Douglas Partners
Geotechnics / Environment / Groundwater

Report on
Geotechnical Investigation

Proposed North Kellyville New Primary School
120-126 Hezlett Road, Kellyville

Prepared for
GHD Pty Ltd

Project 85998.00
August 2017

Integrated Practical Solutions

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
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Reviewer	Michael	22 August 2017

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Report on Geotechnical Investigation
Proposed North Kellyville New Primary School
120-126 Hezlett Road, Kellyville

1. Introduction

This report presents the results of geotechnical investigations undertaken by Douglas Partners Pty Ltd (DP) for the proposed new school site at 120-126 Hezlett Road, Kellyville. The investigation was carried out in accordance with DP's proposal SYD170387 Rev1 dated 10 May 2017, and subsequent email proposal for additional investigations for Lot 100 in DP 1216659 (Lot 100), dated 12 July 2017. The first phase of work was commissioned on 10 May 2017 by Mr Michael Abbott of GHD Pty Ltd, and the second phase by Mr Michael Dean of GHD Pty Ltd on 19 July 2017. The work was undertaken in consultation with Mr Carl Sakellaris of GHD Pty Ltd, project manager for the development.

It is understood that development will include the construction of a two-storey building with a footprint of approximately 4000 m^2. It is further understood that the facade of the proposed building is likely to be a lightweight cladding system such as FD cladding. Site investigation was carried out to provide information on subsurface conditions for the design of earthworks, excavatability, retaining walls and foundations.

The investigation, completed in two phases during June 2017 and July 2017, included the drilling of fourteen boreholes, and laboratory testing of selected soil samples recovered from the boreholes. Details of the field work are presented in this report, together with comments and recommendations on the items described above.

The site is legally known as Lot 100 and 101 in DP 1216659, but commonly known as 120-126 Hezlett Road, Kellyville. It is noted that the site was formerly known as 56-58 Hezlett Road, Kellyville, but it is understood that due to the extent of anticipated development in the area, the road was renumbered during 2016.

2. Site Description and Regional Geology

The site is located at 120-126 Hezlett Road, Kellyville (Lots 100 and 101 in DP 1216659). The site is rectangular in shape, with an area comprising approximately 3.89 hectares, with maximum north to south and east to west dimensions of 130 m and 280 m, respectively.

The site is generally vacant, with the majority of the site being grassed open area, with two approximately 30 m by 50 m dams on the western portion of the site. Ripped topsoil was located on the eastern portion of the site and localised accumulations of building debris in the southern portion of the site. An unsealed access road (Prentice Avenue Extension) runs in an approximate east to west direction, roughly 30 m from the southern boundary of the site. Localised large trees were observed near the dams, and smaller trees were also found scattered throughout the site. A filling stockpile approximately 4 m in height was observed along the southern boundary of the site, just southeast of the dam in the south-western corner of the site.

Topographically, the site slopes downwards toward the west from approximately RL 82 m to RL 74 m, with a total elevation change of over 8 m (i.e. average slope of about 2 degrees).

The site is bounded by Hezlett Road to the east, residential dwellings to the north, vacant bushland to the west and a semi-rural property along the southern boundary.

The approximate site boundaries and features are shown on Drawing 1 in Appendix B.

Reference to the Sydney 1:100 000 Geological Series Sheet indicates that the site is located in an area underlain by Ashfield Shale of the Triassic Group. The Ashfield Shale generally consists of laminite and dark grey siltstone. Overlying soils are typically clayey, moderately to highly reactive and of a low permeability. Field investigation confirmed the presence of Ashfield Shale underlying the site.

Review of available Acid Sulfate Soils Maps indicates that the site is located well outside areas potentially affected by Acid Sulfate Soils (ASS). ASS normally occurs in alluvial or estuarine soils below RL 12 m relative to Australian Height Datum. The subject site is above RL 74 m AHD and includes residual soils, and it is therefore unlikely that ASS is present in natural soils at the site.

3. Field Work

3.1 Methods

The field work included the following:

- Borehole drilling, which was commenced using spiral flight augers, and with four boreholes extended into the underlying rock using rotary coring techniques to obtain 50 mm diameter samples of the underlying rock.
- During the first phase of investigation, three rock cored boreholes (Boreholes 1 to 3) and five shallow boreholes (Boreholes 4 to 8) were drilled using a bobcat-mounted drilling rig, with standard penetration tests (SPT) undertaken at 1.0 m depth within the soil in all bores (excluding Boreholes 5 and 8, due to prior auger refusal) for strata identification and to assess the insitu strength. The rock cored boreholes were drilled to depths in the range 3.40 m to 7.36 m.
- During the second phase of investigation, the same rig was re-mobilised to the site to drill a fourth rock cored borehole (Borehole 10), and four shallow boreholes for collection of bulk samples (Boreholes 9, 11, 12, and 14: terminated at depths of between 0.4 m and 0.6 m). Six of the shallow boreholes were continued to practical refusal at depths in the range 0.85 m to 2.3 m. Sampling of residual soils was completed in a fifth shallow borehole (Borehole 13), which was excavated using hand tools.
- Collection of disturbed samples and ‘undisturbed’ U50 tubes from the upper clay portions of four boreholes (Boreholes 1, 3, 9 and 10); and
- Logging of the soil and rock profile in each borehole.

All field work was carried out under the direction of an experienced geotechnical engineer. It is noted that minor alterations have been made to the borehole logs from the first phase of work.

Borehole locations are given in Drawing 1, Appendix B. The surface levels (relative to Australian Height Datum (AHD)) for most test locations were inferred using the provided survey drawing prepared by C.M.S. Surveyors Pty Ltd (Drawing 15977, Issue 1), with position co-ordinates estimated using the software package “Google Earth Pro”. The co-ordinates and surface levels are considered to have an approximate accuracy of 0.5 m in both plan and elevation, with the exception being for Boreholes 9 and 10, which were surveyed using a differential GPS, with an inferred accuracy of 0.1 m in both plan and elevation. The co-ordinates and surface levels are shown on the borehole logs.

3.2 Results

Details of the conditions encountered in the boreholes are presented in Borehole Logs in Appendix C. Explanatory notes defining classification methods and descriptive terms used in logging the boreholes are also given in Appendix C.

The typical progression of strata encountered in the boreholes is:

TOPSOIL:	Clayey silt topsoil with some localised sand and gravel and surficial vegetation to depths of 100 mm to 400 mm in all bores except Borehole 2;
FILLING:	Brown silty clay filling in Borehole 9 and 10 (Lot 100) to depths of between 0.4 m to 0.7 m, and 0.2 m to 0.4 m along the southern portion of the site (Borehole 13 and 14), with some gravel and sand to depths of between 0.5 m and 0.6 m (Borehole 3 and 6, respectively), and gravelly sand filling to 0.25 m in Borehole 2.
RESIDUAL CLAY:	Stiff to very stiff silty clay, with trace ironstone gravel, to depths in excess of 0.6 m, to 2.0 m depth in Borehole 4 (eastern site boundary);
WEATHERED SHALE / LAMINITE:	Extremely low to low strength, extremely weathered grey, brown and orange brown shale or laminite, generally low to medium strength and highly to moderately weathered from 0.2 m below the top of rock. Shale generally highly fractured to fragmented.
SILTSTONE / LAMINITE:	Medium to high strength, slightly weathered to fresh, grey, highly fractured to fractured and locally fragmented from depths of between approximately 4.3 m to 5.6 m for Lot 101, and from depths of between 0.5 m to 0.9 m in Lot 100.

No free groundwater was observed in the boreholes during auger drilling. Backfilling of the boreholes immediately following completion of the boreholes precluded long-term measurement of any groundwater levels that might be present. Groundwater levels depend on factors such as soil permeability and weather conditions and will vary with time.

4. Laboratory Testing

Samples recovered from the field investigation were tested in the laboratory to determine moisture contents, Atterberg Limits, Shrink-Swell and Aggressivity (pH, Chloride, Sulfates and Electrical Conductivity). The detailed results are given in Appendix D and are summarised in Tables 1 and 2. Soil testing of near surface clay soils for 4 day soaked California bearing ratio (CBR) are presented in Table 3. Point Load Strength Index testing (Is_{50}) was completed on the less fractured, higher strength sections of rock core, with assessment of rock strength predominantly completed via tactile methods in the fractured rock. The Is_{50} results are presented on the borehole logs.

Table 1 – Summary Shrink-Swell and Atterberg Laboratory Test Results

Bore hole ID	Depth (m)	Material	FMC (%)	PL (%)	LL (%)	PI (%)	Linear Shrinkage (%)	ISS (%)
1	0.5-0.95	Silty Clay	24.8	25	57	32	12.0	-
2	1.0	Silty Clay	19.5	22	45	23	-	-
3	0.5-0.95	Silty Clay	23.7	-	-	-	-	1.7
4	0.5	Silty Clay	19.7	21	45	24		-
5	0.8	Silty Clay	12.1	20	30	10	-	-
8	0.5	Silty Clay	21.0	20	35	15	-	-
9	0.1-0.55	Filling	16.7	-	-	-	-	1.2
9	0.4-0.5	Filling	17.3	23	37	14	-	-
10	0.3-0.37	Filling	13.7	23	36	13	-	-

Where: FMC = Field Moisture Content
SMDD = Standard Maximum Dry Density
I_{SS} = Shrink-Swell Index
LL = Liquid Limit
PL = Plastic Limit
PI = Plastic Index
"-" = Not Tested

The results of the laboratory testing indicate that the samples tested were generally of low to medium plasticity and will be susceptible to changes in volume with variations in soil moisture content.

Table 2 – Summary of Aggressivity Laboratory Test Results

Borehole	Depth (m)	Material	pH	Chloride (mg/kg)	Sulfate (mg/kg)	Electrical Conductivity (µS/cm)
1	1	Silty Clay	5.3	<10	170	94
2	1.0-1.45	Silty Clay	5	<10	56	33
3	0.5	Silty Clay	6	<10	26	39
4	1.0	Silty Clay	5	<10	110	78
9	0.4-0.5	Filling	6.3	<10	37	38
10	0.3-0.37	Filling	7.2	<10	<10	26

Note: Each analyte was tested as a 1:5 mixture of soil:water

The results of aggressivity testing, and comparison with Table 6.4.2(C) in AS2159-2009 “Piling: Design and Installation” indicates an exposure classification of ‘Non-aggressive’ to subsurface concrete or steel elements in clay residual and filling soils.

Table 3: Summary of Results for California Bearing Ratio and Moisture Content Testing

Sample ID	Sample Description	FMC (%)	OMC (%)	MDD (%)	CBR (%)	Swell (%)
Borehole 11, 0.1-0.4m	Weathered Shale	15.4	18.0	1.70	9	1.0
Borehole 12, 0.1-0.5m	Silty Clay	20.1	21.5	1.67	7	0.5
Borehole 13, 0.4-0.6m	Silty Clay	18.4	19.5	1.70	7	0.0
Borehole 14, 0.2-0.6m	Silty Clay	21.7	20.5	1.69	6	0.0

Notes: FMC = Field Moisture Content, OMC = Optimum Moisture Content, MDD = Maximum Dry Density, “-” not tested

5. Proposed Development

It is understood that the development at the site will include a two-storey building approximately 150 m long and 50 m wide. The facade of the building is likely to be a lightweight cladding system such as FC cladding. Structural working loads have been not been provided at this stage of the development. Excavation depths in the order of up to 5 m may be required due to the topography and likely cut and fill works.

6. Comments

6.1 Excavation Conditions

Excavation within the filling, natural clays and weathered rock should be readily achievable using conventional earth moving equipment. Some light to medium ripping assistance or the careful use of rock hammers, grinders or rock saws may be required for layers of higher strength within the weathered shale and siltstone. Low productivity during excavation should be expected within such materials.

If seepage of groundwater into the excavation occurs it will need to be collected during construction by the judicious placement of drainage sumps and by intermittent pumping or gravity discharge. At this stage, it is not possible to estimate the likely extent and rate of seepage although it is anticipated from the extent of fracturing in the rock that it should be readily handled by sump and pump measures. It is suggested that monitoring of flow during the early phases of excavation be undertaken to assess long term drainage requirements.

Any off-site disposal of material will require an assessment for re-use or classification of the soil in accordance with *Environmental Guidelines: Assessment, Classification and Management of Non-Liquid Wastes* (NSW EPA, 2014), prior to disposal. This includes filling and natural materials (including virgin excavated natural materials (VENM)), such as may be removed from the site. The type and extent of testing undertaken will depend on the final use or destination of the spoil, and requirements of the receiving site.

6.2 Batters and Retaining Walls

Retaining walls and batters up to 5 m high are anticipated for the development.

Batters within stiff (or better) clay should be constructed to gradients no steeper than 1.5:1 (H:V) in the temporary condition or 2:1 in the permanent condition. Permanent batters should be covered with topsoil and vegetation or shotcreted to limit the potential for erosion.

Cantilevered retaining walls for which some deflection is acceptable may be designed on the basis of a triangular earth pressure distribution using a bulk unit weight of 20 kN/m^3 for the retained material, and an active earth pressure coefficient (k_a) of 0.3 (level backfill conditions). In situations where the wall movements must be reduced, an ‘at rest’ coefficient of 0.55 should be used instead of the above K_a values. Due allowance should be made for surcharge pressures acting on the walls (e.g. existing foundations or construction loads).

Subsoil drainage should be included behind the wall to prevent the build-up of hydrostatic pressure.

6.3 Site Preparation and Earthworks

The following subgrade preparation is recommended below building floor slabs and pavements:

- Remove all root affected topsoil, filling and vegetation affected materials. This will include grubbing out any tree roots.
- Moisture condition any exposed natural clay layer beneath floor slabs and pavements prior to test rolling.
- Moisture conditioning generally involves tyning of surficial clays (to about 300 mm depth) and either adding moisture or drying out of clays so that they are within 2% of standard optimum moisture content (SOMC). Field moisture contents are generally dependent on climatic conditions, therefore assessment of the extent of moisture conditioning of subgrades required will need to be made at the commencement (and during) earthworks on-site.
- Test (or ‘Proof’) roll the exposed surface using a minimum 12 tonne smooth drum roller in non-vibration mode. The surface should be rolled a minimum of six times 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.
- Any new filling should be free of oversize particles (>100 mm) and deleterious material.
- Place new filling in layers of 250 mm maximum loose thickness and compact to dry density ratio (DDR) between 98 % and 102 % relative to standard compaction for fill beneath floor slabs and to a minimum of 100 % relative to standard compaction for fill beneath pavements. Moisture contents should be maintained within 2 % of SOMC.

- Engineering control of the filling as defined in AS 3798 "Guidelines for earthworks for commercial and residential developments." Where filling to support structural loads is proposed (i.e. within the building footprint) Level 1 geotechnical inspection and testing should be carried out.

6.4 Pavement Design

Following stripping of unsuitable materials and excavation to design levels (refer Section 6.3), pavement subgrade materials within the site are anticipated to mostly be within clay residual and filling soils. Based on CBR test results, and allowing for some variability, it is suggested that a design subgrade CBR of 6% be adopted. If imported material is used to level the site and form subgrade levels, the design CBR value will depend on the type and depth of imported material.

The design CBR value is based on the provision of adequate surface and subsoil drainage to maintain the subgrade as close to the optimum moisture content as possible. Subsoil drainage should also be installed adjacent to pavement edges abutting lawns or garden areas.

6.5 Foundations

6.5.1 Site Classification

The results of field work indicate that the site is underlain by filling up to 0.7 m depth, overlying residual clay soils then weathered siltstone. The presence of greater than 0.4 m depth of uncontrolled filling together with the presence of mature trees within the proposed building footprint, will result in a 'P' classification for the site when assessed in accordance with the "uncontrolled fill" and "abnormal moisture condition" provisions of AS 2870 - 2011 "Residential Slabs and Footings".

Notwithstanding this classification, the laboratory testing indicates that the clays at the site are of generally moderate reactivity and likely to be susceptible to shrink-swell movements in response to seasonal variations in soil moisture content. Based on the soil depth, and the results of laboratory testing, the natural soil profile, prior to cut and fill activities, would generally be consistent with a Class 'M' site.

If the uncontrolled filling is removed and replaced as controlled structural filling, it should be feasible to re-classify the site

6.5.2 Footings

If the uncontrolled filling is removed from beneath building footprints, it should be feasible to found lightly loaded structures with footing loads up to about 500 kN uniformly within natural clay (stiff or better) or controlled filling. For settlement sensitive structures, or for footing loads greater than 500 kN, it is suggested that the building loaded be transferred into the underlying bedrock using either pad, strip or pile footings.

The design of shallow or piled footings, for axial compression loading, may be based on the maximum Limit State Design or Working Stress parameters given in Table 4.

Table 4: Foundation Design Parameters

Material Description	Working Stress Design Values		Limit State Design Values		Elastic Modulus (MPa)
	Allowable End Bearing Pressure (kPa)	Shaft Adhesion (kPa)	Ultimate End Bearing Pressure (kPa)	Shaft Adhesion (kPa)	
Natural Clays (stiff or better)	150	NA	300	NA	20
Shale/laminite, extremely low to low strength	700	70	3,000	100	100
Shale/laminite, low to medium strength	1,500	150	6,000	350	200
Shale/Siltstone, medium strength, slightly fractured	2,500	250	10,000	600	1,000

The bearing pressures in Table 4 are based upon four cored boreholes that are mostly located in the eastern half of the site. Further cored boreholes are recommended when the detailed design phase is commenced to confirm the uniform good quality and depth of the low to medium strength shale founding layer.

The near surface rock is variably weathered and highly variable in strength for the upper 2 – 4 m. All the deeper boreholes were terminated in medium strength rock, which suggests that if high building loads result from the design, it should be feasible to optimise footing design by founding in the higher strength rock that appears to underlie the site at depths below approximately 1 m in the north-east part of the site (Lot 100), and depths below 5 m elsewhere within the site.

It should be noted that the allowable pressures for “Working Stress Design Values” given in Table 4 are based on a ‘limiting settlement’ of 1% of the footing width. The design of footings is usually governed by settlement criteria and performance rather than the ultimate bearing capacity or Ultimate Limit State condition.

Footings founded on natural clay soils will also need to consider the effect of soil reactivity, equivalent to a ‘M’ classification, and the effect of adjacent trees (refer to Appendix H of AS 2870).

The foundation design parameters require that the foundation excavations (e.g. for pad footings or bored piers) are clean and free of loose debris and water immediately prior to the placement of concrete.

The design of piers to resist uplift loads (e.g. tension piles) may be based on two-thirds of the allowable shaft adhesion value given above for axial compression. “Cone pull-out” failure mechanisms should also be considered.

All foundations should be constructed below the zone of influence of any existing or proposed service trenches. Where footings are located immediately adjacent and upslope of a retaining wall the footings should extend 0.5 m below the ‘zone of influence’ of the retaining wall. The ‘zone of influence’ is conservatively defined by an imaginary line extending up at 45º from the base of the wall or service trench.

Foundation excavations should be inspected by an experienced geotechnical professional prior to pouring concrete, to confirm that the material is adequate for the required bearing capacity.

6.5.3 Floor Slabs

The lowest risk approach for the support of floor slabs is to fully suspend the slabs with appropriate measures to accommodate free surface movements equivalent to a Class ‘M’ site. This may require the use of void formers below any slab and subfloor beams.

Alternatively, the floor slab could act independently of the footing system and designed to be supported by the soil profile, although this would require sufficient tolerance for differential movement of the slab due to seasonal shrinking and swelling of the clays. For this approach, however, there is a higher risk of subsequent cracking of the floor slab.

Weathered siltstone will provide adequate support for a slab-on-grade. The final surface should be trimmed and scraped clean of debris etc. prior to pouring concrete. A gravel layer should be provided beneath the floor slab and should slope towards a sump pit, to allow sub-floor drainage. Adequate provision for access and maintenance of drains should be incorporated into the design.

Where a combination of natural clays and weathered siltstone are exposed at the bulk excavation level and a slab-on-ground is adopted an articulation joint should be placed in the ground slab at this transition point to allow for movements associated with the shrink-swell or settlement of natural clays.

6.5.4 Site Maintenance

Reference is made to Appendix B of AS 2870 – 2011, which provides advice on normal maintenance requirements to ensure the adequate performance of structures that have been designed and constructed in accordance with AS 2870 – 2011.

Presented in Appendix E is a copy of the CSIRO Building Technology File BTF 18 entitled, ‘Foundation Maintenance and Footing Performance, A Homeowners Guide’, which further describes appropriate site maintenance requirements set out within Appendix B of AS 2870 – 2011.

7. Limitations

Douglas Partners (DP) has prepared this report for this project at 120-126 Hezlett Road, Kellyville in accordance with DP’s proposal SYD170387 (Rev1) dated 10 May 2017, and subsequent email proposal for additional investigations for Lot 100 in DP 1216659 (Lot 100), dated 12 July 2017. Acceptance was received for the first phase of work from Mr Michael Abbott of GHD Pty Ltd, dated 10 May 2017, and for the second phase of work from Mr Michael Dean of GHD Pty Ltd, dated 19 July 2017. The work was carried out under a modified GHD QA023 Sub-consultancy agreement. This report is provided for the exclusive use of GHD Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or relied upon 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.

This report must be read in conjunction with all of 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.
The scope for work for this report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site, which has been addressed under separate cover. 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 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

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

Drawings

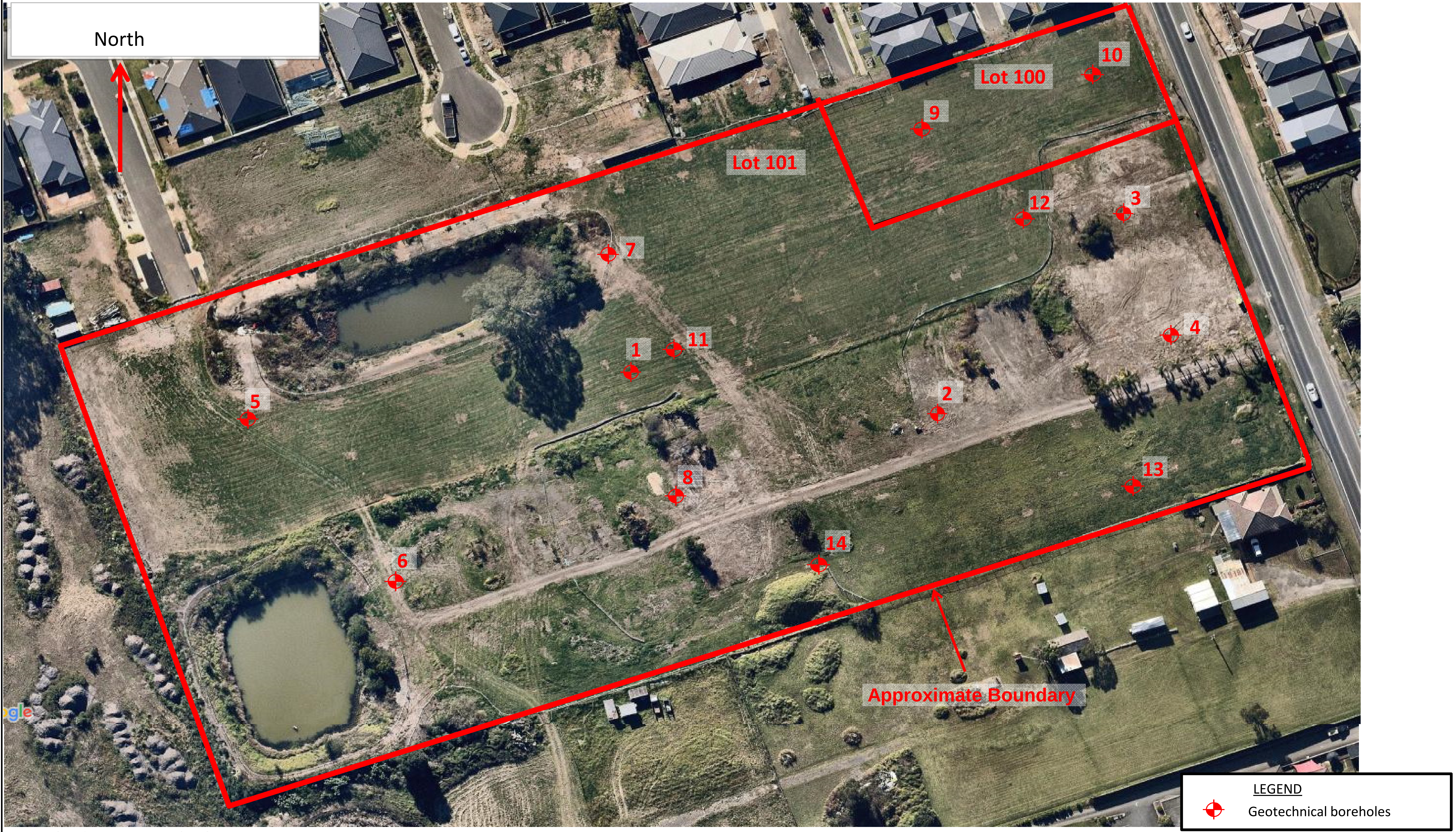

Image taken from NearMap, dated 22 July 2017

Douglas Partners *Geotechnics / Environment / Groundwater*	CLIENT: GHD Pty Ltd		TITLE:	**Test Location Plan**	PROJECT No:	85998.00
	OFFICE: Sydney	DRAWN BY: HDS		**Proposed North Kellyville New Primary School**	DRAWING No:	1
	SCALE: Not to Scale	DATE: 21.08.17		**120-126 Hezlett Road, Kellyville (Lots 100 and 101, DP 1216659)**	REVISION:	2

Appendix C

Results of Field Work

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

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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 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 Descriptions

Rock Quality Designation

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

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

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

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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
$\underline{\nabla}$	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

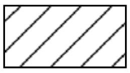
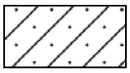
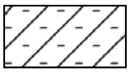
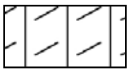
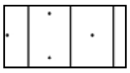
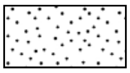
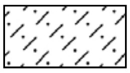
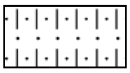
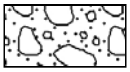
Symbols & Abbreviations

Graphic Symbols for Soil and Rock

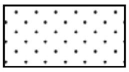
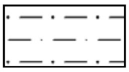
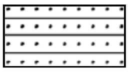
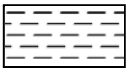
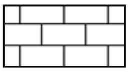
General

■	Asphalt
	Road base
	Concrete
	Filling

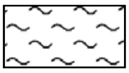
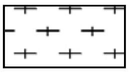
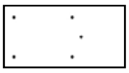
Soils

	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

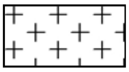
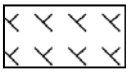
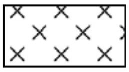
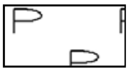
Sedimentary Rocks

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

Metamorphic Rocks

	Slate, phyllite, schist
	Gneiss
	Quartzite

Igneous Rocks

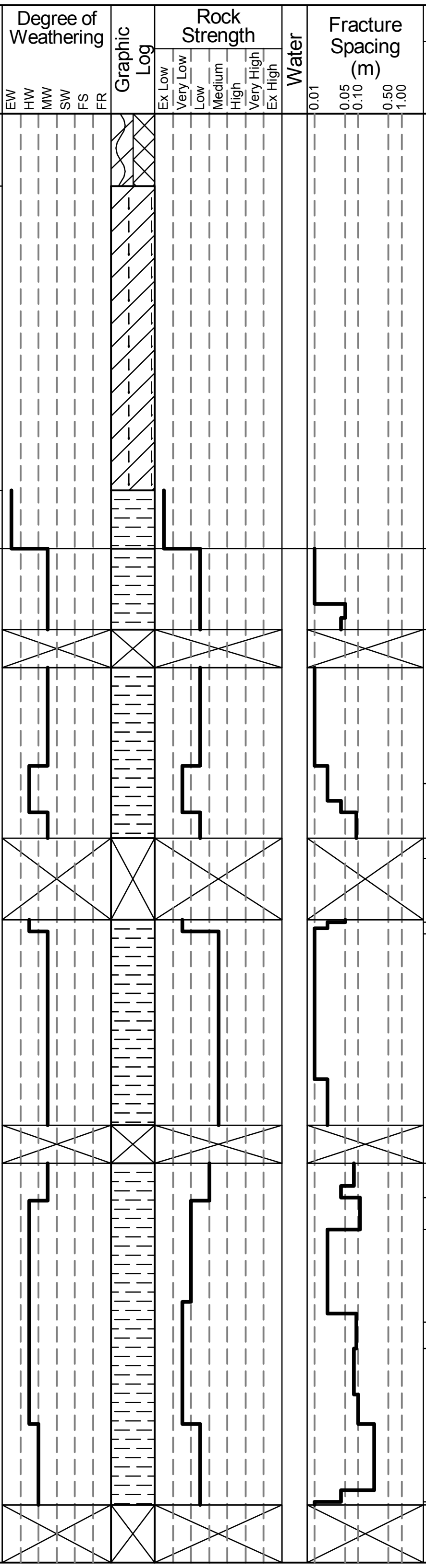
	Granite
	Dolerite, basalt, andesite
	Dacite, epidote
	Tuff, breccia
	Porphyry

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 76 AHD
EASTING: 310317
NORTHING: 6270145
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 85998.00
DATE: 19/6/2017
SHEET 1 OF 2



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
76		TOPSOIL/FILLING - estimated firm to stiff, brown clayey silt topsoil filling with some fine sand and rootlets, moist		D			
	0.25	SILTY CLAY - estimated stiff, orange-brown, medium to high plasticity silty clay with trace fine sand and subangular gravel, moist (residual) 0.5m: very stiff, orange-brown mottled red-brown and brown	Note: Unless otherwise stated, rock is fractured along smooth planar bedding dipping 0°- 5°	D			
				U_{50}			pp = 450
75	1			S			4,11,30/145mm refusal
	1.3	SHALE - extremely low strength, extremely weathered, light grey, grey, brown and orange-brown shale					
	1.5	SHALE - low strength, moderately weathered, fragmented to highly fractured, grey-brown shale with some ironstained bands	1.5m: fg to 1.68m 1.69m: B, sh, fe stn, pl, sm 1.78m: CORE LOSS: 130mm	C	100	0	PL(A) = 1.75
	1.91			C	81	0	
74	2		2.25m: B0°- 5°, fe stn, pl, sm 2.31m: B5°, cly co, pl, sm				PL(A) = 0.67
			2.5m: CORE LOSS: 280mm 2.57m: fg to 2.4m				
	2.78	2.82m: low to medium strength, then very low to low strength	2.75, 2.77m: B, sh, fe stn, pl, sm 2.79m: B, sh, fe stn, pl, sm 2.83m: fg to 3.33m	C	66	0	
73	3						
			3.33m: B0°- 5°, fe stn, pl, sm	C	100	0	PL(A) = 1.14
	3.49		3.49m: CORE LOSS: 130mm				
	3.62		3.62m: B0°- 5°, fe stn, pl, sm 3.74m: B0°- 10°, cly co, ir, ro 3.85m: B0°- 5°, cln / fe stn, pl, sm	C	90	15	
72	4		4.14m: B, sh, cly inf, pl, sm 4.17m: fg to 4.2m 4.26, 4.34, 4.42m: B0°- 5°, cln / fe stn, ir / pl, sm 4.52m: Cz to 4.56m 4.75m: B, sh, fe stn, pl, sm				PL(A) = 0.57
			4.79m: B, cly inf, pl, sm	C	80	0	

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** HW to 1.5m
TYPE OF BORING: 150mm diameter auger to 1.5m; NMLC-Coring to 7.36m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

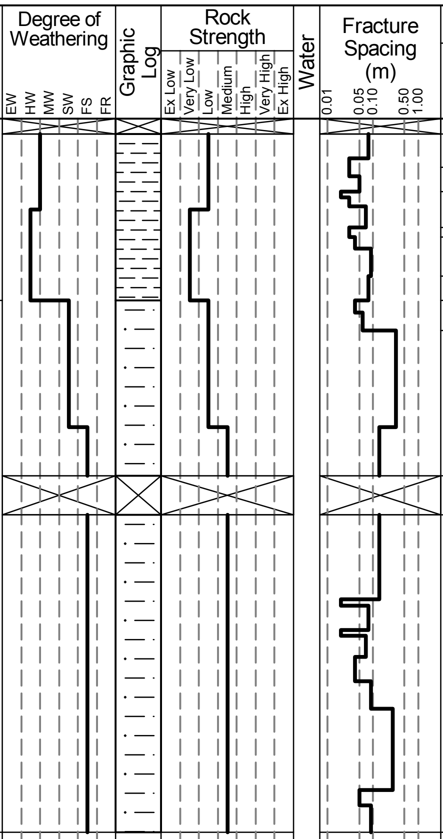
Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 76 AHD
EASTING: 310317
NORTHING: 6270145
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 85998.00
DATE: 19/6/2017
SHEET 2 OF 2



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
71	5.05	SHALE - low strength, moderately weathered, fragmented to highly fractured, grey-brown shale with some ironstained bands (cont.)	4.8m: CORE LOSS: 250mm 5.05m: fg to 5.13m 5.16m: Cz to 5.19m 5.24, 5.26, 5.29m: B0°- 10°, cln / fe stn, ir, ro / sm 5.36m: B, sh, fe stn / he, pl	C	80	0	
	5.6	SILTSTONE - low strength becoming medium strength, slightly weathered becoming fresh, fragmented, grey to dark grey slightly carbonaceous siltstone	5.39-5.43m: B0°- 10°, cln / fe stn, ir, ro / sm 5.52m: Cz to 5.54m 5.6m: Cz to 5.64m 5.7m: fg to 6.02m				PL(A) = 0.4
70	6						
	6.31		6.16m: J30°, ir, ro 6.18m: CORE LOSS: 130mm 6.31m: fg to 6.45m (possibly DB) 6.69, 6.71, 6.78, 6.82m: B0°- 5°, fe stn, pl, sm	C	90	41	PL(A) = 1.9
69	7		6.95m: B5°- 15°, ir, sm 7.22, 7.26m: B0°- 5°, fe stn, pl, sm				PL(A) = 1.88
	7.36	Bore discontinued at 7.36m - limit of investigation					
68	8						
67	9						

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** HW to 1.5m
TYPE OF BORING: 150mm diameter auger to 1.5m; NMLC-Coring to 7.36m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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: NORTH KELLYVILLE JUNE 2017

1.5 – 6.0 m

BORE: 1 PROJECT: NORTH KELLYVILLE JUNE 2017

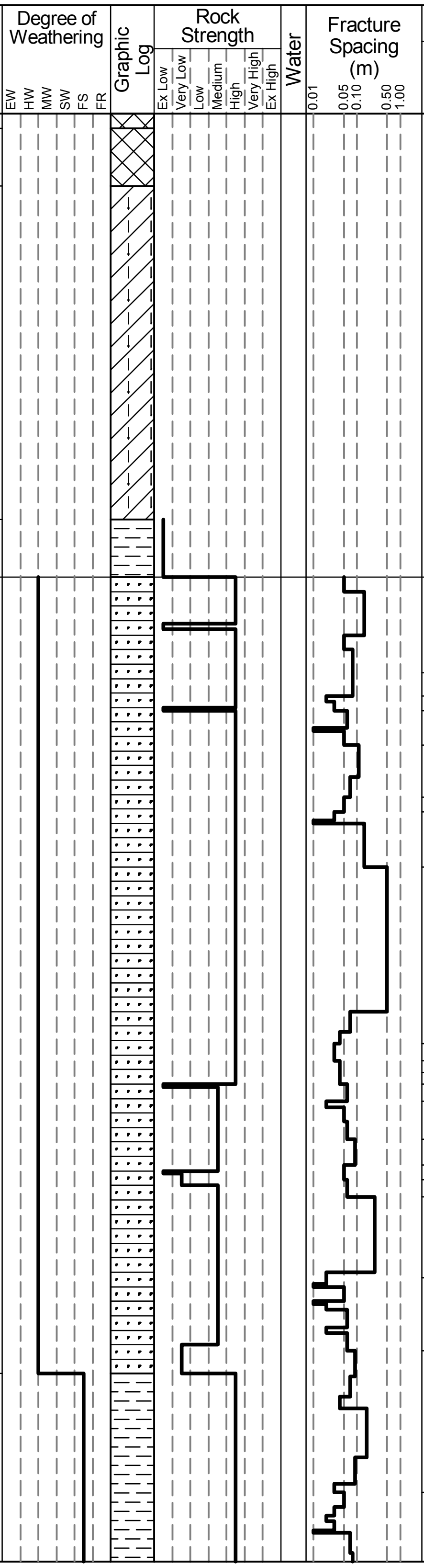
6.0 – 7.36 m

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 81 AHD
EASTING: 310393
NORTHING: 6270128
DIP/AZIMUTH: 90°/--

BORE No: 2
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 1 OF 2



Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
0.05	FILLING - estimated dense, grey, fine medium gravel filling		D			
0.25	FILLING - estimated dense, brown, fine to coarse sand filling with some silt, moist. Fine to medium gravel fraction					
	SILTY CLAY - estimated stiff, orange-brown, medium plasticity silty clay with trace fine sand and gravel, moist	Note: Unless otherwise stated, rock is fractured along smooth planar bedding dipping 0°- 5°	D			
1			D			
			S			5,14,25 N = 39
1.4	SHALE - extremely low strength, extremely weathered, brown, grey and orange-brown shale					
1.6	LAMINITE - high then medium strength, moderately to highly weathered, fragmented to fractured, grey-brown laminite with approximately 25% fine sandstone laminations	1.65m: B0°- 5°, cly co, fe stn, pl, sm 1.85m: B0°- 5°, cly co, pl, sm 1.93m: B0°- 5°, slt vn, pl, sm 2.01-2.03m: B0°- 5°, fe stn, pl, sm 2.06m: B0°- 5°, cly co, pl, sm 2.18m: 2.18m: B0°- 5°, cly co, fe stn, pl, sm	C	100	0	PL(A) = 2.04
		2.36, 2.45m: B0°- 5°, slt vn, pl, sm 2.41, 2.44m: B0°- 5°, cly co, pl, sm 2.6m: B0°- 5°, cln / fe stn, pl, sm 3.17m: B0°- 5°, cly inf, pl, sm 3.21-3.24m: Cz 3.27m: B0°- 5°, cly inf, pl, sm 3.31m: B0°- 5°, fe stn, pl, sm 3.35m: B0°- 5°, fe stn, pl, sm 3.41, 3.43, 3.48m: B0°- 5°, fe stn, pl, sm 3.54m: B0°- 5°, slt vn, pl, sm 3.63m: B0°- 5°, cly co, pl, sm	C	100	0	PL(A) = 1.82 PL(A) = 0.98
4.35	SHALE - high strength, fresh stained, slightly fractured, grey to grey-brown shale	3.68m: B0°- 5°, fe stn, pl, sm 3.74m: B0°- 5°, fe stn, pl, sm 4.02, 4.04,4.05,4.10,4.11, 4.13, 4.19, 4.21m: B0°- 5°, fe stn, pl, sm 4.27m: B0°- 5°, fe stn, pl, sm 4.76m: J0°- 15°, ir, ro	C	100	66	PL(A) = 2.27

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB/SI **CASING:** HW to 1.6m

TYPE OF BORING: 150mm diameter auger to 1.6m; NMLC-Coring to 5.51m

WATER OBSERVATIONS: No free groundwater observed whilst augering

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)

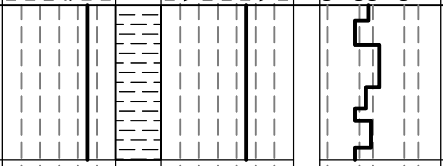
Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 81 AHD
EASTING: 310393
NORTHING: 6270128
DIP/AZIMUTH: 90°/--

BORE No: 2
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 2 OF 2



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
76		SHALE - high strength, fresh stained, slightly fractured, grey to grey-brown shale *(continued)*	5.17m: B0°- 10°, ir, ro 5.34, 5.38m: B0°- 10°, ir, ro	C	100	66	PL(A) = 2.29
	5.51	Bore discontinued at 5.51m - limit of investigation					
75	6						
74	7						
73	8						
72	9						

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB/SI **CASING:** HW to 1.6m
TYPE OF BORING: 150mm diameter auger to 1.6m; NMLC-Coring to 5.51m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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: 2 **PROJECT: NORTH KELLYVILLE** **JUNE 2017**

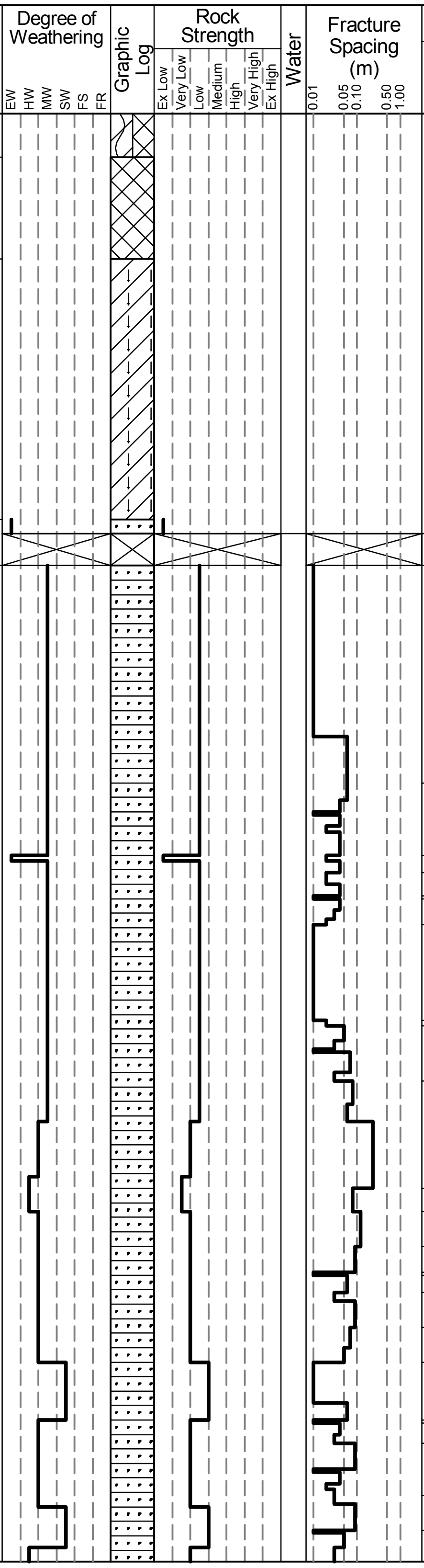
1.6 – 5.51 m

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 81.5 AHD
EASTING: 310446
NORTHING: 6270190
DIP/AZIMUTH: 90°/--

BORE No: 3
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 1 OF 2



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
	0.15	TOPSOIL/FILLING - estimated firm, brown, medium plasticity, clayey silt topsoil filling with some rootlets and fine to medium grained sand moist		D			
81	0.5	FILLING - estimated soft to firm, brown, medium to high plasticity, silty clay filling with some fine to medium sand, gravel, moist to wet		D			
	1	SILTY CLAY - estimated stiff to very stiff, orange-brown, medium to high plasticity, silty clay with trace fine to medium sand and subangular gravel, moist 0.8m: very stiff	Note: Unless otherwise stated, rock is fractured along rough planar bedding dipping 0°- 5°	U_{50}			pp = 500-550
				S			4,5,25 N = 30
80	1.4	LAMINITE - extremely low strength, extremely weathered, light brown, grey and orange-brown laminite	1.45m: CORE LOSS: 110mm				PL(A) = 1.44
79	1.56 2	LAMINITE - low strength, moderately weathered, fragmented to highly fractured, grey, brown laminite with orange-brown iron staining, with some very low and medium strength, highly weathered bands and laminated carbonaceous siltstone bands	1.56m: B0°- 5°, cln / fe stn, pl, sm (some may be drilling induced) 1.8m: fg to 2.15m 2.25m: B5°, slt vn, pl, sm 2.31, 2.37, 2.41, 2.42, 2.46, 2.48, 2.52m: B0°- 10°, fe stn or cln or slt vn, pl, ro, or sm 2.56m: Cs, 5°, silt, 20 mm 2.62, 2.64, 2.66m: B0°- 5°, slt vn, pl, sm	C	92	7	PL(A) = 1.47
78	3	3.48m: grading to very low to low strength	2.7m: B0°- 5°, fe stn, pl, ro 2.71m: B0°- 5°, pl, ro 2.8-3.12m: B0°- 5°, cln or fe stn, pl, sm, (some may be drilling induced) 3.13m: B0°- 5°, fe stn, pl, ro 3.15m: B0°- 5°, cly co, pl, sm 3.34m: Cz, fe stn, 80 mm 3.71m: B0°- 5°, fe stn, pl, ro 3.79m: B0°- 5°, fe stn, pl, ro 3.91m: B0°- 5°, cly inf, pl, sm 4m: B0°- 5°, fe stn, pl, ro 4.01m: B0°- 5°, fe stn, pl, ro	C	100	8	PL(A) = 2.36
77	4	4.32m: increasing proportion of carbonaceous siltstone laminations	4.07-4.10m: B0°- 5°, fe stn, pl, ro 4.19-4.26m: Cz 4.31-4.45m: B0°- 5°, cln / ve stn, pl, sm (some may be drilling induced) 4.51m: B0°- 5°, fe stn, pl, ro 4.52-4.56m: Cz	C	100	8	PL(A) = 0.48

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** HW to 1.4
TYPE OF BORING: 150mm diameter auger to 1.4m; NMLC-Coring to 7.23m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

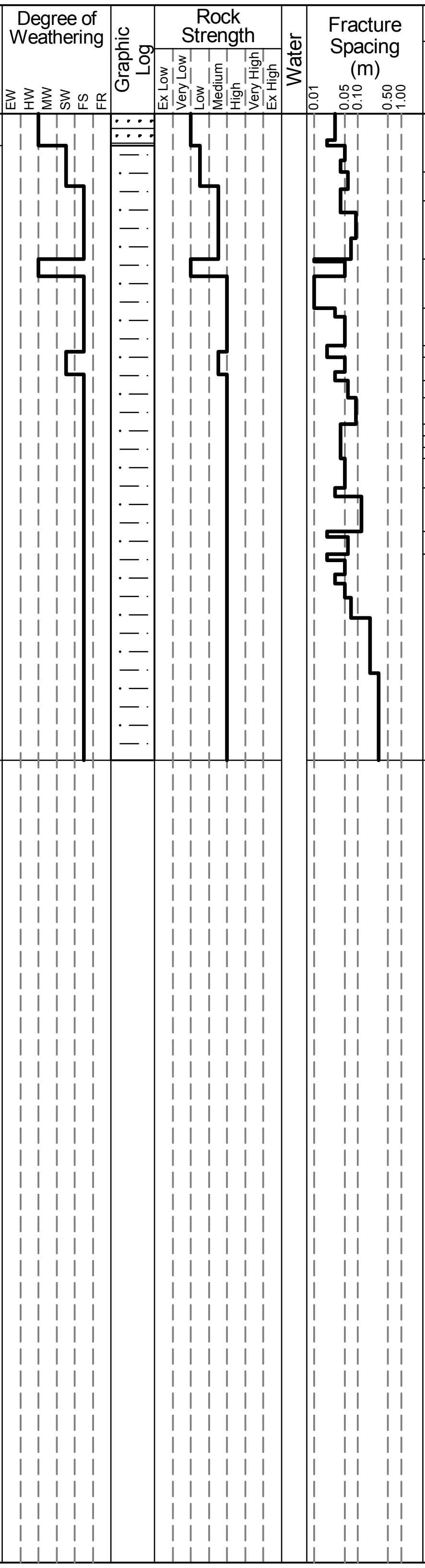
Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 81.5 AHD
EASTING: 310446
NORTHING: 6270190
DIP/AZIMUTH: 90°/--

BORE No: 3
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 2 OF 2



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Sampling & In Situ Testing Type	Core Rec. %	RQD %	Test Results & Comments
76	5.11	SILTSTONE - low to medium strength, slightly weathered becoming fresh, highly fractured to fractured, grey siltstone with some medium strength bands (carbonaceous siltstone) 5.56m: becoming medium to high strength, fresh	4.59, 4.68, 4.69, 4.73, 4.75m: B0°- 5°, fe stn, pl, ro 4.77, 4.8m: J0°- 20°, fe stn, ir, ro 4.89, 4.9, 4.95, 5.06, 5.09, 5.11, 5.16m: B0°- 5°, fe stn, pl, ro 5.2-5.26m: fg 5.3m: J5°- 20°, ir, ro 5.5, 5.51, 5.56m: B0°- 5°, pl, sm	C	100	8	PL(A) = 2.24
75	6 7		5.67-5.7m: Cz 5.8-5.82m: B0°- 10°, pl, sm 5.84-5.89m: Cz 5.92m: B0°- 10°, fe stn, pl, sm 5.98m: B0°- 10°, fe stn, pl, sm 6.07m: J20°- 45°, ir, ro 6.11m: B0°- 10°, pl, sm 6.15m: B0°- 10°, pl, sm 6.19, 6.24m: B5°- 15°, pl, sm 6.29, 6.32m: B0°- 10°, cbs stn, pl, sm 6.44, 6.46m: B0°- 10°, pl, sm 6.52, 6.54m: B0°- 10°, pl, sm	C	100	48	PL(A) = 1.48 PL(A) = 1.33
74 73 72	7.23 8 9	Bore discontinued at 7.23m - limit of investigation					

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** HW to 1.4
TYPE OF BORING: 150mm diameter auger to 1.4m; NMLC-Coring to 7.23m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

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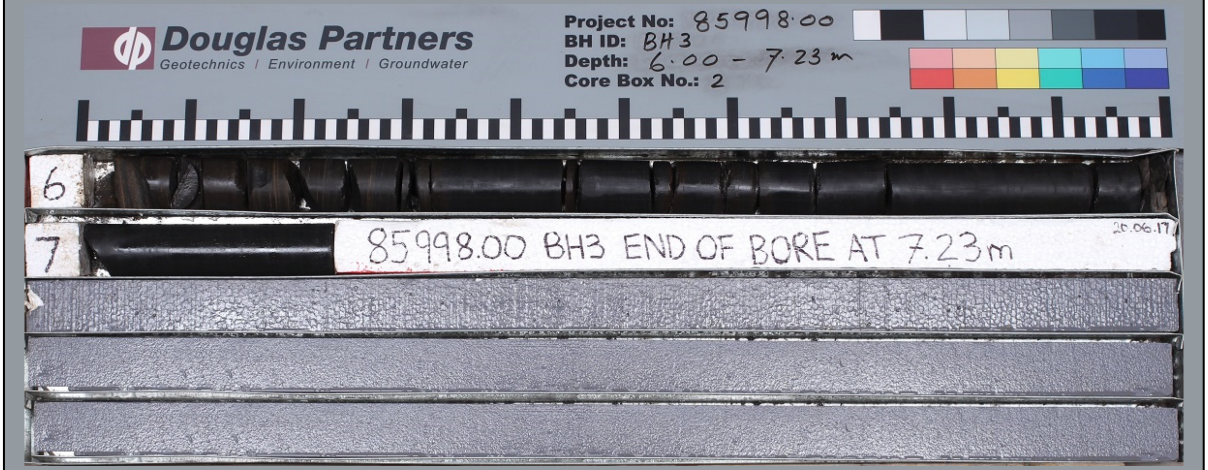
BORE: 3 PROJECT: NORTH KELLYVILLE JUNE 2017

1.45 – 6.0 m

BORE: 3 PROJECT: NORTH KELLYVILLE JUNE 2017



6.0 – 7.23 m

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 83 AHD
EASTING: 310457
NORTHING: 6270453
DIP/AZIMUTH: 90°/--

BORE No: 4
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
83		TOPSOIL/FILLING - estimated soft to firm, brown, medium to high plasticity, clayey silt topsoil filling with some fine sand and rootlets, moist 0.15m: clay increasing		D	0.1				
	0.3	SILTY CLAY - estimated stiff to very stiff, orange-brown, medium plasticity, silty clay with some fine to medium ironstone gravel and fine sand, moist		D	0.5				
		0.7m: very stiff							
82	1			D	1.0				1
				S	1.45		6,7,10 N = 17		
		1.5m: hard with some relict rock structure							
81	2 2.0	SHALE - extremely low to very low strength, extremely to highly weathered, brown, grey and orange-brown shale							2
	2.3	Bore discontinued at 2.3m - auger refusal likely on low strength shale		D	2.3				
80	3								3
79	4								4

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** Uncased
TYPE OF BORING: 150mm diameter auger to 2.3m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

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Geotechnics | Environment | Groundwater

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 73 AHD
EASTING: 310218
NORTHING: 6270125
DIP/AZIMUTH: 90°/--

BORE No: 5
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
73		TOPSOIL/FILLING - estimated firm, brown, medium plasticity, clayey silt/silty clay topsoil filling with some rootlets, moist	▨	D	0.1				
	0.25	SILTY CLAY - estimated stiff to very stiff, light grey mottled orange-brown, medium plasticity silty clay moist 0.5m: very stiff to hard	▨	D	0.5				
	0.7	SHALE - extremely low to very low strength, extremely to highly weathered, brown and grey shale	▨	D	0.8				
	0.85	Bore discontinued at 0.85m - auger refusal likely on low strength shale							
72	1								1
71	2								2
70	3								3
69	4								4

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** Uncased
TYPE OF BORING: 150mm diameter auger to 0.85m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 76 AHD
EASTING: 310257
NORTHING: 6270075
DIP/AZIMUTH: 90°/--

BORE No: 6
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
76		TOPSOIL/FILLING - estimated firm, brown, medium plasticity, clayey silt topsoil filling with some fine to medium gravel, sand and trace rootlets, moist		D	0.1				
	0.15	FILLING - estimated firm to stiff, brown, medium to high plasticity, silty clay filling with some fine gravel and sand, moist		D	0.5				
	0.6	SILTY CLAY - estimated stiff, orange-brown, medium to high plasticity, silty clay with trace fine gravel, moist 0.9m: very stiff							
75	1			D	1.0				1
				S	1.45		3,6,10 N = 16		
	1.65	SHALE - extremely low to very low strength, extremely to highly weathered, brown and grey shale		D	1.7				
	1.7	Bore discontinued at 1.7m - auger refusal likely on low strength shale							
74	2								2
73	3								3
72	4								4

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** Uncased
TYPE OF BORING: 150mm diameter auger to 1.7m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 75 AHD
EASTING: 310311
NORTHING: 6279176
DIP/AZIMUTH: 90°/--

BORE No: 7
PROJECT No: 85998.00
DATE: 26/6/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Sampling & In Situ Testing: Depth	Sampling & In Situ Testing: Sample	Sampling & In Situ Testing: Results & Comments	Water	Well Construction Details
75		TOPSOIL/FILLING - estimated soft to firm, brown, medium to high plasticity, clayey silt topsoil filling with some fine sand and rootlets, moist 0.15m: becomes silty clay filling, no rootlets		D	0.1				
	0.4	SILTY CLAY - estimated stiff to very stiff, orange-brown, medium plasticity, silty clay with some fine to medium ironstone gravel and fine sand, moist 0.8m: very stiff		D	0.5				
74	1	1.0m: hard		D S	1.0		4,13 refusal bouncing		1
	1.2 1.25	SHALE - very low strength, highly weathered, light grey, brown and orange-brown shale							
		Bore discontinued at 1.25m - auger refusal likely on low strength shale							
73	2								2
72	3								3
71	4								4

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** Uncased
TYPE OF BORING: 150mm diameter auger to 1.25m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 79 AHD
EASTING: 310326
NORTHING: 6270107
DIP/AZIMUTH: 90°/--

BORE No: 8
PROJECT No: 85998.00
DATE: 20/6/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
79	0.05	FILLING - estimated medium dense, light grey sand, moist							
	0.35	TOPSOIL/FILLING - (historic topsoil) estimated firm to stiff, brown, medium plasticity, clayey silt topsoil filling, moist		D	0.1				
	0.7	SILTY CLAY - estimated stiff to very stiff, orange-brown, medium plasticity, silty clay with some fine to medium ironstone gravel and fine sand, moist 0.6m: hard		D	0.5				
	0.9	SHALE - very low strength, highly weathered, light grey-brown shale		D	0.7 0.8				
		Bore discontinued at 0.9m - auger refusal likely on low strength shale		D	0.9				
78	1								1
77	2								2
76	3								3
75	4								4

RIG: Bobcat **DRILLER:** GT **LOGGED:** LB **CASING:** Uncased
TYPE OF BORING: 150mm diameter auger to 0.9m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 77.9 AHD
EASTING: 310389.1
NORTHING: 6270212.2
DIP/AZIMUTH: 90°/--

BORE No: 9
PROJECT No: 85998.00
DATE: 28/7/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Sampling & In Situ Testing: Depth	Sampling & In Situ Testing: Sample	Sampling & In Situ Testing: Results & Comments	Water	Well Construction Details
		FILLING - dark brown, clayey silt (topsoil) filling with grass rootlets, humid		A	0.0				
	0.1	FILLING - brown silty clay filling, humid			0.1		0.1-0.55m: U_{50} sample		
				A	0.4				
					0.5				
	0.7	SHALE - extremely low strength, extremely weathered, grey shale		A	0.7				
	0.8	SHALE - low strength, extremely to highly weathered, grey-brown shale		A	0.8				
77	0.9	Bore discontinued at 0.9m - auger refusal			0.9				
	1								1
76									

RIG: Bobcat **DRILLER:** GM **LOGGED:** JN **CASING:** Uncased

TYPE OF BORING: Solid flight auger (TC-bit) to 0.9m

WATER OBSERVATIONS: No free groundwater observed whilst augering

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)

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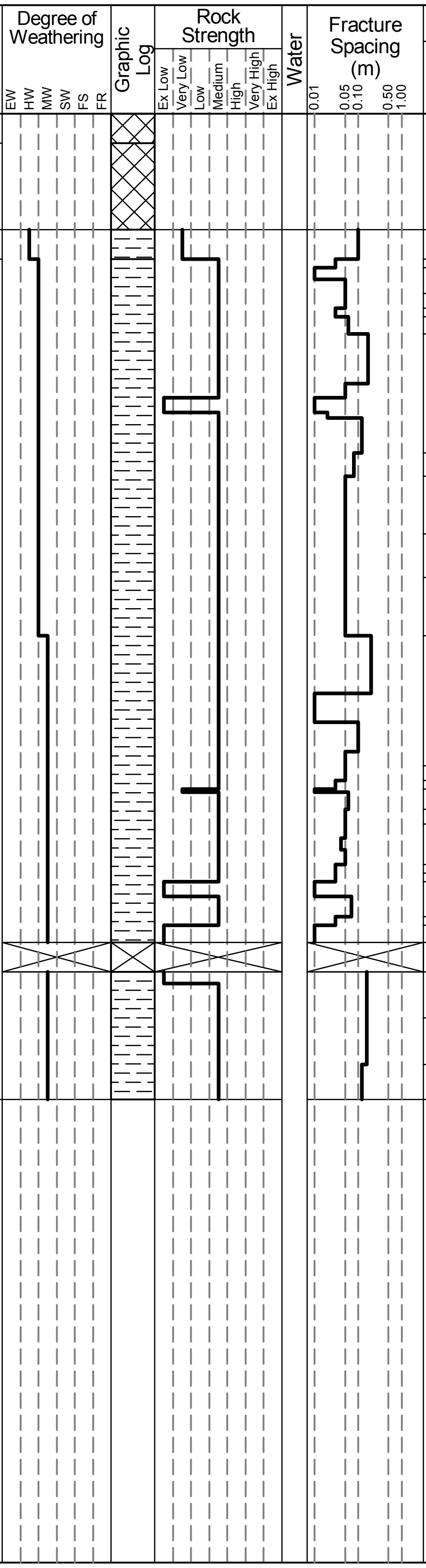
BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 79.9 AHD
EASTING: 310433.1
NORTHING: 6270227.3
DIP/AZIMUTH: 90°/--

BORE No: 10
PROJECT No: 85998.00
DATE: 28/7/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata
	0.1	FILLING - dark brown, clayey silt (topsoil) filling with grass rootlets, humid
	0.4	FILLING - brown silty clay filling, humid
	0.5	SHALE - very low strength, highly weathered, fractured, light grey shale
79	1	SHALE - medium strength, highly to moderately then moderately weathered, highly fractured then fractured, grey-brown shale with some extremely low strength bands
78	2	
77	2.96 3	
	3.4	Bore discontinued at 3.4m - target depth reached
76	4	
75		



Discontinuities

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

Note: Unless otherwise stated, rock is fractured along rough to smooth planar bedding, some with iron staining, dipping 0°- 10°
0.5m: B5°, pl, sm, fe stn
0.53m: fg, 40mm
0.62m: J30°, un, sm, cln
0.67m: J30°, un, fe
0.7-0.85m: J70°- 90°, un, sm, cln
0.76m: J30°, pl, sm, cln
0.98m: Cs, 50mm
1.05-1.12m: J45°- 90°, un, sm, cln
1.17m: B0°, pl, sm, fe stn, cly co
1.25-1.5m: J (x5) 30°- 45°, un, ti, fe stn
1.45m: J45°, pl, sm, cln
1.55m: B0°, pl, sm, fe stn, cly co
1.6-1.8m: J (x4) 30°- 45°, un, ti, fe stn
1.8-1.95m: J70°- 90°, un, sm, fe stn
2m: fg, 100mm
2.2m: J45°, un, sm, fe stn
2.25m: B0°- 10°, un, ro, fe stn
2.3m: B0°- 10°, un, sm, cly, 3mm
2.33m: Ds, 10mm
2.4m: J30°, un, ro, fe stn
2.45, 2.5m: B10°, pl, sm, cly, 5mm
2.59m: J0°- 45°, cu, ro, fe stn
2.62m: B0°- 45°, un, sm, cly, 1mm
2.65m: Cs, 50mm
2.77m: J30°, pl, ro, fe stn
2.8m: Cs, 60mm
2.86m: CORE LOSS: 100mm
2.96m: Cs, 40mm
3.12m: B5°, pl, ro, fe stn, cly, 5mm
3.28m: J30°, pl, ro, fe stn, cly, 2mm

Sampling & In Situ Testing

Type	Core Rec. %	RQD %	Test Results & Comments
A			
U_{50}			
A			
C	100	27	PL(A) = 0.33
C	91	22	PL(A) = 0.64
C	100	100	PL(A) = 0.83

RIG: Bobcat **DRILLER:** GM **LOGGED:** JN **CASING:** HQ to 0.4m
TYPE OF BORING: Solid flight auger (TC-bit) to 0.37m; NMLC-Coring to 3.4m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

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BORE: 10 PROJECT: NORTH KELLYVILLE JULY 2017

0.4 – 3.40 m

BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 77 AHD
EASTING: 310327
NORTHING: 6270154
DIP/AZIMUTH: 90°/--

BORE No: 11
PROJECT No: 85998.00
DATE: 28/7/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
77		FILLING - dark brown, clayey silt (topsoil) filling with grass rootlets, humid	▨						
	0.1	SHALE - extremely low strength, extremely weathered, grey shale	▤	B	0.1				
	0.3	SHALE - low strength, extremely to highly weathered, grey-brown shale	▤						
	0.4	Bore discontinued at 0.4m - target depth reached			0.4				
76	1								1

RIG: Bobcat **DRILLER:** GM **LOGGED:** JN **CASING:** Uncased
TYPE OF BORING: Solid flight auger (TC-bit) to 0.4m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

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BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 81 AHD
EASTING: 310415
NORTHING: 6270187
DIP/AZIMUTH: 90°/--

BORE No: 12
PROJECT No: 85998.00
DATE: 28/7/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
81		FILLING - dark brown, clayey silt (topsoil) filling with grass rootlets, humid							
	0.1	SILTY CLAY - red-brown silty clay filling, humid		B	0.1 0.5				
	0.6	Bore discontinued at 0.6m - target depth reached							
80	1								1

RIG: Bobcat **DRILLER:** GM **LOGGED:** JN **CASING:** Uncased
TYPE OF BORING: Solid flight auger (TC-bit) to 0.6m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

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BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 81 AHD
EASTING: 310445
NORTHING: 6270113
DIP/AZIMUTH: 90°/--

BORE No: 13
PROJECT No: 85998.00
DATE: 28/7/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Sampling & In Situ Testing Depth	Sampling & In Situ Testing Sample	Sampling & In Situ Testing Results & Comments	Water	Well Construction Details
81		FILLING - dark brown, clayey silt (topsoil) filling with grass rootlet, moist							
	0.15	FILLING - grey-brown silty clay filling, humid							
	0.4	SILTY CLAY - red-brown silty clay, humid		B	0.4 0.6				
	0.6	Bore discontinued at 0.6m - target depth reached							
80	1								1

RIG: Hand tools **DRILLER:** JN **LOGGED:** JN **CASING:** Uncased
TYPE OF BORING: Hand tools to 0.6m
WATER OBSERVATIONS: No free groundwater observed
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)

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BOREHOLE LOG

CLIENT: GHD Pty Ltd
PROJECT: Proposed North Kellyville New Primary School
LOCATION: 120-126 Hezlett Road, Kellyville

SURFACE LEVEL: 79 AHD
EASTING: 310365
NORTHING: 6270089
DIP/AZIMUTH: 90°/--

BORE No: 14
PROJECT No: 85998.00
DATE: 28/7/2017
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
79		FILLING - brown silty clay filling, humid	▩						
	0.2	SILTY CLAY - orange-brown silty clay, humid	▨	B	0.2 0.6				
	0.6	Bore discontinued at 0.6m - target depth reached							
78	1								1

RIG: Bobcat **DRILLER:** GM **LOGGED:** JN **CASING:** Uncased
TYPE OF BORING: Solid flight auger (TC-bit) to 0.6m
WATER OBSERVATIONS: No free groundwater observed whilst augering
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)

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Appendix D

Laboratory Test Results

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Sydney Laboratory
96 Hermitage Road West Ryde NSW 2114
Phone: (02) 9809 0666
Fax: (02) 9809 0666
Email: mick.gref@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Michael Gref
Nata Accredited Laboratory Number: 828

Report Number:	**85998.00-1**
Issue Number:	1
Date Issued:	10/07/2017
Client:	GHD Pty Ltd Level 15/133 Castlereagh Street, Sydney NSW 2000
Contact:	Carl Sakellaris
Project Number:	85998.00
Project Name:	Proposed New School
Project Location:	56-58 Hezlett Road, North Kellyville
Work Request:	1114
Sample Number:	17-1114A
Date Sampled:	19/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**2 (1.0m)**
Material:	Silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	45		
Plastic Limit (%)	22		
Plasticity Index (%)	**23**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	19.5

Material Test Report

Douglas Partners
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WORLD RECOGNISED ACCREDITATION

Approved Signatory: Michael Gref
Nata Accredited Laboratory Number: 828

Report Number:	**85998.00-1**
Issue Number:	1
Date Issued:	10/07/2017
Client:	GHD Pty Ltd Level 15/133 Castlereagh Street, Sydney NSW 2000
Contact:	Carl Sakellaris
Project Number:	85998.00
Project Name:	Proposed New School
Project Location:	56-58 Hezlett Road, North Kellyville
Work Request:	1114
Sample Number:	17-1114B
Date Sampled:	19/06/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**4 (0.5m)**
Material:	Silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	45		
Plastic Limit (%)	21		
Plasticity Index (%)	**24**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	19.7

Material Test Report

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NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Michael Gref
Nata Accredited Laboratory Number: 828

Report Number: **85998.00-1**
Issue Number: 1
Date Issued: 10/07/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Contact: Carl Sakellaris
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1114
Sample Number: 17-1114C
Date Sampled: 19/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **5 (0.8m)**
Material: Silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	30		
Plastic Limit (%)	20		
Plasticity Index (%)	**10**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	12.1

Material Test Report

Douglas Partners Pty Ltd
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Nata Accredited Laboratory Number: 828

Report Number: **85998.00-1**
Issue Number: 1
Date Issued: 10/07/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Contact: Carl Sakellaris
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1114
Sample Number: 17-1114D
Date Sampled: 19/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **8 (0.5m)**
Material: Silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	35		
Plastic Limit (%)	20		
Plasticity Index (%)	**15**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	21.0

Material Test Report

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Nata Accredited Laboratory Number: 828

Report Number: **85998.00-1**
Issue Number: 1
Date Issued: 10/07/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Contact: Carl Sakellaris
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1114
Sample Number: 17-1114E
Date Sampled: 19/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **1 (0.50 - 0.95m)**
Material: Silty clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	57		
Plastic Limit (%)	25		
Plasticity Index (%)	**32**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Linear Shrinkage (%)	12.0		
Cracking Crumbling Curling	None		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	24.8

Material Test Report

Douglas Partners
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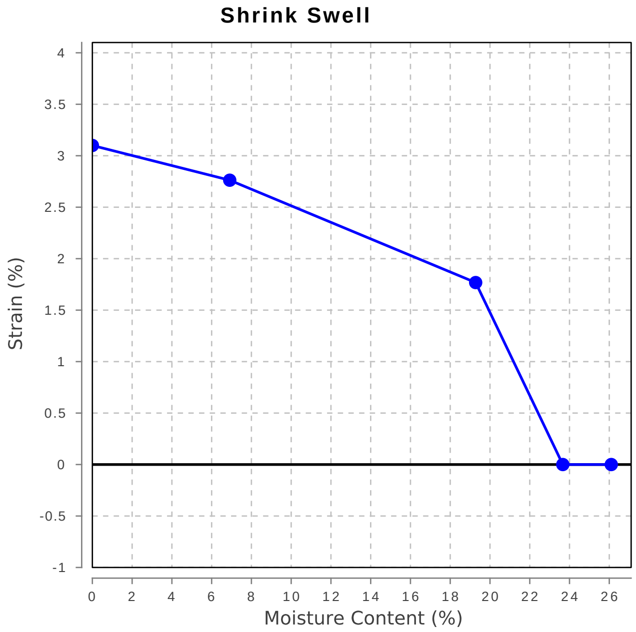
Nata Accredited Laboratory Number: 828

Report Number: **85998.00-1**
Issue Number: 1
Date Issued: 10/07/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Contact: Carl Sakellaris
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1114
Sample Number: 17-1114F
Date Sampled: 19/06/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **3 (0.50 - 0.95m)**
Material: Silty clay

Shrink Swell Index (AS 1289 7.1.1 & 2.1.1)	
Iss (%)	**1.7**
Visual Description	Silty clay
* Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.	

Core Shrinkage Test	
Shrinkage Strain - Oven Dried (%)	**3.1**
Estimated % by volume of significant inert inclusions	3
Cracking	Moderately Cracked
Crumbling	No
Moisture Content (%)	23.7

Swell Test	
Initial Pocket Penetrometer (kPa)	350
Final Pocket Penetrometer (kPa)	250
Initial Moisture Content (%)	24.0
Final Moisture Content (%)	26.1
Swell (%)	**0.0**
* NATA Accreditation does not cover the performance of pocket penetrometer readings.	



Material Test Report

Douglas Partners
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Report Number: **85998.00-1**
Issue Number: 1
Date Issued: 10/07/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Contact: Carl Sakellaris
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1114

Approved Signatory: Michael Gref
Nata Accredited Laboratory Number: 828

Moisture Content AS 1289 2.1.1

Sample Number	Sample Location	Moisture Content	Material
17-1114A	2 (1.0m)	19.5 %	Silty clay
17-1114B	4 (0.5m)	19.7 %	Silty clay
17-1114C	5 (0.8m)	12.1 %	Silty clay
17-1114D	8 (0.5m)	21.0 %	Silty clay
17-1114E	1 (0.50 - 0.95m)	24.8 %	Silty clay

Material Test Report

Douglas Partners Pty Ltd
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Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Mark Matthews
Nata Accredited Laboratory Number: 828

Report Number: **85998.00-2A**
Issue Number: 1
Date Issued: 09/08/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1302
Sample Number: 17-1302A
Date Sampled: 28/07/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **9 (0.4-0.5m)**
Material: Brown silty clay filling

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	37		
Plastic Limit (%)	23		
Plasticity Index (%)	**14**		

Material Test Report

Douglas Partners Pty Ltd
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Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Mark Matthews
Nata Accredited Laboratory Number: 828

Report Number:	**85998.00-2A**
Issue Number:	1
Date Issued:	09/08/2017
Client:	GHD Pty Ltd Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number:	85998.00
Project Name:	Proposed New School
Project Location:	56-58 Hezlett Road, North Kellyville
Work Request:	1302
Sample Number:	17-1302B
Date Sampled:	28/07/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**10 (0.3-0.37m)**
Material:	Brown silty clay filling

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Preparation Method	Dry Sieve		
Sample History	Oven Dried		
Liquid Limit (%)	36		
Plastic Limit (%)	23		
Plasticity Index (%)	**13**		

Material Test Report

Douglas Partners
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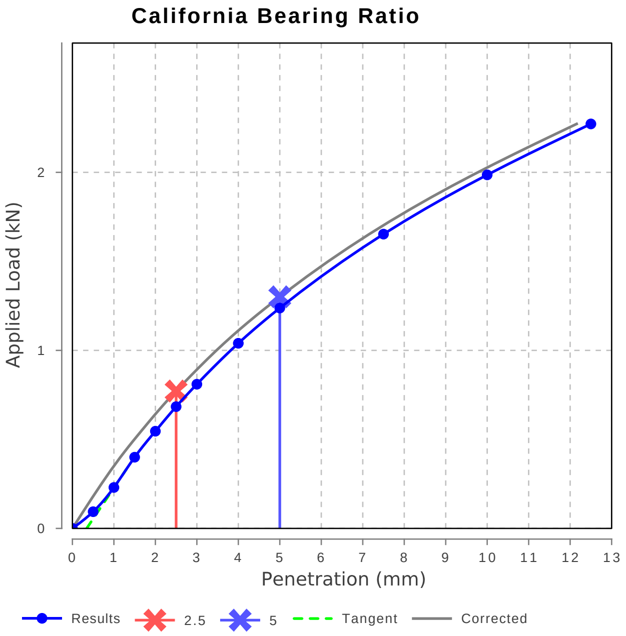
NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Mark Matthews
Nata Accredited Laboratory Number: 828

Report Number: **85998.00-2A**
Issue Number: 1
Date Issued: 09/08/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1302
Sample Number: 17-1302D
Date Sampled: 28/07/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **12 (0.1-0.5m)**
Material: Red-brown silty clay filling

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**7**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.67		
Optimum Moisture Content (%)	21.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	99.5		
Dry Density after Soaking (t/m^3)	1.66		
Field Moisture Content (%)	20.1		
Moisture Content at Placement (%)	21.3		
Moisture Content Top 30mm (%)	22.9		
Moisture Content Rest of Sample (%)	22.5		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	0.5		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

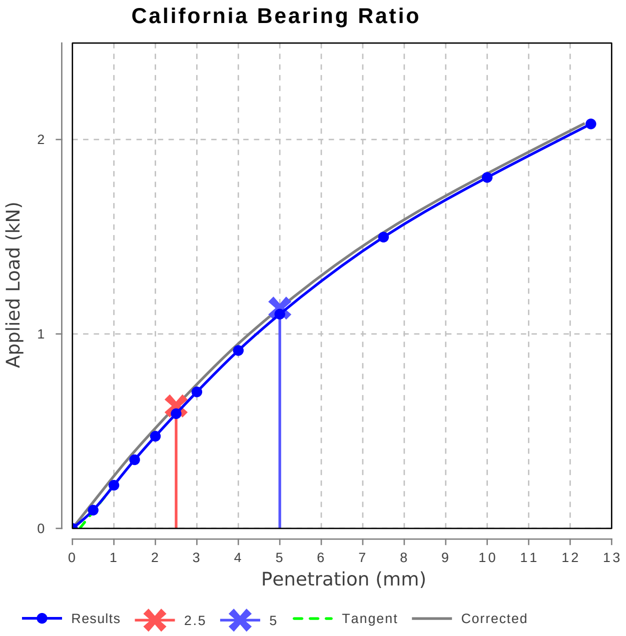
Report Number:	**85998.00-2A**
Issue Number:	1
Date Issued:	09/08/2017
Client:	GHD Pty Ltd Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number:	85998.00
Project Name:	Proposed New School
Project Location:	56-58 Hezlett Road, North Kellyville
Work Request:	1302
Sample Number:	17-1302E
Date Sampled:	28/07/2017
Sampling Method:	Sampled by Engineering Department
Sample Location:	**14 (0.2-0.6m)**
Material:	Orange brown silty clay filling

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Sydney Laboratory
96 Hermitage Road West Ryde NSW 2114
Phone: (02) 9809 0666
Fax: (02) 9809 0666
Email: mark.matthews@douglaspartners.com.au
Accredited for compliance with ISO/IEC 17025 - Testing

NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Mark Matthews
Nata Accredited Laboratory Number: 828

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**6**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.69		
Optimum Moisture Content (%)	20.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.5		
Dry Density after Soaking (t/m^3)	1.69		
Field Moisture Content (%)	21.7		
Moisture Content at Placement (%)	20.5		
Moisture Content Top 30mm (%)	22.6		
Moisture Content Rest of Sample (%)	21.6		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	0.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Sydney Laboratory
96 Hermitage Road West Ryde NSW 2114
Phone: (02) 9809 0666
Fax: (02) 9809 0666
Email: mark.matthews@douglaspartners.com.au

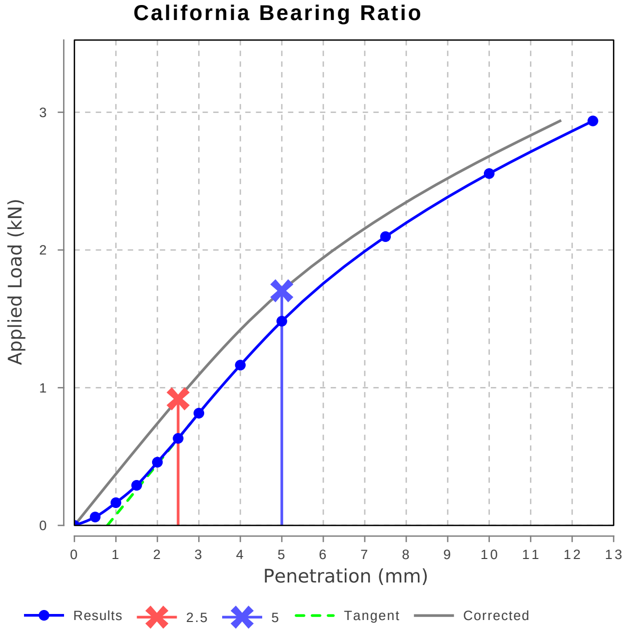
Accredited for compliance with ISO/IEC 17025 - Testing

NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Mark Matthews
Nata Accredited Laboratory Number: 828

Report Number: **85998.00-2A**
Issue Number: 1
Date Issued: 09/08/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1302
Sample Number: 17-1302F
Date Sampled: 28/07/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **11 (0.1-0.4m)**
Material: Grey shale

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**9**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.70		
Optimum Moisture Content (%)	18.0		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.69		
Field Moisture Content (%)	15.4		
Moisture Content at Placement (%)	17.8		
Moisture Content Top 30mm (%)	21.4		
Moisture Content Rest of Sample (%)	20.6		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	1.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

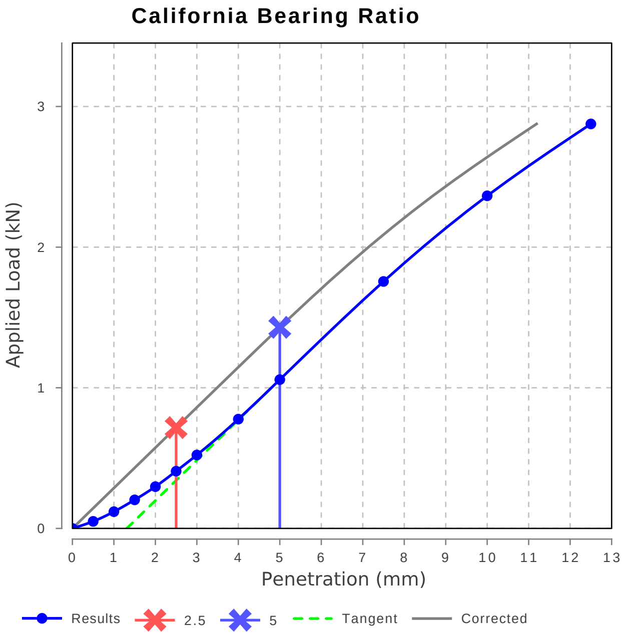
Report Number: **85998.00-2A**
Issue Number: 1
Date Issued: 09/08/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1302
Sample Number: 17-1302G
Date Sampled: 28/07/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **13 (0.4-0.6m)**
Material: Red-brown silty clay filling

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Sydney Laboratory
96 Hermitage Road West Ryde NSW 2114
Phone: (02) 9809 0666
Fax: (02) 9809 0666
Email: mark.matthews@douglaspartners.com.au

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Mark Matthews
Nata Accredited Laboratory Number: 828

California Bearing Ratio (AS 1289 6.1.1 & 2.1.1)		Min	Max
CBR taken at	5 mm		
CBR %	**7**		
Method of Compactive Effort	Standard		
Method used to Determine MDD	AS 1289 5.1.1 & 2.1.1		
Maximum Dry Density (t/m^3)	1.70		
Optimum Moisture Content (%)	19.5		
Laboratory Density Ratio (%)	100.0		
Laboratory Moisture Ratio (%)	100.0		
Dry Density after Soaking (t/m^3)	1.69		
Field Moisture Content (%)	18.4		
Moisture Content at Placement (%)	19.5		
Moisture Content Top 30mm (%)	21.0		
Moisture Content Rest of Sample (%)	20.2		
Mass Surcharge (kg)	4.5		
Soaking Period (days)	4		
Swell (%)	0.0		
Oversize Material (mm)	19		
Oversize Material Included	Excluded		
Oversize Material (%)	0		



Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Sydney Laboratory
96 Hermitage Road West Ryde NSW 2114
Phone: (02) 9809 0666
Fax: (02) 9809 0666
Email: mark.matthews@douglaspartners.com.au

Report Number: **85998.00-2A**
Issue Number: 1
Date Issued: 09/08/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1302

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Mark Matthews
Nata Accredited Laboratory Number: 828

Moisture Content AS 1289 2.1.1

Sample Number	Sample Location	Moisture Content	Material
17-1302A	9 (0.4-0.5m)	17.3 %	Brown silty clay filling
17-1302B	10 (0.3-0.37m)	13.7 %	Brown silty clay filling

Material Test Report

Report Number: **85998.00-2B**
Issue Number: 1
Date Issued: 09/08/2017
Client: GHD Pty Ltd
Level 15/133 Castlereagh Street, Sydney NSW 2000
Project Number: 85998.00
Project Name: Proposed New School
Project Location: 56-58 Hezlett Road, North Kellyville
Work Request: 1302
Sample Number: 17-1302C
Date Sampled: 28/07/2017
Sampling Method: Sampled by Engineering Department
Sample Location: **9 (0.1-0.55m)**
Material: Brown silty clay filling

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Sydney Laboratory
96 Hermitage Road West Ryde NSW 2114
Phone: (02) 9809 0666
Fax: (02) 9809 0666
Email: mick.gref@douglaspartners.com.au

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NATA
WORLD RECOGNISED ACCREDITATION

Approved Signatory: Michael Gref
Nata Accredited Laboratory Number: 828

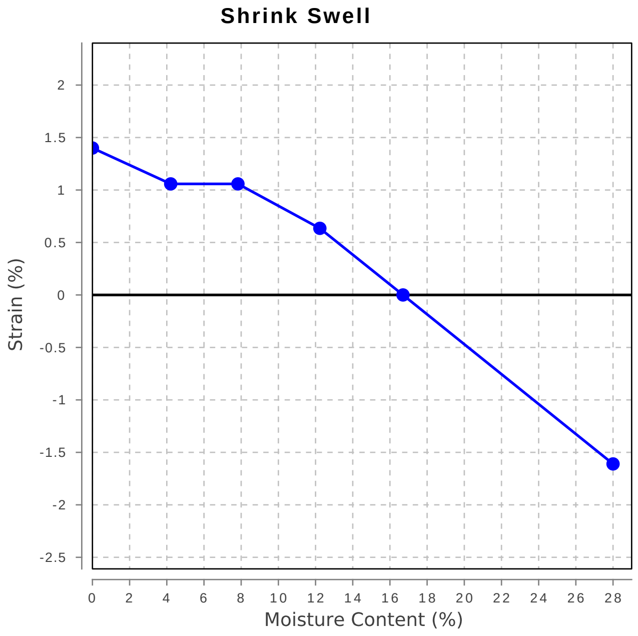
Shrink Swell Index (AS 1289 7.1.1 & 2.1.1)	
Iss (%)	**1.2**
Visual Description	Brown silty clay filling

* Shrink Swell Index (Iss) reported as the percentage vertical strain per pF change in suction.

Core Shrinkage Test	
Shrinkage Strain - Oven Dried (%)	**1.4**
Estimated % by volume of significant inert inclusions	10
Cracking	Slightly Cracked
Crumbling	No
Moisture Content (%)	16.7

Swell Test	
Initial Pocket Penetrometer (kPa)	>400
Final Pocket Penetrometer (kPa)	>400
Initial Moisture Content (%)	19.9
Final Moisture Content (%)	28.0
Swell (%)	**1.6**

* NATA Accreditation does not cover the performance of pocket penetrometer readings.



CERTIFICATE OF ANALYSIS 170240

Client:

Douglas Partners Pty Ltd
96 Hermitage Rd
West Ryde
NSW 2114

Attention: Atha Kapitanof

Sample log in details:

Your Reference:	**85998.00, Kellyville**
No. of samples:	4 soils
Date samples received / completed instructions received	28/06/17 / 28/06/17

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:	6/07/17 / 6/07/17
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: Your Reference	UNITS ------------- -	170240-1 BH1	170240-2 BH2	170240-3 BH3	170240-4 BH4
Depth	------------	1.0	1.0-1.45	0.5	1.0
Date Sampled		19/06/2017	19/06/2017	20/06/2017	20/06/2017
Type of sample		Soil	Soil	Soil	Soil
Date prepared	-	04/07/2017	04/07/2017	04/07/2017	04/07/2017
Date analysed	-	04/07/2017	04/07/2017	04/07/2017	04/07/2017
pH 1:5 soil:water	pH Units	5.3	5.0	6.0	5.0
Electrical Conductivity 1:5 soil:water	µS/cm	94	33	39	78
Chloride, Cl 1:5 soil:water	mg/kg	<10	<10	<10	<10
Sulphate, SO4 1:5 soil:water	mg/kg	170	56	26	110

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 25°C 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 ll Duplicate ll %RPD	Spike Sm#	Spike % Recovery
Date prepared	-			04/07/2017	[NT]	[NT]	LCS-1	04/07/2017
Date analysed	-			04/07/2017	[NT]	[NT]	LCS-1	04/07/2017
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	[NT]	[NT]	LCS-1	101%
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	[NT]	[NT]	LCS-1	95%
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	113%
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	LCS-1	118%

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
NR: Test not required
<: Less than

PQL: Practical Quantitation Limit
RPD: Relative Percent Difference
>: Greater than

NT: Not tested
NA: Test not required
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.

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CHAIN OF CUSTODY

Project Name: Kellyville, Proposed New School...To:
Project No: 85998.00 Sampler: Luke Blacklock ....
Project Mgr: Atha Kapitanof……Mob. Phone: 0418 747 383
Email: atha.kapitanof@douglaspartners.com.au ....
Date Required: Normal Lab Quote No. ……………………..............................

Envirolab Services
12 Ashley Street, Chatswood NSW 2068
Attn: Tania Notaras
Phone: 02 9910 6200 Fax: 02 9910 6201
Email: tnotaras@envirolabservices.com.au

Sample ID	Sample Depth	Lab ID	Sampling Date	Sample Type S - soil W – water	Container type	pH	SO_4	Cl^-	Electrical Cond.	Other	Notes
BH1	1.0	1	19/06/17	S		x	x	x	x		
BH2	1.0-1.45	2	19/06/17	S		x	x	x	x		
BH3	0.5	3	20/06/17	S		x	x	x	x		
BH4	1.0	4	20/06/17	S		x	x	x	x		

ENVIROLAB GROUP
Envirolab Services
12 Ashley St
Chatswood NSW 2067
Ph: (02) 9910 6200
Job No: 170240
Date Received: 28.6.17
Time Received: 16.15
Received by: JE
Temp: [✓ Cool]/Ambient -2.2°C
Cooling: Ice/[✓ Icepack]
Security: [✓ Intact]/Broken/None

Lab Report No. ....
Send Results to: Douglas Partners Address: 96 Hermitage Road, West Ryde 2114
Phone: (02) 9809 0666
Fax: (02) 9809 4095
Relinquished by: L.Blacklock Signed: Date & Time: 28/06/17 - 0730 Received By: JE ELS Date & Time: 28.6.17 16.15
Relinquished by: Signed: Date & Time: Received By: Date & Time:

Envirolab Services Pty Ltd
ABN 37 112 535 645
12 Ashley St Chatswood NSW 2067
ph 02 9910 6200   fax 02 9910 6201
customerservice@envirolab.com.au
www.envirolab.com.au

CERTIFICATE OF ANALYSIS 172431

Client Details

Client	Douglas Partners Pty Ltd
Attention	Huw Smith
Address	96 Hermitage Rd, West Ryde, NSW, 2114

Sample Details

Your Reference	**85998.00, North Kellyville, Proposed New School**
Number of Samples	2 soils
Date samples received	31/07/2017
Date completed instructions received	31/07/2017

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.

Report Details

Date results requested by	07/08/2017
Date of Issue	04/08/2017

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Accredited for compliance with ISO/IEC 17025 - Testing. **Tests not covered by NATA are denoted with ***

Results Approved By
Priya Samarawickrama, Senior Chemist

Authorised By
David Springer, General Manager

Misc Inorg - Soil			
Our Reference		172431-1	172431-2
Your Reference	UNITS	Bore 9	Bore 10
Depth		0.4-0.5	0.3-0.37
Date Sampled		28/07/2017	28/07/2017
Type of sample		Soil	Soil
Date prepared	-	01/08/2017	01/08/2017
Date analysed	-	01/08/2017	01/08/2017
pH 1:5 soil:water	pH Units	6.3	7.2
Electrical Conductivity 1:5 soil:water	µS/cm	38	26
Chloride, Cl 1:5 soil:water	mg/kg	<10	<10
Sulphate, SO4 1:5 soil:water	mg/kg	37	<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 25°C 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					Duplicate				Spike Recovery %	
Test Description	Units	PQL	Method	Blank	#	Base	Dup.	RPD	LCS-1	[NT]
Date prepared	-			01/08/2017	[NT]	[NT]	[NT]	[NT]	01/08/2017	[NT]
Date analysed	-			01/08/2017	[NT]	[NT]	[NT]	[NT]	01/08/2017	[NT]
pH 1:5 soil:water	pH Units		Inorg-001	[NT]	[NT]	[NT]	[NT]	[NT]	102	[NT]
Electrical Conductivity 1:5 soil:water	µS/cm	1	Inorg-002	<1	[NT]	[NT]	[NT]	[NT]	99	[NT]
Chloride, Cl 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	[NT]	[NT]	114	[NT]
Sulphate, SO4 1:5 soil:water	mg/kg	10	Inorg-081	<10	[NT]	[NT]	[NT]	[NT]	109	[NT]

Result Definitions

NT	Not tested
NA	Test not required
INS	Insufficient sample for this test
PQL	Practical Quantitation Limit
<	Less than
>	Greater than
RPD	Relative Percent Difference
LCS	Laboratory Control Sample
NS	Not specified
NEPM	National Environmental Protection Measure
NR	Not Reported

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.

Australian Drinking Water Guidelines recommend that Thermotolerant Coliform, Faecal Enterococci, & E.Coli levels are less than 1cfu/100mL. The recommended maximums are taken from "Australian Drinking Water Guidelines", published by NHMRC & ARMC 2011.

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.

Douglas Partners
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CHAIN OF CUSTODY

Project Name: NORTH Kellyville, Proposed New School.. To:
Project No: ~~85998.00~~ 85998.00 Sampler: JN...
Project Mgr: Huw Smith……Mob. Phone: 0457 846 970 Attn:
Email: huw.smith@douglaspartners.com.au ....
Date Required: Normal Lab Quote No. ……………………..

Envirolab Services
12 Ashley Street, Chatswood NSW 2068
Tania Notaras
Phone: 02 9910 6200 Fax: 02 9910 6201
Email: tnotaras@envirolabservices.com.au

Sample ID	Sample Depth	Lab ID	Sampling Date	Sample Type S - soil W – water	Container type	pH	SO_4	Cl^-	Electrical Cond.	Other	Notes
~~BH~~ BORE 9	0·4-0·5	1	28/7/17	S	Jar	✓	✓	✓	✓		
BORE 10	0·3-0·37	2	28/7/17	S	Jar	✓	✓	✓	✓		

ENVIROLAB GROUP
Envirolab Services
12 Ashley St
Chatswood NSW 2067
Ph: (02) 9910 6200
Job No: 172431
Date Received: 31.7.17
Time Received: 14:30
Received by: JE
Temp: [✓ Cool]/Ambient
Cooling: Ice/[✓ Icepack]
Security: [✓ Intact]/Broken/None

Lab Report No. ....
Send Results to: Douglas Partners Address: 96 Hermitage Road, West Ryde 2114
Phone: (02) 9809 0666
Fax: (02) 9809 4095
Relinquished by: HDS Signed: Date & Time: ~~28/06/17 - 0730~~ 31/7/17 1100 Received By: Date & Time:
Relinquished by: Signed: Date & Time: Received By: Date & Time:

Appendix E

CSIRO Notes

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

BTF 18
replaces
Information
Sheet 10/91

Buildings can and often do move. This movement can be up, down, lateral or rotational. The fundamental cause of movement in buildings can usually be related to one or more problems in the foundation soil. It is important for the homeowner to identify the soil type in order to ascertain the measures that should be put in place in order to ensure that problems in the foundation soil can be prevented, thus protecting against building movement.

This Building Technology File is designed to identify causes of soil-related building movement, and to suggest methods of prevention of resultant cracking in buildings.

Soil Types

The types of soils usually present under the topsoil in land zoned for residential buildings can be split into two approximate groups – granular and clay. Quite often, foundation soil is a mixture of both types. The general problems associated with soils having granular content are usually caused by erosion. Clay soils are subject to saturation and swell/shrink problems.

Classifications for a given area can generally be obtained by application to the local authority, but these are sometimes unreliable and if there is doubt, a geotechnical report should be commissioned. As most buildings suffering movement problems are founded on clay soils, there is an emphasis on classification of soils according to the amount of swell and shrinkage they experience with variations of water content. The table below is Table 2.1 from AS 2870, the Residential Slab and Footing Code.

Causes of Movement

Settlement due to construction
There are two types of settlement that occur as a result of construction:

- Immediate settlement occurs when a building is first placed on its foundation soil, as a result of compaction of the soil under the weight of the structure. The cohesive quality of clay soil mitigates against this, but granular (particularly sandy) soil is susceptible.
- Consolidation settlement is a feature of clay soil and may take place because of the expulsion of moisture from the soil or because of the soil's lack of resistance to local compressive or shear stresses. This will usually take place during the first few months after construction, but has been known to take many years in exceptional cases.

These problems are the province of the builder and should be taken into consideration as part of the preparation of the site for construction. Building Technology File 19 (BTF 19) deals with these problems.

Erosion
All soils are prone to erosion, but sandy soil is particularly susceptible to being washed away. Even clay with a sand component of say 10% or more can suffer from erosion.

Saturation
This is particularly a problem in clay soils. Saturation creates a bog-like suspension of the soil that causes it to lose virtually all of its bearing capacity. To a lesser degree, sand is affected by saturation because saturated sand may undergo a reduction in volume – particularly imported sand fill for bedding and blinding layers. However, this usually occurs as immediate settlement and should normally be the province of the builder.

Seasonal swelling and shrinkage of soil
All clays react to the presence of water by slowly absorbing it, making the soil increase in volume (see table below). The degree of increase varies considerably between different clays, as does the degree of decrease during the subsequent drying out caused by fair weather periods. Because of the low absorption and expulsion rate, this phenomenon will not usually be noticeable unless there are prolonged rainy or dry periods, usually of weeks or months, depending on the land and soil characteristics.

The swelling of soil creates an upward force on the footings of the building, and shrinkage creates subsidence that takes away the support needed by the footing to retain equilibrium.

Shear failure
This phenomenon occurs when the foundation soil does not have sufficient strength to support the weight of the footing. There are two major post-construction causes:

- Significant load increase.
- Reduction of lateral support of the soil under the footing due to erosion or excavation.
- In clay soil, shear failure can be caused by saturation of the soil adjacent to or under the footing.

GENERAL DEFINITIONS OF SITE CLASSES

Class	Foundation
A	Most sand and rock sites with little or no ground movement from moisture changes
S	Slightly reactive clay sites with only slight ground movement from moisture changes
M	Moderately reactive clay or silt sites, which can experience moderate ground movement from moisture changes
H	Highly reactive clay sites, which can experience high ground movement from moisture changes
E	Extremely reactive sites, which can experience extreme ground movement from moisture changes
A to P	Filled sites
P	Sites which include soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise

Tree root growth

Trees and shrubs that are allowed to grow in the vicinity of footings can cause foundation soil movement in two ways:

- Roots that grow under footings may increase in cross-sectional size, exerting upward pressure on footings.
- Roots in the vicinity of footings will absorb much of the moisture in the foundation soil, causing shrinkage or subsidence.

Unevenness of Movement

The types of ground movement described above usually occur unevenly throughout the building's foundation soil. Settlement due to construction tends to be uneven because of:

- Differing compaction of foundation soil prior to construction.
- Differing moisture content of foundation soil prior to construction.

Movement due to non-construction causes is usually more uneven still. Erosion can undermine a footing that traverses the flow or can create the conditions for shear failure by eroding soil adjacent to a footing that runs in the same direction as the flow.

Saturation of clay foundation soil may occur where subfloor walls create a dam that makes water pond. It can also occur wherever there is a source of water near footings in clay soil. This leads to a severe reduction in the strength of the soil which may create local shear failure.

Seasonal swelling and shrinkage of clay soil affects the perimeter of the building first, then gradually spreads to the interior. The swelling process will usually begin at the uphill extreme of the building, or on the weather side where the land is flat. Swelling gradually reaches the interior soil as absorption continues. Shrinkage usually begins where the sun's heat is greatest.

Effects of Uneven Soil Movement on Structures

Erosion and saturation

Erosion removes the support from under footings, tending to create subsidence of the part of the structure under which it occurs. Brickwork walls will resist the stress created by this removal of support by bridging the gap or cantilevering until the bricks or the mortar bedding fail. Older masonry has little resistance. Evidence of failure varies according to circumstances and symptoms may include:

- Step cracking in the mortar beds in the body of the wall or above/below openings such as doors or windows.
- Vertical cracking in the bricks (usually but not necessarily in line with the vertical beds or perpends).

Isolated piers affected by erosion or saturation of foundations will eventually lose contact with the bearers they support and may tilt or fall over. The floors that have lost this support will become bouncy, sometimes rattling ornaments etc.

Seasonal swelling/shrinkage in clay

Swelling foundation soil due to rainy periods first lifts the most exposed extremities of the footing system, then the remainder of the perimeter footings while gradually permeating inside the building footprint to lift internal footings. This swelling first tends to create a dish effect, because the external footings are pushed higher than the internal ones.

The first noticeable symptom may be that the floor appears slightly dished. This is often accompanied by some doors binding on the floor or the door head, together with some cracking of cornice mitres. In buildings with timber flooring supported by bearers and joists, the floor can be bouncy. Externally there may be visible dishing of the hip or ridge lines.

As the moisture absorption process completes its journey to the innermost areas of the building, the internal footings will rise. If the spread of moisture is roughly even, it may be that the symptoms will temporarily disappear, but it is more likely that swelling will be uneven, creating a difference rather than a disappearance in symptoms. In buildings with timber flooring supported by bearers and joists, the isolated piers will rise more easily than the strip footings or piers under walls, creating noticeable doming of flooring.

Trees can cause shrinkage and damage

As the weather pattern changes and the soil begins to dry out, the external footings will be first affected, beginning with the locations where the sun's effect is strongest. This has the effect of lowering the external footings. The doming is accentuated and cracking reduces or disappears where it occurred because of dishing, but other cracks open up. The roof lines may become convex.

Doming and dishing are also affected by weather in other ways. In areas where warm, wet summers and cooler dry winters prevail, water migration tends to be toward the interior and doming will be accentuated, whereas where summers are dry and winters are cold and wet, migration tends to be toward the exterior and the underlying propensity is toward dishing.

Movement caused by tree roots

In general, growing roots will exert an upward pressure on footings, whereas soil subject to drying because of tree or shrub roots will tend to remove support from under footings by inducing shrinkage.

Complications caused by the structure itself

Most forces that the soil causes to be exerted on structures are vertical – i.e. either up or down. However, because these forces are seldom spread evenly around the footings, and because the building resists uneven movement because of its rigidity, forces are exerted from one part of the building to another. The net result of all these forces is usually rotational. This resultant force often complicates the diagnosis because the visible symptoms do not simply reflect the original cause. A common symptom is binding of doors on the vertical member of the frame.

Effects on full masonry structures

Brickwork will resist cracking where it can. It will attempt to span areas that lose support because of subsided foundations or raised points. It is therefore usual to see cracking at weak points, such as openings for windows or doors.

In the event of construction settlement, cracking will usually remain unchanged after the process of settlement has ceased.

With local shear or erosion, cracking will usually continue to develop until the original cause has been remedied, or until the subsidence has completely neutralised the affected portion of footing and the structure has stabilised on other footings that remain effective.

In the case of swell/shrink effects, the brickwork will in some cases return to its original position after completion of a cycle, however it is more likely that the rotational effect will not be exactly reversed, and it is also usual that brickwork will settle in its new position and will resist the forces trying to return it to its original position. This means that in a case where swelling takes place after construction and cracking occurs, the cracking is likely to at least partly remain after the shrink segment of the cycle is complete. Thus, each time the cycle is repeated, the likelihood is that the cracking will become wider until the sections of brickwork become virtually independent.

With repeated cycles, once the cracking is established, if there is no other complication, it is normal for the incidence of cracking to stabilise, as the building has the articulation it needs to cope with the problem. This is by no means always the case, however, and monitoring of cracks in walls and floors should always be treated seriously.

Upheaval caused by growth of tree roots under footings is not a simple vertical shear stress. There is a tendency for the root to also exert lateral forces that attempt to separate sections of brickwork after initial cracking has occurred.

The normal structural arrangement is that the inner leaf of brickwork in the external walls and at least some of the internal walls (depending on the roof type) comprise the load-bearing structure on which any upper floors, ceilings and the roof are supported. In these cases, it is internally visible cracking that should be the main focus of attention, however there are a few examples of dwellings whose external leaf of masonry plays some supporting role, so this should be checked if there is any doubt. In any case, externally visible cracking is important as a guide to stresses on the structure generally, and it should also be remembered that the external walls must be capable of supporting themselves.

Effects on framed structures
Timber or steel framed buildings are less likely to exhibit cracking due to swell/shrink than masonry buildings because of their flexibility. Also, the doming/dishing effects tend to be lower because of the lighter weight of walls. The main risks to framed buildings are encountered because of the isolated pier footings used under walls. Where erosion or saturation cause a footing to fall away, this can double the span which a wall must bridge. This additional stress can create cracking in wall linings, particularly where there is a weak point in the structure caused by a door or window opening. It is, however, unlikely that framed structures will be so stressed as to suffer serious damage without first exhibiting some or all of the above symptoms for a considerable period. The same warning period should apply in the case of upheaval. It should be noted, however, that where framed buildings are supported by strip footings there is only one leaf of brickwork and therefore the externally visible walls are the supporting structure for the building. In this case, the subfloor masonry walls can be expected to behave as full brickwork walls.

Effects on brick veneer structures
Because the load-bearing structure of a brick veneer building is the frame that makes up the interior leaf of the external walls plus perhaps the internal walls, depending on the type of roof, the building can be expected to behave as a framed structure, except that the external masonry will behave in a similar way to the external leaf of a full masonry structure.

Water Service and Drainage

Where a water service pipe, a sewer or stormwater drainage pipe is in the vicinity of a building, a water leak can cause erosion, swelling or saturation of susceptible soil. Even a minuscule leak can be enough to saturate a clay foundation. A leaking tap near a building can have the same effect. In addition, trenches containing pipes can become watercourses even though backfilled, particularly where broken rubble is used as fill. Water that runs along these trenches can be responsible for serious erosion, interstrata seepage into subfloor areas and saturation.

Pipe leakage and trench water flows also encourage tree and shrub roots to the source of water, complicating and exacerbating the problem.
Poor roof plumbing can result in large volumes of rainwater being concentrated in a small area of soil:

- Incorrect falls in roof guttering may result in overflows, as may gutters blocked with leaves etc.
- Corroded guttering or downpipes can spill water to ground.
- Downpipes not positively connected to a proper stormwater collection system will direct a concentration of water to soil that is directly adjacent to footings, sometimes causing large-scale problems such as erosion, saturation and migration of water under the building.

Seriousness of Cracking

In general, most cracking found in masonry walls is a cosmetic nuisance only and can be kept in repair or even ignored. The table below is a reproduction of Table C1 of AS 2870.

AS 2870 also publishes figures relating to cracking in concrete floors, however because wall cracking will usually reach the critical point significantly earlier than cracking in slabs, this table is not reproduced here.

Prevention/Cure

Plumbing
Where building movement is caused by water service, roof plumbing, sewer or stormwater failure, the remedy is to repair the problem. It is prudent, however, to consider also rerouting pipes away from the building where possible, and relocating taps to positions where any leakage will not direct water to the building vicinity. Even where gully traps are present, there is sometimes sufficient spill to create erosion or saturation, particularly in modern installations using smaller diameter PVC fixtures. Indeed, some gully traps are not situated directly under the taps that are installed to charge them, with the result that water from the tap may enter the backfilled trench that houses the sewer piping. If the trench has been poorly backfilled, the water will either pond or flow along the bottom of the trench. As these trenches usually run alongside the footings and can be at a similar depth, it is not hard to see how any water that is thus directed into a trench can easily affect the foundation's ability to support footings or even gain entry to the subfloor area.

Ground drainage
In all soils there is the capacity for water to travel on the surface and below it. Surface water flows can be established by inspection during and after heavy or prolonged rain. If necessary, a grated drain system connected to the stormwater collection system is usually an easy solution.

It is, however, sometimes necessary when attempting to prevent water migration that testing be carried out to establish watertable height and subsoil water flows. This subject is referred to in BTF 19 and may properly be regarded as an area for an expert consultant.

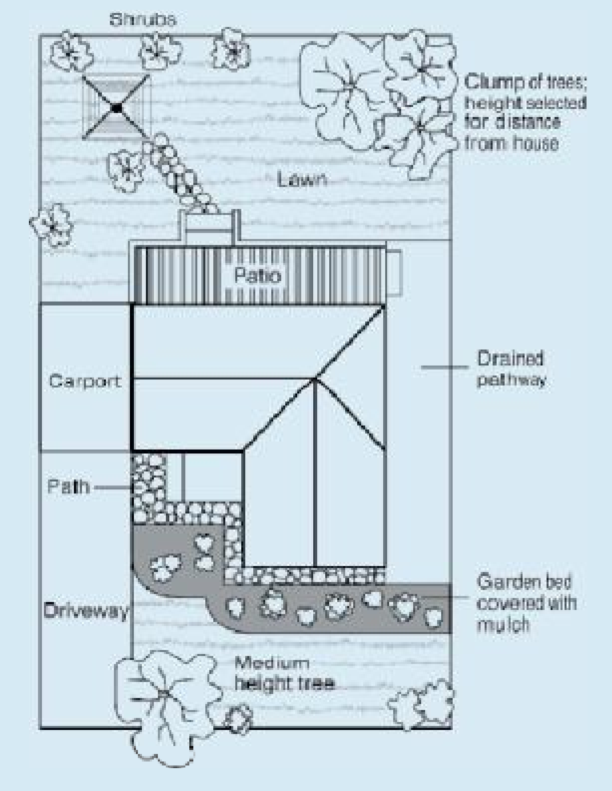
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

For this reason, particularly where problems exist or are likely to occur, it is recommended that an apron of paving be installed around as much of the building perimeter as necessary. This paving

CLASSIFICATION OF DAMAGE WITH REFERENCE TO WALLS

Description of typical damage and required repair	Approximate crack width limit (see Note 3)	Damage category
Hairline cracks	<0.1 mm	0
Fine cracks which do not need repair	<1 mm	1
Cracks noticeable but easily filled. Doors and windows stick slightly	<5 mm	2
Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weathertightness often impaired	5–15 mm (or a number of cracks 3 mm or more in one group)	3
Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window and door frames distort. Walls lean or bulge noticeably, some loss of bearing in beams. Service pipes disrupted	15–25 mm but also depend on number of cracks	4

Gardens for a reactive site



should extend outwards a minimum of 900 mm (more in highly reactive soil) and should have a minimum fall away from the building of 1:60. The finished paving should be no less than 100 mm below brick vent bases.

It is prudent to relocate drainage pipes away from this paving, if possible, to avoid complications from future leakage. If this is not practical, earthenware pipes should be replaced by PVC and backfilling should be of the same soil type as the surrounding soil and compacted to the same density.

Except in areas where freezing of water is an issue, it is wise to remove taps in the building area and relocate them well away from the building – preferably not uphill from it (see BTF 19).

It may be desirable to install a grated drain at the outside edge of the paving on the uphill side of the building. If subsoil drainage is needed this can be installed under the surface drain.

Condensation

In buildings with a subfloor void such as where bearers and joists support flooring, insufficient ventilation creates ideal conditions for condensation, particularly where there is little clearance between the floor and the ground. Condensation adds to the moisture already present in the subfloor and significantly slows the process of drying out. Installation of an adequate subfloor ventilation system, either natural or mechanical, is desirable.

Warning: Although this Building Technology File deals with cracking in buildings, it should be said that subfloor moisture can result in the development of other problems, notably:

- Water that is transmitted into masonry, metal or timber building elements causes damage and/or decay to those elements.
- High subfloor humidity and moisture content create an ideal environment for various pests, including termites and spiders.
- Where high moisture levels are transmitted to the flooring and walls, an increase in the dust mite count can ensue within the living areas. Dust mites, as well as dampness in general, can be a health hazard to inhabitants, particularly those who are abnormally susceptible to respiratory ailments.

The garden

The ideal vegetation layout is to have lawn or plants that require only light watering immediately adjacent to the drainage or paving edge, then more demanding plants, shrubs and trees spread out in that order.

Overwatering due to misuse of automatic watering systems is a common cause of saturation and water migration under footings. If it is necessary to use these systems, it is important to remove garden beds to a completely safe distance from buildings.

Existing trees

Where a tree is causing a problem of soil drying or there is the existence or threat of upheaval of footings, if the offending roots are subsidiary and their removal will not significantly damage the tree, they should be severed and a concrete or metal barrier placed vertically in the soil to prevent future root growth in the direction of the building. If it is not possible to remove the relevant roots without damage to the tree, an application to remove the tree should be made to the local authority. A prudent plan is to transplant likely offenders before they become a problem.

Information on trees, plants and shrubs

State departments overseeing agriculture can give information regarding root patterns, volume of water needed and safe distance from buildings of most species. Botanic gardens are also sources of information. For information on plant roots and drains, see Building Technology File 17.

Excavation

Excavation around footings must be properly engineered. Soil supporting footings can only be safely excavated at an angle that allows the soil under the footing to remain stable. This angle is called the angle of repose (or friction) and varies significantly between soil types and conditions. Removal of soil within the angle of repose will cause subsidence.

Remediation

Where erosion has occurred that has washed away soil adjacent to footings, soil of the same classification should be introduced and compacted to the same density. Where footings have been undermined, augmentation or other specialist work may be required. Remediation of footings and foundations is generally the realm of a specialist consultant.

Where isolated footings rise and fall because of swell/shrink effect, the homeowner may be tempted to alleviate floor bounce by filling the gap that has appeared between the bearer and the pier with blocking. The danger here is that when the next swell segment of the cycle occurs, the extra blocking will push the floor up into an accentuated dome and may also cause local shear failure in the soil. If it is necessary to use blocking, it should be by a pair of fine wedges and monitoring should be carried out fortnightly.

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