Douglas Partners
Geotechnics / Environment / Groundwater

Report on
Geotechnical Investigation

School Upgrades
Irrawang High School, 80 Mount Hall Rd, Raymond Terrace

Prepared for
NSW Department of Education

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Integrated Practical Solutions

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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.

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Report on Geotechnical Investigation
School Upgrades
Irrawang High School, 80 Mount Hall Rd, Raymond Terrace

1. Introduction

This report presents the results of a geotechnical investigation undertaken in connection with proposed school upgrades at Irrawang High School, 80 Mount Hall Rd, Raymond Terrace. The investigation was undertaken in accordance with Douglas Partners Pty Ltd (DP) proposal 216008.00.P.001.Rev0 dated 15 June 2022 and acceptance received from Elisa Tanaka from Department of Education through School Infrastructure NSW on 5 July 2022.

The aim of the investigation was to assess the subsurface soil and groundwater conditions across the site in order to provide:

- Site classification in accordance with AS 2870 (2011);
- Site hazard factor and site sub-soil class in accordance with AS1170.4 – earthquake loading;
- Suitability of site won soils for reuse as controlled fill material;
- Earthworks preparation measures and material compaction requirements;
- Geotechnical retaining wall design parameters, including earth pressure coefficients;
- Suitable foundation types; and
- Geotechnical footing design parameters, including allowable bearing capacity and estimated settlements.

The investigation included the drilling of five boreholes. Details of the field work are presented in this report, together with preliminary comments and recommendations on the items listed above.

This report must be read in conjunction with the attached notes ‘About This Report’ in Appendix A, and any other attached explanatory notes, and should be kept in its entirety without separation of individual pages or sections.

2. Proposed Development

It is understood that the upgrade of Irrawang High School is to include the following:

- New two storey learning hub located immediately west of the existing ‘Block G’;
- Extension of the library (single storey) from the western extent of ‘Block G’;
- A new covered school entry way (proposed Stage 2);
- Relocation of demountable classroom (Clontarf Academy) approximately 65 m north, from ‘Block G’ to ‘Block F’;

- Relocation of two demountable classrooms approximately 65 m north, from ‘Block G’ to ‘Block F’, it is further understood that these would be removed at the end of the project;
- New covered walkways;
- New support drop off bay; and
- Refurbishment of selected classrooms and buildings.

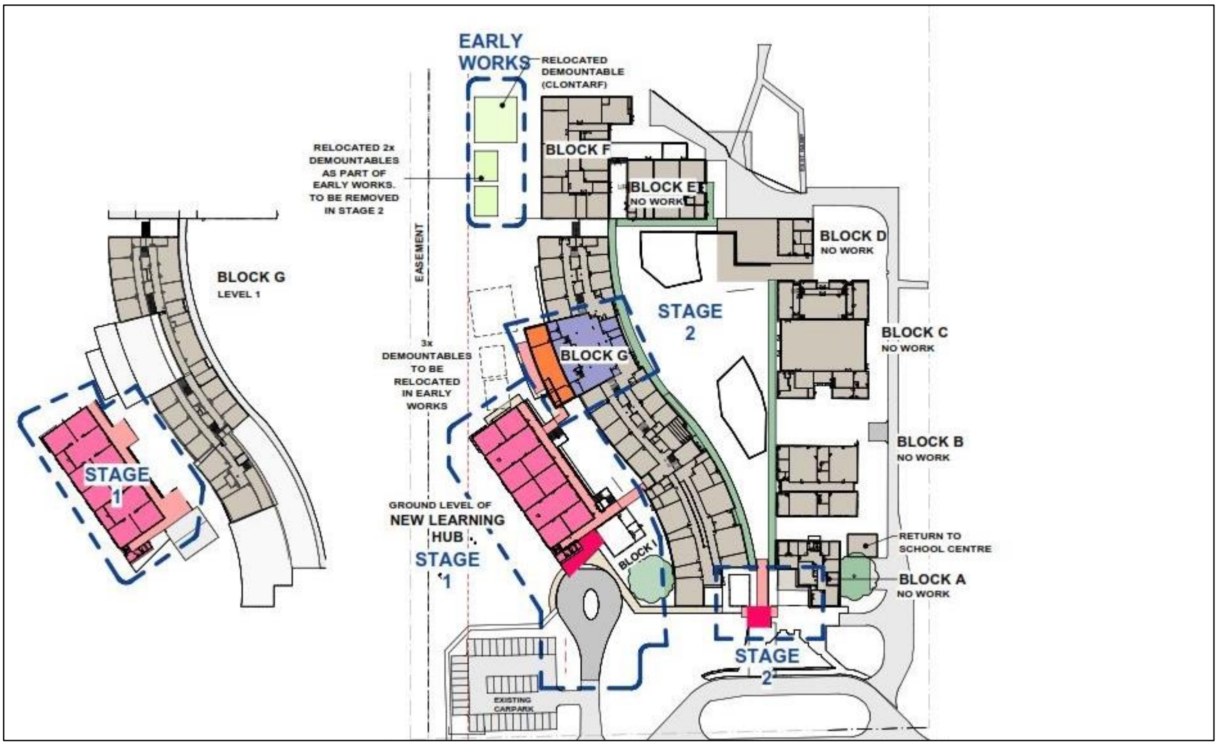

Figure 1: Proposed development, with proposed new learning hub and support unit in pink, library extension in orange and new location of demountable buildings in pale yellow. From EJE Architecture Drawing “Staging Plan”, Drawing No. A-006 Rev L, dated 31 May 2022, provided by APP.

For the purpose of the investigation, the client provided the following drawings from EJE Architecture, dated 31 May 2022:

- “Staging Plan”, Drawing No. A-006 Rev L;
- “New Learning Hub – Ground Floor”, Drawing No. A-100 Rev A;
- “New Learning Hub– Level 1”, Drawing No. A-101 Rev A;
- ““New Learning Hub – Roof Plan”, Drawing No. A-102 Rev A;
- “Block G – Ground Level – Zone A”, Drawing No. A-103 Rev N;
- “Elevations – Sheet 1 – New Learning Hub”, Drawing No. A-200 Rev B dated, 17 September 2020;
- “Elevations – Library Extension and Covered Entry”, Drawing No. A-220 Rev C, dated 7 December 2021;
- “Sections – Sheet 1 – New Learning Hub”, Drawing No. A-300 Rev B; dated 17 September 2020; and

- “Concept Images – Sheets 1 and 2””, Drawing Nos. A-990 and A-991, undated.

The following report was also provided for this assessment:

- Aurecon Australasia Pty Ltd, “Geotechnical Investigation report - Irrawang High School”, Reference 509790 Rev 0, dated 10 August 2020 (Aurecon, 2020).

At the time of the investigation, building and /or column loads were not provided.

3. Site Description and Regional Geology

The site is situated within the western grounds of the Irrawang High School campus, located at 80 Mount Hall Road, Raymond Terrace. The site is bordered to the south by an existing car park and Mount Hall Road, to the east by existing one and two storey school buildings, to the north and west by agricultural land (refer to Figure 2 below and Drawing R.002.D.001 in Appendix D).

Figure 2: Aerial photo of the site, proposed building footprints in yellow. Source – Metromap (19 September 2021).

At the time of investigation, the site was predominantly surfaced with short grass at the proposed locations of the demountable classrooms and the library extension. The area of the new learning hub is partially covered by a bitumen chip seal in the staff car park.

The site slopes down to the south-west at approximately 4°, with surface levels ranging from 20.0 AHD to 25.6 AHD at field test locations.

Parts of the proposed locations for the demountable classrooms, library extension and new learning hub and surrounds at the time of the investigation are shown in Figure 3 to Figure 5.

Figure 3: Proposed location of demountable classrooms, looking approximately south.

Figure 4: Proposed location of library extension, looking south-west.

Figure 5: Proposed location of new learning hub, looking north.

Reference to the NSW Seamless Geology Map prepared by The Geological Survey of NSW indicate that Irrawang High School is underlain by Muree Sandstone of the Maitland Group which typically consists of sandstone, conglomerate and minor clay.

4. Previous Investigations

A previous investigation by Aurecon for the proposed development (Aurecon, 2020) included three boreholes within the current development footprint (one at the southern end of the demountable buildings footprint, and two within the proposed learning hub footprint). The bores were drilled with a utility mounted drilling rig to TC-bit refusal on bedrock at depths of 4.0 m and 4.15 m within the demountable and learning hub footprints, respectively. One borehole within the learning hub footprint was progressed to 9.95 m depth with NMLC coring of the underlying sandstone. The boreholes typically encountered the following:

- Fill / low plasticity clay to 1.7 m depth (southern extent of the proposed learning hub footprint only);
- Firm, low plasticity clay / sandy clay (considered likely to be low plasticity silt fill) to depths between 1.5 m and 2 m depth;
- Stiff to very stiff, or very stiff then hard, low to medium plasticity sandy clay / clay (extremely weathered sandstone) to 4.0 m and 4.15 m depth (refusal);
- Medium to high strength sandstone, highly weathered to 6.9 m, then moderately weathered to 10 m depth (limit of investigation);
- Laboratory testing on samples of clay fill and residual site clays from the bores indicated the following:
    - Clay fill samples reported low susceptibility to shrink-swell movement with a shrink-swell index of 0.1% ΔpF. Plasticity testing returned liquid limits of 22% and 23%, and linear shrinkages of 3.0%.
    - Residual clay samples reported low to medium susceptibility to shrink-swell movement. Plasticity testing returned a liquid limit of 22% and linear shrinkage of 1.0% for the residual clay and liquid limits of 42% and 46%, and linear shrinkages of 8.5% and 10% for the underlying extremely weathered sandstone. It is noted that the samples tested were collected from a depth below the depth of suction (H_S) for the local area.

DP previously undertook a geotechnical investigation (Project 49529.01, March 2010) in connection with a proposed equipment storage shed and COLA, located about 30 m north-east of the proposed demountable building (Clontarf Academy) footprint. Two hand augered boreholes were undertaken up to 0.95 m depth and encountered fill to 0.2 m, over very stiff sandy silt to 0.5 m and very stiff to hard sandy clay to 0.8 m. The boreholes refused on extremely low strength sandstone (likely hard sandy clay with the current logging standards). Laboratory testing carried out on a sample of sandy clay indicated high susceptibility to shrink-swell movement, with a shrink-swell index of 3.5% per ΔpF

Previous test pit investigation by DP to depths of between 1.7 m and 2.3 m, located approximately 80 m south of the proposed learning hub footprint, typically encountered the following:

- Firm to stiff sandy silt to between 0.35 m and 0.5 m depth, overlying stiff to very stiff clay to between 1.0 m and 2.0 m depth, further overlying extremely low strength sandstone (likely hard sandy clay with the current logging standards) to depths between 1.3 m and 2.3 m. Very low strength sandstone was encountered in several pits at around 1.7 m to 2.0 m depth.
- Laboratory testing carried out on clay samples high susceptibility to shrink-swell movement, with shrink-swell indices typically between 3.6% and 4.8% per ΔpF.

Relevant information from the previous geotechnical investigation has been used in the current assessment.

5. Field Work

5.1 Field Work Methods

The field work was undertaken on 11 July 2022 and comprised the drilling of five bores (designated Bores 1 to 5) at the locations indicated on Drawing 1, Appendix D.

Bores 1 to 3 and 5 were drilled with a 90 mm diameter hand auger due to site access restrictions (boggy ground and adjacent underground services). Bore 4 was drilled using a continuous 4WD push tube sampling rig.

Dynamic cone penetrometer tests (DCPs) were undertaken adjacent to each bore up to 1.2 m depth to provide information on the strength consistency of the subgrade soils. 'Disturbed' samples were collected for laboratory testing purposes. The subsurface conditions encountered in the bores were logged and sampled by a geotechnical engineer from DP.

The bores were reinstated with drilled spoil at the completion of drilling and sampling, which was compacted in layers using hand tools within about 1 m of the surface. The UTM coordinates and surface levels at the bores were recorded using a differential GPS, which has a horizontal and vertical accuracy of approximately 0.1 m.

5.2 Field Work Results

The subsurface conditions encountered in the bores, and the DCP results are detailed on the attached borehole logs. These should be read in conjunction with the attached notes About this Report and the explanatory notes which comment on the sampling methods, soil descriptions, and symbols and abbreviations used in their preparation.

The subsurface conditions are summarised below:

- **Topsoil (Fill):** Silt / sandy silt with rootlets encountered in Bores 1 to 4 to 0.1 m depth and in Bore 5 to 0.3 m depth.

- **Sandy Clay / Sandy Silt / Silty Clay (Fill)**: Fill was encountered to depths of 1.8 m and 1.6 m in Bores 3 and 4, respectively and to a depth of 1.1 m at Bore 5. The material at Bores 3 and 4 was noted to be 'fill possibly alluvial'. The results of the penetrometer testing indicated localised weaker layers described as firm which supports the description of fill at these bores.
- **Clayey Silt / Sandy Silt / Silty Sand (Alluvial):** Underlying the fill/topsoil, to 0.7m and 0.8 m depth in Bores 1 and 2.
- **Clay / Silty Clay (Residual):** Stiff grading very stiff with depth encountered in all bores to termination. Bores 1 to 3 were terminated prior to the target depth of 2.5 m due to slow progress of the hand auger. Bore 5 refused at 1.3 m depth on possible very low strength sandstone.

Free groundwater was not observed in Bore 1 prior to backfilling. Seepage was observed in Bores 2 to 5 at depths ranging between 0.6 m and 1.6 m depth during augering. It should be noted that groundwater depths and ground moisture conditions are affected by climatic conditions and soil permeability, and will therefore vary with time. Field work was undertaken immediately following a period of heavy and prolonged rainfall, and as such groundwater levels may be elevated or perched above the rock / residual soils.

6. Laboratory Testing

Geotechnical laboratory testing was carried out on selected samples retrieved from the boreholes and comprised the following:

- Three Atterberg limits and linear shrinkage tests; and
- One particle size distribution test.

The laboratory test results are presented in Table 1 and Table 2. Detailed laboratory report sheets are attached in Appendix C.

Table 1: Results of Laboratory Testing - Atterberg Limits

Bore	Depth (m)	Description	FMC (%)	LL (%)	PL (%)	PI (%)	LS (%)
2	0.8 - 0.9	CLAY	36.6	67	21	46	17.0
4	1.4 – 1.5	FILL(?) / Sandy CLAY	13.1	35	15	20	9.0
5	0.6 – 0.8	FILL / Silty CLAY	22.1	50	16	34	13.5

Notes to Table 1:
FMC - Field Moisture Content
LL - Liquid Limit
PL - Plastic Limit
PI - Plasticity Index
LS – Linear Shrinkage

Table 2: Results of Laboratory Testing – Particle Size Distribution

Bore	Depth (m)	Description	Gravel (%)	Sand (%)	Silt and clay (%)
4	1.4 – 1.5	FILL(?) / Sandy CLAY	0	64	36

7. Comments

7.1 General

Fill and alluvial soils were encountered at each bore location and were underlain by residual soils. Weathered rock was encountered at one bore (Bore 5) at 1.3 m.

Based on the results of the investigation, it is considered that the existing fill is not suitable to support structural loads and therefore there are two feasible alternative footing systems for the support of buildings at the site. They are as follows:

i. Option 1: Suspend the foundation slab on piers / piles founded on residual clay or weathered rock. Further advice for the support of structural loads on piles are presented in Section 7.8;

ii. Option 2: Design the foundation slab as a raft slab founded on controlled fill. This option would require the removal and recompaction of existing or import new fill to support the footings. Further advice on the requirements for reuse and placement of fill are presented in Section 7.2 and 7.3 and geotechnical comment on high level footings are presented in Section 7.7.

7.2 Reuse of Excavated Material

The upper soil profile generally comprised topsoil and silt-rich materials (ie sandy silt or clayey silt encountered to 0.7m and 0.8 m depth in Bores 1 and 2, and to 0.9 m and 0.45 m in Bores 3 and 4, respectively). Silt rich materials could be reused as controlled fill, but such materials are expected to be difficult to place and compact as such materials are sensitive to soil-moisture changes and it may be more practical to remove the materials and use imported materials such as a low plasticity clayey gravel.

It should also be noted that the natural silty sand will also require careful moisture conditioning as it can become difficult to compact if it is too wet.

7.3 Site Preparation and Earthworks

The following procedure is suggested for site preparation in the event footings are designed to be supported on engineered fill:

- Excavate topsoil and any deleterious material, noting that fill was encountered to depths of up to 1.8 m within the new learning hub bores and to 1.1 m in the library extension bore;

- Roll the stripped surface with at least six passes of a minimum 12 tonne deadweight roller (or as large as can be practicably used at the site), with a final test roll pass accompanied by a careful visual inspection to detect any localised soft or loose zones. These zones should be removed and replaced with approved engineered fill. In this regard, the probability of localised 'soft spots' within the subgrade related to the removal of trees, stumps and footings should be recognised during test rolling;
- Ensure all fill is free of organic or other deleterious material, with a maximum particle size of 75 mm, and placed in near horizontal layers of maximum 300 mm loose thickness;
- Compact each layer of fill to at least 98% standard maximum dry density ratio before placing the next layer;
- Maintain moisture contents for fill exhibiting clay-like properties within 2% of OMC for standard compaction; and
- Seal or cover any compacted silty or sandy clay foundation soil, at or close to footing formation level, as soon as practicable, to reduce the opportunity for softening / swelling.

Geotechnical inspections and testing with reference to Level 1 requirements as presented in the earthworks guidelines (AS 3798, 2007) should be undertaken.

7.4 Retaining Walls

The design of flexible or rigid walls with a single prop could be undertaken using a triangular pressure distribution and the earth pressure parameters given in Table 3. Flexible walls are those which are free to rotate or tilt (such as cantilevered walls) and should be designed using an active earth pressure coefficient (Ka). Rigid walls are those which are restrained against rotation or tilt (ie single anchored / propped walls) and should be designed using the at-rest earth pressure coefficient (Ko). It is recommended that all permanent retaining walls be drained for full height in order to minimise hydrostatic pressure build-up behind the walls.

Depending upon the material to be retained behind the wall, the lateral pressure coefficients given in Table 3 are suggested for design.

Table 3: Earth Pressure Coefficients (non-sloping crest backfill)

Material	Unit Weight (kN/m^3)	At rest Ko	Active Ka	Passive Kp	Ultimate Passive Pressure (kPa)
Fill or Alluvial sand / silt / clay	20	0.7	0.5	-	-
Stiff or stronger residual clays	20	0.6	0.4	2.5	100 kPa
Very low strength (or stronger) sandstone	23		-		500

For design of retaining walls:

- Due allowance should be made for surcharge loadings (over and above the lateral earth pressure coefficients presented above) where the finished ground level above retaining walls is above horizontal and where additional loading is likely to be applied from existing or future upslope structures, construction equipment or from traffic;
- It is recommended that provision be made in design for build-up of hydrostatic pressure behind walls, as described above, unless full wall height drainage is installed behind the wall;
- Drainage material behind the wall, as above, should be installed for the full height of the wall, for a width of at least 0.3 m. The material must be free draining and granular and have a perforated or slotted drainage pipe at the heel of the wall to rapidly remove the water into a formal stormwater system;
- High level wall footings could be designed for the allowable bearing pressures presented in this report, reduced by one-third to allow for the effects of lateral loads.

High plasticity clay has the potential to exert significantly higher pressures than those indicated in Table 3 when swelling, and should be excluded from the zone behind the wall extending up from the heel of the wall at 1H:1V. Material in this zone should only comprise low plasticity materials. Over-compacted dry clay fill (ie dry density ratio >102% standard at moisture more than 2% below OMC) can also experience significant swelling (as well as softening) and should be avoided in this zone.

It is recommended that a factor of safety of 2 be adopted for overturning and sliding stability, and 1.5 for global stability.

For limit state design methods, the ultimate parameters provided in Table 3 will need to be factored in accordance with AS 4678 (2002). Guidance on the selection of material strength partial factors is provided in Section 5.2 of AS 4678 (2002) and is dependent upon the nature and state of the natural in-situ soil/rock or fill material.

7.5 Site Classification

The presence of ‘uncontrolled’ fill to depths greater than 0.4 m, triggers the classification of the site as ‘Class P’ and therefore footings are required to be designed in accordance with engineering principles.

Based on the results of the subsurface conditions, laboratory results and laboratory data included in the previously geotechnical report for the school (Aurecon, 2020), characteristic surface movements (y_s) of up to 40 mm have been calculated, which would be consistent with the ‘Class M’ classification if it weren’t for the existing ‘Class P’ classification.

It should be noted that potential tree effects on suction changes have not been assessed. In addition, it should be noted that the above y_s values do not take into account settlement induced by footing loading of the foundation soils.

The process of cutting and filling will affect the site classification. The above classification should be revised if any significant cutting or filling is proposed, as required by AS 2870 (2011). If site levels are to be raised, fill intended to support footings should be placed and compacted to the requirements of AS3798 and Section 7.3 of this report.

Site classifications, as above, are based on the information obtained from test bores and on the results of laboratory testing and have involved some interpolation between data points. In the event that the conditions encountered during construction are different to those presented in this report, it is recommended that advice be sought from this office.

An implication of the soil profiles is that different foundation conditions may be encountered within the building footprints. Articulation joints should be provided within masonry walls in accordance with TN61 (CCAA, 2008) in order to reduce the effects of differential movement.

It should be noted that these classifications are dependent on proper site maintenance, which should be carried out in accordance with the attached CSIRO Sheet BTF 18 and Appendix B of AS2870 (2011).

7.6 Earthquake Site Sub-Soil Classification and Hazard Factor

AS 1170.4 (2007) provides site sub-soil classifications for general structures based on simplified soil profiles. The site is predominantly underlain by firm to stiff silts and loose sands up to 1.8 m depth, then stiff or better residual clays, with sandstone encountered (in the previous Aurecon investigation) at depths greater than 3 m, therefore a site sub-soil classification of Class Ce is suggested.

Figure 3.2(A) of AS 1170.4 – Amendment 2 (2018) indicates a hazard factor (Z) of 0.11 for the Raymond Terrace area.

7.7 Upper Level Footings

Depending on structural loads and allowable movements, high level pad or strip footings would likely be suitable for light weight and flexible buildings provided they are supported in engineered fill which has been placed and compacted in accordance with this report. Due to the variable depth to rock across the site, it is recommended that all footings are founded in materials of similar compressibility (ie all soil or all rock).

For footings founding in the natural stiff (or better) clays or engineered fill, the design of pad footings up to 1 m wide and strip footings up to 0.6 m wide should be based on a maximum allowable bearing pressure of 100 kPa. Settlements due to a working pressure of 100 kPa for a 1 m square pad or 0.6 m wide strip footing founding in such materials below 0.7 m depth are estimated to be less than 10 mm. Higher footing loads may be feasible, subject to specific settlement analysis and geotechnical advice (primarily with respect to risk of soil softening).

All footing excavations in natural soils should be inspected and tested by an appropriately qualified geotechnical engineer prior to the placement of steel reinforcing and concrete, to confirm that adequate founding stratum has been penetrated and the design assumptions are appropriate for the materials tested.

7.8 Uncased Bored Piles

Uncased bored piles are considered to be a possible alternative to shallow foundations.

The ultimate parameters shown in Table 4 below are suggested for the design of bored piles subject to vertical compressive and uplift loads, with length to diameter ratios of at least four and at least two pile diameters of embedment in the founding stratum. These values are also contingent upon dry conditions being encountered in the base of the pile and removal of all loose or disturbed material from the base of the pile.

A factor of safety of 2.5 should be applied to all ultimate values for working stress analysis. Alternatively, a basic geotechnical strength reduction factor (ϕ_{gb}) of 0.48 is recommended for limit state design of piles in accordance with AS 2159 (2009). This is based on the data presented in this report, the method of soil strength assessment used in this investigation and after assessing the overall design average risk rating (ARR) for the site, design and installation risk factors anticipated for a low redundancy piling system. Higher values of ϕ_{gb} may be applied if additional investigation is carried out at the site, or higher geotechnical strength reduction factor (ϕ_g) may be adopted if selected piles are subjected to confirmatory load testing.

It is recommended that the contribution of skin friction in the upper 1 m of soil (due to seasonal shrink swell behaviour) and any shaft length that has been disturbed by temporary casing or backfilling be ignored in any pile capacity calculations.

Table 4: Design Parameters for Bored Piles

Stratum	Ultimate Unfactored Pressure (kPa)	
	End Bearing	Shaft Adhesion
Stiff clays	450	20
Very stiff clays to hard clay	900	35
Very low strength or stronger sandstone	1800	50

For bored pile foundations loaded as per the allowable bearing pressures in Table 4 above and with an appropriate factor of safety, it is considered that settlements under such applied loading will be less than 1% of the pile diameter.

Bored pile excavations should have any groundwater removed, or a tremie should be used to displace groundwater above the concrete if groundwater inflow rates exceed pumping rates. Accordingly, it is recommended that DP be engaged during pile excavation to undertake pile hole inspections to confirm the design parameters provided in Table 4.

The parameters given above are reliant on clean, rough sockets which are free of smear on the sides of the holes. Piles should be poured as soon as practicable after drilling.

8. References

AS 1170.4. (2007). *Structural Design Actions, Part 4: Earthquake Actions in Australia.* Reconfirmed 2018. Incorporating Amendments 1 & 2: Standards Australia.

AS 2159. (2009). *Piling - Design and Installation.* Standards Australia.

AS 2870. (2011). *Residential Slabs and Footings.* Standards Australia.

AS 3798. (2007). *Guidelines on Earthworks for Commercial and Residential Developments.* Standards Australia.

AS 4678. (2002). *Earth-retaining structures.* Standards Australia.

Aurecon. (2020). *Geotechnical Investigation Report - Irrawang High School.* Reference 509790 Rev 0: Aurecon Australasia Pty Ltd.

CCAA. (2008). *TN61, Articulated Walling.* Technical Note 61, 3rd Edition: Cement Concrete & Aggregates Australia.

9. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for this project at Hunter River High School, 36 Elkin Avenue, Heatherbrae in accordance with DP's proposal 216008.00.P.001.Rev0 dated 15 June 2022 and acceptance received from Elisa Tanaka from Department of Education through School Infrastructure NSW on 5 July 2022. The work was carried out under Part D - Standard Form Agreement SINSW03421/22, dated 5 July 2022. This report is provided for the exclusive use of NSW Department of Education 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 on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

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

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

The assessment of atypical safety hazards arising from this advice is restricted to the (geotechnical / environmental / groundwater) components set out in this report and based on known project conditions and stated design advice and assumptions. While some recommendations for safe controls may be provided, detailed 'safety in design' assessment is outside the current scope of this report and requires additional project data and assessment.

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

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

Douglas Partners Pty Ltd

Appendix A

About This Report
Terminology, Symbols and Abbreviations
Soil Descriptions
Sampling, Testing and Excavation Methodology
CSIRO Sheet BTF 18

About this Report

November 2020

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.

continued next page

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.

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Terminology, Symbols and Abbreviations

November 2020

Introduction to Terminology, Symbols and Abbreviations

Douglas Partners' reports, investigation logs, and other correspondence may use terminology which has quantitative or qualitative connotations. To remove ambiguity or uncertainty surrounding the use of such terms, the following sets of notes pages may be attached Douglas Partners' reports, depending on the work performed and conditions encountered:

- Soil Descriptions;
- Rock Descriptions; and
- Sampling, insitu testing, and drilling methodologies

In addition to these pages, the following notes generally apply to most documents.

Abbreviation Codes

Site conditions may also be presented in a number of different formats, such as investigation logs, field mapping, or as a written summary. In some of these formats textual or symbolic terminology may be presented using textual abbreviation codes or graphic symbols, and, where commonly used, these are listed alongside the terminology definition. For ease of identification in these note pages, textual codes are presented in these notes in the following style `XW`. Code usage conforms with the following guidelines:

- Textual codes are case insensitive, although herein they are generally presented in upper case; and
- Textual codes are contextual (i.e. the same or similar combinations of characters may be used in different contexts with different meanings (for example `PL` is used for plastic limit in the context of soil moisture condition, as well as in `PL(A)` for point load test result in the testing results column)).

Data Integrity Codes

Subsurface investigation data recorded by Douglas Partners is generally managed in a highly structured database environment, where records "span" between a top and bottom depth interval. Depth interval "gaps" between records are considered to introduce ambiguity, and, where appropriate, our practice guidelines may require contiguous data sets. Recording meaningful data is not always appropriate (for example assigning a "strength" to a concrete pavement) and the following codes may be used to maintain contiguity in such circumstances.

Term	Description	Abbreviation Code
Core loss	No core recovery	`KL`
Unknown	Information was not available to allow classification of the property. For example, when auguring in loose, saturated sand auger cuttings may not be returned.	`UK`
No data	Information required to allow classification of the property was not available. For example if drilling is commenced from the base of a hole predrilled by others	`ND`
Not Applicable	Derivation of the properties not appropriate or beyond the scope of the investigation. For example providing a description of the strength of a concrete pavement	`NA`

Graphic Symbols

Douglas Partners' logs contain a "graphic" column which provides a pictorial representation of the basic composition of the material. The symbols used are directly representing the material name stated in the adjacent "Description of Strata" column, and as such no specific graphic symbology legend has been provided in these notes.

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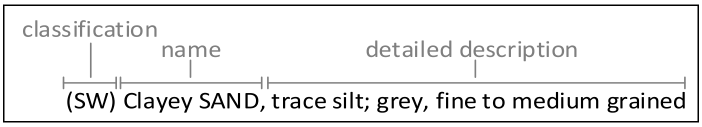
Introduction

All materials which are not considered to be "in-situ rock" are described in general accordance with the soil description model of AS 1726-2017 Part 6.1.3, and can be broken down into the following description structure:



The "classification" comprises a two character "group symbol" providing a general summary of dominant soil characteristics. The "name" summarises the particle sizes within the soil which most influence it's behaviour. The detailed description presents more information about the soil's composition, condition, structure, and origin.

Classification, naming and description of soils requires the relative proportion of particles of different sizes within the whole soil mixture to be considered.

Particle size designation and Behaviour Model

Solid particles within a soil are differentiated on the basis of size.

The engineering behaviour properties of a soil can subsequently be modelled to be either "fine grained" (also known as "cohesive" behaviour) or "coarse grained" ("non cohesive" behaviour), depending on the relative proportion of fine or coarse fractions in the soil mixture.

Particle Size Fraction	**Particle Size (mm)**	**Behaviour Model**	
		Behaviour	**Approximate Dry Mass**
Boulder	>200	Excluded from particle behaviour model as "oversize"	
Cobble	63 - 200		
Gravel[1]	2.36 - 63	Coarse	>65%
Sand[1]	0.075 - 2.36		
Silt	0.002 - 0.075	Fine	>35%
Clay	<0.002		

[1] – refer grain size subdivision descriptions below

The behaviour model boundaries defined above are not precise, and the material behaviour should be assumed from the name given to the material (which considers the particle fraction which dominates the behaviour, refer "component proportions" below), rather than strict observance of the proportions of particle sizes. For example, if a material is named a "Sandy CLAY", this is indicative that the material exhibits fine grained behaviour, even if the dry mass of coarse grained material may exceed 65%.

Component proportions

The relative proportion of the dry mass of each particle size fraction is assessed to be a "primary", "secondary", or "minor" component of the soil mixture, depending on its influence over the soils behaviour.

Component Proportion Designation	**Definition[1]**	**Relative Proportion**	
		In Fine Grained Soil	**In Coarse Grained Soil**
Primary	The component (particle size designation, refer above) which dominates the engineering behaviour of the soil	The clay/silt component with the greater proportion	The sand/gravel component with the greater proportion
Secondary	Any component which is not the primary, but is significant to the engineering properties of the soil	Any component with greater than 30% proportion	Any granular component with greater than 30%; or Any fine component with greater than 12%
Minor[2]	Present in the soil, but not significant to it's engineering properties	All other components	All other components

[1] As defined in AS1726-2017 6.1.4.4

[2] In the detailed material description, minor components are split into two further sub categories. Refer "identification of minor components" below

Composite Materials

In certain situations a lithology description may describe more than one material, for example, collectively describing a layer of interbedded sand and clay. In such a scenario, the two materials would be described independently, with the names preceded or followed by a statement describing the arrangement by which the materials co-exist. For example "INTERBEDDED Silty CLAY AND SAND".

Classification

The soil classification comprises a two character group symbol. The first symbol identifies the primary component. The second symbol identifies either the grading or presence of fines in a coarse grained soil, or the plasticity in a fine grained soil. Refer AS1726-2017 6.1.6 for further clarification.

Soil Name

For most soils the name is derived with the primary component included as the noun (in upper case), preceded by any secondary components stated in an adjective form. In this way the soil name also describes the general composition and indicates the dominant behaviour of the material.

Component[1]	Prominence in Soil Name
Primary	Noun (eg "CLAY")
Secondary	Adjective modifier (eg "Sandy")
Minor	No influence

[1] – for determination of component proportions, refer component proportions on previous page

For materials which cannot be disaggregated, or which are not comprised of rock or mineral fragments, the names "ORGANIC MATTER" or "ARTIFICIAL MATERIAL" may be used, in accordance with AS1726-2017 Table 14.

Commercial or colloquial names are not used for the soil name where a component derived name is possible (for example "Gravelly SAND" rather than "CRACKER DUST").

Materials of "fill" or "topsoil" origin are generally assigned a name derived from the primary/secondary component (where appropriate). In log descriptions this is preceded by uppercase "FILL" or "TOPSOIL". Origin uncertainty is indicated in the description by the characters `(?)`, with the degree of uncertainty described (using the terms "probably" or "possibly" in the origin column, or at the end of the description.

Identification of minor components

Minor components are identified in the soil description immediately following the soil name. The minor component fraction is usually preceded with a term indicating the relative proportion of the component.

Minor Component Proportion Term	Relative Proportion	
	In Fine Grained Soil	In Coarse Grained Soil
With	All fractions: 15-30%	Clay/silt: 5-12% sand/gravel: 15-30%
Trace	All fractions: 0-15%	Clay/silt: 0-5% sand/gravel: 0-15%

The terms "with" and "trace" generally apply only to gravel or fine particle fractions. Where cobbles/boulders are encountered in minor proportions (generally less than about 12%) the term "occasional" may be used. This term describes the sporadic distribution of the material within the confines of the investigation excavation only, and there may be considerable variation in proportion over a wider area which is difficult to factually characterize due to the relative size of the particles and the investigation methods.

Soil Composition

Plasticity

Descriptive Term	Laboratory liquid limit range	
	Silt	Clay
Non-plastic materials	Not applicable	Not applicable
Low plasticity	≤50	≤35
Medium plasticity	Not applicable	>35 and ≤50
High plasticity	>50	>50

Note, Plasticity descriptions generally describe the plasticity behaviour of the whole of the fine grained soil, not individual fine grained fractions.

Grain Size

Type		Particle size (mm)
Gravel	Coarse	19 - 63
	Medium	6.7 - 19
	Fine	2.36 – 6.7
Sand	Coarse	0.6 - 2.36
	Medium	0.21 - 0.6
	Fine	0.075 - 0.21

Grading

Grading Term	Particle size (mm)
Well	A good representation of all particle sizes
Poorly	An excess or deficiency of particular sizes within the specified range
Uniformly	Essentially of one size
Gap	A deficiency of a particular particle size with the range

Note, AS1726-2017 provides terminology for additional attributes not listed here.

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Soil Condition

Moisture

The moisture condition of soils is assessed relative to the plastic limit for fine grained soils, while for coarse grained soils it is assessed based on the appearance and feel of the material. The moisture condition of a material is considered to be independent of stratigraphy (although commonly these are related), and this data is presented in its own column on logs.

Applicability	Term	Tactile Assessment	Abbreviation code
Fine	Dry of plastic limit	Hard and friable or powdery	`<PL`
	Near plastic limit	Can be moulded	`≈PL`
	Wet of plastic limit	Water residue remains on hands when handling	`>PL`
	Near liquid limit	“oozes” when agitated	`≈LL`
	Wet of liquid limit	“oozes”	`>LL`
Coarse	Dry	Non-cohesive and free running	`D`
	Moist	Feels cool, darkened in colour, particles may stick together	`M`
	Wet	Feels cool, darkened in colour, particles may stick together, free water forms when handling	`W`

The abbreviation code `NDF`, meaning “not-assessable due to drilling fluid use” may also be used.

Note, observations relating to free ground water or drilling fluids are provided independent of soil moisture condition.

Consistency/Density/Compaction/Cementation/Extremely Weathered Rock

These concepts give an indication of how the material may respond to applied forces (when considered in conjunction with other attributes of the soil). This behaviour can vary independent of the composition of the material, and on logs these are described in an independent column and are generally mutually exclusive (i.e it is inappropriate to describe both consistency and compaction at the same time). The method by which the behaviour is described depends on the behaviour model and other characteristics of the soil as follows:

- In fine grained soils, the “consistency” describes the ease with which the soil can be remoulded, and is generally correlated against the materials undrained shear strength;
- In granular materials, the relative density describes how tightly packed the particles are, and is generally correlated against the density index;
- In anthropogenically modified materials the compaction of the material is described qualitatively;
- In cemented soils (both natural and anthropogenic), the cemented “strength” is described qualitatively, relative to the difficulty with which the material is disaggregated; and
- In soils of extremely weathered rock origin, the engineering behaviour may be governed by relic rock features, and expected behaviour needs to be assessed based the overall material description

Quantitative engineering performance of these materials may be determined by laboratory testing, or estimated by correlated field tests (for example penetration or shear vane testing). In some cases performance may be assessed by tactile or other subjective methods, in which case investigation logs will show the estimated value enclosed in round brackets, for example `(VS)`.

Consistency (fine grained soils)

Consistency Term	Tactile Assessment	Undrained Shear Strength (kPa)	Abbreviation Code
Very soft	Extrudes between fingers when squeezed	<12	`VS`
Soft	Mouldable with light finger pressure	>12 - ≤25	`S`
Firm	Mouldable with strong finger pressure	>25 - ≤50	`F`
Stiff	Cannot be moulded by fingers	>50 - ≤100	`ST`
Very stiff	Indented by thumbnail	>100 - ≤200	`VST`
Hard	Indented by thumbnail with difficulty	>200	`H`
Friable	Easily crumbled or broken into small pieces by hand	-	`FR`

Relative Density (coarse grained soils)

Relative Density Term	Density Index	Abbreviation Code
Very loose	<15	`VL`
Loose	>15-≤35	`L`
Medium dense	>35-≤65	`MD`
Dense	>65-≤85	`D`
Very dense	>85	`VD`

Note, tactile assessment of relative density is difficult, and generally requires penetration testing, hence a tactile assessment guide is not provided.

Compaction (anthropogenically modified soil)

Compaction Term	Abbreviation Code
Well compacted	`WC`
Poorly compacted	`PC`
Moderately compacted	`MC`
Variably compacted	`VC`

Cementation (natural and anthropogenic)

Cementation Term	Abbreviation Code
Moderately cemented	`MCE`
Weakly cemented	`WKCE`
Cemented	`CE`
Strongly bound	`SB`
Weakly bound	`WB`
Unbound	`UB`

Extremely Weathered Rock

AS1726-2017 considers weathered rock material to be soil if the unconfined compressive strength is less than 0.6 MPa (i.e. very low strength rock). These materials may be identified as “extremely weathered rock” in reports and by the abbreviation code `XWR` on log sheets. This identification is not correlated to any specific qualitative or quantitative behaviour, and the engineering properties of this material must therefore be assessed according to engineering principles with reference to any relic rock structure, fabric, or texture described in the description.

Soil Origin

Term	Description	Abbreviation Code
Residual	Derived from in-situ weathering of the underlying rock	`RES`
Extremely weathered material	Formed from in-situ weathering of geological formations. Has strength of less than ‘very low’ as per as1726 but retains the structure or fabric of the parent rock.	`XWM`
Alluvial	Deposited by streams and rivers	`ALV`
Estuarine	Deposited in coastal estuaries	`EST`
Marine	Deposited in a marine environment	`MAR`
Lacustrine	Deposited in freshwater lakes	`LCS`
Aeolian	Carried and deposited by wind	`AEO`
Colluvial	Soil and rock debris transported down slopes by gravity	`COL`
Topsoil	Mantle of surface soil, often with high levels of organic material	`TOP`
Fill	Any material which has been moved by man	`FILL`
Littoral	Deposited on the lake or sea shore	`LIT`
Unidentifiable	Not able to be identified	`UID`

Cobbles and Boulders

The presence of particles considered to be “oversize” may be described using one of the following strategies:

- Oversize encountered in a minor proportion (when considered relative to the wider area) are noted in the soil description; or
- Where a significant proportion of oversize is encountered, the cobbles/boulders are described independent of the soil description, in a similar manner to composite soils (described above) but qualified with “MIXTURE OF”.

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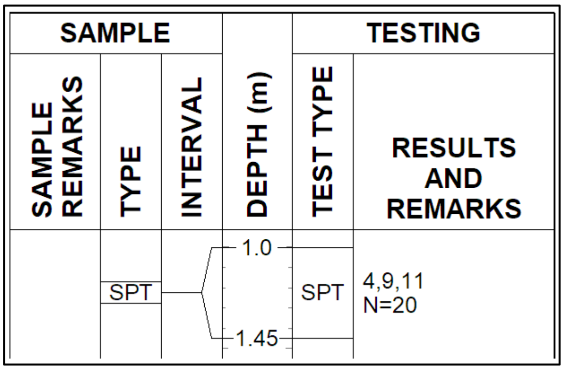
Sampling, Testing and Excavation Methodology

Terminology
Symbols
Abbreviations

November 2020

Sampling and Testing

A record of samples retained and field testing performed is usually shown on a Douglas Partners' log with samples appearing to the left of a depth scale, and selected field and laboratory testing (including results, where relevant) appearing to the right of the scale, as illustrated below:



Sampling

The type or intended purpose for which a sample was taken is indicated by the following abbreviation codes.

Sample Type	Code
Auger sample	`A`
Acid sulfate sample	`ASS`
Bulk sample	`B`
Core sample	`C`
Disturbed sample	`D`
Sample from SPT test	`SPT`
Environmental sample	`E`
Gas sample	`G`
Jar sample	`J`
Undisturbed tube sample	`U`[1]
Water sample	`W`
Piston sample	`P`
Core sample for unconfined compressive strength testing	`UCS`

[1] – numeric suffixes indicate tube diameter/width in mm

The above codes only indicate that a sample was retained, and not that testing was scheduled or performed.

Field and Laboratory Testing

A record that field and laboratory testing was performed is indicated by the following abbreviation codes.

Test Type	Code
Pocket penetrometer (kPa)	`PP`
Photo ionisation detector (ppm)	`PID`
Standard Penetration Test `x/y` =*x* blows for *y* mm penetration `HB` = hammer bouncing	`SPT`
Shear vane (kPa)	`V`
Unconfined compressive strength, (MPa)	`UCS`

Field and laboratory testing (continued)

Test Type	Code
Point load test, (MPa), axial `(A)`, diametric `(D)`, irregular `(I)`	`PLT(_)`
Dynamic cone penetrometer, followed by blow count penetration increment in mm (cone tip, generally in accordance with AS1289.6.3.2)	`DCP/150`
Perth sand penetrometer, followed by blow count penetration increment in mm (flat tip, generally in accordance with AS1289.6.3.3)	`PSP/150`

Groundwater Observations

▷	seepage/inflow
▽	standing or observed water level
`NFGWO`	no free groundwater observed
`OBS`	Observations obscured by drilling fluids

Drilling or Excavation Methods/Tools

The drilling/excavation methods used to perform the investigation may be shown either in a dedicated column down the left hand edge of the log, or stated in the log footer. In some circumstances abbreviation codes may be used.

Method	Abbreviation Code
Excavator/backhoe bucket	`B`[1]
Toothed bucket	`TB`[1]
Mud/blade bucket	`MB`[1]
Ripping tyne/ripper	`RT`
Rock breaker/hydraulic hammer	`RB`
Hand auger	`HA`[1]
NMLC series coring	`NMLC`
HMLC series coring	`HMLC`
NQ coring	`NQ`
HQ coring	`HQ`
PQ coring	`PQ`
Push tube	`PT`[1]
Rock roller	`RR`[1]
Solid flight auger. Suffixes: `(TC)` = tungsten carbide tip, `(V)` = v-shaped tip	`SFA`[1]
Sonic drilling	`SON`[1]
Vibrocore	`VC`[1]
Wash bore (unspecified bit type)	`WB`[1]
Existing exposure	`X`
Hand tools (unspecified)	`HT`
Predrilled	`PD`
Specialised bit (refer report)	`SPEC`[1]
Diatube	`DT`[1]
Hollow flight auger	`HFA`[1]
Vacuum excavation	`VE`

[1] – numeric suffixes indicate tool diameter/width in mm

Foundation Maintenance and Footing Performance:
A Homeowner's Guide

CSIRO

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.

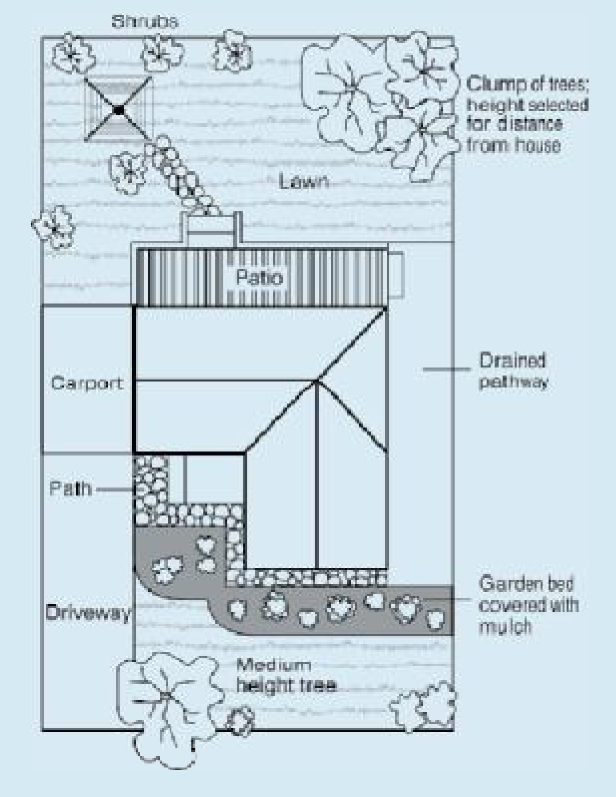
Protection of the building perimeter
It is essential to remember that the soil that affects footings extends well beyond the actual building line. Watering of garden plants, shrubs and trees causes some of the most serious water problems.

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.

This BTF was prepared by John Lewer FAIB, MIAMA, Partner, Construction Diagnosis.

The information in this and other issues in the series was derived from various sources and was believed to be correct when published.

The information is advisory. It is provided in good faith and not claimed to be an exhaustive treatment of the relevant subject.

Further professional advice needs to be obtained before taking any action based on the information provided.

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Appendix B

Field Work Results

BOREHOLE LOG

CLIENT: NSW Department of Education
PROJECT: School Upgrades
LOCATION: Irrawang High School, 80 Mount Hall Road, Raymond Terrace

SURFACE LEVEL: 24.4 AHD
COORDINATE E:384438 **N:** 6374484
DATUM/GRID: MGA94 Zone 56
DIP/AZIMUTH: 90°/---

LOCATION ID: 1
PROJECT No: 216008.00
DATE: 11/07/22
SHEET: 1 of 1

CONDITIONS ENCOUNTERED

GROUNDWATER: 11/07/22, No free groundwater observed

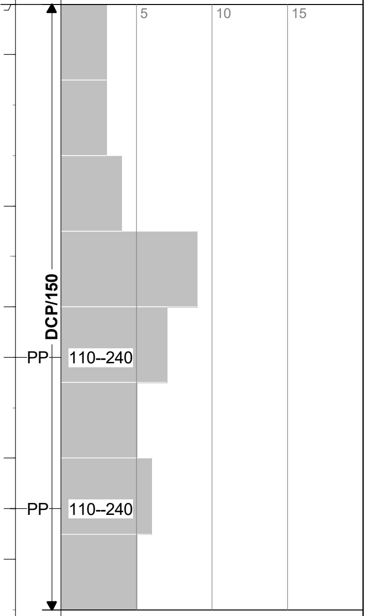
RL (m)	DEPTH (m)	DESCRIPTION OF STRATA	GRAPHIC	ORIGIN(#)	CONSIS.(*) / DENSITY.(*)	MOISTURE
	0.0	TOPSOIL/ (ML) SILT, with sand, with clay; dark brown; silt fraction low plasticity; sand fraction fine to medium; trace rootlets, trace fine to medium sub-angular gravel		TOP	NA	>PL
24	0.1	(ML) Clayey SILT, with sand, trace gravel; dark brown; silt fraction low plasticity; gravel fraction fine to medium		ALV	ST	>PL
	0.45	(SM) Sandy SILT, with clay, trace gravel; pale grey brown; silt fraction low plasticity; sand fraction fine; gravel fraction fine to medium, sub-angular to sub-rounded		ALV	D	W
23	0.7	(CH) CLAY, trace sand; brown mottled orange red; clay fraction high plasticity; sand fraction fine 1.6m: pale grey mottled red orange below 1.6m depth 1.8-2.0m: some rock structure evident		RES	ST TO VST VST	>PL
22	2.0	Borehole discontinued at 2.00m depth Slow progress				

SAMPLE

REMARKS	TYPE	INTERVAL DEPTH (m)
	D	0.0–0.1
	D	0.1–0.4
	D	0.6–0.7
	D	0.7–0.9
	D	1.0–1.1
	D	1.6–1.7

TESTING AND REMARKS

TEST TYPE	RESULTS AND REMARKS
DCP/150	0.0–1.2 m
PP	110–240
PP	110–240
PP	110–240
PP	110–240
PP	110–240



NOTES: (#)Soil origin is "probable" unless otherwise stated. (*)Consistency/Relative density shading is for visual reference only - no correlation between cohesive and granular materials is implied.

PLANT: Hand Tools
METHOD: 90mm diameter hand auger to 2.0m
REMARKS: Coordinates obtained using a differential GPS unit typically accurate to ±0.1m

OPERATOR: Butcher
CASING:

LOGGED: Chaplin

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Refer to explanatory notes for symbol and abbreviation definitions

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NSW Department of Education
PROJECT: School Upgrades
LOCATION: Irrawang High School, 80 Mount Hall Road, Raymond Terrace

SURFACE LEVEL: 25.6 AHD
COORDINATE E:384441 **N:** 6374500
DATUM/GRID: MGA94 Zone 56
DIP/AZIMUTH: 90°/---

LOCATION ID: 2
PROJECT No: 216008.00
DATE: 11/07/22
SHEET: 1 of 1

CONDITIONS ENCOUNTERED

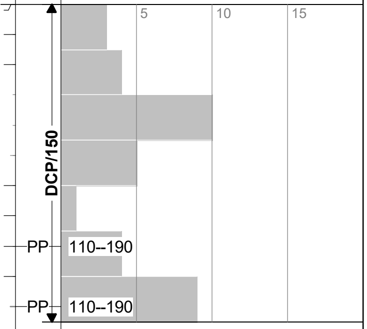
GROUNDWATER	RL (m)	DEPTH (m)	DESCRIPTION OF STRATA	ORIGIN[#]	CONSIS.[*] DENSITY.[*]	MOISTURE
		0.0	TOPSOIL/ (ML) Sandy SILT, trace gravel; dark brown; silt fraction low plasticity; sand fraction fine to coarse; gravel fraction fine to medium sub-angular; with trace rootlets	TOP	NA	>PL
		0.1	(ML) Sandy SILT, with clay, trace gravel; brown; silt fraction low plasticity; sand fraction fine to medium; gravel fraction fine to medium sub-angular to sub-rounded	ALV	ST	>PL
Water seepage @ 0.6m	25	0.6	(SM) Silty SAND, trace gravel; brown; sand fraction fine; gravel fraction fine to medium sub-rounded to sub-angular	ALV	L	W
		0.8	(CH) CLAY, trace sand; brown mottled orange; clay fraction high plasticity; sand fraction fine	RES	ST	>PL
	24	1.5	1.5m: pale grey mottled red orange		VST	
		1.9	Borehole discontinued at 1.90m depth Slow progress			

SAMPLE

TYPE	INTERVAL DEPTH (m)
D	0.0 – 0.1
D	0.1 – 0.2
D	0.6 – 0.7
D	0.8 – 0.9
D	1.2 – 1.3
D	1.5 – 1.6

TESTING AND REMARKS

DEPTH (m)	TEST TYPE	RESULTS AND REMARKS
0.0 – 1.0	DCP/150	
0.8	PP	110--190
1	PP	110--190
1.3	PP	110--190
1.5	PP	210--280



NOTES: [#]Soil origin is "probable" unless otherwise stated. [*]Consistency/Relative density shading is for visual reference only - no correlation between cohesive and granular materials is implied.

PLANT: Hand Tools
METHOD: 90mm diameter hand auger to 1.9m
REMARKS: Coordinates obtained using a differential GPS unit typically accurate to ±0.1m

OPERATOR: Chaplin
CASING:

LOGGED: Chaplin

Refer to explanatory notes for symbol and abbreviation definitions

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: NSW Department of Education
PROJECT: School Upgrades
LOCATION: Irrawang High School, 80 Mount Hall Road, Raymond Terrace

SURFACE LEVEL: 25.5 AHD
COORDINATE E:384424 **N:** 6374392
DATUM/GRID: MGA94 Zone 56
DIP/AZIMUTH: 90°/---

LOCATION ID: 3
PROJECT No: 216008.00
DATE: 11/07/22
SHEET: 1 of 1

CONDITIONS ENCOUNTERED

GROUNDWATER: 11/07/22, Water seepage @ 1.5m

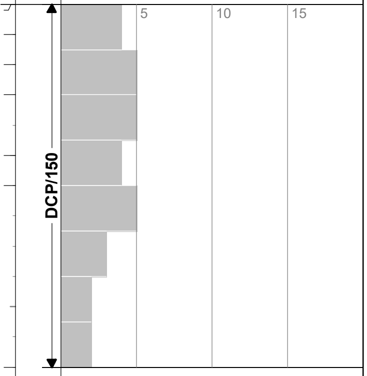
DEPTH (m)	DESCRIPTION OF STRATA	ORIGIN(#)	CONSIS.(*) DENSITY.(*)	MOISTURE
0.0–0.1	TOPSOIL/ (ML) Sandy SILT, with clay; dark brown; silt fraction low plasticity; sand fraction fine to medium; with rootlets	TOP	ST	>PL
0.1–0.9	FILL(?)/ (ML) Sandy SILT, with clay, with gravel; brown; silt fraction low plasticity; sand fraction fine to medium; gravel fraction fine to medium, sub-angular to sub-rounded; clay nodules, brown orange	FILL possibly ALV	ST	<PL =PL
0.9–1.8	FILL(?)/ (CL-CI) Sandy CLAY; dark brown; clay fraction low to medium plasticity; sand fraction fine to coarse	FILL possibly ALV	F TO ST (ST)	>PL
1.8–2.1	(CH) CLAY; brown; high plasticity	RES	ST TO VST	>PL
2.1	Borehole discontinued at 2.10m depth Slow progress			

SAMPLE

TYPE	DEPTH (m)
D	0.0–0.1
D	0.2–0.3
D	0.5–0.6
D	1.2–1.3
D	1.8–1.9

TESTING AND REMARKS

DEPTH (m)	TEST TYPE	RESULTS AND REMARKS
0.0–1.2	DCP/150	
1.8	PP	180–210



NOTES: (#)Soil origin is "probable" unless stated otherwise. (*)Consistency/Relative density shading is for visual reference only - no correlation between cohesive and granular materials is implied.

PLANT: Hand Tools
METHOD: 90mm diameter hand auger to 2.1m
REMARKS: Coordinates obtained using a differential GPS unit typically accurate to ±0.1m

OPERATOR: Chaplin
CASING:
LOGGED: Chaplin

Refer to explanatory notes for symbol and abbreviation definitions

BOREHOLE LOG

CLIENT: NSW Department of Education
PROJECT: School Upgrades
LOCATION: Irrawang High School, 80 Mount Hall Road, Raymond Terrace

SURFACE LEVEL: 20.1 AHD
COORDINATE **E:**384425 **N:** 6374357
DATUM/GRID: MGA94 Zone 56
DIP/AZIMUTH: 90°/---

LOCATION ID: 4
PROJECT No: 216008.00
DATE: 11/07/22
SHEET: 1 of 1

CONDITIONS ENCOUNTERED

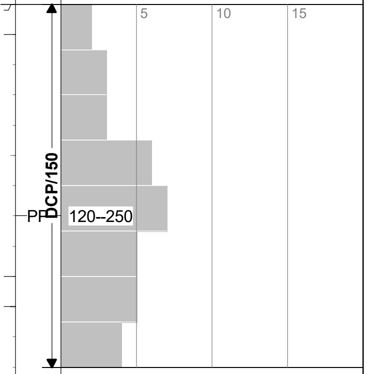
GROUNDWATER	DEPTH (m)	DESCRIPTION OF STRATA	ORIGIN(#)	CONSIS.(*) DENSITY.(*)	MOISTURE
Water seepage @ 1.6m	0.0	FILL/TOPSOIL/ (ML) Sandy SILT; dark brown; silt fraction low plasticity; sand fraction fine to medium; with rootlets and organics	FILL and TOP	NA	>PL
	0.1	FILL/ (ML) Sandy SILT, with clay, trace gravel; dark brown; silt fraction low plasticity; sand fraction fine to medium; gravel fraction fine to medium, sub-angular to sub-rounded; with trace rootlets clay nodules, brown orange	FILL	NA	<PL
	0.45	FILL(?)/ (CL-CI) Sandy CLAY; dark brown; clay fraction low to medium plasticity; sand fraction fine to coarse	FILL possibly ALV	NA	<PL >PL
	1.6	(CH) CLAY; pale grey mottled red orange; high plasticity	RES	ST VST	>PL
	2.5	Borehole discontinued at 2.50m depth Limit of investigation			

SAMPLE

TYPE	DEPTH (m)
D	0.0–0.1
D	0.9–1.0
D	1.4–1.5
D	2.2–2.4

TESTING AND REMARKS

TEST TYPE	DEPTH (m)	RESULTS AND REMARKS
DCP/150	0.0–1.2	
PP		120–250
PP	1.6	150–200
PP	2.4	220



NOTES: (#)Soil origin is "probable" unless stated otherwise. (*)Consistency/Relative density shading is for visual reference only - no correlation between cohesive and granular materials is implied.

PLANT: Push Tube Rig
METHOD: PTR to 2.5m
REMARKS: Coordinates obtained using a differential GPS unit typically accurate to ±0.1m

OPERATOR: Chaplin
CASING:

LOGGED: Chaplin

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Refer to explanatory notes for symbol and abbreviation definitions

BOREHOLE LOG

CLIENT: NSW Department of Education
PROJECT: School Upgrades
LOCATION: Irrawang High School, 80 Mount Hall Road, Raymond Terrace

SURFACE LEVEL: 21.8 AHD
COORDINATE **E:**384440 **N:** 6374420
DATUM/GRID: MGA94 Zone 56
DIP/AZIMUTH: 90°/---

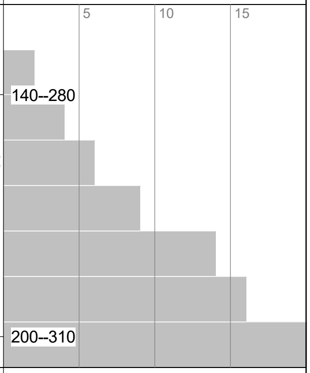
LOCATION ID: 5
PROJECT No: 216008.00
DATE: 11/07/22
SHEET: 1 of 1

CONDITIONS ENCOUNTERED

GROUNDWATER	RL (m)	DEPTH (m)	DESCRIPTION OF STRATA	GRAPHIC	ORIGIN(#)	CONSIS.(*) ▩ DENSITY.(*) ▦	MOISTURE
Water seepage @ 1.3m		0.0	TOPSOIL/FILL/ (ML) Sandy SILT, trace clay; dark brown; silt fraction low plasticity; sand fraction fine to medium; with rootlets and organics		TOP and FILL	NA	>PL
		0.3	FILL/ (CI-CH) Silty CLAY, with sand, trace gravel; brown mottled grey red orange; clay fraction medium to high plasticity; sand fraction fine to coarse; gravel fraction fine, sub-angular to sub-rounded 1.1m: trace hard plastics in soil		FILL	NA	>PL
		1.1	(CH) Silty CLAY; brown mottled red orange; high plasticity		RES	VST	>PL
		1.3	Borehole discontinued at 1.30m depth Virtual auger refusal on possible rock				

SAMPLE / **TESTING AND REMARKS**

REMARKS	TYPE	INTERVAL	DEPTH (m)	TEST TYPE	RESULTS AND REMARKS
	D	0.0–0.3	0.0	DCP/150 (0.0–1.2)	
			0.3	PP	140–280
	D	0.3–0.5	0.5		
	D	0.6–0.8	0.6 0.8		
	D	0.9–1.0	0.9 1.0		
	D	1.1–1.2	1.1	PP	200–310
			1.2		



NOTES: (#)Soil origin is "probable" unless otherwise stated. (*)Consistency/Relative density shading is for visual reference only - no correlation between cohesive and granular materials is implied.

PLANT:
METHOD: Hand auger to 1.3m
REMARKS: Coordinates obtained using a differential GPS unit typically accurate to ±0.1m

OPERATOR:
CASING:

LOGGED: Chaplin

Refer to explanatory notes for symbol and abbreviation definitions

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Appendix C

Laboratory Test Results

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Newcastle Laboratory
15 Callistemon Close Warabrook Newcastle NSW 2310
Phone: (02) 4960 9600
Email: dan.byrnes@douglaspartners.com.au

Report Number:	**216008.00-2**
Issue Number:	1
Date Issued:	15/08/2022
Client:	NSW Department of Education Level 5 NSW, 2000, Sydney NSW 2000
Project Number:	216008.00
Project Name:	School Upgrades
Project Location:	36 Elkin Avenue and 80 Mount Hall Rd, Heatherbrae & Raymond Terrace NSW
Work Request:	8691
Sample Number:	NC-8691A
Date Sampled:	12/07/2022
Dates Tested:	26/07/2022 - 10/08/2022
Sampling Method:	Sampled by Douglas Partners *The results apply to the sample as received*
Sample Location:	**2 , Depth: 0.8 - 0.9m**
Material:	Clay

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Dan Byrnes
Technical Supervisor / Associate
Laboratory Accreditation Number: 828

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	36.6

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	67		
Plastic Limit (%)	21		
Plasticity Index (%)	**46**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	17.0		
Cracking Crumbling Curling	Curling		

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Results relate only to the items tested/sampled.

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Newcastle Laboratory
15 Callistemon Close Warabrook Newcastle NSW 2310
Phone: (02) 4960 9600
Email: dan.byrnes@douglaspartners.com.au

ilac-MRA NATA

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Dan Byrnes
Technical Supervisor / Associate
Laboratory Accreditation Number: 828

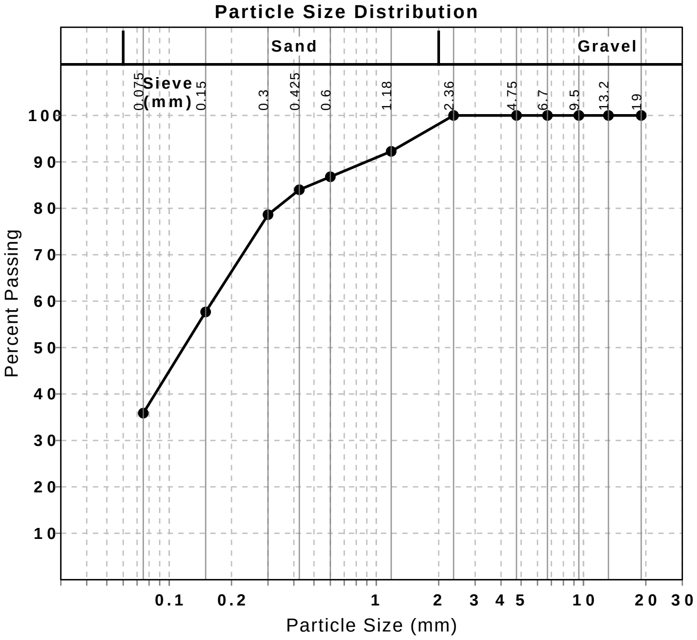
Report Number: **216008.00-2**
Issue Number: 1
Date Issued: 15/08/2022
Client: NSW Department of Education
Level 5 NSW, 2000, Sydney NSW 2000
Project Number: 216008.00
Project Name: School Upgrades
Project Location: 36 Elkin Avenue and 80 Mount Hall Rd, Heatherbrae & Raymond Terrace NSW
Work Request: 8691
Sample Number: NC-8691B
Date Sampled: 12/07/2022
Dates Tested: 26/07/2022 - 10/08/2022
Sampling Method: Sampled by Douglas Partners
The results apply to the sample as received
Sample Location: **4 , Depth: 1.4 - 1.5m**
Material: FILL: Clayey SILT

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	13.1

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

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	9.0		
Cracking Crumbling Curling	None		

Particle Size Distribution (AS1289 3.6.1)						
Sieve	Passed %	Passing Limits		Retained %	Retained Limits	
19 mm	**100**			0		
13.2 mm	**100**			0		
9.5 mm	**100**			0		
6.7 mm	**100**			0		
4.75 mm	**100**			0		
2.36 mm	**100**			0		
1.18 mm	**92**			8		
0.6 mm	**87**			5		
0.425 mm	**84**			3		
0.3 mm	**79**			5		
0.15 mm	**58**			21		
0.075 mm	**36**			22		



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Results relate only to the items tested/sampled.

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater

Douglas Partners Pty Ltd
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ilac-MRA NATA

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Dan Byrnes
Technical Supervisor / Associate
Laboratory Accreditation Number: 828

Report Number: **216008.00-2**
Issue Number: 1
Date Issued: 15/08/2022
Client: NSW Department of Education
Level 5 NSW, 2000, Sydney NSW 2000
Project Number: 216008.00
Project Name: School Upgrades
Project Location: 36 Elkin Avenue and 80 Mount Hall Rd, Heatherbrae & Raymond Terrace NSW
Work Request: 8691
Sample Number: NC-8691C
Date Sampled: 12/07/2022
Dates Tested: 26/07/2022 - 10/08/2022
Sampling Method: Sampled by Douglas Partners
The results apply to the sample as received
Sample Location: **5 , Depth: 0.6 - 0.8m**
Material: FILL: Silty CLAY

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	22.1

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	50		
Plastic Limit (%)	16		
Plasticity Index (%)	**34**		

Linear Shrinkage (AS1289 3.4.1)		Min	Max
Moisture Condition Determined By	AS 1289.3.1.2		
Linear Shrinkage (%)	13.5		
Cracking Crumbling Curling	Curling		

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Appendix D

Drawing R.002.001 – Site and Test Location Plan

LOCALITY

Legend

- ⌖ Approximate Borehole Location and Number
- ☐ Approximate Lot Boundary
- — 2m contour

0 10 20 30 40 50 m

Notes:
1. Base image from Metromaps (dated 19 September 2021).
2. Locality image from WhereIS Maps.
3. Test locations are approximate only and are shown with reference to existing site features.

Douglas Partners
Geotechnics · Environment · Groundwater

CLIENT: NSW Department of Education
OFFICE: Newcastle
DRAWN BY: KMF
SCALE: 1:1000 @ A3
DATE: August 2022

TITLE: Site and Test Location Plan
School Upgrades
Irrawang High School
80Mount Hall Road, Raymond Terrace

N

PROJECT No: 216008.00
DRAWING No:R.002.D.001
REVISION: 0