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Integrated Practical Solutions

Report on
Limited Geotechnical Investigation

Proposed Business Park
813-913 Wallgrove Road, Horsley Park

Prepared for
Gazcorp Pty Ltd

Project 73207.00
November 2012

Douglas Partners

Geotechnics / Environment / Groundwater

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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
Author		19 November 2012
Reviewer	Michael Thom	19 November 2012

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Report on Limited Geotechnical Investigation
Proposed Business Park
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1. Introduction

This report presents the results of a limited geotechnical investigation undertaken by Douglas Partners Pty Ltd (DP) for a proposed business park at 813-913 Wallgrove Road, Horsley Park. The work was commissioned by Mr Michael De Zilva of Gazcorp Pty Ltd (Gazcorp), owners of the site, and was carried out in accordance with the agreed scope of works, as outlined in DP's proposal dated 2 October 2012.

It is understood that the site is proposed for development into an industrial business park, similar to that located to the north of the site. The current concept plan indicates one central road will enter the site in a westerly direction from Wallgrove Road and will branch into two smaller cul-de-sac roads that head north. The roads will provide access to 15 new industrial lots of varying size that will support warehouses ranging in size from a few thousand square metres to more than 56,000 square metres. Associated road and car parking pavements, offices, subdivisional services and landscaping are also proposed.

The development is currently at the concept design stage where it is envisaged that extensive cut to fill earthworks will be required to level the site from its current undulating landform. The purpose of the investigation was to provide geotechnical comments and advice on the feasibility of earthworks, in particular the excavation of the upper 15 m of the prominent hill at the southern central part of the site.

The geotechnical investigation included the drilling of one borehole, laboratory testing of selected rock core samples recovered from the borehole, followed by engineering analysis and reporting. The details of the field and laboratory work are presented in the report, together with comments on excavation and construction practice.

2. Site Description

The site is located on the western side of Wallgrove Road immediately south of the Sydney water supply pipe lines and opposite the entry to the Austral Bricks site at Horsley Park. The site is an irregularly shaped elongated parcel of land that covers approximately 52 hectares with approximate average dimensions of 1160 m east to west and 450 m north to south.

The ground surface within the site is undulating with a prominent hill located at the southern central part of the site. Ground surface levels fall from the crest of the hill to the north, east and west at approximate slopes generally between two and ten degrees, although slightly steeper in places. Ground surface levels fall from reduced levels of RL 96 m, relative to Australian height datum (AHD) to RL 60 m AHD at the eastern and western ends of the site.

At the time of the site investigation, the site was operating as a rural grazing lot for cattle and horses. There was an unsealed access track along the northern boundary and several sheet metal clad farm sheds scattered across the site. Several rural dams were also present, most situated within the western half of the site.

Substantial vegetation, which included mature tree growth, is present at scattered locations within the site but is mostly at lower elevations to the north, east and west.

3. Geology

Reference to the Sydney 1:100,000 Geological Series Sheet indicates that the site is underlain by Bringelly Shale, which generally consists of shale, carbonaceous claystone, claystone, laminite, fine to medium-grained lithic sandstone, rare coal and tuff. The weathered portion of this formation typically includes clays and silty clays of medium to high plasticity.

The field work confirmed the presence of predominantly shale and siltstone bedrock, with sandstone beds from a depth of 1.1 m. Overlying soils comprised shallow topsoil and silty clay.

4. Field Work Methods

The field work was conducted over two days on 8 and 9 October 2012. The geotechnical investigation included:

- A walkover inspection of the site by a senior geotechnical engineer.
- Drilling of one borehole (BH1) using a truck-mounted DT100 drill rig. Initially the bore was drilled using solid flight augers fitted with a Tungsten-Carbide (TC) bit until practical refusal on rock occurred at a depth of 1.7 m. Drilling was then advanced within extremely low strength rock to 2.5 m depth by rotary wash bore methods and then further advanced to a depth of 18 m within higher strength rock using NMLC diamond core methods. Borehole BH1 was sited close to the top of the hill at the southern central part of the site.
- Standard penetration test (SPT) at 1 m depth in the overburden materials where silty clay was intersected.
- Collection of soil and rock core samples from the borehole for examination, logging and to provide laboratory test specimens for point load strength index testing.

The borehole location was selected to coincide with the highest point of the site where the proposed excavation for bulk earthworks will be the deepest. The approximate borehole location is shown on Drawing No. 1, presented in Appendix B. The location was chosen based on drill rig accessibility and existing buried services. Prior to drilling at the site, the bore location was scanned for the presence of in-ground service lines. The surface level for the borehole was interpolated from the site survey plan provided by Gazcorp and prepared by A Allen Consulting Surveyors Pty Ltd (Ref No. 004-08, dated 14 February 2008). The interpolated level is provided on the borehole log presented in Appendix C.

5. Field Work Results

Details of the subsurface conditions encountered are given on the borehole log presented in Appendix C, together with notes defining classification methods and descriptive terms.

A summary of the typical sequence of subsurface conditions encountered at BH1 is presented below:

Topsoil:	Comprising approximately 100 mm thickness of brown, fine grained sandy clay with some grass rootlets. The topsoil was generally firm and moist.
Residual Clay: (Natural)	Intersected below the topsoil and extending to a depth of 1.1 m. Consisting of brown, silty clay with a trace of fine grained sand. The clay was generally stiff to very stiff and moist.
Weathered Rock:	Intersected from a depth of 1.1 m and consisting of interbedded sandstone, siltstone and shale. The rock was initially highly weathered from 2.5 m depth, slightly weathered from 4.8 m depth and then fresh below 10.5 m depth. The rock was initially of typically low strength (varies between extremely low and medium strength) to a depth of 7.2 m and then remained medium strength to a depth of 16 m before increasing to high strength. The degree of fracturing varied considerably above 9 m depth, although was mostly less fractured within the sandstone layers. The rock was slightly fractured to unbroken below a depth of 9 m. Bedding was essentially near horizontal and joints ranged in slope angle from 30 to 40 degrees in sandstone to 30 to 90 degrees in siltstone and shale. Thin clay seams and clay smears were identified in the rock core sample, generally along bedding separations.

No free groundwater was encountered during auger drilling. Once water was introduced into the borehole to facilitate rotary and NMLC drilling, further observation of groundwater seepage flows and levels was precluded. Long term/ongoing groundwater depth monitoring was beyond the scope of the investigation.

6. Laboratory Testing

Rock core samples were collected from borehole BH1 during the field investigation. Several sub-samples of the core were subjected to point load strength index testing in their axial direction for classification according to rock strength. The test results are presented on the log sheets in Appendix C, at the relevant depth.

7. Proposed Development

The proposed development will ultimately include the construction of a new business park at the site. The current concept plan for the business park indicates one central road will enter the site in a westerly direction from Wallgrove Road and will branch into two smaller cul-de-sac roads that head north. The roads will provide access to 15 new industrial lots of varying size that will support warehouses ranging in size from a few thousand square metres to more than 56,000 square metres.

Associated road and car parking pavements, offices, subdivisional services and landscaping are also proposed. A copy of the current concept plan is presented in Appendix B.

The development is currently at the concept design stage where it is envisaged that extensive cut to fill earthworks will be proposed to level the site from its current undulating landform. Excavation to a depth of approximately 15 m below the crest of the hill at the southern central part of the site is proposed.

8. Geotechnical Model

Based on the investigation results, current site conditions below the hill at the southern central part of the site can be characterised as including a shallow topsoil layer overlying natural clay soils to a depth of approximately 1.1 m overlying weathered and fractured to slightly fractured sandstone, siltstone and shale bedrock.

Proposed cut to fill bulk earthworks will result in excavation of the upper 15 m of the hill and thus will remove all overburden soils. Excavation will also remove all underlying highly to slightly weathered, extremely low to medium strength sandstone and siltstone, as well as approximately 4.5 m depth of fresh, low to medium strength shale. A bulk excavation depth of approximately RL 81 m AHD has been assumed. Based on the ground surface level recorded for borehole BH1, the rock surface lies at the reduced level listed in Table 1 below.

Table 1: Level at Rock Surface from Bore Log

Bore No.	Rock Depth (m)	Rock Surface Level (AHD)
BH1	1.1	Approx. 95.0

The rock core sample extracted from BH1 is fractured to slightly fractured to an approximate depth of 7.2 m, then slightly fractured to 13 m depth and slightly fractured to unbroken to a depth of 15 m and beyond. The core sample also showed some inclined joints, most dipping at slopes of 30 to 40 degrees in sandstone and 30 to 90 degrees in siltstone and shale.

Although point load index strength testing indicates predominantly low to medium rock strengths, it is likely that some higher strength bands will be encountered, although the fractured nature of the rock and the presence of joints will facilitate ripping and excavation. Higher strength rock may require additional effort to break down into a suitable size for reuse as filling (say 150 mm minus). Based on the result of the one borehole, the approximate depth to each rock class is presented in Table 2.

Table 2: Summary of Geotechnical Model

Bore No.	Surface RL (AHD)	Approx. Depth (m) to / RL (AHD) at Top of Various Bedrock Classes			
		Class V	Class IV	Class III	Class II
BH1	96.0	1.1 / 94.9	2.4 / 93.6	4.8 / 91.2	8.7 / 87.3

9. Comments

9.1 Excavation

Based on the advised excavation depth of 15 m at the highest point on the site it is considered that excavation will encounter a thin layer of overburden soils and then mostly siltstone and shale at lower elevations with some sandstone near the crest of the hill. Given the near horizontal nature of rock bedding, it is likely that the sandstone layer will be restricted to the upper parts of the hill and that siltstone and shale will outcrop within excavations at lower elevations. Excavations within soil will require the use of at least medium sized excavators and scrapers for excavation efficiency.

Excavations within the underlying fractured to slightly fractured rock will require larger plant, including large dozers of at least D10 size for pre-ripping, 30 tonne excavators fitted with rock hammers for higher strength layers and possibly large scrapers for loading and carting of spoil to filling areas, subject to rock size. Large rock fragments may result on ripping which may necessitate load and transport by trucks. If scrapers are suited to the task, they will probably need to work in pairs for push-pull loading and will probably require pushing by large dozer. The geometry of rock joints, fractures and bedding planes will assist site excavation.

Excavations will remove rock of various classes and strengths. Although Table 2 in Section 8 provides approximate reduced levels for the top of each rock class at the one test borehole, contractors are advised that higher strength rock is also likely, particularly when encountering sandstone layers or deep within the excavation. It is probable that a considerable portion of Class II siltstone and shale will be exposed on this site within excavation depths exceeding 8 m. Hence, contractors tendering for the work should select appropriate excavation machinery.

Although the earthworks are expected to be cut to fill balanced, any excavated material to be disposed of off-site should be tested for contaminants to allow Waste Classification Assessment in accordance with NSW EPA requirements. DP would be pleased to assist with this work, if required.

9.2 Earthworks

Earthworks will be required to raise ground surface levels above current levels within the northern, eastern and western parts of the site. The following site preparation and filling placement measures are recommended:

- Prior to filling commencement, remove all vegetation and root affected soil from the proposed filling area.
- Rip the exposed surface to a depth of not less than 300 mm and recompact to a minimum dry density ratio of 98%, relative to Standard compaction, adjusting the moisture content of the ripped and recompacted surface to within 2% of Standard optimum moisture content. Proof roll the treated surface using a minimum 10 tonne smooth drum roller in non-vibration mode. The surface should be rolled with a minimum of six passes with the last two passes observed by an experienced geotechnical engineer to detect any ‘soft spots’.
- Any heaving materials identified during proof rolling should be treated as directed by the geotechnical engineer, which is likely to require the localised removal and replacement of unsuitable soil.

- Place all new filling in layers of 300 mm maximum compacted thickness. The filling should be free of oversize particles (>150 mm) and deleterious material.
- Compact all filling to a minimum dry density ratio of 98%, relative to Standard compaction, whilst maintaining a moisture content within 2% of Standard optimum moisture content. The minimum dry density ratio should be increased to 100% relative to Standard compaction within the upper 300 mm of pavement subgrades and building footprints. A maximum dry density ratio of 102% is recommended for all filling to reduce the potential for swelling post-compaction.
- Maintain the moisture within the clay until the area is covered by buildings or pavements. Recent monitoring of foundation/floor slab movement measured heave of up to 60 mm for a warehouse floor slab cast on dry clay filling.
- Density testing of the filling should be carried out in accordance with AS3798 “Guidelines for Earthworks for Commercial and Residential Developments”. Filling placed beneath building platforms and pavements should be carried out to a Level 1 inspection and testing programme.

The same filling placement measures are recommended when removing existing dams and backfilling with controlled filling. Prior to placement of filling though, it will be necessary to pump out all existing water from the dam, remove all soft and wet sediments from the sides and base, remove all existing filling within dam embankments and strip the base of each dam to a suitable natural ground surface. Once stripped and prepared, all dams should be inspected by an experienced geotechnical engineer. The base on which filling is proposed should be proof rolled in the presence of the geotechnical engineer.

9.3 Further Geotechnical Investigations

This report has addressed proposed excavation and filling activities only. For detailed design and construction of the business park, including individual development of each industrial lot, further geotechnical investigations would be required to address design and construction issues pertaining to:

- Retaining walls and possibly anchor design;
- Shallow and deep footing systems and foundation design parameters;
- Detailed excavation for footings and service trenches;
- Groundwater and seepage; and
- Road pavements.

10. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for the proposed business park at 813-913 Wallgrove Road, Horsley Park in accordance with DP’s proposal dated 2 October 2012 and acceptance received from Mr Michael De Zilva from Gazcorp Pty Ltd (Gazcorp) dated 4 October 2012. The work was carried out under DP’s conditions of engagement. This report is provided for the exclusive use of Gazcorp for the specific project and purpose as described in the report. It should not be used for other projects, other sites or by a third party. DP has necessarily relied upon information provided by the client and/or their agents.

The results provided in the report are considered to be indicative of the sub-surface conditions on the site only to the depths investigated at the specific sampling and/or testing locations, and only 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 the attached notes 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.

Douglas Partners Pty Ltd

Appendix A

About this Report

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

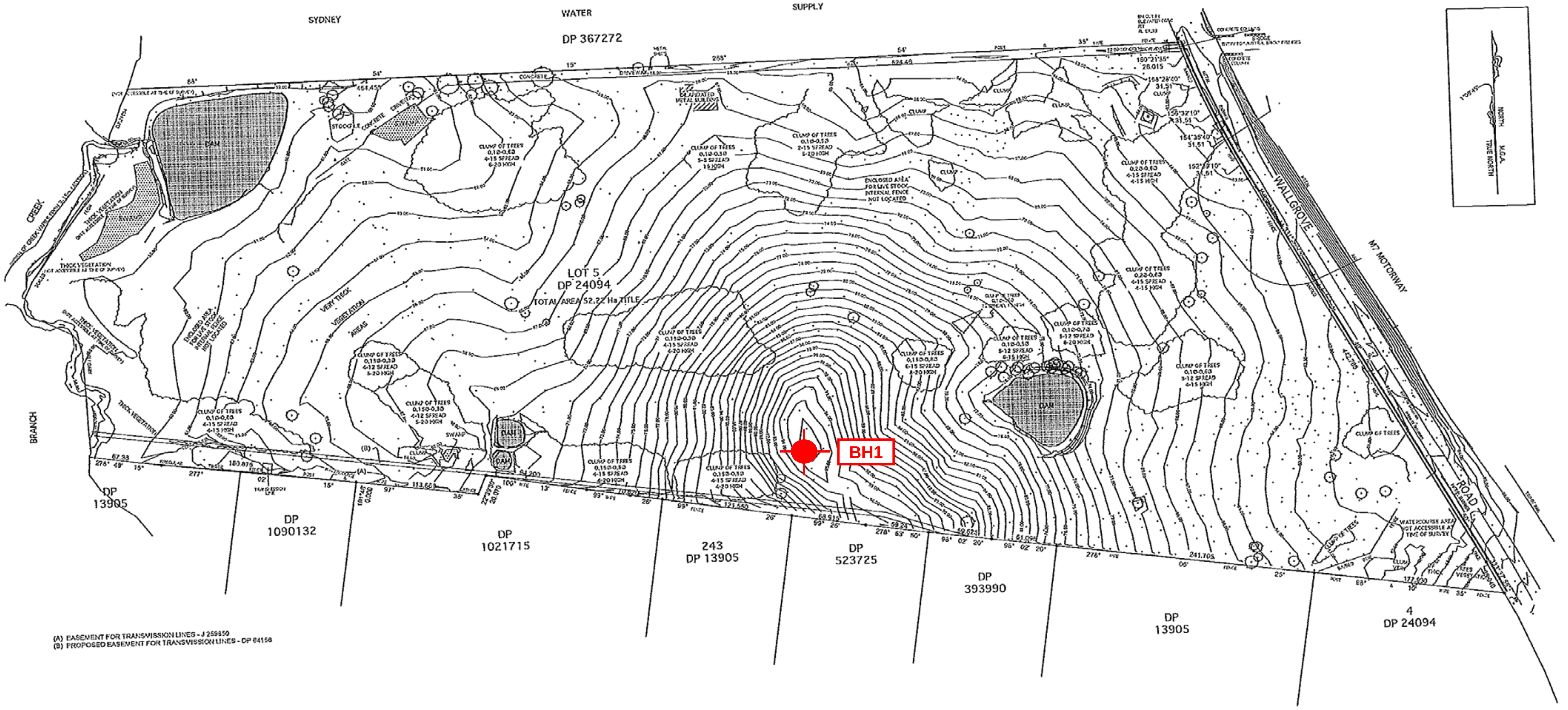
Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate 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.

Appendix B

Drawing No. 1 – Approximate Location of Borehole



Base survey plan prepared by A Allen Consulting Surveyors Pty Ltd, Ref No.004-08, Issue A

● Borehole

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Gazcorp Pty Ltd		
OFFICE:	Sydney	DRAWN BY:	RCB
SCALE:	As marked	DATE:	7.11.12

TITLE: **Approximate Location of Borehole**
Proposed Business Park
813-913 Wallgrove Road, Horsley Park

PROJECT No: 73207.00
DRAWING No: 1
REVISION:

Appendix C

Field Work Results

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.

Soil Descriptions

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

Douglas Partners

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

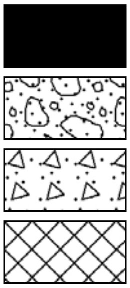
fg	fragmented
bnd	band
qtz	quartz

July 2010

Symbols & Abbreviations

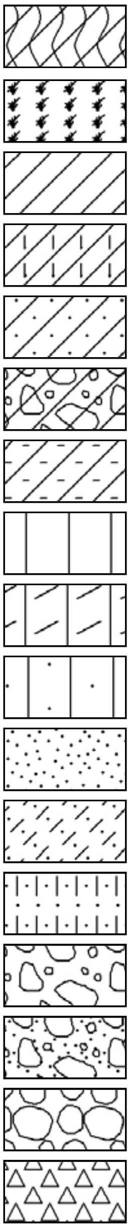
Graphic Symbols for Soil and Rock

General



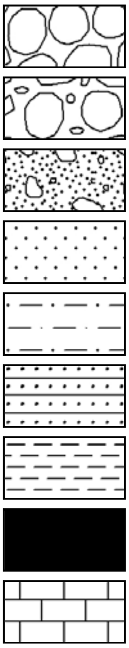
- Asphalt
- Road base
- Concrete
- Filling

Soils



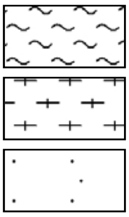
- Topsoil
- Peat
- Clay
- Silty clay
- Sandy clay
- Gravelly clay
- Shaly clay
- Silt
- Clayey silt
- Sandy silt
- Sand
- Clayey sand
- Silty sand
- Gravel
- Sandy gravel
- Cobbles, boulders
- Talus

Sedimentary Rocks



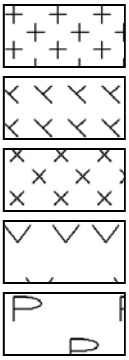
- Boulder conglomerate
- Conglomerate
- Conglomeratic sandstone
- Sandstone
- Siltstone
- Laminite
- Mudstone, claystone, shale
- Coal
- Limestone

Metamorphic Rocks



- Slate, phyllite, schist
- Gneiss
- Quartzite

Igneous Rocks



- Granite
- Dolerite, basalt, andesite
- Dacite, epidote
- Tuff, breccia
- Porphyry

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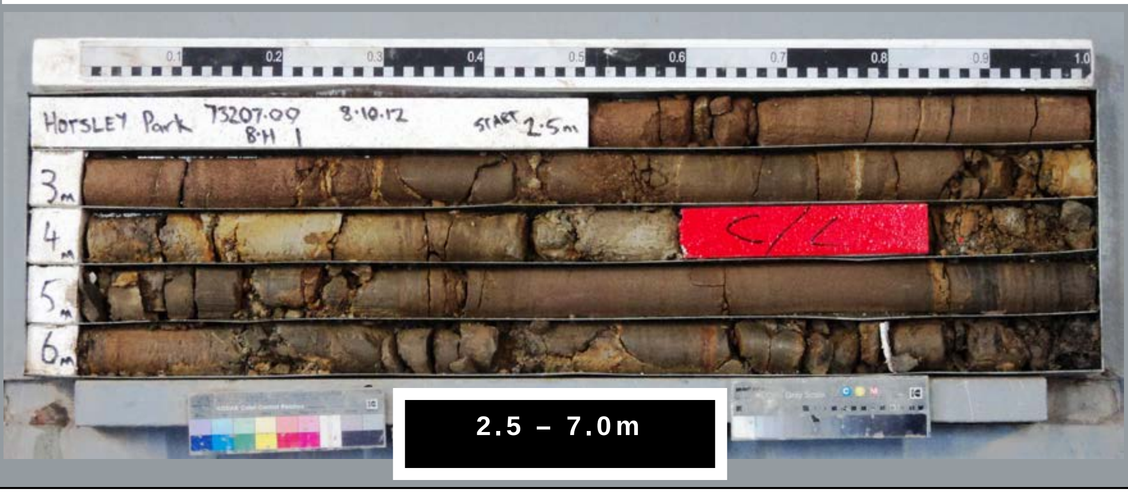
BORE 1 PROJECT 73207 OCT 2012



2.5 – 7.0m

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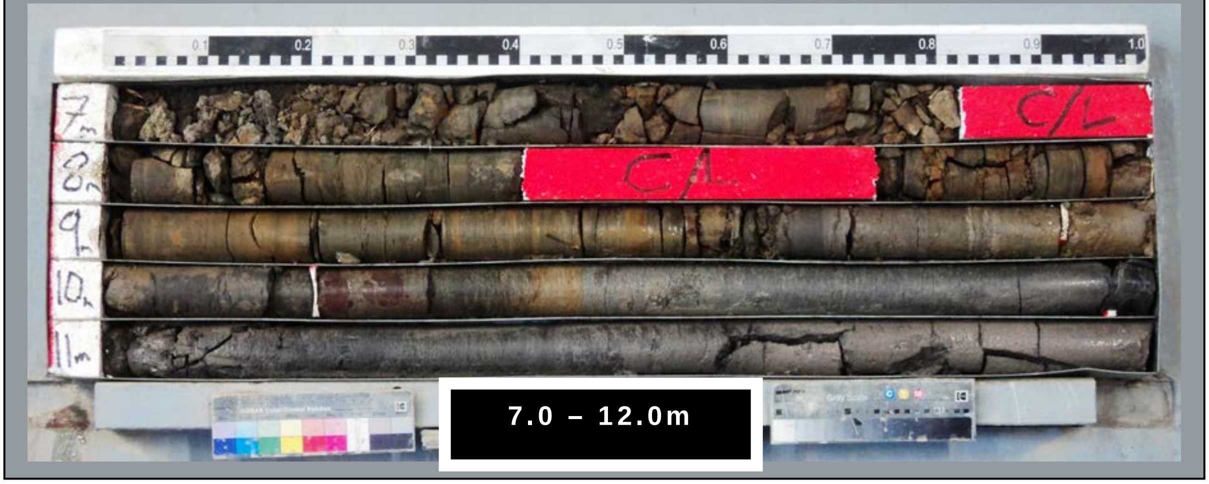
PROPOSED BUSINESS CENTRE – HORSLEY PARK

BORE 1 PROJECT 73207 OCT 2012



7.0 – 12.0m

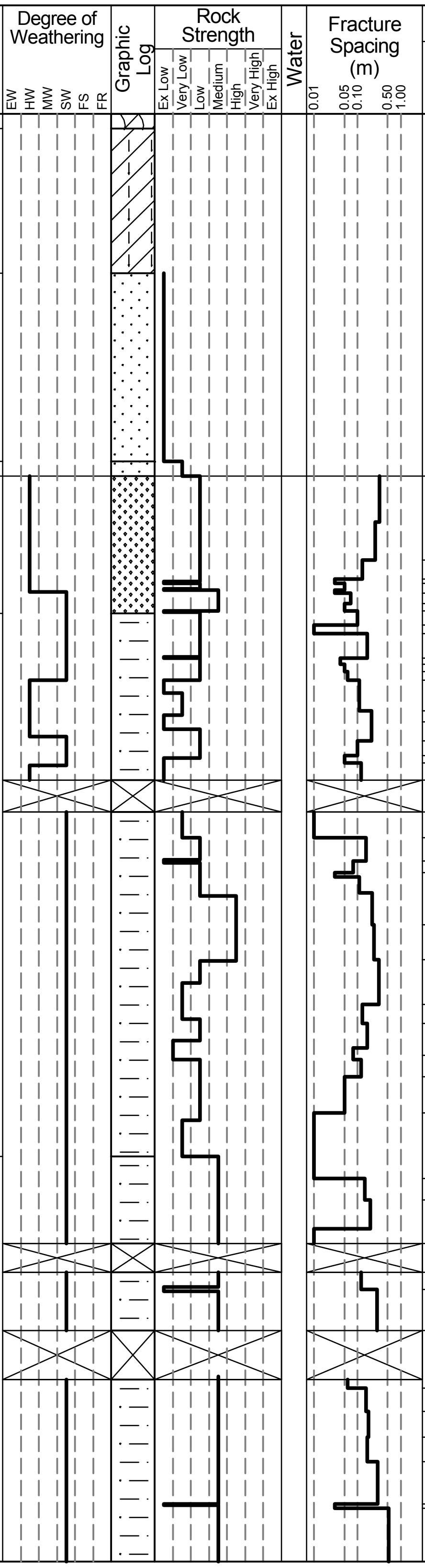
BOREHOLE LOG

CLIENT: GAZCORP Pty Ltd
PROJECT: Proposed Business Centre
LOCATION: 813-913 Wallgrove Rd, Horsley Park

SURFACE LEVEL: 96.0 AHD*
EASTING: 300830
NORTHING: 6255190
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 73207
DATE: 8/10/2012
SHEET 1 OF 2

RL	Depth (m)	Description of Strata
96	0.1	TOPSOIL - brown, fine grained sandy clay topsoil with some grass rootlets, damp
		SILTY CLAY - brown, silty clay with trace of fine grained sand, moist
95	1.1	SANDSTONE - extremely low strength, light grey-brown, fine to medium grained sandstone
94	2.4	SANDSTONE - very low strength, brown, fine to medium grained sandstone
	2.5	SANDSTONE - low strength, highly weathered, fractured and slightly fractured, brown, medium grained sandstone
93	3.45	SILTSTONE - low strength, highly and slightly weathered, fractured and slightly fractured, grey-brown siltstone. Some extremely low and very low strength bands
91	4.82	
90		5.4-5.85m: high strength, fine grained sandstone band
89		6.65-7.2m: fragmented to fractured
	7.2	SILTSTONE - medium strength, slightly weathered, slightly fractured, grey-brown siltstone with some fine grained sandstone laminations. Some extremely low strength bands
88	8.0	
87	8.74	



Discontinuities

B - Bedding J - Joint
S - Shear F - Fault

Note: Unless otherwise stated, rock is fractured along rough planar bedding dipping 0°- 10°

2.82m: B10°, fe, cly co, 2mm
3.08m: B5°, he
3.21m: J30°, ro, un, fe, cly
3.24 & 3.29m: B0°- 5°, fe, cly
3.31m: J45°- 55°, ro, cu, fe, cly
3.38m: J25°- 55°, ro, st, fe
3.43m: B0°- 5°, fe, cly, 5mm
3.53m: B0°, fe, cly, 3mm
3.59m: B0°, fe, cly, 2mm
3.76m: B0°, fe, cly & J50°, he
3.8m: B5°, fe
3.85m: J45°, ro, pl, fe
3.91-4.0m: Ds, 90mm
4.12-4.25m: Ds, 130mm
4.2m: B5°, fe, cly
4.33m: B5°, fe
4.43m: J45°, sm, pl, cln
4.48-4.6m: Ds, 120mm
4.6m: CORE LOSS: 220mm
4.82-5.0m: fg
5.0-5.2m: J, sv, ro, un, fe, cly
5.16m: B5°, fe, cly, 5mm
5.24-5.38m: B (x3) 0°, fe, cly co
5.6m: J90°, ro, pl, fe
5.84m: B0°, fe, cly, 10mm
6.15m: J85°, ro, un, fe, cly
6.28m: J45°, ro, pl, cln
6.5 & 6.53m: J65°, ro, un, fe, cly
6.65m: J85°, ro, un, fe, cly
6.65-6.9m: B (x5) 0°- 5°, fe
6.9-7.35m: fg, fe (possible drilling break)
7.35m: J75°, ro, un, fe
7.5m: J85°, ro, pl, fe
7.8m: CORE LOSS: 200mm
8m: J70°, ro, pl, cln
8.12m: B0°, cly, 10mm

Sampling & In Situ Testing

Type	Core Rec. %	RQD %	Test Results & Comments
A			
A			
A			
S			12,19,25/100mm refusal
C	100	60	PL(A) = 0.2 PL(A) = 0.4
C	92	37	PL(A) = 0.2 PL(A) = 2
C	100	20	PL(A) = 0.2 PL(A) = 0.5
C	74	68	PL(A) = 0.5 PL(A) = 0.7

RIG: DT100 **DRILLER:** SS **LOGGED:** SI **CASING:** HW to 2.0m
TYPE OF BORING: Solid flight auger to 1.7m; Rotary to 2.5m; NMLC-Coring to 18.0m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: 50% water loss at 6.3m. Level interpolated from A Allen Consulting Surveyors Pty Ltd plan, Ref No. 004-0.8, Issue A

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)

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BORE 1 PROJECT 73207 OCT 2012

12.0 – 17.0m

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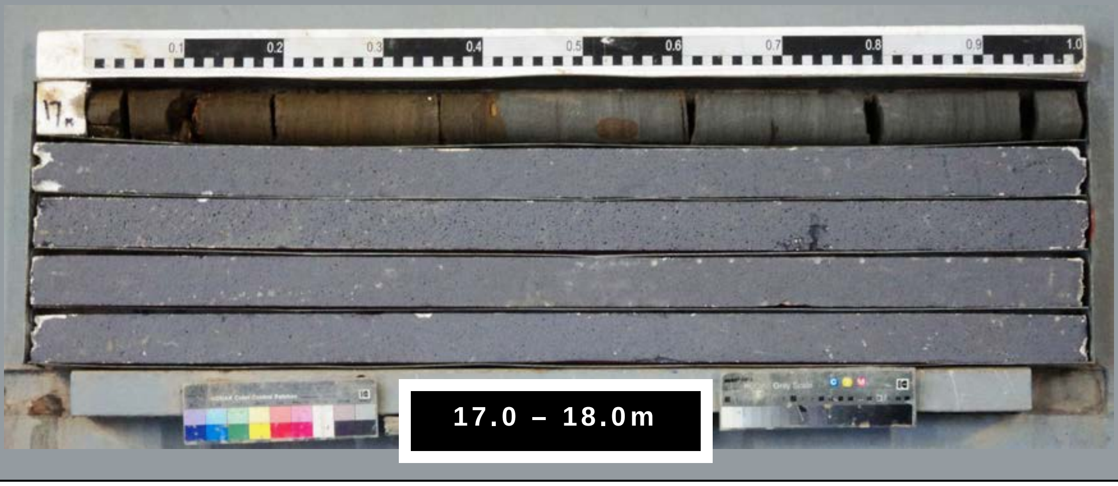
PROPOSED BUSINESS CENTRE – HORSLEY PARK

BORE 1 PROJECT 73207 OCT 2012



17.0 – 18.0m

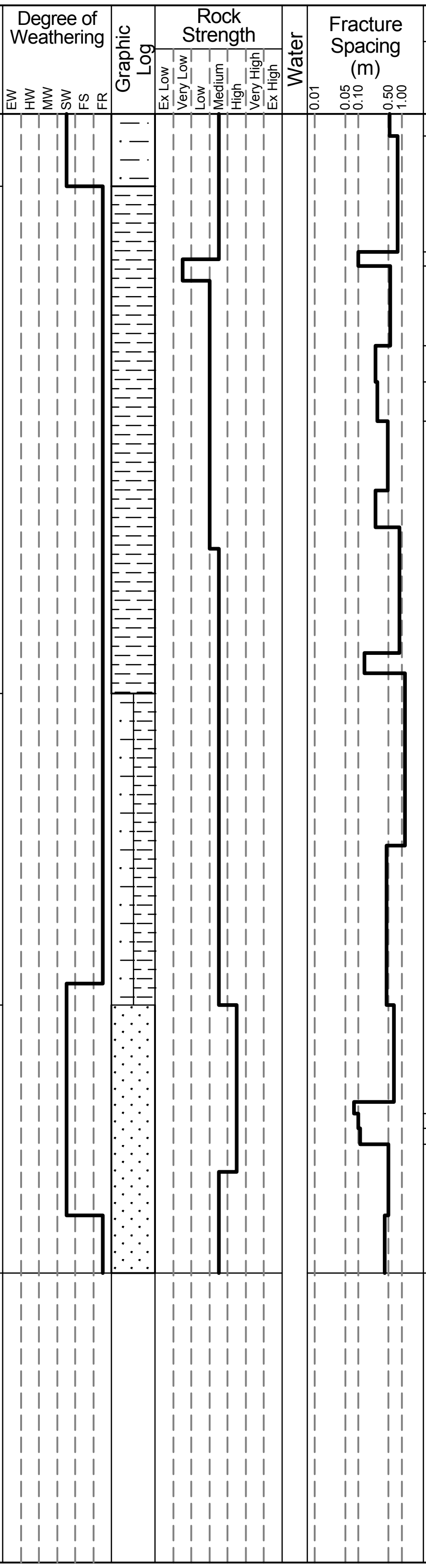
BOREHOLE LOG

CLIENT: GAZCORP Pty Ltd
PROJECT: Proposed Business Centre
LOCATION: 813-913 Wallgrove Rd, Horsley Park

SURFACE LEVEL: 96.0 AHD*
EASTING: 300830
NORTHING: 6255190
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 73207
DATE: 8/10/2012
SHEET 2 OF 2

RL	Depth (m)	Description of Strata
86		
	10.5	SHALE - low to medium and medium strength, fresh, slightly fractured, grey shale
85	11	
84	12	
83	13	
82	14 14.0	SILTSTONE/SHALE - medium strength, fresh, slightly fractured and unbroken, grey-brown siltstone/shale
81	15	
80	16	
	16.15	SANDSTONE - high then medium strength, slightly weathered then fresh, slightly fractured, light grey-brown to grey, fine to medium grained sandstone with some siltstone laminations
79	17	
78	18 18.0	Bore discontinued at 18.0m
77	19	



Discontinuities

B - Bedding J - Joint
S - Shear F - Fault

8.4m: CORE LOSS: 340mm
8.8m: J75°, ro, un, fe
8.96m: J70°, ro, pl, fe
9.14m: J45°, ro, pl, fe
9.31m: B0°, fe
9.6m: B0°, cln
9.63m: B0°, cly, 10mm
10.15m: J35°, sm, pl, cln
10.95m: J30°, sm, pl, cln
11.05m: J65°, sm, pl, cln
11.6m: J90°, ro, un, cln
11.85m: J85°, ro, pl, cln
12.12m: J35°, sm, pl, cly
12.6m: B0°, cly vn
12.85m: J70°, ro, un, cln
13.72m: J70°, ro, un, cln
13.86m: J45°, ro, un, cln
15.05m: B0°, fe
15.5m: J75°, ro, un, cln
16.15m: J55°, ro, un, fe
16.82m: J40°, ro, un, fe
16.9m: B0°, fe
17m: J90°, ro, un, fe
17.11m: B0°, fe
17.6m: B0°, fe

Sampling & In Situ Testing

Type	Core Rec. %	RQD %
C	100	100
C	100	93
C	100	100
C	100	97

Test Results & Comments

PL(A) = 0.4
PL(A) = 0.5
PL(A) = 0.3
PL(A) = 0.3
PL(A) = 0.5
PL(A) = 0.4
PL(A) = 0.9
PL(A) = 0.4
PL(A) = 0.4
PL(A) = 1.3
PL(A) = 2.3
PL(A) = 0.8

RIG: DT100 **DRILLER:** SS **LOGGED:** SI **CASING:** HW to 2.0m

TYPE OF BORING: Solid flight auger to 1.7m; Rotary to 2.5m; NMLC-Coring to 18.0m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS: 50% water loss at 6.3m. Level interpolated from A Allen Consulting Surveyors Pty Ltd plan, Ref No. 004-0.8, Issue A

SAMPLING & IN SITU TESTING LEGEND

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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)

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