Douglas Partners
Geotechnics / Environment / Groundwater

Report on
Geotechnical Investigation

Proposed Residential Unit Development
Lot 3008 Lord Sheffield Circuit, Penrith

Prepared for
St Hilliers Group

Project 85755.00
December 2016

Integrated Practical Solutions

Document Set ID: 8115318
Version: 1, Version Date: 29/03/2018

Douglas Partners
Geotechnics | Environment | Groundwater

Document History

Document details

Project No.	85755.00	Document No.	R.001.Rev0
Document title	Report on Geotechnical Investigation Proposed Residential Unit Development		
Site address	Lot 3008 Lord Sheffield Circuit, Penrith		
Report prepared for	St Hilliers Group		
File name	85755.00.R.001.Rev0.docx		

Document status and review

Status	Prepared by	Reviewed by	Date issued
Revision 0	Konrad Schultz	Michael J Thom	15/12/2016

Distribution of copies

Status	Electronic	Paper	Issued to
Revision 0	1	0	Mr Frank Katsanevas (St Hilliers Group)

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

	Signature	Date
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ISO 9001 Quality Management

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Report on Geotechnical Investigation
Proposed Residential Unit Development
Lot 3008 Lord Sheffield Circuit, Penrith

1. Introduction

This report presents the results of a geotechnical investigation undertaken for a proposed residential unit development at Lot 3008 Lord Sheffield Circuit, Penrith. The investigation was commissioned in an email dated 14 November 2016 by Mr Frank Katsanevas of St Hilliers Group and was undertaken in accordance with Douglas Partners Pty Ltd (DP) proposal SYD161383 dated 14 November 2016.

It is understood that the development of the site will include the construction of residential units up to four storeys in height with on grade car parking.

The aim of the investigation was to provide information on the subsurface soil and groundwater conditions to allow an assessment of:

- the geotechnical suitability of the site for the proposed development;
- an appropriate site classification in accordance with the requirements of AS2870;
- recommendations on site preparation and earthworks;
- recommendations on excavations and retaining structures;
- an appropriate foundation system for the proposed development, including an assessment of allowable bearing pressures and likely settlements; and
- suitable parameters for the design of new pavements.

The investigation included borehole drilling followed by laboratory testing of selected samples. The details of the field and laboratory work are presented in this report, together with comments and recommendations on the issues listed above.

The field work was carried out in conjunction with investigation on Lots 3003, 3004 and 3005 which comprised six boreholes for a similar residential development.

2. Site Description and Regional Geology

The site, known as Lot 3008 in DP 1184498, is a lozenge shape with maximum plan dimensions approximately 100 m by 34 m and an area of 2750 m^2 with the location and boundary shown on Drawing 1 in Appendix A. It is bounded to the south and west by the Lord Sheffield Circuit reserve and to the north and east by residential development similar to the current site.

The site surface is near flat at RL 27 m relative to the Australian Height Datum (AHD), sloping very gently to water features north of the site. At the time of the investigation the site was being used as a temporary construction facility with construction materials and demountable buildings covering most of the site.

The Penrith 1:100 000 Geology Series Sheet indicates that the site is underlain by Quaternary aged alluvial soils of the Cranebrook Formation which include gravel, sand, silt and clay. The alluvium is in turn underlain by Triassic aged Bringelly Shale of the Wianamatta Group which typically comprises shale, carbonaceous claystone, fine to medium grained lithic sandstone and rare coal seams and tuff.

Acid sulfate soil (ASS) risk mapping indicates that the site is not located within an area of known ASS occurrence.

The results of the borehole confirmed the mapping with alluvium, sandstone and laminate encountered during the investigation.

3. Field Work

3.1 Methods

In accordance with the brief, a truck-mounted drilling rig was used to drill one borehole at an accessible location on the site, minimising interference with the construction activities. The borehole was initially drilled using solid flight augers and rotary mud flush through soil, with regular standard penetration tests (SPT) for strata identification and sampling for laboratory testing. Once refusal occurred on the underlying "Penrith" gravel, the hole was cased and a down hole percussion casing advancing system (Tubex) was used to penetrate the gravel layer until bedrock was encountered, then NMLC sized diamond drilling techniques were used to recover continuous rock core samples.

Observation for groundwater during the augering, rotary drilling and casing advancing within the boreholes;

The co-ordinates (easting and northing) and surface level (AHD) at the borehole location were measured with reference to Map Grid of Australia (MGA) Zone 56 using a differential GPS which is accurate to about 20 mm.

The ground surface levels at the borehole locations were interpolated from a survey drawing provided to DP by the client (Ref: Drawing No. SP1040-001, by S.P. Site Setout Pty Ltd, dated 1 November 2016).

The location of the borehole is shown on Drawing 1 in Appendix A.

3.2 Results

The field work results are presented on the borehole log in Appendix B, together with notes explaining descriptive terms and classification methods used.

The subsurface profile encountered within Borehole BH1 is summarised as follows:

FILLING:	variably compacted, silty clay filling to 0.7 m depth;
ALLUVIUM:	Generally stiff clay and medium dense clayey sand soils to a depth of 5.2 m.
ALLUVIUM (PENRITH GRAVEL):	Very dense gravel with some cobbles in a sandy clay matrix to a depth 12.1 m where sandstone bedrock was encountered;
BEDROCK:	Initially extremely low to very low strength sandstone, becoming high and very high strength sandstone (at 12.7 m depth) and laminite (at 14.2 m depth). The borehole was terminated high strength rock at approximate depths of 15.8 m.

Groundwater was observed at a depth of 5.7 m (RL 21.1 m) during casing advancing within the borehole. The level is generally consistent with other recent groundwater observations on nearby sites. It should be noted that groundwater levels will vary with changes in rainfall and other activities that change soil permeability.

4. Laboratory Testing

One soil sample was tested in the laboratory to determine the pH, sulphate and chloride ion concentrations as well as the electrical conductivity to assess the aggressivity potential of the soil towards buried concrete and steel structures. The results of the chemical properties are included in Appendix B and are summarised in Table 1.

Table 1: Results of pH, Sulphate, Chloride and Electrical Conductivity Testing

Bore	Material	Sample Depth (m)	pH	Electrical Conductivity (µS/cm)	Chloride Ion (mg/kg)	Sulphate Ion (mg/kg)
TBA	Sand	5.5	8.7	120	50	10

Comparison of the results of the aggressivity testing with Tables 6.4.2(C) and 6.5.2(C) in Australian Standard AS 2159 Piling Design and Installation - 2009, indicates that the subsurface conditions are mildly aggressive towards buried concrete elements and non-aggresive to buried steel elements.

5. Proposed Development

It is understood that a four level residential unit development with on-grade car parking will cover most of the site. Whilst no details are available at the time of reporting, it is expected that cut and fill on the site will be less than 0.5 m to construct and level building platform.

Typical column loads for this type of development are expected to be in the order of 1000 – 2000 kN.

6. Comments

6.1 Site Classification

Site classification in accordance with AS 2870 – 2011 (Reference 1) can be used often to assess reactive movements of foundation soils and hence provide an indication of the potential for cracking to occur in brittle materials such as concrete, block work and tiles. The borehole indicates that that up to 0.7 m of uncontrolled filling is present and therefore the site in its current condition is classified 'Class P'. However, reclassification of the site may be possible if suitable documentation can be provided to confirm appropriate compaction levels in existing or new filling that will provide support for buildings, floor slabs and pavements. If it is not possible to confirm compaction levels in existing filling it should be removed and replaced.

6.2 Excavation Condition and Vibrations

Based on the results of the borehole relatively straightforward ground conditions can be are anticipated for shallow bulk earthworks (up to approximately 0.5 m depth) and deeper detailed excavations for lift overruns, footings/headstock and general earthworks.

It is assumed that the majority of the excavation will occur in the upper 2.5 m of the site and will generally comprise variably compacted sandy gravelly clay filling over stiff to very stiff silty/sandy clay. These types of materials can be readily removed with conventional earthmoving equipment or hydraulic excavators and possibly with some light ripping.

Whilst some excavations may be in close proximity to the adjacent structures in the east and north, it is expected that vibrations during construction will be relatively low due to the straightforward ground conditions.

A maximum peak particle velocity of 8 mm/sec (in any component direction) at the foundation level of adjacent structures is suggested for both structural and human comfort considerations, although this vibration limit may need to be reduced if there are sensitive buildings or equipment nearby.

Vertical batters for footing excavations up to 1 m depth are considered appropriate at this site, provided there is no requirement for access by site personnel. Short term temporary batter slopes of 1H:1V (H = horizontal, V = vertical) should be used for excavations up to 2.5 m deep. The above batters are provided on the basis that there is no surcharge from stockpiled materials and building or vehicular loads to a setback distance of at least the excavation depth behind the crest of excavations.

Retaining walls will be required to support any permanent excavations.

6.3 Re-use of Excavated Material

The current investigation and previous work on nearby sites indicate that the near surface filling and natural soils at the site would be suitable for re-use after moisture conditioning has been carried out, although they are mostly of medium plasticity and relatively high reactivity, therefore their re-use should be strictly controlled under structures and pavements.

6.4 Site Preparation

The following general procedure is suggested for site preparation and filling at the site:

- Strip to design subgrade level. If reclassification of the site is required and suitable documentation cannot be sourced, then all 'uncontrolled' filling should also be removed, unless footings are constructed and found on natural soils.
- Scarify and moisture condition the exposed surface;
- Roll the exposed surface with at least six passes of a minimum 12 tonne deadweight roller with a final test roll pass accompanied by careful visual inspection to ensure that any deleterious materials such as soft, wet or highly compressible soil and any organics are identified and removed;
- Replacement and additional filling should be placed in loose layer thicknesses not greater than 300 mm and compacted to a dry density ratio of 98 - 102% (for lightly loaded building floor slabs) and 100% (for pavements) relative to Standard compaction and with moisture contents maintained within 2% of Standard optimum moisture content. Replacement and new filling should be free of oversize particles (>100 mm) and deleterious material.
- Maintain moisture contents for clay filling in the range 2% dry to 2% wet of optimum moisture content for Standard compaction, as the long term equilibrium moisture content is typically marginally dry of the optimum moisture content in this area; and
- Seal or cover any natural or compacted clay foundation soil, at or close to formation level, as soon as practicable, to reduce the opportunity for desiccation and cracking or swelling and softening.

Compaction testing to a Level 1 standard, as defined in Section 8 of AS 3798 – 2007 (Reference 2) is required where structural loads are supported by filling. A Level 1 report must also be prepared at the completion of the works stating that the filling has been completed as recommended above and as required by AS 2870 – 2011 (Reference 1).

6.5 Footings

6.5.1 Shallow Pad and Strip Footings

For relatively lightly loaded structure such as garden retaining walls or similar, it should be feasible to found in controlled filling or natural stiff clay soils using an allowable bearing pressure of 100 kPa.

6.5.2 Piles

For more highly loaded or settlement sensitive structures. piles founding in the underlying very stiff clay/medium dene sand, 'Penrith' gravel or bedrock should be suitable.

Driven concrete or timber piles founding in very stiff clays are technically feasible but damage to the adjacent residential structures caused by vibration during installation will have to be assessed before driven piles could be selected.

It should be feasible to use continuous flight auger (CFA) piles to found on or within the dense "Penrith" gravel encountered at a depth of 5.9 m within the borehole. If higher capacities are required, conventional, cased bored piers could be used to penetrate the gravel (with some difficulty) and found within the high strength bedrock beneath the site at.

Preliminary design of piles could be based on the parameters provided in Table 2.

Table 2: Design Parameters for CFA and Bored Piles

Material Description	**Allowable End-Bearing Pressure (kPa)**	**Allowable Shaft Adhesion (kPa)** [1]	**Ultimate End-Bearing Pressure (kPa)**	**Ultimate Shaft Adhesion (kPa)**[1]	**Elastic Modulus (MPa)**
Stiff to Very Stiff Silty/Sandy Clay At least 5 pile diameters below ground level	250	30	1,200	100	40
Very Dense Gravel	2,000	50(2)	6,000	100 (2)	80
Medium Strength Sandstone/Laminite	3,500	300	30,000	600	1,000
High Strength Sandstone/Laminite	6,000	500	100,000	1,000	2,000

Notes: [1] Reduce by 50% for uplift loads and ensure cone-pull out criteria are met
[2] For piles bearing in the gravel layer

It should be noted that the serviceability limit-state is likely to govern the design of the piles. An appropriate geotechnical strength reduction factor ($Ø_g$) should be selected by the pile designer using the procedure outlined in Australian Standard AS 2159 – 2009 Piling – Design and Installation.

Settlement of a pile is dependent on the loads applied to the pile and the foundation conditions in the socket zone and below the pile toe. The total settlement of a pile designed using the 'allowable' parameters provided in Table 2 would be expected to be less than 1% of the pile diameter.

If heavily-loaded piles for the proposed multi-storey building are designed to be founded on the gravel layer (i.e. in the instance that drilling through the gravel is unsuccessful using CFA pilling methods), the installation of test piles and/or pile load testing should be undertaken to confirm the pile capacity, pile settlement, foundation design parameters, and an appropriate geotechnical strength reduction factor.

Soil decompression can occur during CFA piling when a strong stratum is encountered. In this case, the augers continue to rotate but the rate of auger progression decreases and soil from around the auger is displaced upwards towards the surface. Decompression can cause weakening and settlement of the soils adjacent to the pile and should be avoided by monitoring auger speed and progression closely.

CFA piles are a proprietary product which involves a ‘blind’ drilling technique and relies predominantly on monitoring from on-board equipment and the operator. For these reasons, CFA piles should be certified by the piling contractor.

If bored piles are used, the drilling of rock sockets can be witnessed by a geotechnical consultant to confirm that the foundation conditions satisfy the design parameters adopted.

6.6 Retaining Structures

Retaining walls, for temporary and permanent support of existing soils or newly filled areas, may be designed on the basis of an average bulk unit weight of 20 kN/m^3 and a triangular earth pressure distribution based on a lateral active earth pressure coefficient (Ka) of 0.35 where some wall movement is acceptable. An “at rest” earth pressure coefficient (Ko) of 0.5 should be used where wall movement is to be limited. All surcharge loads including any nearby footings should be included in the design.

Drainage of the ground behind impermeable walls and discharge of the collected water to the existing stormwater system should be provided otherwise the walls should be designed for full hydrostatic pressures.

6.7 Pavement Design

Preliminary pavement design could be based on a California bearing ratio of 3% for filling reworked in accordance with Section 6.4 or natural soils. This value should be confirmed by testing during construction.

7. References

1. Australian Standard AS2870-2011, 'Residential Slabs and Footings', April 2011, Standards Australia
2. Australian Standard AS3798-2007, 'Guidelines on Earthworks for Commercial and Residential Developments', April 2007, Standards Australia

8. Limitations

Douglas Partners (DP) has prepared this report for this project at Lot 3008 Lord Sheffield Circuit, Penrith in accordance with DP’s proposal WOL 161383 dated 14 November 2016 and acceptance received from St Hilliers Group dated 14 November 2016. The work was carried out under DP’s Conditions of Engagement). This report is provided for the exclusive use of St Hilliers Group for this project only and for the purposes as described in the report. It should not be used for other projects or purposes or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are indicative of the sub-surface conditions on the site only at the specific sampling and/or testing locations, and then only to the depths investigated and at the time the work was carried out. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of human influences. Such changes may occur after DP's field testing has been completed.

DP's advice is based upon the conditions encountered during this investigation. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across the site between and beyond the sampling and/or testing locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

This report must be read in conjunction with all of the attachments and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the (geotechnical / environmental / groundwater) components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report
Results of Field Work
Drawing 1

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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This report is the property of Douglas Partners Pty Ltd. The report may only be used for the purpose for which it was commissioned and in accordance with the Conditions of Engagement for the commission supplied at the time of proposal. Unauthorised use of this report in any form whatsoever is prohibited.

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- 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 with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- 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 first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps 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.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

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

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

Where information obtained from this report 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. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

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

Sampling Methods

Sampling

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

Disturbed samples taken during drilling provide information on colour, type, 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 into the soil and withdrawing it to obtain 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.

Test Pits

Test pits are usually excavated with a backhoe or an excavator, allowing close examination of the in-situ soil if it is safe to enter into the pit. The depth of excavation is limited to about 3 m for a backhoe and up to 6 m for a large excavator. A potential disadvantage of this investigation method is the larger area of disturbance to the site.

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) 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 samples.

Continuous Spiral Flight Augers

The borehole is advanced using 90-115 mm diameter continuous spiral flight augers which are withdrawn at intervals to allow sampling or in-situ testing. This is a relatively economical means of drilling in clays and sands above the water table. Samples are returned to the surface, or may be collected after withdrawal of the auger flights, but they are disturbed and may be mixed with soils from the sides of the hole. Information from the drilling (as distinct from specific sampling by SPTs or undisturbed samples) is of relatively low reliability, due to the remoulding, possible mixing or softening of samples by groundwater.

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud 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 the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

A continuous core sample can be obtained using a diamond tipped core barrel, usually with a 50 mm internal diameter. Provided full core recovery is achieved (which is not always possible in weak rocks and granular soils), this technique provides a very reliable method of investigation.

Standard Penetration Tests

Standard penetration tests (SPT) are used as a means of estimating the density or strength of soils and also of obtaining a relatively undisturbed sample. The test procedure is described in Australian Standard 1289, Methods of Testing Soils for Engineering Purposes - Test 6.3.1.

The test is carried out in a borehole by driving a 50 mm diameter split sample tube under the impact of a 63 kg hammer with a free fall of 760 mm. It is normal for the tube to be driven in three successive 150 mm increments and the 'N' value is taken as the number of blows for the last 300 mm. In dense sands, very hard clays or weak rock, the full 450 mm penetration may not be practicable and the test is discontinued.

The test results are reported in the following form.

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

  4,6,7
  N=13

- In the case where the test is discontinued before the full penetration depth, say after 15 blows for the first 150 mm and 30 blows for the next 40 mm as:

  15, 30/40 mm

The results of the SPT tests can be related empirically to the engineering properties of the soils.

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

Dynamic penetrometer tests (DCP or PSP) are carried out by driving a steel rod into the ground using a standard weight of hammer falling a specified distance. As the rod penetrates the soil the number of blows required to penetrate each successive 150 mm depth are recorded. Normally there is a depth limitation of 1.2 m, but this may be extended in certain conditions by the use of extension rods. Two types of penetrometer are commonly used.

- Perth sand penetrometer - a 16 mm diameter flat ended rod is driven using a 9 kg hammer dropping 600 mm (AS 1289, Test 6.3.3). This test was developed for testing the density of sands and is mainly used in granular soils and filling.
- Cone penetrometer - a 16 mm diameter rod with a 20 mm diameter cone end is driven using a 9 kg hammer dropping 510 mm (AS 1289, Test 6.3.2). This test was developed initially for pavement subgrade investigations, and correlations of the test results with California Bearing Ratio have been published by various road authorities.

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

Soil types are described according to the predominant particle size, qualified by the grading of other particles present:

Type	Particle size (mm)
Boulder	>200
Cobble	63 - 200
Gravel	2.36 - 63
Sand	0.075 - 2.36
Silt	0.002 - 0.075
Clay	<0.002

The sand and gravel sizes can be further subdivided as follows:

Type	Particle size (mm)
Coarse gravel	20 - 63
Medium gravel	6 - 20
Fine gravel	2.36 - 6
Coarse sand	0.6 - 2.36
Medium sand	0.2 - 0.6
Fine sand	0.075 - 0.2

The proportions of secondary constituents of soils are described as:

Term	Proportion	Example
And	Specify	Clay (60%) and Sand (40%)
Adjective	20 - 35%	Sandy Clay
Slightly	12 - 20%	Slightly Sandy Clay
With some	5 - 12%	Clay with some sand
With a trace of	0 - 5%	Clay with a trace of sand

Definitions of grading terms used are:

- Well graded - a good representation of all particle sizes
- Poorly graded - an excess or deficiency of particular sizes within the specified range
- Uniformly graded - an excess of a particular particle size
- Gap graded - a deficiency of a particular particle size with the range

Cohesive Soils

Cohesive soils, such as clays, are classified on the basis of undrained shear strength. The strength may be measured by laboratory testing, or estimated by field tests or engineering examination. The strength terms are defined as follows:

Description	Abbreviation	Undrained shear strength (kPa)
Very soft	vs	<12
Soft	s	12 - 25
Firm	f	25 - 50
Stiff	st	50 - 100
Very stiff	vst	100 - 200
Hard	h	>200

Cohesionless Soils

Cohesionless soils, such as clean sands, are classified on the basis of relative density, generally from the results of standard penetration tests (SPT), cone penetration tests (CPT) or dynamic penetrometers (PSP). The relative density terms are given below:

Relative Density	Abbreviation	SPT N value	CPT qc value (MPa)
Very loose	vl	<4	<2
Loose	l	4 - 10	2 -5
Medium dense	md	10 - 30	5 - 15
Dense	d	30 - 50	15 - 25
Very dense	vd	>50	>25

Soil Descriptions

Soil Origin

It is often difficult to accurately determine the origin of a soil. Soils can generally be classified as:

- Residual soil - derived from in-situ weathering of the underlying rock;
- Transported soils - formed somewhere else and transported by nature to the site; or
- Filling - moved by man.

Transported soils may be further subdivided into:

- Alluvium - river deposits
- Lacustrine - lake deposits
- Aeolian - wind deposits
- Littoral - beach deposits
- Estuarine - tidal river deposits
- Talus - scree or coarse colluvium
- Slopewash or Colluvium - transported downslope by gravity assisted by water. Often includes angular rock fragments and boulders.

Rock Descriptions

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 1993. The terms used to describe rock strength are as follows:

Term	Abbreviation	Point Load Index $Is_{(50)}$ MPa	Approx Unconfined Compressive Strength MPa*
Extremely low	EL	<0.03	<0.6
Very low	VL	0.03 - 0.1	0.6 - 2
Low	L	0.1 - 0.3	2 - 6
Medium	M	0.3 - 1.0	6 - 20
High	H	1 - 3	20 - 60
Very high	VH	3 - 10	60 - 200
Extremely high	EH	>10	>200

* Assumes a ratio of 20:1 for UCS to $Is_{(50)}$

Degree of Weathering

The degree of weathering of rock is classified as follows:

Term	Abbreviation	Description
Extremely weathered	EW	Rock substance has soil properties, i.e. it can be remoulded and classified as a soil but the texture of the original rock is still evident.
Highly weathered	HW	Limonite staining or bleaching affects whole of rock substance and other signs of decomposition are evident. Porosity and strength may be altered as a result of iron leaching or deposition. Colour and strength of original fresh rock is not recognisable
Moderately weathered	MW	Staining and discolouration of rock substance has taken place
Slightly weathered	SW	Rock substance is slightly discoloured but shows little or no change of strength from fresh rock
Fresh stained	Fs	Rock substance unaffected by weathering but staining visible along defects
Fresh	Fr	No signs of decomposition or staining

Degree of Fracturing

The following classification applies to the spacing of natural fractures in diamond drill cores. It includes bedding plane partings, joints and other defects, but excludes drilling breaks.

Term	Description
Fragmented	Fragments of <20 mm
Highly Fractured	Core lengths of 20-40 mm with some fragments
Fractured	Core lengths of 40-200 mm with some shorter and longer sections
Slightly Fractured	Core lengths of 200-1000 mm with some shorter and loner sections
Unbroken	Core lengths mostly > 1000 mm

Rock Quality Designation

The quality of the cored rock can be measured using the Rock Quality Designation (RQD) index, defined as:

$$\text{RQD \%} = \frac{\text{cumulative length of 'sound' core sections} \geq 100 \text{ mm long}}{\text{total drilled length of section being assessed}}$$

where 'sound' rock is assessed to be rock of low strength or better. The RQD applies only to natural fractures. If the core is broken by drilling or handling (i.e. drilling breaks) then the broken pieces are fitted back together and are not included in the calculation of RQD.

Stratification Spacing

For sedimentary rocks the following terms may be used to describe the spacing of bedding partings:

Term	Separation of Stratification Planes
Thinly laminated	< 6 mm
Laminated	6 mm to 20 mm
Very thinly bedded	20 mm to 60 mm
Thinly bedded	60 mm to 0.2 m
Medium bedded	0.2 m to 0.6 m
Thickly bedded	0.6 m to 2 m
Very thickly bedded	> 2 m

Symbols & Abbreviations

Introduction

These notes summarise abbreviations commonly used on borehole logs and test pit reports.

Drilling or Excavation Methods

C	Core Drilling
R	Rotary drilling
SFA	Spiral flight augers
NMLC	Diamond core - 52 mm dia
NQ	Diamond core - 47 mm dia
HQ	Diamond core - 63 mm dia
PQ	Diamond core - 81 mm dia

Water

▷	Water seep
▽	Water level

Sampling and Testing

A	Auger sample
B	Bulk sample
D	Disturbed sample
E	Environmental sample
U_{50}	Undisturbed tube sample (50mm)
W	Water sample
pp	pocket penetrometer (kPa)
PID	Photo ionisation detector
PL	Point load strength Is(50) MPa
S	Standard Penetration Test
V	Shear vane (kPa)

Description of Defects in Rock

The abbreviated descriptions of the defects should be in the following order: Depth, Type, Orientation, Coating, Shape, Roughness and Other. Drilling and handling breaks are not usually included on the logs.

Defect Type

B	Bedding plane
Cs	Clay seam
Cv	Cleavage
Cz	Crushed zone
Ds	Decomposed seam
F	Fault
J	Joint
Lam	lamination
Pt	Parting
Sz	Sheared Zone
V	Vein

Orientation

The inclination of defects is always measured from the perpendicular to the core axis.

h	horizontal
v	vertical
sh	sub-horizontal
sv	sub-vertical

Coating or Infilling Term

cln	clean
co	coating
he	healed
inf	infilled
stn	stained
ti	tight
vn	veneer

Coating Descriptor

ca	calcite
cbs	carbonaceous
cly	clay
fe	iron oxide
mn	manganese
slt	silty

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

July 2010

Symbols & Abbreviations

Graphic Symbols for Soil and Rock

General

■	Asphalt
▨	Road base
▨	Concrete
▩	Filling

Soils

▨	Topsoil
▨	Peat
▨	Clay
▨	Silty clay
▨	Sandy clay
▨	Gravelly clay
▨	Shaly clay
▥	Silt
▥	Clayey silt
▥	Sandy silt
▨	Sand
▨	Clayey sand
▥	Silty sand
▨	Gravel
▨	Sandy gravel
▨	Cobbles, boulders
▨	Talus

Sedimentary Rocks

▨	Boulder conglomerate
▨	Conglomerate
▨	Conglomeratic sandstone
▨	Sandstone
▤	Siltstone
▤	Laminite
▤	Mudstone, claystone, shale
■	Coal
▦	Limestone

Metamorphic Rocks

▨	Slate, phyllite, schist
▨	Gneiss
□	Quartzite

Igneous Rocks

▨	Granite
▨	Dolerite, basalt, andesite
▨	Dacite, epidote
▨	Tuff, breccia
□	Porphyry

July 2010

BOREHOLE LOG

CLIENT: St Hilliers Group
PROJECT: Proposed Residential Unit Development
LOCATION: Lot 3008 Lord Sheffield Circuit, Penrith

SURFACE LEVEL: 26.8 AHD
EASTING: 286701
NORTHING: 6263240
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 85755.00
DATE: 21/11/2016
SHEET 1 OF 2

Degree of Weathering: EW HW MW SW FS FR
Rock Strength: Ex Low, Very Low, Low, Medium, High, Very High, Ex High
Fracture Spacing (m): 0.01 0.05 0.10 0.50 1.00
Discontinuities: B - Bedding J - Joint S - Shear F - Fault

Depth (m)	Description of Strata	Water	Sampling & In Situ Testing: Type	Core Rec. %	RQD %	Test Results & Comments
	FILLING - light grey to grey, silty clay and shale fragments filling		A			
			A			
0.7	SILTY CLAY - stiff, light brown silty clay with some fine sand, moist		A			
			S			4,6,8 N = 14
2.0	CLAYEY SAND - medium dense, light grey-brown fine grained clayey sand, moist		S			7,9,10 N = 19
			S			7,7,11 N = 18
5.0	SAND - medium light grey-brown, fine grained sand with some silt and clay, moist 5.7m: becoming wet	▼	S			4,4,12 N = 16
5.9	SANDY GRAVEL - medium dense, light grey-brown clayey sandy gravel and cobbles (very high to extremely high strength sandstone to 300 mm in size), wet. Penrith Gravel					

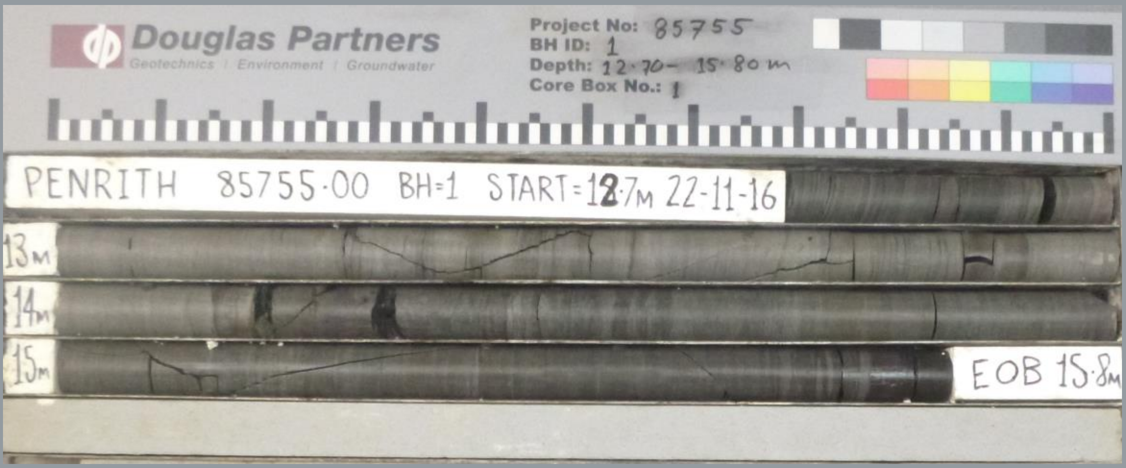
RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HQ to 12.7m
TYPE OF BORING: Solid flight auger to 2.5m; Rotary to 7.0m; ODEX to 12.7m; NMLC-Coring to 15.8m
WATER OBSERVATIONS: Free groundwater observed at 5.7m whilst ODEX drilling
REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
Geotechnics / Environment / Groundwater

BORE 1 PROJECT 85755.00 November 2016



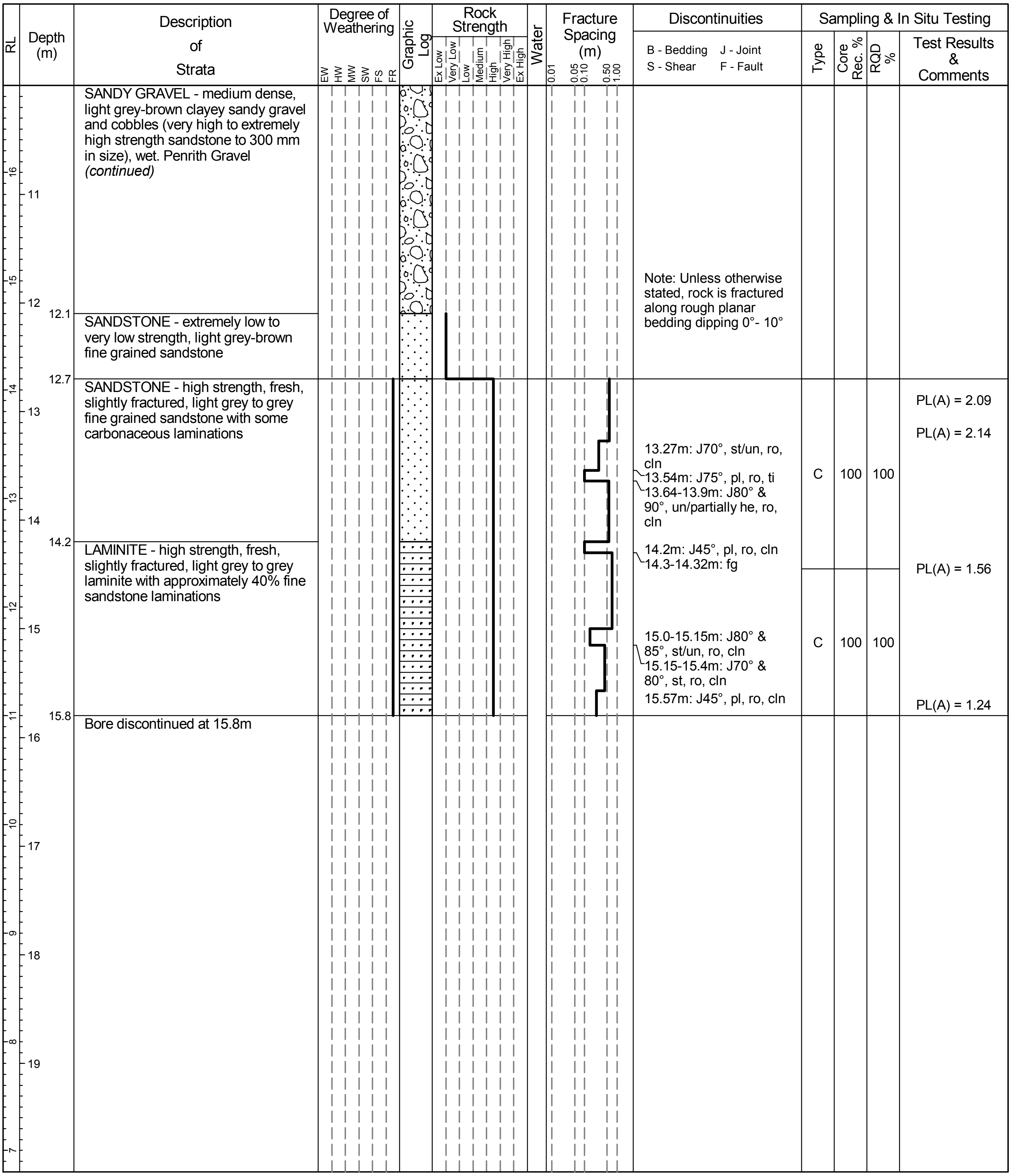
12.7 – 15.8m

BOREHOLE LOG

CLIENT: St Hilliers Group
PROJECT: Proposed Residential Unit Development
LOCATION: Lot 3008 Lord Sheffield Circuit, Penrith

SURFACE LEVEL: 26.8 AHD
EASTING: 286701
NORTHING: 6263240
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 85755.00
DATE: 21/11/2016
SHEET 2 OF 2



Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
	SANDY GRAVEL - medium dense, light grey-brown clayey sandy gravel and cobbles (very high to extremely high strength sandstone to 300 mm in size), wet. Penrith Gravel *(continued)*					
12.1	SANDSTONE - extremely low to very low strength, light grey-brown fine grained sandstone	Note: Unless otherwise stated, rock is fractured along rough planar bedding dipping 0°- 10°				
12.7	SANDSTONE - high strength, fresh, slightly fractured, light grey to grey fine grained sandstone with some carbonaceous laminations	13.27m: J70°, st/un, ro, cln 13.54m: J75°, pl, ro, ti 13.64-13.9m: J80° & 90°, un/partially he, ro, cln	C	100	100	PL(A) = 2.09 PL(A) = 2.14
14.2	LAMINITE - high strength, fresh, slightly fractured, light grey to grey laminite with approximately 40% fine sandstone laminations	14.2m: J45°, pl, ro, cln 14.3-14.32m: fg 15.0-15.15m: J80° & 85°, st/un, ro, cln 15.15-15.4m: J70° & 80°, st, ro, cln 15.57m: J45°, pl, ro, cln	C	100	100	PL(A) = 1.56 PL(A) = 1.24
15.8	Bore discontinued at 15.8m					

RIG: Scout 4 **DRILLER:** RKE **LOGGED:** SI **CASING:** HQ to 12.7m
TYPE OF BORING: Solid flight auger to 2.5m; Rotary to 7.0m; ODEX to 12.7m; NMLC-Coring to 15.8m
WATER OBSERVATIONS: Free groundwater observed at 5.7m whilst ODEX drilling
REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	G	Gas sample	PID	Photo ionisation detector (ppm)
B	Bulk sample	P	Piston sample	PL(A)	Point load axial test Is(50) (MPa)
BLK	Block sample	U_x	Tube sample (x mm dia.)	PL(D)	Point load diametral test Is(50) (MPa)
C	Core drilling	W	Water sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	▷	Water seep	S	Standard penetration test
E	Environmental sample	▼	Water level	V	Shear vane (kPa)

Douglas Partners
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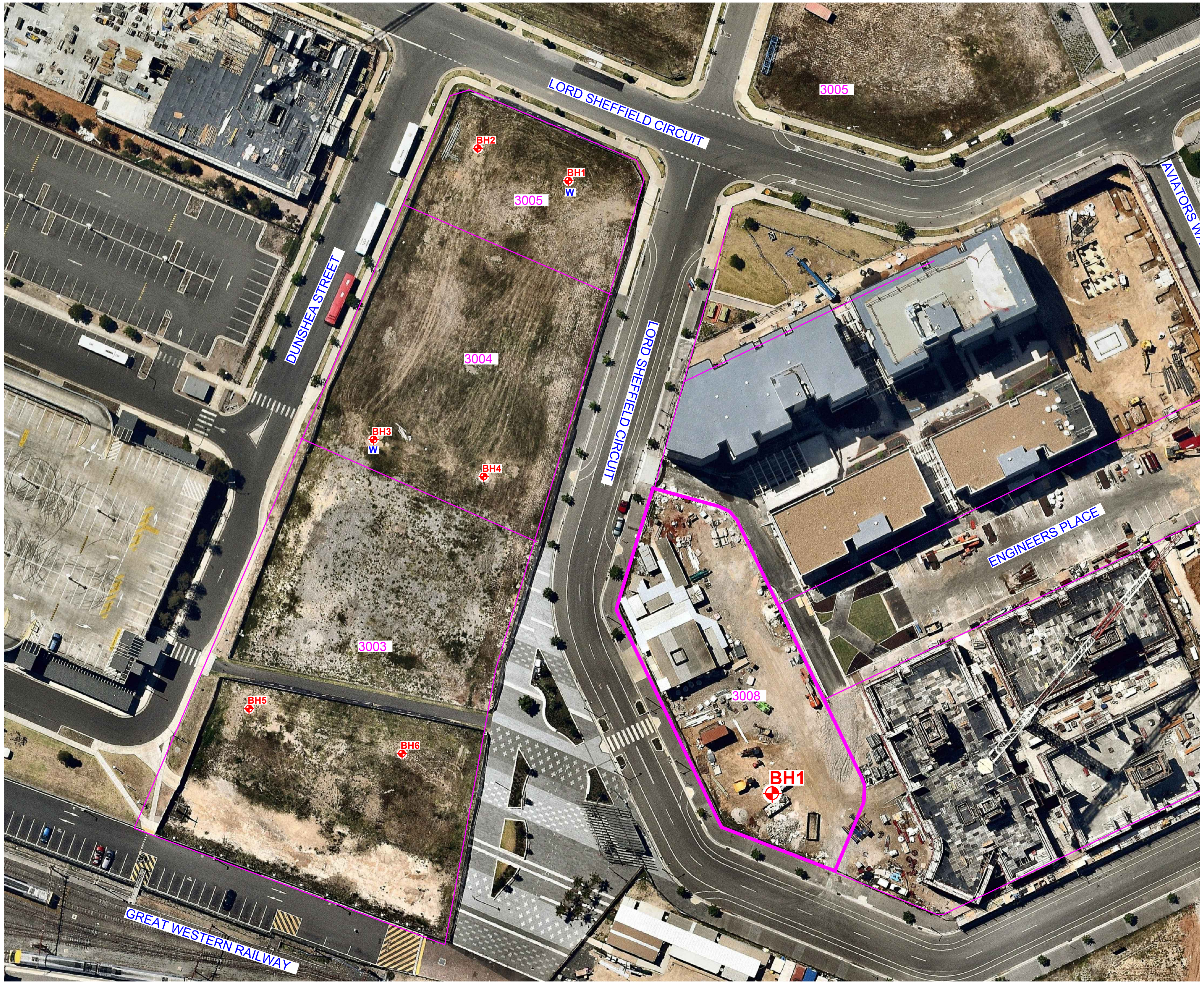

Locality Plan

NOTE:
1: Base image from Nearmap.com
(Dated Novenber 2016)
2: Test locations are approximate only and are shown
with reference to existing features.

0 10 20 30 40 50 75 100m
1:1000 @ A3

LEGEND

⊕ Borehole 1m into bedrock
W Standpipe piezometer
— Site boundary

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Geotechnics / Environment / Groundwater

CLIENT: St Hilliers Group
OFFICE: Sydney
DRAWN BY: PSCH
SCALE: 1:1000 @ A3
DATE: 13.12.2016

TITLE: **Location of Borehole**
Lots 3008
Lord Sheffield Circuit, PENRITH

N

PROJECT No: 85755.00
DRAWING No: 1
REVISION: 0

Appendix B

Results of Laboratory Testing

12 Ashley Street, Chatswood, NSW 2067
tel: +61 2 9910 6200

email: sydney@envirolab.com.au
envirolab.com.au

Envirolab Services Pty Ltd - Sydney | ABN 37 112 535 645

CERTIFICATE OF ANALYSIS 158857

Client:
Douglas Partners Pty Ltd
96 Hermitage Rd
West Ryde
NSW 2114

Attention: Konrad Schultz

Sample log in details:

Your Reference:	**85755.00, Proposed High-Rise Unit Development**
No. of samples:	1 soil
Date samples received / completed instructions received	09/12/2016 / 09/12/2016

Analysis Details:

Please refer to the following pages for results, methodology summary and quality control data.
Samples were analysed as received from the client. Results relate specifically to the samples as received.
Results are reported on a dry weight basis for solids and on an as received basis for other matrices.
Please refer to the last page of this report for any comments relating to the results.

Report Details:

Date results requested by: / Issue Date:	16/12/16 / 14/12/16
Date of Preliminary Report:	Not Issued

NATA accreditation number 2901. This document shall not be reproduced except in full.
Accredited for compliance with ISO/IEC 17025 - Testing **Tests not covered by NATA are denoted with *.**

Results Approved By:

David Springer
General Manager

Misc Inorg - Soil		
Our Reference:	UNITS	158857-1
Your Reference	-------------	BH1
Depth	------------	5.5
Date Sampled		21/11/2016
Type of sample		soil
Date prepared	-	13/12/2016
Date analysed	-	13/12/2016
pH 1:5 soil:water	pH Units	8.7
Electrical Conductivity 1:5 soil:water	µS/cm	120
Chloride, Cl 1:5 soil:water	mg/kg	50
Sulphate, SO4 1:5 soil:water	mg/kg	10

Method ID	Methodology Summary
Inorg-001	pH - Measured using pH meter and electrode in accordance with APHA latest edition, 4500-H+. Please note that the results for water analyses are indicative only, as analysis outside of the APHA storage times.
Inorg-002	Conductivity and Salinity - measured using a conductivity cell at 25oC in accordance with APHA latest edition 2510 and Rayment & Lyons.
Inorg-081	Anions - a range of Anions are determined by Ion Chromatography, in accordance with APHA latest edition, 4110-B. Alternatively determined by colourimetry/turbidity using Discrete Analyer.

QUALITY CONTROL Misc Inorg - Soil	UNITS	PQL	METHOD	Blank	Duplicate Sm#	Duplicate results Base II Duplicate II %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			13/12/2016	[NT]	[NT]	LCS-1	13/12/2016
Date analysed	-			13/12/2016	[NT]	[NT]	LCS-1	13/12/2016
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	[NT]	[NT]	LCS-1	100%
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	[NT]	[NT]	LCS-1	102%
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	96%
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	107%

Report Comments:

Asbestos ID was analysed by Approved Identifier:	Not applicable for this job
Asbestos ID was authorised by Approved Signatory:	Not applicable for this job

INS: Insufficient sample for this test	PQL: Practical Quantitation Limit	NT: Not tested
NR: Test not required	RPD: Relative Percent Difference	NA: Test not required
<: Less than	>: Greater than	LCS: Laboratory Control Sample

Quality Control Definitions

Blank: This is the component of the analytical signal which is not derived from the sample but from reagents, glassware etc, can be determined by processing solvents and reagents in exactly the same manner as for samples.

Duplicate: This is the complete duplicate analysis of a sample from the process batch. If possible, the sample selected should be one where the analyte concentration is easily measurable.

Matrix Spike : A portion of the sample is spiked with a known concentration of target analyte. The purpose of the matrix spike is to monitor the performance of the analytical method used and to determine whether matrix interferences exist.

LCS (Laboratory Control Sample) : This comprises either a standard reference material or a control matrix (such as a blank sand or water) fortified with analytes representative of the analyte class. It is simply a check sample.

Surrogate Spike: Surrogates are known additions to each sample, blank, matrix spike and LCS in a batch, of compounds which are similar to the analyte of interest, however are not expected to be found in real samples.

Laboratory Acceptance Criteria

Duplicate sample and matrix spike recoveries may not be reported on smaller jobs, however, were analysed at a frequency to meet or exceed NEPM requirements. All samples are tested in batches of 20. The duplicate sample RPD and matrix spike recoveries for the batch were within the laboratory acceptance criteria.
Filters, swabs, wipes, tubes and badges will not have duplicate data as the whole sample is generally extracted during sample extraction.
Spikes for Physical and Aggregate Tests are not applicable.
For VOCs in water samples, three vials are required for duplicate or spike analysis.

Duplicates: <5xPQL - any RPD is acceptable; >5xPQL - 0-50% RPD is acceptable.
Matrix Spikes, LCS and Surrogate recoveries: Generally 70-130% for inorganics/metals; 60-140% for organics (+/-50% surrogates) and 10-140% for labile SVOCs (including labile surrogates), ultra trace organics and speciated phenols is acceptable.

In circumstances where no duplicate and/or sample spike has been reported at 1 in 10 and/or 1 in 20 samples respectively, the sample volume submitted was insufficient in order to satisfy laboratory QA/QC protocols.

When samples are received where certain analytes are outside of recommended technical holding times (THTs), the analysis has proceeded. Where analytes are on the verge of breaching THTs, every effort will be made to analyse within the THT or as soon as practicable.

Where sampling dates are not provided, Envirolab are not in a position to comment on the validity of the analysis where recommended technical holding times may have been breached.

Measurement Uncertainty estimates are available for most tests upon request.