELDWORK

Fieldwork was carried between 26 April and 2 May 2012 and comprised the drilling of four boreholes (FP_BH1, FP_BH3, FP_BH4 and FP_BH5). A CES Engineering Geologist was present during fieldwork to locate and log boreholes.

The boreholes were drilled using a truck mounted E50 drilling rig. Boreholes were advanced through soils using solid flight augers fitted with a steel 'V' shaped bit. Standard Penetration Tests (SPTs) were carried out to assess soil strength. Upon refusal of the 'V' shaped bit, a tungsten-carbide 'TC' bit was fitted to the solid flight augers and used to advance the borehole until refusal in rock.

Rotary coring techniques were implemented to advance boreholes in rock. Recovered rock core was boxed onsite, photographed and taken to a core storage facility. Groundwater levels and inflows observed during fieldwork were also recorded. Groundwater monitoring wells were installed in boreholes FP_BH1, FP_BH4 and FP_BH5. These were installed as part of the environmental investigation and to facilitate assessment of fluctuations in groundwater levels. Where monitoring instrumentation was not installed, the boreholes were backfilled with soil cuttings and sand and capped with concrete.

Borehole locations were located by measuring their distance from salient features and the positions plotted on a site survey plan and grid coordinates and ground levels interpolated. Borehole depths and positions are summarised in Table 1 and shown in Figure 2. Borehole logs are enclosed in Appendix A.

Table 1: Borehole Locations and Depths

Borehole	Easting	Northing	Termination depth	
			(mbgl)	(mAHD)
FP_BH1	333824	6250726	15.0	-11.9
FP_BH3	333810	6250752	15.2	-12.4
FP_BH4	333765	6250854	14.0	-12.1
FP_BH5	333776	6250723	15.0	-11.5

3.2 GEOTECHNICAL MAPPING

Borehole FP_BH2 could not be carried out at the initial proposed location or at a feasibly close location due to the presence of below ground Ausgrid infrastructure. To provide geotechnical information in the absence of FP_BH2, field mapping of rock exposures along Slip Street was undertaken.

A CES Engineering Geologist conducted the geotechnical mapping of the exposed rock face at Slip Street. The following observations were made:

- The rock face is orientated north-north-west to south-south-east and is approximately 2.2m to 2.9m in height. The rock face is near vertical.
- The rock face was observed to consist of fine to medium grained, pale grey with some orange iron staining, Sandstone. The Sandstone was predominantly moderately weathered with some areas of slightly weathered material.
- The Sandstone was assessed to be of medium to high strength and distinctly bedded. The bedding was assessed to be widely spaced (between 600mm to 2000mm), dipping between horizontal to 15^{o}. Bedding partings were observed to be near planar, rough, clean and tight.
- Groundwater was not observed to be seeping from any part of the rock face.

The information obtained from the mapping exercise has been considered together with the observations made in the geotechnical boreholes to prepare the geotechnical model summarised in Table 2.

3.3 GEOTECHNICAL LABORATORY TESTING

Soil and rock samples obtained during the fieldwork were tested by Envirolab Services Pty Ltd (Envirolab) and SGS Australia Pty Ltd (SGS), respectively, which are NATA accredited testing laboratories. Laboratory testing for soil aggressivity towards buried structures (pH, chloride and sulphate levels), point load strength index, and uniaxial compressive strength were undertaken. The laboratory test results are presented in Appendix B and summarised in Tables 4 and 5.

4 RESULTS OF THE INVESTIGATION

4.1 SUBSURFACE CONDITIONS

A geotechnical model for the site has been prepared and is presented in Table 2. For a detailed description of the subsurface conditions encountered at each borehole, refer to the borehole logs in Appendix A, together with the explanatory sheets describing the terms and symbols used.

Table 2: Summary of Subsurface Conditions and Inferred Geotechnical Model

Geotechnical Unit	Depth to Base of Unit		Thickness (m)	Description
	(mbgl)	(mAHD)		
Pavement	0.05 to 0.6	1.85 to 3.1	0.05 to 0.6	ASPHALT CONCRETE, BRICK and REGULAR CONCRETE
1. Fill	1.7 to 4.2	0.7 to -2.3	1.5 to 4.15	FILL: gravelly sandy clay, sandy clay, clayey sand, sand • Low plasticity • Loose density • Firm to stiff consistency • Brown to pale brown/pale grey • Sand is fine to coarse grained • Gravel is fine to coarse comprising fragments of sandstone, ironstone, brick, glass, plastic, blue metal, and concrete.
2. Marine Deposits (Observed in FP_BH4 and FP_BH5 only)	5.5 to 9.8	-2.9 to -7.9	2.6 to 5.6	SAND, silty SAND, sandy CLAY • Low plasticity • Very loose to medium density • Soft to firm consistency • Dark grey to pale grey/brown • Sand is fine to coarse grained • With some shell fragments.
3. Weathered Sandstone	6.75 to 13.8	-3.65 to -10.5	2.6 to 8.3	SANDSTONE • Fine to medium grained. • Pale grey with orange/red mottle. • Partings are closely to widely spaced and dip near horizontal to 30^o. • Joints are widely spaced and dip between 60^o to 70^o. • Seams are widely spaced, near horizontal, with firm to stiff clay infill • Very low to medium strength. • Extremely to moderately weathered.

Geotechnical Unit	Depth to Base of Unit		Thickness (m)	Description
	(mbgl)	(mAHD)		
				• Heavily iron stained.
4. Sandstone - Slightly Weathered to Fresh Sandstone	Base not penetrated (Boreholes terminated at depths between 14.0 and 15.2)	Base not penetrated (Boreholes terminated at elevations between -11.5 to -12.4)	Not Applicable (Base not penetrated)	SANDSTONE • Fine to medium grained. • Pale grey. • Partings are closely to widely spaced and dip near horizontal to 30°. • Joints are widely spaced and dip between 60° to 70°. • Seams are widely spaced, near horizontal, with firm to stiff clay infill • Medium to high strength • Partially iron stained.

4.2 GROUNDWATER

Standing groundwater levels were measured using a dip meter in the open boreholes. The results of this monitoring are shown in Table 3.

Table 3: Summary of Groundwater Levels

Location	Observation Details			Groundwater Level	
	Date	Time	Period after Drilling	(mbgl)	(mAHD)
FP_BH1	27/04/2012	7:00	15 hours	3.65	-0.55
	03/05/2012	9:00	6 days 17 hours	3.05	0.05
	07/05/2012	13:00	10 days 21 hours	2.85	0.25
FP_BH4	03/05/2012	11:00	19 hours	2.40	-0.50
	07/05/2012	15:00	4 days 23 hours	2.60	-0.70
FP_BH5	07/05/2012	17:00	9 days 22 hours	2.65	0.85

It should be noted that groundwater levels can vary with time, especially after periods of heavy rain or due to tidal influences.

4.3 LABORATORY TEST RESULTS FOR SOIL

Laboratory test results for soils are shown in Table 4 with the complete test results enclosed in Appendix B.

Table 4: Summary of Laboratory Test Results of Soils

Geotechnical Unit	pH	Chloride (mg/kg)	Sulphate (mg/kg)
Unit 2 (Marine Deposits)	8.2 and 8.4	520 and 810	76 and 110

4.4 LABORATORY TEST RESULTS FOR ROCK

A total of 14 Point Load Index Tests (I_{s50}) were carried out on recovered core samples and four Uniaxial Compressive Strength Tests. The results of these tests are summarised in Table 5 and included in full in Appendix B.

Table 5: Summary of Laboratory Test Results of Rock

Geotechnical Unit	Point Load Strength Index $Is_{(50)}$ (MPa)		Uniaxial Compressive Strength (MPa)
	Diametral	Axial	
Unit 3 (Weathered Sandstone)	0.4 to 1.86	0.9 to 2.0	25.3 to 29.3
Unit 4 (Sandstone)	0.69 to 2.76	0.76 to 2.11	27.7

5 DISCUSSION AND RECOMMENDATIONS

5.1 FOUNDATIONS

It is understood by CES that the proposed hotel expansion involves the construction of a 25 storey tower over Slip Street. For such a development CES consider the most appropriate foundation system to be deep footings as detailed below.

5.1.1 Deep Footings

Bored piles or continuous flight auger piles into Unit 3 (Weathered Sandstone) or Unit 4 (Sandstone) could be adopted. CES would expect that with appropriate capacity piling rigs fitted with suitable rock auger attachments or a reverse circulation drilling rig, piles should be able to penetrate into Unit 3 (Weathered Sandstone) and Unit 4 (Sandstone). An experienced geotechnical practitioner should observe boring of the piles in order to assess the rock levels and to confirm that the rock is suitable for the adopted design parameters.

Table 6: Foundation Design Parameters

Geotechnical Unit	Allowable Bearing Pressures (MPa)	Allowable Shaft Adhesion for Piles (kPa)
Unit 3 (Weathered Sandstone)	3.5	250
Unit 4 (Sandstone)	12	1500

To adopt the end bearing pressures in the above table, piles should have a minimum embedment of at least 3 pile diameters into the relevant bearing stratum before shaft adhesion is adopted. A rough socket with grooves of depth at least 1mm to 4mm and width greater than 5mm spacing of

50mm to 200mm should be provided. The socket should be cleaned and roughened by a suitable scraper such as a tooth, orientated perpendicular to the auger shaft.

For uplift capacity, the shaft adhesion value should be multiplied by 0.6. In addition to shaft adhesion, the uplift capacity should be checked for a cone pullout failure mode assuming a cone angle of 70° considering the submerged weight of the soil or rock and adopting a factor of safety of 1.0 against pullout.

It is envisaged that bored piles will require temporary liners through Unit 1 (Fill) and Unit 2 (Marine Deposits) due to the observed shallow groundwater levels. The use of temporary casing will reduce the risk of sidewall instability due to groundwater inflow. Piles should be cleaned, dewatered and concreted without delay to prevent softening of the pile base.

Piling contractors should undertake their own assessment of rock core to assess suitability of piling plant.

5.2 PRELIMINARY GROUNDWATER ASSESSMENT

The results of the groundwater observations carried out in the boreholes during the fieldwork indicate that groundwater is likely to be encountered at shallow depths, -0.70mAHD to 0.85mAHD. It should be noted that groundwater levels vary over time especially after periods of heavy rain and due to tidal influences.

A more detailed assessment of groundwater levels and fluctuations will be provided following completion of a period of groundwater monitoring. The results of this groundwater monitoring will be provided in a supplementary groundwater monitoring report.

5.3 SOIL AGGRESSIVITY

The results of the soil aggressivity testing indicate that Unit 2 (Marine Deposits) may be considered non-aggressive to concrete and steel as determined with reference to Australian Standard AS2159-2009.

5.4 GEOTECHNICAL CONSTRAINTS

Based on the results of the geotechnical investigation, the following geotechnical constraints are assessed:

- Groundwater was observed at relatively shallow depths. It is therefore recommended that temporary casing is used in bored piles to provide support to the pile bore walls.

6 SUMMARY

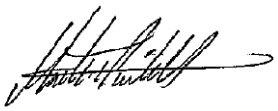
The following is a brief summary of the findings of the geotechnical investigation. This is a summary only and this report and the corresponding ESA should be read in full.

- The site typically comprises a pavement surfacing underlain by uncontrolled Fill, overlying Marine Deposits that in turn are underlain by Weathered Sandstone and Sandstone bedrock.
    - Fill was encountered to depths of between 1.7m and 4.2m and comprised:
        - Firm to stiff, low plasticity, gravelly, sandy clay. The gravel is fine to coarse comprising fragments of sandstone, ironstone, brick, glass, plastic, blue metal, and concrete.
        - Firm to stiff, low plasticity, sandy clay.
        - Loose, fine to coarse, sand
        - Loose, fine to coarse clayey sand.
    - Marine Deposits were encountered to depths between 5.5m and 9.8m and comprised:
        - Very loose to medium dense, fine to coarse sand.
        - Very loose to medium dense, fine to coarse silty sand.
        - Soft to firm, low plasticity, sandy clay.
        - Shell fragments were observed in the Marine Deposits.
    - Weathered Sandstone was encountered at depths of between 6.75m and 13.8m and comprised:
        - Very low to medium strength, pale grey with orange/red mottle, extremely to moderately weathered, fine to medium grained Sandstone that is heavily iron stained with partings and seams of firm to stiff clay.
    - Sandstone bedrock (base of unit not penetrated in the boreholes) that comprised:
        - Medium to high strength, pale grey, slightly weathered to fresh, fine to medium grained Sandstone with closely to widely spaced partings, widely spaced joints and widely spaced seams with firm to stiff clay.
- Deep bored piles or continuous flight auger piles into appropriate quality Sandstone could be adopted.
- Groundwater was observed at relatively shallow depths. Temporary casing should therefore be used in bored piles to provide support to the pile bore walls.
- A program of groundwater monitoring is being undertaken and a supplementary report will be provided to further assess groundwater conditions at the site as per the DGR.

7 CLOSURE

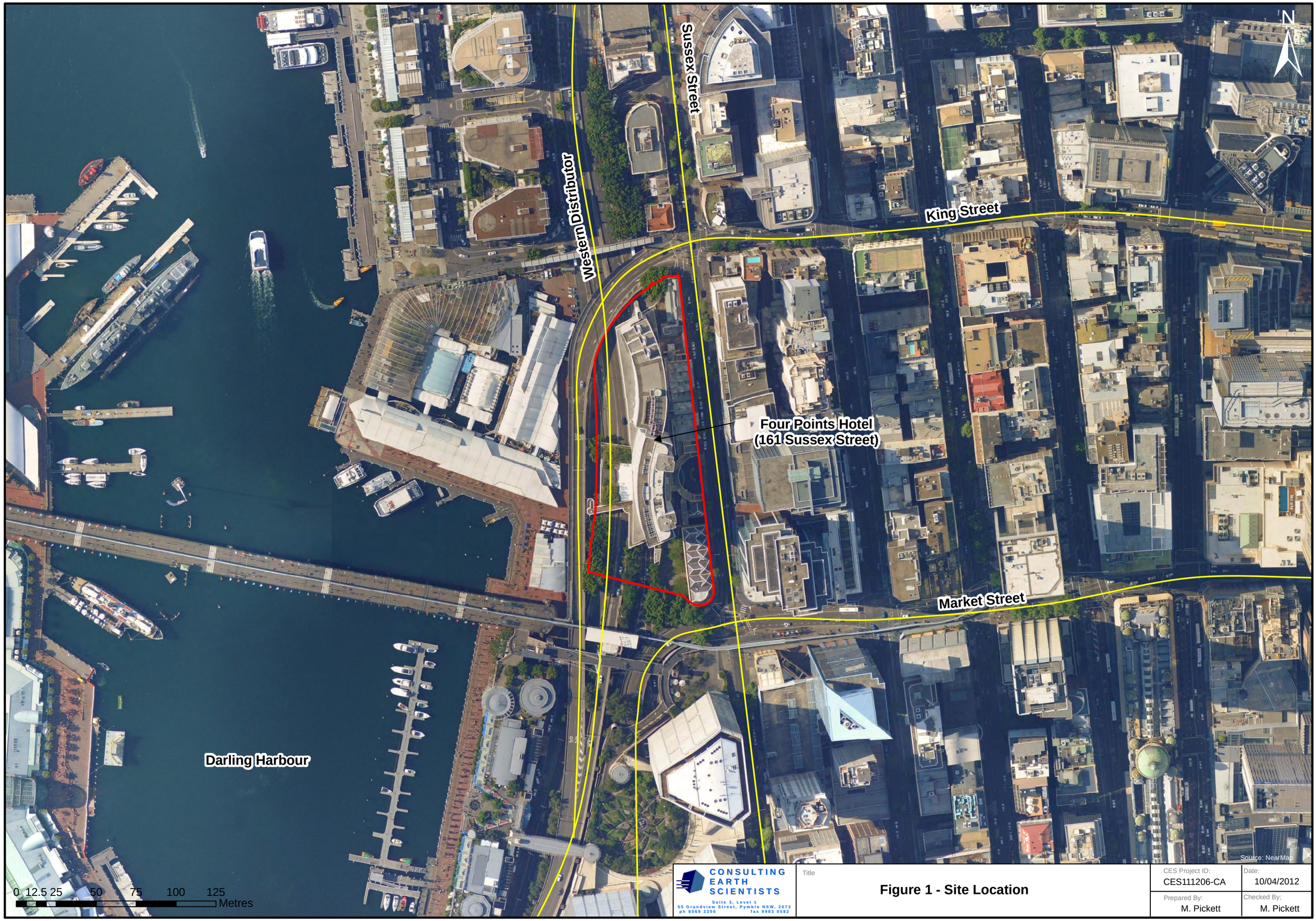
If you have any queries regarding the above or require any clarification, please do not hesitate to contact the undersigned on 8569 2200.

For and on behalf of Consulting Earth Scientists Pty Ltd



Mark Pickett
Engineering Geologist

FIGURES



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Title

Figure 1 - Site Location

CES Project ID:	Date:
CES111206-CA	10/04/2012
Prepared By: M. Pickett	Checked By; M. Pickett

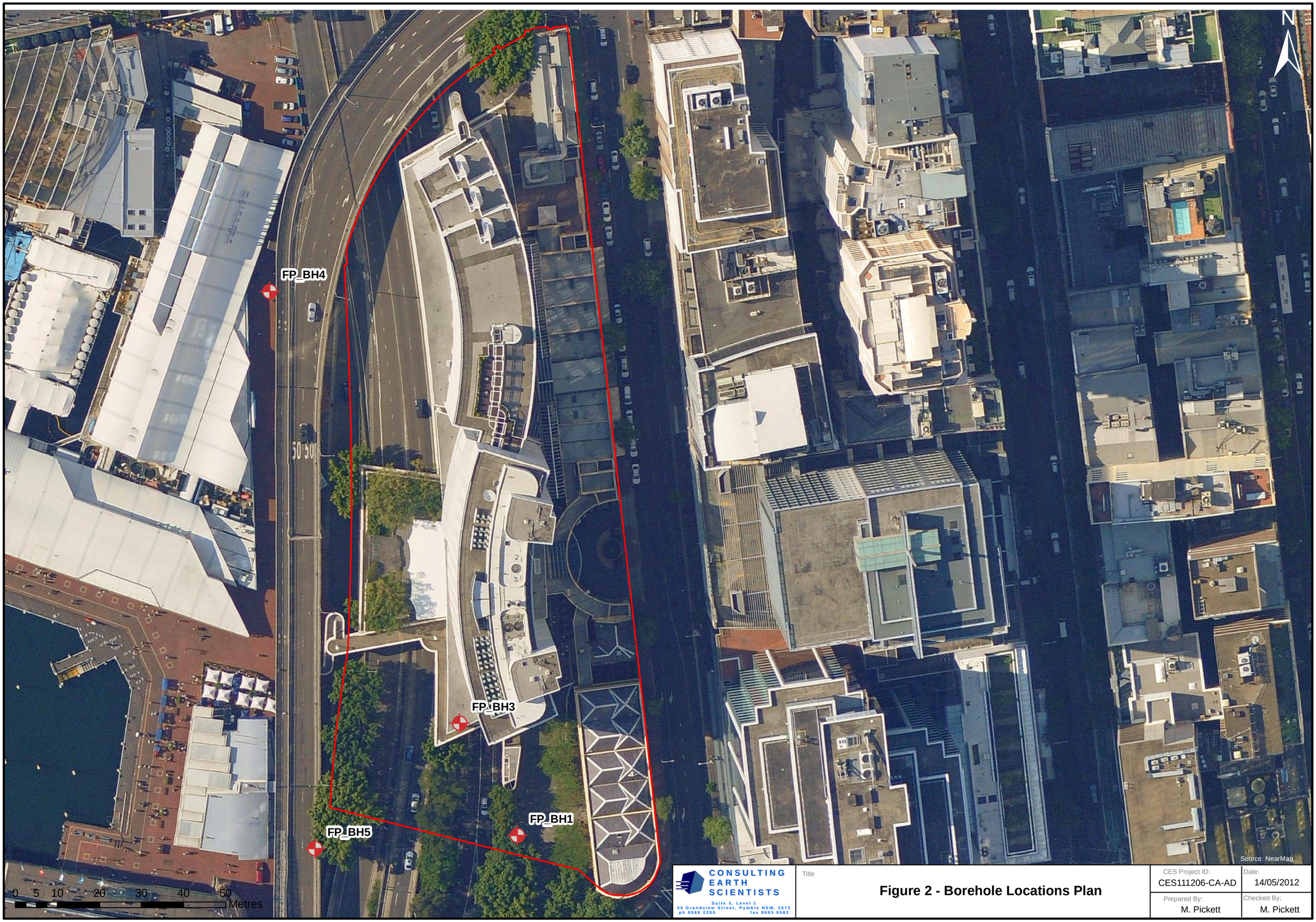

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Figure 2 - Borehole Locations Plan

CES Project ID:	Date:
CES111206-CA-AD	14/05/2012
Prepared By: M. Pickett	Checked By; M. Pickett

APPENDIX A

Borehole Logs, Core Photos and Explanatory Notes

Borelog Symbols and Notes

Suite 3, Level 1• 55 Grandview Street• Pyrmont NSW 2073
Telephone: 02 88569 2200 • Fax: 02 9983 0582 •

DRILLING INFORMATION:

Support		Method				Water	
None	No support provided	HA	HAND AUGER	BB	BLADE BIT		Inflow of water
Mud	Drilling mud used	RA	ROTARY AIR				Water Loss
NQ	NQ size drilling pipe (69.9 mm ODia)	ADV	Auger 'V'-STEEL BIT				Water Level during drilling / excavation
HQ	HQ size drilling pipe (88.9 mm ODia)	ADTC	Auger 'TUNGSTEN-CARBIDE' BIT				Stabilised Water Level
PQ	PQ size drilling pipe (139.9mm ODia)	NMLC	DIAMOND CORING				

SAMPLING:

Sample ID

ddmmyy-01-SM Date-Sample Number-Initials of Sampler

Note : Sample Depth is indicated by horizontal lines which define the start and end depths

Type		
	D	Small Disturbed Sample
	U50	Undisturbed 50mm dia. tube sample
	B	Bulk Disturbed Sample
	PT	Geoprobe Push Tube Sample in
	J	Environmental Sample collected in a laboratory supplied glass jar
	SPT	SPT Split Tube Sampler

FIELD TESTS:

Standard Penetration Test (SPT)

2 / 3 / 4	Number of blows per 150mm over a depth of 450mm
N = 7	SPT "N" number = sum of last two blow counts
R	Refusal. SPT not able to penetrate
HB	Hammer Bouncing

Vane Shear

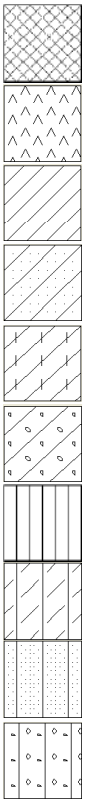
VS=30 Vane Shear Reading of 30 kPa

Pocket Penetromenter

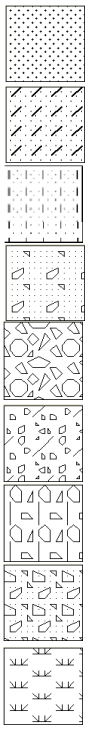
PP=100 Pocket Penetrometer Reading of 100 kPa

SYMBOLS:

Soils

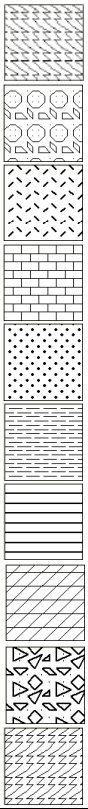


FILL
TOPSOIL
CLAY
SANDY CLAY
SILTY CLAY
GRAVELLY CLAY
SILT
CLAYEY SILT
SANDY SILT
GRAVELLY SILT



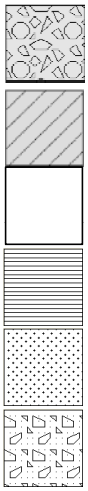
SAND
CLAYEY SAND
SILTY SAND
GRAVELLY SAND
GRAVEL
CLAYEY GRAVEL
SILTY GRAVEL
SANDY GRAVEL
PEAT

Rocks



GNEISS
CONGLOMERATE
GRANITE
LIMESTONE
SANDSTONE
SILTSTONE, MUDSTONE
SHALE
SHALEY CLAY (Extremely Weathered Shale)
VOLCANIC BRECCIA
BASALT

Piezometer Details



CONCRETE
BENTONITE PLUG
PVC SCREEN
WELL SCREEN
GRAVEL PACK
SANDY GRAVEL

NATURAL ROCK DEFECTS:

Description Order:

Fracture Type, Orientation, Infilling, Shape, Roaghness, Other

Fracture Type

JT	Joint
BP	Bedding Plane Parting
SM	Seam
FZ	Fragmented Zone
SZ	Shear Zone
VN	Vein

Orientation

VT	Vertical
HZ (or 0o)	Horizontal
X o	X' degrees from Horizontal

Infilling

CN	Clean
X	Carbonaceous
CLAY	Clay
CA	Calcite
FE	Iron Oxide
MI	Micaceous
QZ	Quartz

Shape

PLN	Planar
CU	Curved
UN	Undulose
ST	Stepped
IR	Irregular

Roughness

POL	Polished
SLK	Slickensided
SO	Smooth
RF	Rough
VR	Very

Others

DIS	Discontinuous
TI	Tight
CO	Coating

SUMMARY OF SOIL LOGGING PROCEDURES (Based on AS 1726-1993 *Geotechnical Site Investigations*)

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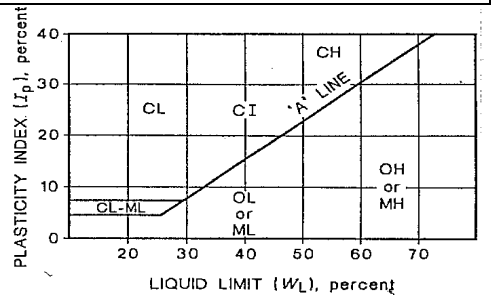
Coarse Material (Gravel and Sands): SOIL NAME: colour - grain size - particle shape - secondary components - minor constituents - moisture condition - relative density - origin - additional observations.
Example (Coarse material): Clayey SAND: dark grey, fine to medium sand, low plasticity, trace of fine gravel, moist and loose. (Alluvial)

Fine Material (Silts and Clays): SOIL NAME: colour - plasticity - secondary components - minor constituents - moisture w.r.t. plasticity - consistency - origin - additional observations.
Example (Fine Material): sandy CLAY: dark grey, low to medium plasticity,fine grained sand, MC > PL, firm to stiff (Alluvial).

Guide to the Description, Identification and Classfication of Soils

Major Divisions				USCS Symbol	Typical Names
>200mm		BOULDERS			
63 to 200mm		COBBLES			
COARSE GRAINED SOILS	More than 50% by dry mass is less than 60mm is greater than 0.076m	Gravel	More than 50% of coarse fraction > 2.36mm	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
				GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels.
		Gravelly Soils		GM	Silty gravels, gravel-sand-silt mixtures.
				GC	Clayey gravels, gravel-sand-clay mixtures.
		SANDS	More than 50% of coarse fraction < 2.36mm	SW	Well-graded sands, gravelly sands, little or no fines.
				SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands.
		Sandy Soils		SM	Silty sands, sand-silt mixtures.
				SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS	More than 50% by dry mass less than 60mm is less than 0.076m	Liquid Limit < 50%		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts.
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays.
				OL	Organic silts and organic silty clays of low plasticity.
		Liquid Limit > 50%		MH	Inorganic silts, micaceous or diatomaneous fine sandy or silty soils, elastic silts.
				CH	Inorganic clays of high plasticity, fat clays.
				OH	Organic clays of medium or high plasticity, organic silts.
HIGHLY ORGANIC SOILS				Pt	Peat and other highly organic soils.

Grain Sizes			
Gravel		Sand	
Coarse -	63 to 20mm	Coarse -	2.36 to 0.6mm
Medium -	20 to 6mm	Medium -	0.6 to 0.2mm
Fine -	6 to 2.36mm	Fine -	0.2 to 0.075mm



GEOLOGICAL ORIGIN:

Fill	- artificial soils / deposits
Alluvium	- soils deposited by the action of water
Aeolian	- soils deposited by the action of wind
Topsoil	- soils supporting plant life containing significant organic cc
Residual	- soils derived from insitu weathering of parent rock.
Colluvial	- transported debris usually unsorted, loose and deposited by gravity towards the base of terrain of high relief

Field Identification of Fine Grained Soils - Silt or Clay?

Dry Strength - Allow the soil to dry completely and then test its strength by breaking and crumbling between the fingers.
High dry strength - Clays; Very slight dry strength - Silts.
Toughness Test - The soil is rolled by hand into a thread about 3mm in diameter. The thread is then folded and re-rolled repeatedly until it has dried sufficiently to break into lumps. In this condition inorganic clays are fairly stiff and tough while inorganic silts produce a weak and often soft thread which may be difficult to form and readily breaks and crumbles.
Dilatancy Test - Add sufficient water to the soil, held in the palm of the hand, to make it soft but not sticky. Shake horizontally, striking vigorously against the other hand several times. Dilatancy is indicated by the appearance of a shiny film on the surface of the soil. If the soil is then squeezed or pressed with the fingers, the surface becomes dull as the soil stiffens and eventually crumbles. These reactions are pronounced only for predominantly silt size material. Plastic clays give no reaction.

Descriptive Terms for Material Portions

COARSE GRAINED SOILS			FINE GRAINED SOILS	
% Fines		*Term/Modifier*	*% Coarse*	*Term/Modifier*
< 5		Omit, or use "trace"	< 15	Omit, or use "trace"
> 5, < 12		"with clay/silt" as applicabl	> 15, < 30	"with sand/gravel" as applicable
> 12		Prefix soil as "silty/clayey"	> 30	Prefix as "sandy/gravelly"

Moisture Condition

Terminology		*for non cohesive soils:*	*for cohesive soils:*
Dry -		cohesionless, free running.	MC < PL. Typically hard and friable.
Moist -		Soils tend to cohere, no free water visible.	MC ~ PL. Soil can be moulded
Wet -		free water visible on soil su	MC > PL. Free water forms on hands during handling

* The plastic Limit (PL) is defined as the moisture content at which the soil crumbles when rolled into threads of 3mm dia.

Plasticity - for Clays & Silts

Low Plasticity		LL ≤35 %. A 3mm dia thread can barely be rolled at any water content.
Medium Plasticity		LL >35 % ≤50 %. The thread is easy to roll and not much time is required to reach PL. Cannot be re-rolled after reaching PL.
High Plasticity		LL > 50 %. It takes considerable time rolling and kneading to reach the PL. The thread can be rerolled several times after reaching the PL.

* Liquid Limit (LL) is defined as the moisture content (%) at which the soil begins to flow.

Consistency - for Clays & Silts

Description	*SPT "N" Value*	*UCS or q_u (kPa)* *	*Field guide to consistency*
Very Soft		<25	Exudes between the fingers when squeezed in hand
Soft		25 - 50	Can be moulded by light finger pressure
Firm		50 - 100	Can be moulded by strong finger pressure
Stiff		100 - 200	Cannot be moulded by fingers.
			Can be indented by thumb
Very Stiff		200 - 400	Can be indented by thumbnail
Hard		>400	Can be indented with difficulty by thumbnail

* UCS = Unconfined Compressive Strength. Can be estimated using a pocket penetrometer although it may overestimate UCS by a factor of 1.5 - 2.0

Relative Density for Gravels and Sands

Description	*SPT "N" Value*	*Relative Density %*	*Field guide (For sand)*
Very Loose	0 - 4	<15	Easily penetrated with a 13mm reinforcing rod pushed by hand
Loose	4 - 10	15 - 35	Can be excavated with a spade. 50mm wooden peg can be easily driven. Easily penetrated with a 13mm reinforcing rod pushed by hand
Medium Dense	10 - 30	35 - 65	Hard shoveling. Penetrated 300mm with 13mm reinforcing rod driven with a 2kg hammer.
Dense	30 - 50	65 - 85	Penetrated 300mm with 13mm reinforcing rod driven with 2kg hammer, requires pick for excavation. 50mm wooden peg is hard to drive.
Very Dense	>50	>85	Penetrated only 25 - 50 mm with 13mm reinforcing rod driven with 2kg hammer.

SUMMARY OF ROCK LOGGING PROCEDURES

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DESCRIPTION ORDER: ROCK TYPE: grain size - colour - strength - weathering - structure - defects - minor constituents - additional observations.

EXAMPLE: SANDSTONE: medium to coarse grained, grey with orange streaks, medium strength, distinctly weathered, laminated, with rare quartz gravel

Rock Type

Rock Type is described on the basis of origin (sedimentary, pyroclastic, metamorphic and igneaous). Common rock types are listed below.

Origin	Definition	Common Types
□ Sedimentary Rocks:	Formed at the Earth's surface from the weathered and eroded fragments of pre-existing rocks (ie. clastic sedimentary rocks), from the hard parts of animals or plants (organic sedimentary rocks), or from the precipitation out of solution of dissolved minerals (chemical sedimentary rocks)	Clastic - conglomerate, sandstone, siltstone*, claystone*, shale. Organic - shelley limestone, coal. Chemical - limestonerock salt, gypsum, chert.
□ Pyroclastic	Fragmented (clastic(rock material) formed by a volcanic explosion or eruption from a volcanic vent.	Tuff, agglomerate, volcanic breccia
□ Metamorphic Rocks:	Formed from the mineralogical and/or textural transformation, in the solid state, of pre-existing rocks due to the action of temperature and/or pressure. Metamorphic rocks that have been subjected to deep burial typically display a foliated texture due to the parallel alignment of some constituent minerals (as in schist) or the segregation of minerals into separate bands of different composition (as in gneiss)	Slate, Gneiss, Schist, Quartzite, Phylite
□ Igneous rocks:	Formed by the cooling and solidification of magma, a hot molten material formed by localised melting within the Earth. If formed beneath the Earth's surface, the rock formed is an 'intrusive igneous rock. Magma extruded at the Earth's surface is known as lava which gives rise to extrusive igneous or volcanic rocks.	Intrusive - Granite, Dolerite, Porphyrite, Diorite. Extrusive - Basalt, Andesite.

* Both siltstone and claystone are also known as mudstone and commonly called shale if thinly laminated with a tendancy to split in parallel planes

Grain Size

Grain size is often only provided for conglomerate and sandstone sedimentary rocks.

* It is noted that the limit of unaided vision is 0.06mm.

Conglomerate		Sandstone	
Coarse -	> 20 mm	Coarse -	0.6 to 2mm
Medium -	6 to 20 mm	Medium -	0.2 to 0.6 mm
Fine -	2 to 6 mm	Fine -	0.06* to 0.2 mm

Colour

Colour is usually described in the as-received moisture condition (ie. wet). Although both wet and dry colours descriptions may be appropriate if significantly different.

Strength

The strength of rock based on point load testing is presented below. Note: the field guide assessment should be confirmed by point load testing when used in earthworks and foundation ir

Rock Strength Descriptions			
Term	**Letter Symbol**	**Point load index (Mpa) Is (50) ***	**Field Guide**
Extremely Low	EL	≤ 0.03	Easily remoulded by hand to a material with soil properties.
Very Low	VL	0.03 - 0.1	May be crumbled in the hand. Sandstone is "sugary" and friable.
Low	L	0.1 - 0.3	A piece of core 150 mm long x 50 mm dia. may be broken by hand and easily scored with a knife. Sharp edges of core may be friable and break during handling.
Medium	M	0.3 - 1.0	A piece of core 150 mm long x 50 mm dia. can be broken by hand with considerable difficulty. Readily scored with knife.
High	H	1.0 - 3	A piece of core 150 mm long x 50 mm dia core cannot be broken by unaided hands, can be slightly scratched or scored with knife.
Very High	VH	3.0 - 10	A piece of core 150 mm long x 50 mm dia. may be broken readily with hand held hammer. Cannot be scratched with pen knife.
Extremely High	EH	≥ 10	A piece of core 150 mm long x 50 mm dia. is difficult to break with hand held hammer. Rings when struck with a hammer.

* rock strength defined by point load strength (Is 50) in direction normal to bedding

Weathering

The classification system for weathering in accordance with AS1726-1993 is provided below.

Weathering		
Residual Soil	RS	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a change in volume but the soil has not significantly transported.
Extremely Weathered	EW	Rock is weathered to such an extent that it has "soil" properties; i.e. it either disintegrates or can be remoulded, in water.
Highly Weathered	HW	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 deposition of weathering products in pores.
Moderately Weathered	MW	Stained or discoloured throughout rock substance but little or no change of rock strength.
Slightly Weathered	SW	Rock is slightly discoloured but shows little or no change of strength from fresh rock.
Fresh	FR	Rock shows no sign of decomposition or staining.

Structure

The structure of the rock mass (as opposed to the rock 'material') should be describbed using the following common terms:

- □ Sedimentary Rocks: Bedded (ie. layers greater than 20 mm thick on average); or Laminated (ie. layers less than 20mm thick on average)
- □ Metamorphic Rocks: Foliated, Banded or Cleaved.
- □ Igneous rocks: Massive or Flowbanded

Defects

Defects are 'natural' fractures in the rock mass and include: joints, faults, sheared planes, seams, bedding partings and veins. They do not include fractures caused by the drilling process or subsequent handling. Defects are an important feature which can have a significant bearing on the engineering behaviour of a rock mass. As such, they should be individually described including: orientation, infilling (eg. clay, Iron oxide, clean etc), shape, roughness and whether the defect is open or tight.

Defect spacing in accordance with P.J.N. Pells et al, 1998, is described below.

Defect Spacing (P.J.N. Pells et al, 1998)*	
Defect Spacing (mm)	Description
>2000	Very Widely Spaced
600 - 2000	Widely Spaced
200 - 600	Moderately Spaced
60 -200	Closely Spaced
20 - 60	Very Closely Spaced
0 - 20	Extremely Closely Spaced

* Spacing relates to of all types of natural fractures, but not articficial breaks, in cored bores

Rock Quality Designation (RQD):

The fracture spacing is shown where applicable and the Rock Quality Designation is

$$RQD\ (\%) = \frac{\text{sum of unbroken core pieces 100 mm or longer}}{\text{Length of Core}}$$

RQD provides information on the extent of fracturing and hence the competency of the rock mass.

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Client:	Cadence Australia
Project:	Four Points Hotel
Location:	Slip Street

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LOG ID: FP_BH1

Sheet: 1 of 4

X-Coord:	333824	GDA 94 MGA 56	**Date Commenced:**	26/04/2012	**Logged by:** MTP
Y-Coord:	6250726		**Date Completed:**	26/04/2012	**Checked by:** MTP
Surface Elevation (R.L) :	3.10	m AHD	**Hole Diameter (mm):**	100mm	

Drilling Information				LITHOLOGY				Samples		Tests		
Depth (mBGL)	R.L. (m)	Method (Support)	Water	Symbol	USCS Symbol	Description SOIL TYPE: plasticity or particle characteristics colour, moisture, secondary and minor components	Consistency / Density	Sample ID	Type	SPT	Pocket Penetrometer (kPa) 100 200 300 400	Well Installation Detail
0	3	ADV				CONCRETE: (200mm thick)						
						FILL: gravelly sandy clay, low plasticity, brown, MC~PL. Sand is fine to coarse grained. Gravel is fine to coarse, sub angular to angular sandstone and brick, with trace of plastic.	F to St	Jar				
1	2											
								Jar		17, 10/50mm N=R HB		
2	1	ADTC				SANDSTONE: fine to medium grained, pale grey/orangish, dry, with some grey, low plasticity clay. Extremely weathered, very low strength.						
3	0					Begin Core Drilling.						
4	-1											
5	-2											
6	-3											
7	-4											
8	-5											
9	-6											
10												

Drill Company:	Macquarie Drilling Pty Ltd	**Operator Name:**	Glen Gartside
Machine Type:	E50	**Operators Licence No.:**	

Refer to Standard Sheets for details of abbreviations

Project ID:	CES111206-CA
Client:	Cadence Australia
Project:	Four Points Hotel
Location:	Slip Street

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LOG ID: FP_BH1

X-Coord:	333824	GDA 94 MGA 56	**Date Commenced:**	26/04/2012	**Logged by:** MTP
Y-Coord:	6250726		**Date Completed:**	26/04/2012	**Checked by:** MTP
Surface Elevation (R.L) :	3.10	m AHD	**Hole Diameter (mm):**	100mm	

Drilling Information				LITHOLOGY				Samples		Tests		
Depth (mBGL)	R.L. (m)	Method (Support)	Water	Symbol	USCS Symbol	Description SOIL TYPE: plasticity or particle characteristics colour, moisture, secondary and minor components	Consistency / Density	Sample ID	Type	SPT	Pocket Penetrometer (kPa) 100 200 300 400	Well Installation Detail
10	-7											
11	-8											
12	-9											
13	-10											
14	-11											
15	-12					End of Borehole.						
16	-13											
17	-14											
18	-15											
19	-16											
20												

Drill Company:	Macquarie Drilling Pty Ltd	**Operator Name:**	Glen Gartside
Machine Type:	E50	**Operators Licence No.:**	

Refer to Standard Sheets for details of abbreviations

Project ID:	CES111206-CA
Client:	Cadence Australia
Project:	Four Points Hotel
Location:	Slip Street

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Corehole ID: FP_BH1

Sheet: 3 of 4

X-Coord:	6250726	**Date Commenced:**	26/04/2012	**Logged by:**	MTP
Y-Coord:	333824	**Date Completed:**	26/04/2012	**Checked by:**	MTP
Surface Elevation (R.L):	3.10 m AHD	**Hole Diameter (mm):**	NMLC		

Drilling Information					LITHOLOGY					Natural Defects		
Depth (mBGL)	R.L. (m)	Method (Support)	% Coreloss	Water	Symbol	Rock Description ROCK TYPE: grain characteristics, colour structure, minor components	Weathering	Estimated Strength MPa (EL 0.03, VL 0.1, L 0.3, M 1, H 3, VH 10, EH)	Is (50) MPa	RQD %	Spacing (mm) (20, 60, 200, 600, 2000)	Description
0												
1	2	ADV										
2	1	ADTC										BP, 0 to 30 degrees, PR, RF, CN to Sn Fe.
3	0		0%			SANDSTONE: fine to medium grained, pale grey with some orange iron staining. Distinctly cross-bedded at 10 to 20 degrees.	MW			87%		BP BP BP
4	-1											BP
5	-2		0%							100%		BP BP BP SM, near horz., grey clay, 15mm thick, PP=75kPa.
6	-3		0%			SANDSTONE: medium to coarse grained, orangish with some pale grey. Distinctly cross-bedded at 10 to 20 degrees. Iron stained throughout.				84%		BP BP
7	-4					SANDSTONE: fine to medium garined, pale grey, massive. Between 7.2m and 7.4m low strength, highly weathered band.	SW					BP BP
8	-5		0%			SANDSTONE: fine to medium grained, pale grey. Distinctly cross-bedded at 10 to 20 degrees. With some dark grey shale laminations.				100%		BP BP
9	-6	NMLC	0%			SANDSTONE: medium grained, pale grey. Indistinctly cross-bedded at 5 to 20 degrees.			D=1.54 A=2.11	93%		BP BP BP BP
10												

Drill Company:	Macquarie Drilling Pty Ltd	**Operator Name:**	Glen Gartside
Machine Type:	E50		

Refer to Standard Sheets for details of abbreviations

Project ID:	CES111206-CA
Client:	Cadence Australia
Project:	Four Points Hotel
Location:	Slip Street

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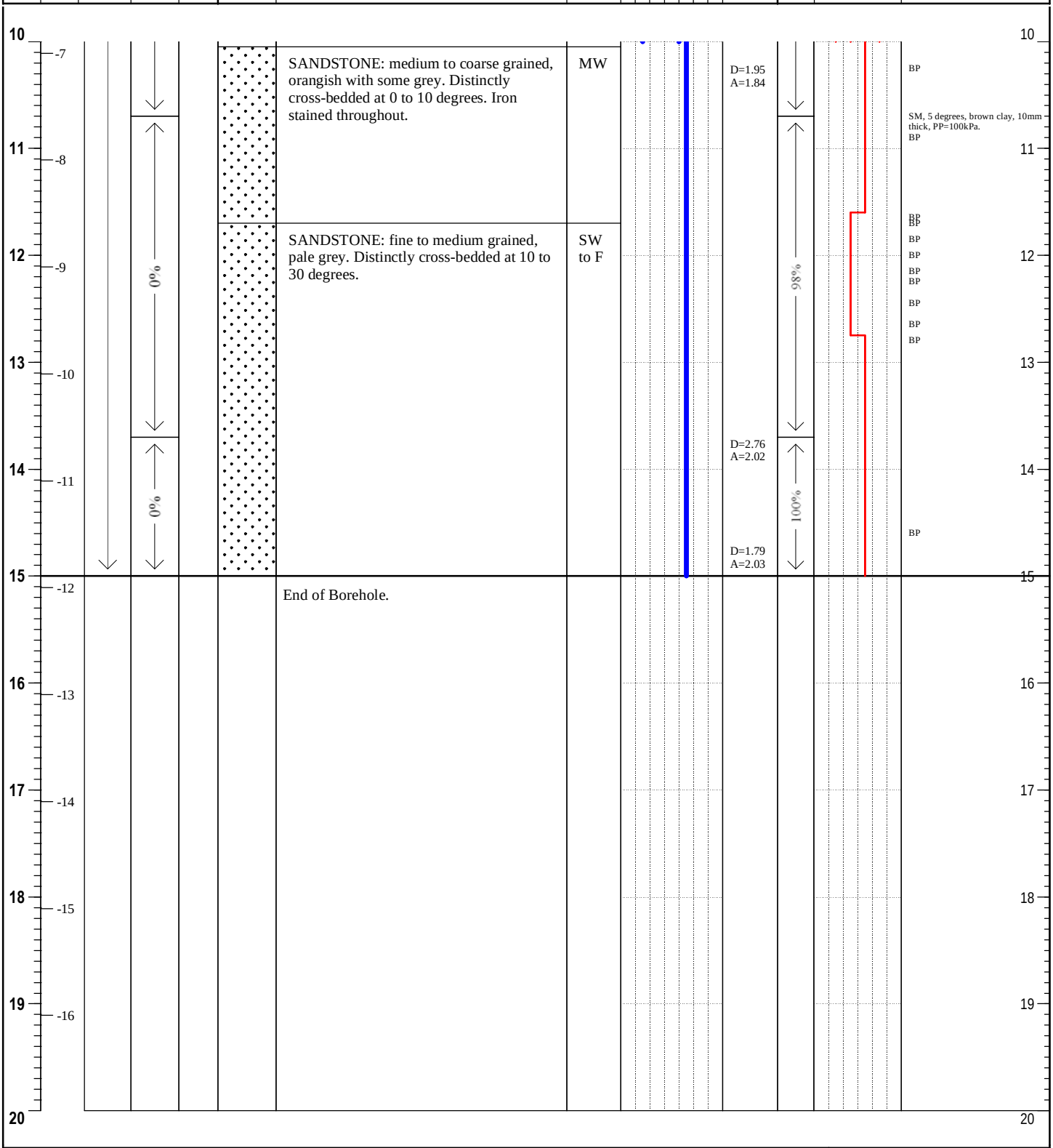
Corehole ID: FP_BH1

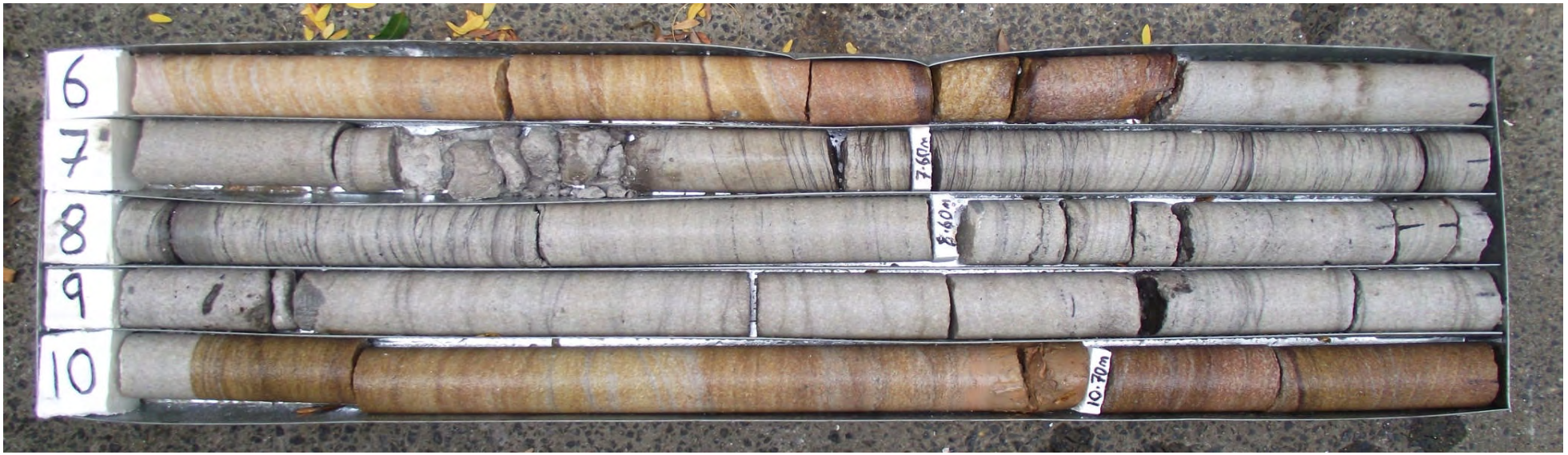
X-Coord:	6250726	**Date Commenced:**	26/04/2012	**Logged by:**	MTP
Y-Coord:	333824	**Date Completed:**	26/04/2012	**Checked by:**	MTP
Surface Elevation (R.L):	3.10 m AHD	**Hole Diameter (mm):**	NMLC		



Drill Company:	Macquarie Drilling Pty Ltd	**Operator Name:**	Glen Gartside
Machine Type:	E50		

Refer to Standard Sheets for details of abbreviations

Date:	26/04/2012	Title:	FP_BH1 Four Points 2.75m to 6.00m	CONSULTING EARTH SCIENTISTS
Prepared by:	M. Pickett			Suite 3, Level 1,
Checked by:	D. Lowe	CES Project ID:	CES111206-CA	55 Grandview Street
Scale:	NTS			Pymble NSW 2073
Size:	A4	Client:	Cadence Australia	ph: 02 8569 2200 fax: 02 9983 0582



Date:	26/04/2012	Title:	FP_BH1 Four Points 6.0m to 11.0m	CONSULTING EARTH SCIENTISTS
Prepared by:	M. Pickett			Suite 3, Level 1,
Checked by:	D. Lowe	CES Project ID:	CES111206-CA	55 Grandview Street
Scale:	NTS			Pymble NSW 2073
Size:	A4	Client:	Cadence Australia	ph: 02 8569 2200 fax: 02 9983 0582

Date:	26/04/2012	Title:	FP_BH1 Four Points 11.0m to 15.00m	CONSULTING EARTH SCIENTISTS
Prepared by:	M. Pickett			Suite 3, Level 1,
Checked by:	D. Lowe	CES Project ID:	CES111206-CA	55 Grandview Street
Scale:	NTS			Pymble NSW 2073
Size:	A4	Client:	Cadence Australia	ph: 02 8569 2200 fax: 02 9983 0582

Project ID:	CES111206-CA	CONSULTING EARTH SCIENTISTS	**LOG ID: FP_BH3**
Client:	Cadence Australia	Suite 3, Level 1 55 Grandview Street, Pymble NSW 2073 PH: (02) 8569 2200 FAX: (02) 9983 0582 www.consultingearth.com.au	Sheet: 1 of 3
Project:	Four Points Hotel		
Location:	Western Distributor (South Bound)		

X-Coord:	333810	GDA 94 MGA 56	**Date Commenced:**	30/04/2012	**Logged by:** MTP
Y-Coord:	6250752		**Date Completed:**	30/04/2012	**Checked by:** MTP
Surface Elevation (R.L) :	2.80	m AHD	**Hole Diameter (mm):**	100mm	

Drilling Information				LITHOLOGY				Samples		Tests		
Depth (mBGL)	R.L. (m)	Method (Support)	Water	Symbol	USCS Symbol	Description SOIL TYPE: plasticity or particle characteristics colour, moisture, secondary and minor components	Consistency / Density	Sample ID	Type	SPT	Pocket Penetrometer (kPa) 100 200 300 400	Well Installation Detail
0	2	ADV				CONCRETE: (610mm thick)						
1	1					FILL: sand, fine to medium grained, pale brown, dry. With some fine, subangular to angular gravel, silt and clay.	L					
2	0					FILL: clay, medium plasticity, dark brown, MC~PL. With some sand and fine subangular to angular gravel.	St MD	Jar		4, 10/50mm HB		
3	-1					FILL: sand, fine to medium grained, reddish/brown, dry. With some clay.						
4	-2					Begin Core Drilling.						
5	-3											
6	-4											
7	-5											
8	-6											
9	-7											
10												

Drill Company:	Macquarie Drilling Pty Ltd	**Operator Name:**	Glen Gartside
Machine Type:	E50	**Operators Licence No.:**	

Refer to Standard Sheets for details of abbreviations

Project ID:	CES111206-CA
Client:	Cadence Australia
Project:	Four Points Hotel
Location:	Western Distributor (southbound)

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Corehole ID: FP_BH3

Sheet: 2of 3

X-Coord:	6250752	**Date Commenced:**	30/04/2012	**Logged by:**	MTP
Y-Coord:	333810	**Date Completed:**	30/04/2012	**Checked by:**	MTP
Surface Elevation (R.L):	2.80 m AHD	**Hole Diameter (mm):**	NMLC		

Drilling Information					LITHOLOGY					Natural Defects		
Depth (mBGL)	R.L. (m)	Method (Support)	% Coreloss	Water	Symbol	Rock Description ROCK TYPE: grain characteristics, colour structure, minor components	Weathering	Estimated Strength MPa (0.03 EL, 0.1 VL, 0.3 L, 1 M, 3 H, 10 VH, EH)	Is (50) MPa	RQD %	Spacing (mm) (20, 60, 200, 600, 2000)	Description
0	1	ADV	0%			SANDSTONE: fine to medium grained, orangish/reddish. Distinctly cross-bedded at 5 to 20 degrees. Iron stained throughout.	MW			80%		BP, 0 to 30 degrees, PR, RF, CN to Sn Fe. BP BP BP BP
3	0		2%			SANDSTONE: fine to medium grained, pale grey with some orange iron staining. Distinctly cross-bedded at 5 to 20 degrees.				93%		BP BP BP BP BP BP BP JT, 60 degrees, PR, RF, Sn Fe and CO of brown clay. BP
4	-1					NO CORE: (0.05m)						
5	-2											
6	-3		0%			SANDSTONE: fine to medium grained, pale grey with some orange iron staining. Distinctly cross-bedded at 5 to 20 degrees.	MW			96%		BP BP BP BP BP BP SM, near horizontal, grey sandy clay, 5mm thick. BP BP BP
7	-4					SANDSTONE: medium to coarse grained, pale grey, massive.	SW		D=0.78 A=0.82			SM, near horizontal, grey clay, 30mm thick, PP=70kPa. BP BP
8	-5											
9	-6	NMLC				SANDSTONE: fine to medium grained, pale grey. Distinctly cross-bedded at 10 to 20 degrees.						
10	-7		%							%		BP

Drill Company:	Macquarie Drilling Pty Ltd	**Operator Name:**	Glen Gartside
Machine Type:	E50		

Refer to Standard Sheets for details of abbreviations

Project ID:	CES111206-CA
Client:	Cadence Australia
Project:	Four Points Hotel
Location:	Western Distributor (southbound)

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Corehole ID: FP_BH3

Sheet: 3of 3

X-Coord:	6250752	**Date Commenced:**	30/04/2012	**Logged by:**	MTP
Y-Coord:	333810	**Date Completed:**	30/04/2012	**Checked by:**	MTP
Surface Elevation (R.L):	2.80 m AHD	**Hole Diameter (mm):**	NMLC		

Drilling Information | **LITHOLOGY** | **Natural Defects**

Depth (mBGL)	R.L. (m)	Method (Support)	% Coreloss	Water	Symbol	Rock Description (ROCK TYPE: grain characteristics, colour structure, minor components)	Weathering	Estimated Strength MPa (EL 0.03, VL 0.1, L 0.3, M 1, H 3, VH 10, EH)	Is (50) MPa	RQD %	Spacing (mm) (20, 60, 200, 600, 2000)	Description
10			0%						D=1.26 A=1.31	100%		BP
11	-8					At -11.2m with some orange iron staining.						BP
												BP
	-9											BP
12												BP
	-10		0%						D=1.30 A=1.45	97%		BP
13												BP
	-11											BP
14						At -14.0m becoming pale grey.	F		D=0.94 A=1.11	100%		BP
	-12		0%									BP
15												SM, near horizontal, grey clay, 5mm thick.
						End of Borehole.						
16	-13											
	-14											
17												
	-15											
18												
	-16											
19												
	-17											
20												

Drill Company:	Macquarie Drilling Pty Ltd	**Operator Name:**	Glen Gartside
Machine Type:	E50		

Refer to Standard Sheets for details of abbreviations

Date:	1/05/2012	Title:	FP_BH3 Four Points 2.1m to 6.0m	CONSULTING EARTH SCIENTISTS
Prepared by:	M. Pickett			Suite 3, Level 1,
Checked by:	D. Lowe	CES Project ID:	CES111206-CA	55 Grandview Street
Scale:	NTS			Pymble NSW 2073
Size:	A4	Client:	Cadence Australia	ph: 02 8569 2200 fax: 02 9983 0582