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Report on
Geotechnical Investigation

Proposed Junior School Building
St Philip's Christian College, Gosford Campus
20 Narara Creek Road, Narara

Prepared for
St Philip's Christian College

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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
Proposed Junior School Building
St Philip’s Christian College, 20 Narara Creek Road, Narara

1. Introduction

This report presents the results of a geotechnical investigation undertaken for a proposed junior school building at St Philip’s Christian College, Narara. The work was commissioned by St Philip’s Christian College and undertaken in consultation with Ian Easton Architect.

It is understood that the proposed development comprise the construction of a two storey building within the eastern portion of the school grounds. The building will be set back into an existing bank and will require excavation up to about 3.5 m depth. Construction work for the junior school building is planned to occur over four stages.

Geotechnical investigation was required to provide the following information:

- Slope stability assessment for the development area in accordance with Chapter 6.4 of the Gosford Development Control Plan 2013 (Ref 1);
- Recommendations on suitable founding strata and site preparation measures to address slope stability issues;
- Geotechnical parameters for the design of footings;
- Retaining wall design parameters; and
- Safe batter slopes.

The investigation included a walkover inspection followed by the drilling of boreholes and excavation of test pits and then by engineering analysis. Details of the field work are given in the report, together with engineering comment relating to design and construction. This report supersedes an earlier draft report issued on 2 June 2015.

2. Site Description

St Philip’s Christian College is located on the southern side of Narara Creek Road at Narara and is identified as Lot 102 in DP 832279. The school grounds comprises an area of about 10 ha and is situated on the northern flanks of a hillside. Only about half of the school site has been developed, with the cluster of school buildings and playing fields all within the lower, northern end. The remainder of the school site is covered with mature bush.

The proposed junior school building is proposed to be constructed to the east of the existing cluster of school buildings, in an area between an existing playing field to the north and an existing single storey demountable classroom block to the south. The school hall is located to the south-west of the proposed development area.

The area is dominated by a batter slope that is typically 7 – 8 m high.

Figure 1 shows a recent aerial view of the proposed development area (hereafter referred to as the “site”) and has been marked-up to show the approximate location of the proposed building. Figure 2 shows the existing batter into which the building would be set.

Figure 1: Area of proposed development.

(Image sourced from Nearmap Photomaps and dated 15 April 2015)

Figure 2: Area of the proposed Junior School Building looking from the north-west of the site.

A detailed survey plan covering the area of the proposed junior school building shows that surface levels along the southern side of the playing field which is located at the base of the bank, are at RL 35 m to RL 36 m, whereas the levels at the crest of the bank are at about RL 43 m to RL 44 m.

3. Regional Geology

The interim Gosford 1:25 000 Geological Series Sheet shows that the site is underlain by rocks of the Terrigal Formation which generally comprises sandstone, siltstone, claystone, conglomerate and minor breccia.

During the site walkover, evidence of filling was noted, and anecdotal information provided by the Building Services Manager for the school suggests that the filling in the local area (including in the area of the playing field) has been placed in an uncontrolled manner and may be poorly compacted and contain large buried objects such as sandstone boulders and vehicle parts.

4. Field Work Methods

Field work was undertaken on 18 March 2015 and comprised the following:

- A walkover inspection by a senior geotechnical engineer to measure site slopes and to check for signs of instability;
- The drilling of two boreholes (Bores 1 and 2) to depths of 1.65 – 3.4 m at the base of the existing batter;
- The drilling of two boreholes (Bores 3 and 4) to depths of 5.9 – 7.45 at the crest of the batter;
- Excavation of four test pits (Pits 5 – 8) to about 1.5 m depth into the existing batter.

The boreholes were drilled using a track-mounted rig fitted with 100 mm diameter spiral flight augers and included Standard Penetration Tests (SPTs) at 1.5 m depth intervals to provide information on the strength of the soils encountered. The pits were excavated using a 4 tonne excavator and were primarily undertaken to check for buried sandstone boulders or other large obstructions in the filling that may pose difficulties for construction works.

The field work was carried out in the presence of an engineering geologist who also prepared engineering logs of the subsurface profile encountered in the bores and pits. Selected samples were retained for logging and identification purposes.

The locations of the tests are shown in Drawing 1 in Appendix B.

5. Field Work Results

5.1 Walkover Inspection

The principal items noted during the inspection were as follows:

- The footprint of the proposed junior school building straddles over a batter slope that is about 7 - 8 m high. The batter falls down to the north at slopes of between 25° and 40°, with the steepest section towards the western end of the batter. The lower third or the eastern half of the batter is significantly flatter and slopes at about 10°- 15°. There was no slumping or significant creep observed in this slope.
- The batter is mainly covered with grass. A mature tree is growing mid-way down the batter at the eastern end of the proposed building footprint, and there are also a few scattered semi-mature trees. No pattern of basal bending or leaning was observed within the trees trunks growing on the slope.
- A 0.8 m high timber retaining wall was located at the toe of the batter. No rotation, leaning or displacement was observed in the wall.
- Several patches of bare soil were present at the western end of the batter and were observed to expose mainly sandy clay filling (refer to Figure 3).

Figure 3: Photo showing the western end of the batter with filling exposed.

- A demountable classroom block is present slightly beyond the crest of the batter. No cracking or evidence of settlement was observed within the building or concrete pavements that surrounded the building.
- The school hall is located to the south-west of the development area, and approximately 10 - 15 m to the south of the batter. No cracking or evidence of settlement was observed in this building.
- Based on comparison of the surface topography with that of the hillside further beyond the development area, it appeared that much of the area to the east of the existing demountable classroom block comprised extensive filling that was estimated to be about 3 – 5 m deep (refer to Figure 4).

Figure 4: Photo showing the western end of the filled area.

- Areas further upslope of the development area had been terraced to accommodate school buildings, roads and footpaths. No signs of settlement or hillside instability were observed in the vicinity of the proposed junior school building.
- Occasional sandstone boulders were protruding from areas of existing filling (refer to Figure 5).

Figure 5: Sandstone boulder exposed within the development area.

- The roofs of the demountable classroom block and hall have gutters and downpipes that appear to drain to a reticulated stormwater drainage system. This include collection pits located in depressions in the ground surface surround the buildings.
- No seepage was observed emanating from the base of retaining walls or from the face of the batter slope at the time of the inspection.

5.2 Boreholes and Test Pits

Subsurface conditions encountered in the boreholes and test pits are detailed in the logs included in Appendix C. These should be read in conjunction with the accompanying explanatory notes, which define the descriptive terms and classification methods.

The conditions in the boreholes and test pits are broadly summarised as follows:

- Bores 1 and 2 at the toe of the batter encountered filling to 0.2 m depth overlying very stiff clay or dense gravelly clayey sand residual soils with sandstone at depths of 0.6 m (Bore 2) to 3.4 m (Bore 1);

- Bores 3 and 4 at the crest of the batter encountered sandy clay or gravelly clay filling to 4.5 - 5.0 m depth overlying stiff sandy clay or very stiff clay residual soil, with sandstone at depths of 5.4 m (Bore 4) to 6.8 m (Bore 3); and
- The test pits encountered mainly sandy clay or sandy gravelly clay filling over the full depth of excavation (approximately 1.5 m).

Figure 6 shows an example of the conditions encountered in the test pits.

Figure 6: Filling encountered at Pit 6.

From the conditions encountered, it appears that the majority of the slope has been constructed by the placement of filling onto the side of the hill rather than cutting into the hillside. SPT blow counts were relatively low (‘N’ values generally less than 5) within the filling indicating that it is poorly compacted.

No free groundwater was observed within the boreholes or the test pits during the course of the field work. It is noted that groundwater levels are affected by factors including rainfall and, therefore, will vary over time.

Surface levels at the test locations were interpolated from a survey plan provided to DP.

6. Proposed Development

A junior school building is proposed to be built at the Gosford Campus of St Philip's Christian College. The building will have two levels with the entry level at RL 44.1 m AHD and the lower level at RL 40.6 m AHD.

The building will require excavation to about 3.5 m depth into the existing batter, although the northern side of the building will protrude beyond the face of the batter and would be supported by concrete columns. Stepped seating and a storage room is proposed below the lower level, effectively making a third level to the building.

Architectural drawings provided to DP indicate that the building may be constructed in four stages, with Stage 1 being for the western portion.

Figures 7 and 8 are excerpts of the architectural drawings showing a plan and section through the proposed building.

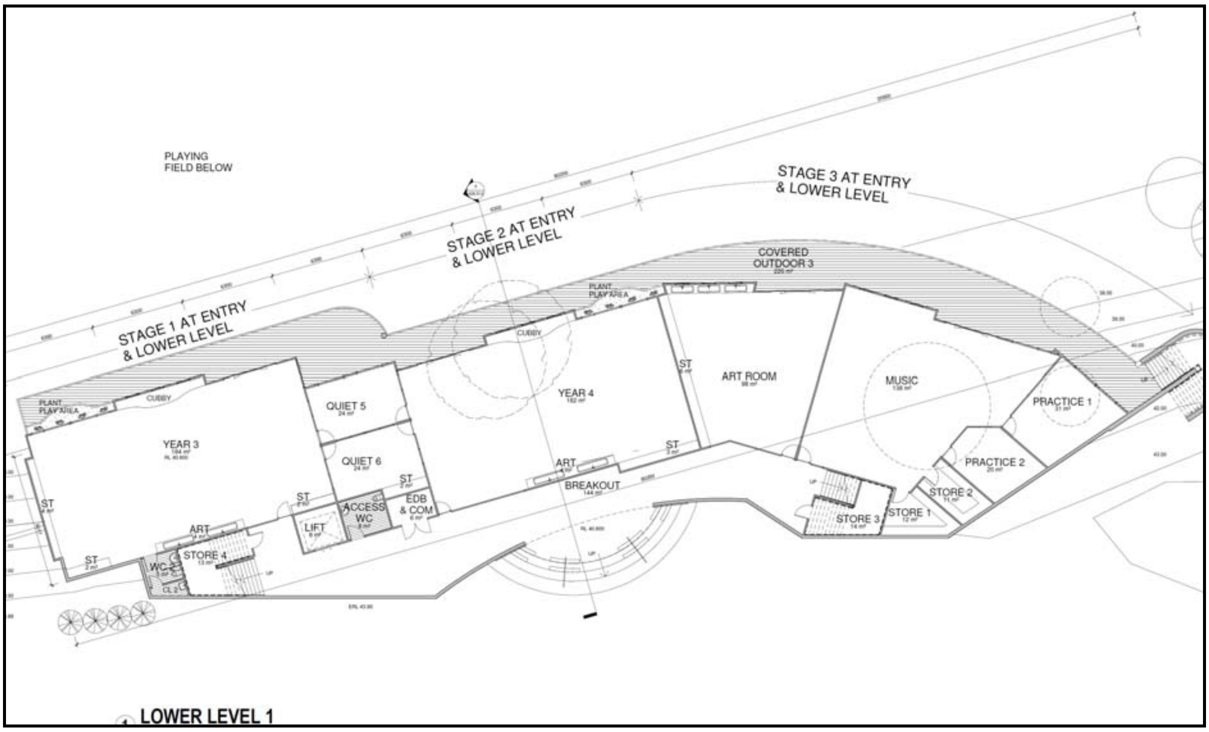


Figure 7: Plan shows the layout of the proposed lower level of the junior school building.

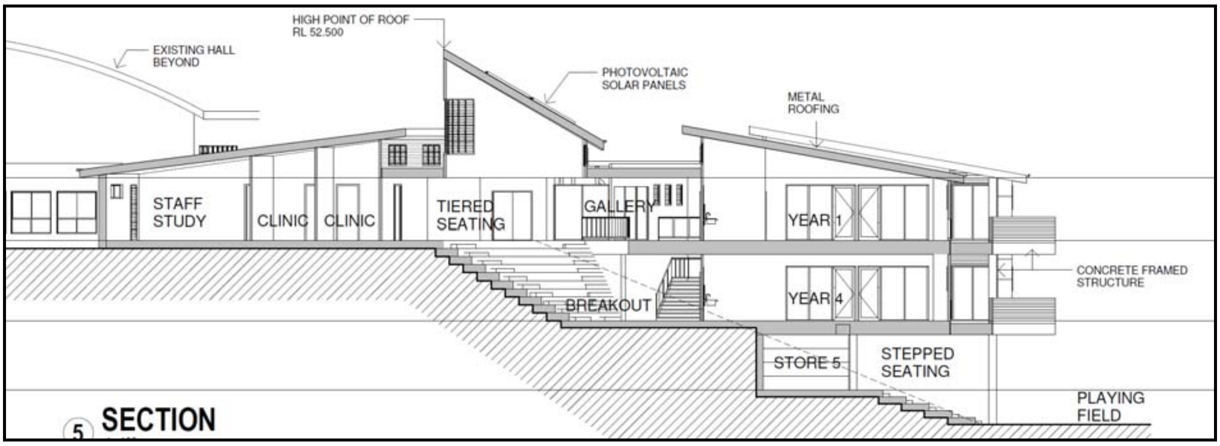


Figure 8: Section through the middle of the proposed junior school building.

7. Comments

7.1 Slope Stability Assessment for DCP 2013

Average slopes across the site are generally in the order of 10 - 15° and the geological unit underlying the site is the Terrigal Formation. Reference to Table M1 of Chapter 6.4 of Gosford City Council's Development Control Plan 2013 (Ref 2) indicates that the site would be "Category 2 - Medium Hazard Area" with respect to landslip hazards.

The site has been assessed with reference to the Australian Geomechanics Society (AGS) Landslide Taskforce "Practice Note Guidelines for Landslide Risk Management" March 2007 (Ref 2). The following sections of this report discuss likelihood, consequence and risk within the framework of the AGS Guidelines.

7.1.1 Identified Hazards and Inferred Consequences

Hazard 1 relates to the slow creep of the filling at the site and has been assessed as "likely" given that the filling appears to be poorly compacted. Due to other issues associated with uncontrolled filling in this area, it is recommended that the filling be reworked by excavation and re-compaction in layers under controlled conditions. Provided that the filling is reworked, the likelihood of creep would reduce to "unlikely". The consequences of creep would be "insignificant" provided the footings and retaining walls for the building are socketed at least 0.5 m into the weathered rock profile, and that retaining walls are designed appropriately and regularly maintained.

Hazard 2 relates to a deep seated failure beneath the proposed building has been assessed to be "rare" provided that adequate controls are put in place with regard to discharging of stormwater runoff from the building and surrounding ground surface. Provided that the amount of infiltration into the soil profile can be restricted, the stability of the slope can be improved. The consequences of a deep seated failure would be "catastrophic" as reconstruction costs would be expected to be in the range 100% to 200% of the value of the proposed development.

Hazard 3 relates to instability within the proposed excavation for the lower level for the proposed building. This has been assessed to have a likelihood category of “unlikely” provided that the excavations are adequately battered during construction. If failure of the slope occurred during construction, the consequence to the proposed buildings would be “minor” as only part of the unfinished structure would be affected, with repair costs estimated to be up to 10% of the value of the project.

Hazard 4 relates to failure of the constructed retaining walls for the proposed building, which would be up to about 4 m high. Based on the results of the boreholes, the excavation for the building is expected to be within mainly sandy clay or gravelly clay filling. Provided that the retaining wall is adequately designed by a structural engineer, and constructed in accordance with the design (including suitable drainage), then the likelihood of failure would be “rare”. Should failure occur, the consequence to the proposed building would be “medium”, with repair costs estimated to be about 60% of the value of the project.

In addition to the above four hazards, depending on the construction methods intended to be used at the site, a further hazard could apply. This relates to the operating of heavy piling equipment on the fill batter, and the risk of initiating slope failure causing the rig to topple. At this stage of the project, DP is not aware of the construction methodology in mind, nor the type of equipment that would be intended to be used, and therefore has not included this hazard within the AGS assessment framework. It is common practice to provide a working platform for tracked piling rigs, and this would be subject to separate analysis and design based on detailed information regarding the configuration of the piling rig. It is recommended that all existing filling within the construction area be reworked and placed under controlled conditions.

7.1.2 Risk Analysis

7.1.2.1 Property Risk

The site has been assessed with reference to the Australian Geomechanics Society Landslide Taskforce “Practice Note Guidelines for Landslide Risk Management” March 2007 (Ref 2). Table 1 summarises the results of this assessment, together with a qualitative assessment of the likelihood of occurrence of a landslide or mass ground movements and its consequence and risk to the property. This table presents levels of risks based on the assumption that the structure is designed and constructed taking into account the advice and recommendations presented in this report.

Table 1: Risk Assessment for Property – Proposed Development

Hazard	Likelihood	Consequence	Risk to Proposed Development
1. Slow creep of soils within the footprint of the proposed building	Unlikely	Insignificant	Very Low
2. Slow deep seated failure beneath proposed building	Rare	Catastrophic	Moderate
3. Rapid gross instability of excavation for lower level of proposed building	Unlikely	Minor	Low
4. Failure of constructed retaining walls supporting the excavation for the lower level of the proposed building	Rare	Minor	Very Low

Reference to the AGS guidelines indicates that for primary or secondary school buildings, for which an importance Level 3 would apply in accordance with Ref 2, a “low” risk level is usually acceptable to society and regulators. In order to mitigate the risk of deep seated failure, control of moisture infiltration into the slope will be required (further comment regarding this is provided in Section 7.8).

7.1.2.2 Risk to Life

The AGS Practice Note Guidelines (Ref 2) also provides a framework for landslide risk management, guidance on risk analysis methods and information on acceptable or tolerable risks for loss of life.

Risk analysis can be broken up into four components, namely:

- Hazard identification
- Frequency analysis
- Consequence analysis, and
- Risk estimation.

For the loss of life, the individual risk can be calculated using:

$R_{LOL} = P_H \times P_{S:H} \times P_{T:S} \times V_{D:T}$

Where,
R_{LOL} is the risk, or annual probability of death of an individual
P_H is the annual probability of the hazardous event
$P_{S:H}$ is the probability of spatial impact by the hazard given the event
$P_{T:S}$ is the temporal probability given the spatial impact, and
$V_{D:T}$ is the vulnerability of the individual

Table 2 details the results of the assessment undertaken in relation to risk to life of the hazards identified at this site.

Table 2: Risk Assessment for Life – Proposed Development

Hazard	$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	Risk $R_{(LOL)}$
1. Slow creep of soils within the footprint of the proposed building	1×10^{-4}	1	0.33 (people in building 8 hours per day)	1×10^{-5} (evacuation highly likely)	3.3×10^{-10}
2. Slow deep seated failure beneath proposed building	1×10^{-5}	1	0.33 (people in building 8 hours per day)	1×10^{-3} (evacuation possible)	3.3×10^{-9}
3. Rapid gross instability of excavation for lower level of proposed building during construction	1×10^{-4}	0.33 (third of excavation fails in area of workers)	0.2 (worker at base of excavation at time of failure 50% of working day)	0.5 (struck by debris)	3.3×10^{-6}
4. Failure of constructed retaining walls supporting the excavation for the lower level of the proposed building	1×10^{-5}	0.1 (section of wall fails – limited by propping from abutting walls)	0.1 (impact onto low use areas – eg storage room, toilet block, stair well, outdoor seating area)	0.5 (pupil struck by wall but not buried)	5×10^{-8}

There are no established individual or societal risk acceptance criteria for the loss of life due to a hazardous event such as a landslide or rock fall. Australian Geoguide LR7 of Ref 2 discusses "acceptable" and "tolerable" levels of risk which have been proposed by several authorities including the ANCOLD Guidelines for Risks from Large Dams, the Australian Geomechanics Society and the NSW Department of Urban Affairs and Planning. The AGS Guidelines (Ref 2) indicates that for schools, an "acceptable" risk level limit of 5×10^{-7}/annum is appropriate, based on a temporal spatial probability of 1.0 (refer to Table C9 of Ref 2).

With the exception of Hazard 3, the risk to life for the hazards listed in Table 2 do not exceed the acceptable limit for a Level 3 importance building. It is noted that Hazard 3 relates to the construction phase of the project in which case only a few workers rather than numerous pupils would be at risk, and for which a reduced level of risk of life of 10^{-5} is considered to be "tolerable" (as at this stage the development would not have attained Level 3 importance). When considering this reduced risk limit, given that the risk to life for Hazard 3 is less than 10^{-5}, the risk to life associated with the proposed development is normally considered by society and regulators to be acceptable.

7.2 Site Classification

Relatively deep filling was encountered at Bores 3 and 4 and also at the test pits. The filling appears to be poorly compacted, and is considered to have been placed in an ‘uncontrolled’ manner without thorough compaction. This material is considered to be unsuitable for the support of structural loads and will, therefore, have a significant implication on the design of foundations.

Consequently, the building area would be classified as Class P in accordance with AS 2870 – 2011: *Residential Slabs and Footings* (Ref 3). Furthermore, where development is to be carried out on a slope where downhill foundation movement is a design consideration, AS 2870 requires sites to be classified as Class P.

7.3 Excavation Conditions

Excavation for the proposed junior school building will be to depths of up to approximately 3.5 m.

Based on the conditions encountered in Bores 3 and 4, excavation will be within existing sandy clay or sandy gravely filling. These materials are anticipated to be readily excavated using conventional earthmoving equipment such as hydraulic excavators. The weathered rock profile is not expected to be intersected during the bulk excavation.

It is understood from site staff that the filling could possibly contain boulders and other obstructions. This has not been confirmed by the geotechnical investigations to date but cannot be ruled out.

7.4 Batter Slopes

Where excavation is sufficiently distant from other buildings, a short term (construction) batter slope of 1.5H:1V is recommended within the filling. Regular monitoring of the stability of the batters should also be undertaken especially following wet weather.

If batters are to be left unsupported and exposed for prolonged periods (say for more than two weeks), then the batters should be covered with plastic sheeting to protect against excessive wetting and drying.

Architectural plans indicate that long term batters would be formed adjacent to the eastern and western ends of the proposed building. It is recommended that these batters be formed at 3H:1V.

7.5 Retaining Walls

In the short term (ie during the early stages of construction), the retaining wall for the proposed building would probably act as a cantilever wall (unless temporary anchors are installed). It is understood that the wall would be a contiguous pile wall which is expected to be socketed into the underlying weathered rock profile.

Due to the proximity of the wall to the proposed building, the wall would need to be designed for 'at-rest' conditions rather than 'active' conditions. Based on recent discussions, it is expected that 'tie-back' anchors or 'dead-man' anchors would be used to reduce the lateral deflection of the wall, with these taken into the natural soil or rock profile some distance behind the wall.

On account of bracing due to anchoring or from the upper level floor slabs, a trapezoidal earth pressure distribution would apply. The maximum earth pressure in this distribution is determined using the 'at-rest' earth pressure coefficient multiplied both by the height of the excavation and the unit weight of the retained material. This pressure is applied over the central half of the wall and increases linearly from zero to full pressure over the upper 0.25H, then decreases linearly to zero pressure over the lowest 0.25H.

As a result of terracing for the building and landscaping to form a level area around the building, the retaining walls would support level backfill. Recommended retaining wall design parameters are presented in Table 3, below. The earth pressure coefficients apply for well drained, level retained materials. Separate account should be made in the design for additional surcharge loads, during or after construction. A suitable factor of safety should be applied to all retaining wall designs.

Table 3: Retaining Wall Design Parameters - Unfactored

Parameter	Symbol	Filling
Bulk unit weight (above water table)	γ_b	20 kN/m^3
'At-rest' earth pressure coefficient for retaining walls that are integral to the building	K_o	0.5

The earth pressure design parameters given above are based on the assumption that full drainage will be provided behind the retaining walls. All retaining walls, regardless of height, should be provided with geotextile encapsulated free draining backfill (such as 10 mm single size aggregate) with a slotted drainage pipe at the base of the wall for the relief of hydrostatic pressures. Water collected by the drainage system should be discharged to a formal stormwater drainage system downslope of the batter (under no circumstances is water to be discharged onto the batter). The contiguous pile wall should be designed for hydrostatic pressures given that drainage is not able to be installed behind the wall.

The retaining walls should be designed by the structural engineer so that they meet or exceed the relevant factors of safety for different failure modes.

7.6 Foundations

On account of the existing batter comprising uncontrolled filling to depths of up to 5 m (eg Bore 3), it is recommended that the building be wholly supported by piles socketed into the underlying rock profile. This would also necessitate the design of the floor slabs and suspended slabs.

To account for the potential slope instability hazards, footings for the building, including footings for the proposed retaining wall, should be keyed at least 0.5 m into the weathered rock.

Given the subsurface conditions encountered in the boreholes, it is expected that uncased concrete bored piers would be a suitable footing system for this project. A few sandstone boulders were observed protruding from the ground surface, and other civil work at the school has encountered buried boulders and other large objects in the filling; whilst no large objects were encountered in the test pits and boreholes, it is possible that some may be present within the fill batter and, if struck during drilling, would present difficulty with installing the piers. Such potential obstructions should be removed during the reworking of the existing filling.

Piers designed to socket into at least extremely low strength weathered sandstone could be designed based on a maximum allowable end bearing pressure of 600 kPa, and a shaft adhesion of 50 kPa within the rock profile.

It is important to note that all foundations should be taken to below the zone of influence of adjacent excavations. For this site, the zone of influence would be defined as a plane extending upwards at 45° above the base of the excavation.

All foundation excavations, including those for retaining walls, should be inspected by a geotechnical engineer prior to casting of concrete. Pier holes should be cleaned and free of water and loose debris prior to concreting, otherwise the capacity of the piers would be adversely affected. It is recommended that a cleaning barrel be used to facilitate cleaning of the pier holes.

7.7 Site Preparation and Earthworks

As mentioned in Section 7.6, the proposed junior school building should be designed to be supported by foundations socketed into the weathered rock, with floor slabs designed as suspended slabs. On account of the steepness of the batter, the lack of compaction control and the inherently greater risk of settlement or instability, it is recommended that the existing filling within the development area be reworked.

Site preparation for the building should be carried out in general accordance with the following methodology:

- Strip existing vegetation and any organic topsoils and stockpile for later use in landscaping (if required);
- Excavate existing uncontrolled filling to expose the underlying natural soil profile, and stockpile the material for reuse;
- The sides of the excavation should be battered as recommended in Section 7.4;
- Roll the exposed surface on the cut bench using at least six passes of a 6 tonne smooth drum roller. The surface of the site should also be graded to shed water away from the hillside and to prevent ponding;
- Present the cut surface for inspection by a geotechnical engineer. A final ‘test roll’ of the area should be carried out in the presence of the engineer to check for any soft or heaving areas which should then be removed;
- Place filling as required to bring the area back up to design level, with the sides of the fill progressively benched into the slope. The filling should be placed in near horizontal layers no

thicker than 250 mm (loose thickness) and be compacted to at least 98% Standard compaction. Moisture contents of the filling should be maintained within -3% to 1% of the optimum moisture content for Standard compaction. Filling should be relatively homogeneous with maximum particle size of 100 mm and be free of organic material; and

- Protect the area after preparation to maintain moisture contents as far as practicable. The placement of subbase gravel, or concrete slab (within building footprint) would normally provide adequate protection, although drainage should also be installed to prevent water ponding on the building platform.

All filling within the footprint of the proposed building should be placed under controlled conditions. Geotechnical inspections and testing should be carried out to a Level 1 standard as defined in AS 3798 - 2007: '*Guidelines on Earthworks for Commercial and Residential Developments'* (Ref 4). This requires full-time attendance by an experienced earthworks technician during the placement and compaction of the filling, together with density testing of the various layers of filling.

7.8 Drainage

From a slope stability management perspective, drainage of the hillside is crucial for this project. As mentioned in Section 7.1.1, the batter comprises poorly compacted clay filling which requires measures to restrict the amount of infiltration into the slope.

These measures should include the following:

- Runoff from all roof surfaces to be piped away from the hillside;
- Surface runoff to be shed to stormwater drainage pits that in turn connect to the piped drainage system;
- Retaining walls for the building or for any landscaping should have geotextile encapsulated free draining gravel over the full height of the rear of the wall, with a drainage pipe at the base of the wall. Water collected by the drain is to be piped away from the hillside;
- Garden beds that require regular watering should be avoided unless they are full contained and any excess infiltration able to be collected and diverted away from the hillside;

Infiltration pits or trenches are not suitable for this site.

7.9 Geotechnical Report Data

The information provided in Table 4 summarises the results of the stability assessment and geotechnical investigation carried out, in accordance with Chapter 6.4 of GCC's DCP 2013 (Ref 1).

Table 4: Summary of Geotechnical Data (in accordance with Chapter 6.4 of GCC DCP 2013)

Site Data	**Land Area 1** **Site of Proposed Junior School Building**
Lot No.	Lot 102 in DP 832279
Street No.	20
Street Name	Narara Creek Road
Suburb	Narara
Assessed by	Darryl Carson
Assessment Date	18 March 2015
Site Classification (AS 2870 – 2011)	P
Land Slope (degrees)	Average slopes ranging from 10° to 15°, locally up to 45° in fill batter
Geological Abbreviation (of underlying rock)	Rnt (Terrigal Formation)
Description of Surficial Soil	Filling and colluvium, overlying residual clay overlying siltstone bedrock
Type of Stability Risk	Soil creep, global failure, instability of construction batter slopes, instability of constructed retaining walls
Risk Assessment (AGS – 2007)	'Moderate' with respect to deep seated failure, otherwise 'Low'
Geotechnical Inspections required during construction	Yes. 'Post development report' also required.
Risks from Adjoining Land	None

7.10 Conclusion

The site has been assessed to be suitable for the proposed development, from a geotechnical perspective, provided that the recommendations made in this report are implemented. These primarily include the following:

- Existing filling within the development area is to be reworked under Level 1 controlled conditions;
- The proposed junior school building is supported by foundations keyed into the weathered rock profile;
- Inspection of all footings is undertaken by a geotechnical engineer to confirm that the target foundation strata is reached and that the pier holes are sufficiently clean prior to pouring concrete;

- Design of the retaining walls to be undertaken by a structural engineer, and suitable drainage provided for all walls. Allowance for hydrostatic forces is to be made for the design of the contiguous pile wall;
- Stormwater flows from the proposed roofs and any surface or subsurface drains should be collected by a stormwater drainage system and discharged to the reticulated stormwater drainage system; and
- Design of the structures are to be in accordance with the guidelines provided in LR7 and LR8 (refer Appendix A).

The omission of any of the recommendations made in this report may result in a greater risk to property or loss of life than shown in Tables 1 and 2. The level of risk to loss of life also assumes that access to the work site is only available for construction personnel.

8. References

1. Gosford City Council, Chapter 6.4 of *Development Control Plan 2013 – Geotechnical Requirements for Development Applications*.
2. Australian Geomechanics Society, *Practice Note Guidelines for Landslide Risk Management*, March 2007.
3. Australian Standard AS2870 – 2011, *Residential Slabs and Footings*, Standards Association of Australia.
4. Australian Standard AS 3798 - 2007: *Guidelines on Earthworks for Commercial and Residential Developments*, Standards Association of Australia.

9. Limitations

Douglas Partners (DP) has prepared this report for a project at St Philip's Christian College, 20 Narara Creek Road, Narara in accordance with DP's Proposal WYG150067 dated 9 March 2015 and subsequent acceptance received from St Philip's Christian College.

The report is provided for the exclusive use of St Philip's Christian College and their agents (Ian Easton Architect and North Construction and Building Pty Ltd) for this project only and for the purpose(s) described in the report. It should not be used for other projects or by a third party. 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 subsurface conditions only at the specific sampling or testing locations, and then only to the depths investigated and at the time the work was carried out. Subsurface conditions can change abruptly due to variable geological conditions and also as a result of human activities. 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 limited by undetected variations in ground conditions between sampling locations. The advice may also be limited by budget constraints imposed by others or by site accessibility.

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

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

The contents of this report do not constitute formal design components such as are required, by Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction of all works (not just geotechnical components) and the controls required to mitigate risk. This report does, however, identify hazards associated with the geotechnical aspects of development and presents the results of a risk assessment associated with the management of these hazards. It is suggested that the developer's principal design company may wish to include the geotechnical hazards and risk assessment information contained in this report, in their own Safety Report. If the principal design company, in the preparation of its project Design Report, wishes to undertake such inclusion by use of specific extracts from this subject DP report, rather than by appending the complete report, then such inclusion of extracts should only be undertaken with DP's express agreement, following DP's review of how any such extracts are to be utilised in the context of the project Safety Report. Any such review shall be undertaken either as an extension to contract for the works associated with this subject DP report or under additional conditions of engagement, with either option subject to agreement between DP and the payee.

Douglas Partners Pty Ltd

Appendix A

About this Report

Appendix C (Ref 3) – Guidelines for Landslide Risk Management

Geoguide LR7 – Landslide Risk

Geoguide LR8 – Construction Practice

About this Report

Douglas Partners

Introduction

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

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

Copyright

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

Borehole and Test Pit Logs

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

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

Groundwater

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

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

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

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

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

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

Site Anomalies

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

Information for Contractual Purposes

Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

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

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}		10 years		The event is expected to occur over the design life.	ALMOST CERTAIN	A
	$5x10^{-2}$		20 years			
10^{-2}		100 years		The event will probably occur under adverse conditions over the design life.	LIKELY	B
	$5x10^{-3}$		200 years			
10^{-3}		1000 years		The event could occur under adverse conditions over the design life.	POSSIBLE	C
	$5x10^{-4}$		2000 years			
10^{-4}		10,000 years		The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
	$5x10^{-5}$		20,000 years			
10^{-5}		100,000 years		The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
	$5x10^{-6}$		200,000 years			
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%		Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
	100%			
60%		Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
	40%			
20%		Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
	10%			
5%		Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
	1%			
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		**CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)**				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

LANDSLIDE RISK

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as *"a measure of the probability and severity of an adverse effect to health, property, or the environment."* This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

TABLE 2: LIKELIHOOD

Likelihood	Annual Probability
Almost Certain	1:10
Likely	1:100
Possible	1:1,000
Unlikely	1:10,000
Rare	1:100,000
Barely credible	1:1,000,000

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

TABLE 1: RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**Unacceptable** without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low. May be too expensive and not practical. Work likely to cost more than the value of the property.
High	H	**Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	**May be tolerated** in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as possible.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are averse to flying and yet it represents a lower risk than choking to death on food. Importantly, the data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

Risk (deaths per participant per year)	**Activity/Event Leading to Death** (NSW data unless noted)
1:1,000	Deep sea fishing (UK)
1:1,000 to 1:10,000	Motor cycling, horse riding , ultra-light flying (Canada)
1:23,000	Motor vehicle use
1:30,000	Fall
1:70,000	Drowning
1:180,000	Fire/burn
1:660,000	Choking on food
1:1,000,000	Scheduled airlines (Canada)
1:2,300,000	Train travel
1:32,000,000	Lightning strike

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

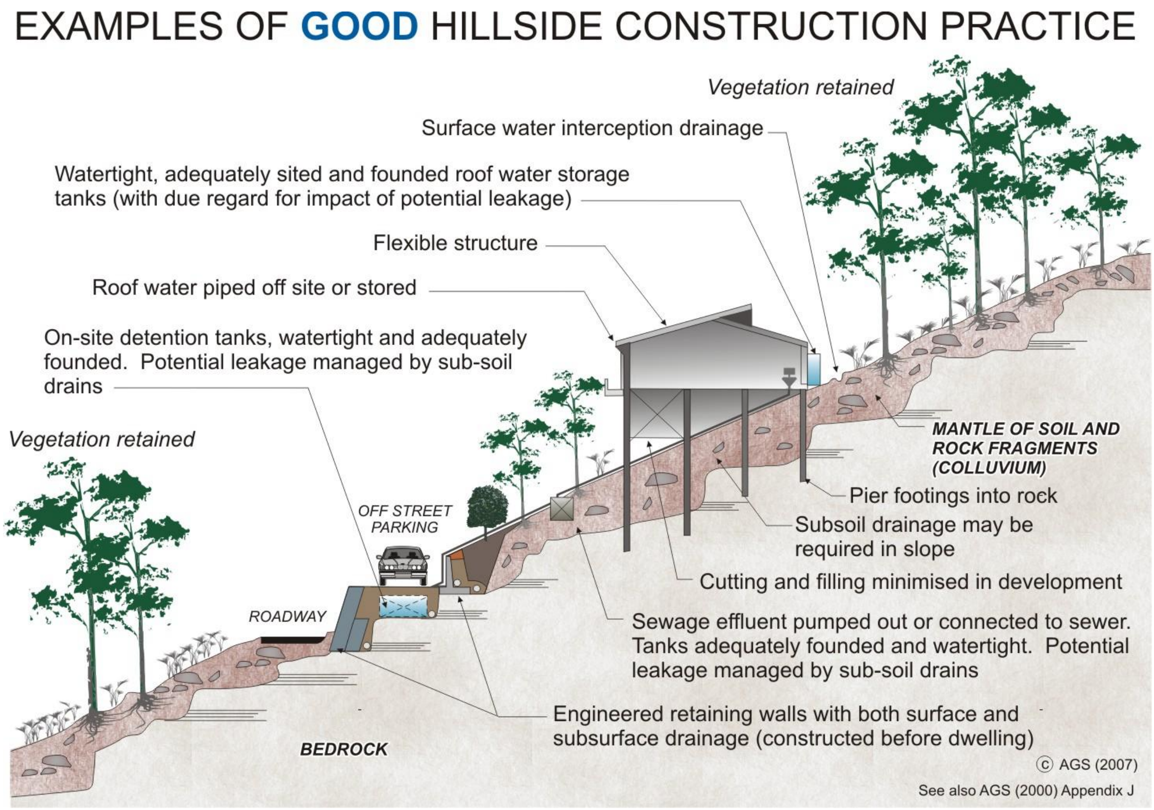
- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
  GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the Australian Geomechanics Society, a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

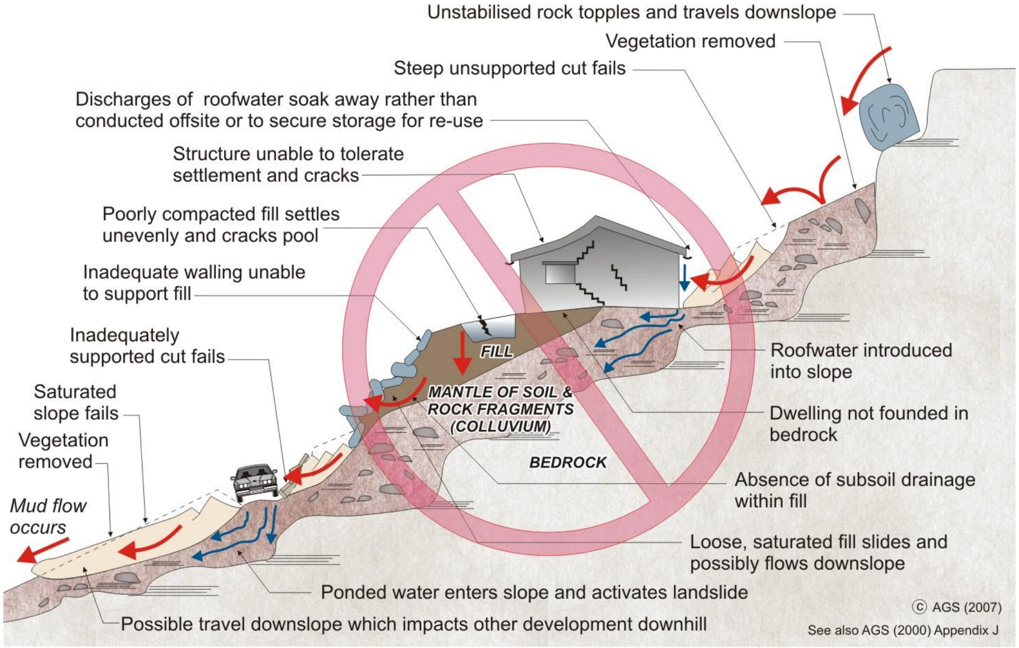
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal

GeoGuide LR10 - Coastal Landslides

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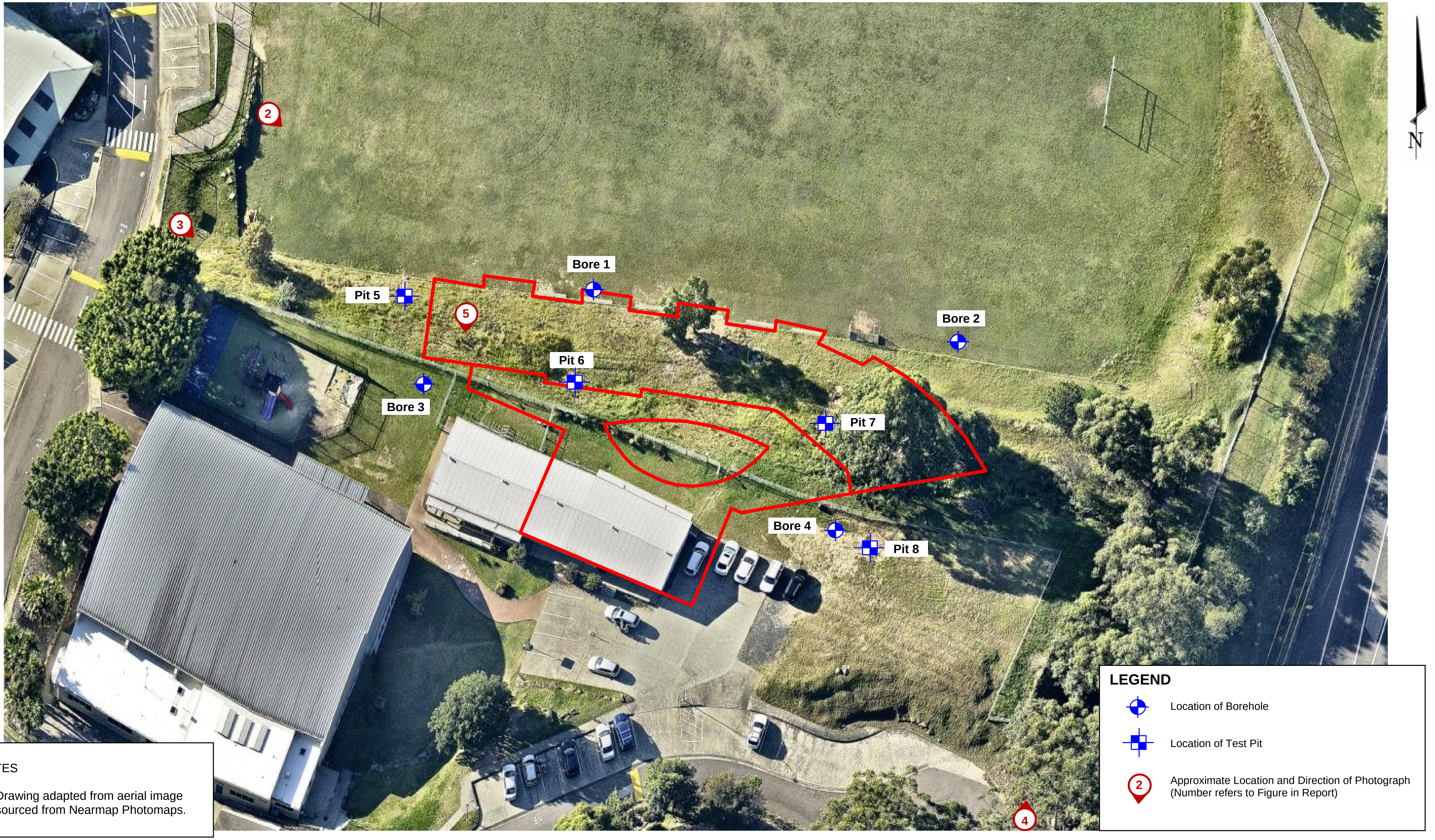
Appendix B

Drawing 1 – Locations of Tests



LEGEND

⊕	Location of Borehole
⊞	Location of Test Pit
②	Approximate Location and Direction of Photograph (Number refers to Figure in Report)

NOTES

1. Drawing adapted from aerial image sourced from Nearmap Photomaps.

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: St Philip's Christian College
OFFICE: Central Coast
DRAWN BY: DRC
SCALE: Not to Scale
DATE: 1.6.2015

TITLE:
Locations of Tests
Proposed Junior School Building
St Philip's Christian College, 20 Narara Creek Road, Narara

PROJECT No: 75957
DRAWING No: 1
REVISION: A

Appendix C

Sampling Methods

Soil Descriptions

Rock Descriptions

Symbols & Abbreviations

Borehole and Test Pit Logs

Sampling Methods

Sampling

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

Disturbed samples taken during drilling provide information on colour, type, inclusions and, depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are taken by pushing a thin-walled sample tube into the soil and withdrawing it to obtain a sample of the soil in a relatively undisturbed state. Such samples yield information on structure and strength, and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Test Pits

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

Large Diameter Augers

Boreholes can be drilled using a rotating plate or short spiral auger, generally 300 mm or larger in diameter commonly mounted on a standard piling rig. The cuttings are returned to the surface at intervals (generally not more than 0.5 m) and are disturbed but usually unchanged in moisture content. Identification of soil strata is generally much more reliable than with continuous spiral flight augers, and is usually supplemented by occasional undisturbed tube samples.

Continuous Spiral Flight Augers

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

Non-core Rotary Drilling

The borehole is advanced using a rotary bit, with water or drilling mud being pumped down the drill rods and returned up the annulus, carrying the drill cuttings. Only major changes in stratification can be determined from the cuttings, together with some information from the rate of penetration. Where drilling mud is used this can mask the cuttings and reliable identification is only possible from separate sampling such as SPTs.

Continuous Core Drilling

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

Standard Penetration Tests

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

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

The test results are reported in the following form.

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

  4,6,7
  N=13

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

  15, 30/40 mm

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

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

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

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

Soil Descriptions

Douglas Partners

Description and Classification Methods

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

Soil Types

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

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

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

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

The proportions of secondary constituents of soils are described as:

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

Definitions of grading terms used are:

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

Cohesive Soils

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

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

Cohesionless Soils

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

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

Soil Descriptions

Soil Origin

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

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

Transported soils may be further subdivided into:

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

Rock Descriptions

Rock Strength

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

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

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

Degree of Weathering

The degree of weathering of rock is classified as follows:

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

Degree of Fracturing

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

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

Rock Quality Designation

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

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

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

Stratification Spacing

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

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

Symbols & Abbreviations

Introduction

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

Drilling or Excavation Methods

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

Water

▷	Water seep
▽	Water level

Sampling and Testing

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

Description of Defects in Rock

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

Defect Type

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

Orientation

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

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

Coating or Infilling Term

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

Coating Descriptor

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

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

Other

fg	fragmented
bnd	band
qtz	quartz

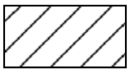
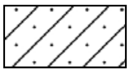
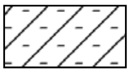
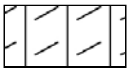
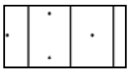
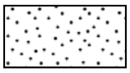
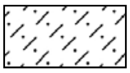
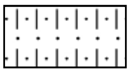
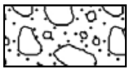
Symbols & Abbreviations

Graphic Symbols for Soil and Rock

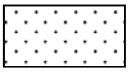
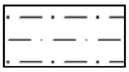
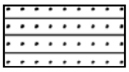
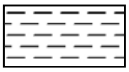
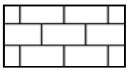
General

■	Asphalt
	Road base
	Concrete
	Filling

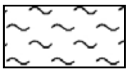
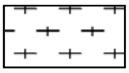
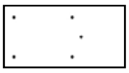
Soils

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

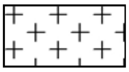
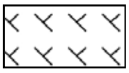
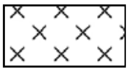
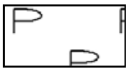
Sedimentary Rocks

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

Metamorphic Rocks

	Slate, phyllite, schist
	Gneiss
	Quartzite

Igneous Rocks

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

BOREHOLE LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 36.0 mAHD*
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
36	0.2	FILLING: Dark brown silty sand topsoil filling with some rootlets, damp							
	1.7	CLAY: Very stiff, brown mottled red brown slightly sandy, slightly gravelly clay, M<Wp - red brown mottled light grey from 1.0m		S	0.5 0.95		6,9,12 N = 21		
				S	1.5 1.8		9,20 refusal		
	3.4	SILTY SANDY CLAY: Hard, light grey silty sandy clay, M<Wp		S	3.0 3.4		7,12,20/100 refusal		
		Bore discontinued at 3.4m . Refusal on sandstone							

RIG: Traccess **DRILLER:** S Kennedy **LOGGED:** T Warriner **CASING:**
TYPE OF BORING: 100mm ϕ Spiral Flight Auger
WATER OBSERVATIONS: No Free Groundwater Observed
REMARKS: * Surface level interpolated from survey plan provided to DP

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 35.2 mAHD*
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 2
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Well Construction Details
				Type	Depth	Sample	Results & Comments		
	0.2	FILLING: Dark brown silty sand topsoil filling with some rootlets, damp							
	0.6	GRAVELLY CLAYEY SAND: Dense, light orange brown gravelly clayey sand, humid		S	0.5 0.65		20 refusal		
	1.65	SANDSTONE: Extremely low strength, extremely weathered brown sandstone - very low strength in parts		S	1.5 1.65		20 refusal		
		Bore discontinued at 1.65m . Refusal							

RIG: Traccess **DRILLER:** S Kennedy **LOGGED:** T Warriner **CASING:**

TYPE OF BORING: 100mm ϕ Spiral Flight Auger

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: * Surface level interpolated from survey plan provided to DP

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 44.0 mAHD*
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 3
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Well Construction Details
44		FILLING: Dark brown sandy clay topsoil filling, M<Wp	▩						
	0.2	FILLING: Brown sandy gravelly clay filling, M=Wp	▩	S	0.5 0.95		2,1,2 N = 3		
			▩	S	1.5 1.95		2,2,2 N = 4		
42	2.0	FILLING: Grey brown sandy clay filling with some gravel and a trace of organics, M>Wp	▩	S	3.0 3.45		2,2,6 N = 8		
			▩	S	4.5 4.95		4,6,5 N = 11		
39	5.0	CLAY: Very stiff, orange brown, slightly gravelly clay with a trace of sand, M<Wp	▨	S	6.0 6.45		pp = 300-400 5,8,12 N = 20		
	6.8	SANDSTONE: Extremely low strength, extremely weathered, orange brown sandstone	░	D	7.0				
			░	S	7.3 7.45		20 refusal		
	7.45	Bore discontinued at 7.45m . Refusal							

RIG: Traccess **DRILLER:** S Kennedy **LOGGED:** T Warriner **CASING:**

TYPE OF BORING: 100mm ϕ Spiral Flight Auger

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: * Surface level interpolated from survey plan provided to DP

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

BOREHOLE LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 43.5 mAHD*
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 4
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water	Well Construction Details
0.1	FILLING: Dark brown sandy clay topsoil filling, M=Wp						
0.3	FILLING: Brown slightly sandy clay filling with a trace of gravel, M=Wp						
	FILLING: Poorly compacted, dark grey brown sandy clayey silt filling with a trace of gravel and organics, moist	S	0.5 0.95		1,1,2 N = 3		
		S	1.5 1.95		pp = 20-40 1,0,0 N = 0		
	- becomes a clayey sand from 3.0m	S	3.0 3.45		2,2,2 N = 4		
4.5	SANDY CLAY: Stiff, light brown mottled grey sandy clay	S	4.5 4.95		pp = 100-150 3,14,20 N = 34		
5.4	SANDSTONE: Extremely low strength, weathered sandstone	S	5.75 5.9		20 refusal		
5.9	Bore discontinued at 5.9m . Refusal						

RIG: Traccess **DRILLER:** S Kennedy **LOGGED:** T Warriner **CASING:**
TYPE OF BORING: 100mm ϕ Spiral Flight Auger
WATER OBSERVATIONS: No Free Groundwater Observed
REMARKS: * Surface level interpolated from survey plan provided to DP

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 38.0 mAHD*
EASTING:
NORTHING:

PIT No: 5
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
38		FILLING: Orange brown sandy gravelly clay filling with a trace of rootlets, M<Wp	▨						
	0.5	FILLING: Grey brown sandy gravelly clay filling, M>Wp	▨						
37	1								1
	1.4	Pit discontinued at 1.4m . Limit of investigation							
36	2								2
35	3								3
34	4								4
33	5								5
32	6								6
31	7								7

RIG: Excavator

LOGGED: T Warriner

SURVEY DATUM:

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: * Surface level interpolated from survey plan provided to DP

☐ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 42.0 mAHD*
EASTING:
NORTHING:

PIT No: 6
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
42		FILLING: Orange brown and light grey sandy gravelly clay filling with occasional sandstone cobbles	▨						
41	1		▨						1
	1.5	Pit discontinued at 1.5m . Limit of investigation							
40	2								2
39	3								3
38	4								4
37	5								5
36	6								6
35	7								7

RIG: Excavator **LOGGED:** T Warriner **SURVEY DATUM:**

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: * Surface level interpolated from survey plan provided to DP

☐ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 41.0 mAHD*
EASTING:
NORTHING:

PIT No: 7
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
				Type	Depth	Sample	Results & Comments		
41		FILLING: Orange brown sandy clay filling with some gravel and a trace of rootlets	▨						
40	1		▨						1
	1.5	Pit discontinued at 1.5m . Limit of investigation							
39	2								2
38	3								3
37	4								4
36	5								5
35	6								6
34	7								7

RIG: Excavator

LOGGED: T Warriner

SURVEY DATUM:

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: * Surface level interpolated from survey plan provided to DP

☐ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: St Philip's Christian School
PROJECT: Proposed Junior School Building
LOCATION: 20 Narara Creek Road, Narara

SURFACE LEVEL: 43.5 mAHD*
EASTING:
NORTHING:

PIT No: 8
PROJECT No: 75957.00
DATE: 18/3/2015
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
	0.05	FILLING: Dark brown sandy clay topsoil/filling, M=Wp	▨						
	0.2	FILLING: Brown slightly sand clay filling with a trace of gravel, M=Wp	▨						
43 42	1	FILLING: Dark grey brown sandy clayey silt filling with a trace of rootlets, glass, paper and bricks	▨						1
	2 2.0	Pit discontinued at 2.0m . Limit of investigation							2
41 40	3								3
39	4								4
38	5								5
37	6								6
36	7								7

RIG: Excavator **LOGGED:** T Warriner **SURVEY DATUM:**

WATER OBSERVATIONS: No Free Groundwater Observed

REMARKS: * Surface level interpolated from survey plan provided to DP

☐ Sand Penetrometer AS1289.6.3.3
☐ Cone Penetrometer AS1289.6.3.2

SAMPLING & IN SITU TESTING LEGEND

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

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