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Integrated Practical Solutions

Report on
Geotechnical Desktop Study

Proposed Wahroonga Adventist School
Fox Valley Road, Wahroonga

Prepared for
Stanton Dahl Architects

Project 73244.00
November 2012

Douglas Partners
Geotechnics | Environment | Groundwater

Document History

Document details

Project No.	73244.00	Document No.	1
Document title	Geotechnical Desktop Study Proposed Wahroonga Adventist School		
Site address	Fox Valley Road, Wahroonga		
Report prepared for	Stanton Dahl Architects		
File name	P:\73244.00 WAHROONGA, Wahroonga Adventist School, Desktop Study PAV\Docs\geotech desktop study\73224 Geotechnical Desktop Study.doc		

Document status and review

Revision	Prepared by	Reviewed by	Date issued
0	Peter Valenti	Fiona MacGregor	16 November 2012
1	Peter Valenti	Fiona MacGregor	22 November 2012

Distribution of copies

Revision	Electronic	Paper	Issued to
0	1	0	Stanton Dahl Architects – Mr David Heap
1	1	3	Stanton Dahl Architects – Mr David Heap

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

	Signature	Date
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Reviewer	F MacGregor	22/11/12

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Report on Geotechnical Desktop Study
Proposed Wahroonga Adventist School
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1. Introduction

This report details the results of a geotechnical desktop study undertaken by Douglas Partners Pty Ltd (DP) for a proposed Kindergarten to Year 12 school to be located at the north-eastern end of the Sydney Adventist Hospital at Fox Valley Road, Wahroonga.

The proposed development will be constructed in a staged approach and will comprise:

- Three buildings of three and four-storeys;
- A single-level basement carpark beneath the school buildings;
- Three playing fields and a store room building; and
- A road providing vehicular access off Fox Valley Road to the school site.

This desktop study was carried out at the request of Stanton Dahl Architects, the architects for the project, on behalf of the client, The Seventh Day Adventist Church, Greater Sydney Conference.

It is understood that a geotechnical assessment is required to provide preliminary geotechnical information for a Development Application (DA) and Environmental Impact Statement (EIS) to The Department of Planning and Infrastructure. DP has also carried out a Phase 1 Contamination Desktop Review which has been reported separately.

Douglas Partners has previously carried out a number of geotechnical investigations in the general area and the information from these investigations has been used to prepare this assessment.

2. Site Description

The site of the proposed school and playing fields is located at the north-eastern corner of the Sydney Adventist Hospital site, at Fox Valley Road, Wahroonga.

The proposed development is divided into two separate areas, namely:

- School buildings and basement carpark; and
- Playing fields.

The area of the proposed school buildings and basement carpark is located immediately north-west of Fox Valley Road, and the area is surrounded by an existing Church to the south-west, residential buildings to the north-east and a temporary carpark and stormwater detention basin to the north-west. The area is currently occupied by school demountable buildings and temporary carparks with one carpark paved with asphaltic concrete (AC) and the other unsealed with gravel surfacing. The existing ground within the existing school grounds and unsealed gravel carpark appear to be flat whereas the ground surface in the remaining site area dips gently towards the north-west at approximately 2 to 5 degrees. A fill batter, sloping at approximately 30 degrees, is orientated north-east to south-west and extends along the northern side of the unsealed gravel carpark and the school grounds. This batter is approximately 0.5 m high at the north-eastern end and increases to approximately 2 m high at the south-western end. Photographs 1 to 6 in Appendix C show the current site conditions within the proposed school building and basement carpark area.

The proposed playing fields are located in the far north-eastern corner of the Sydney Adventist Hospital site and this area is mostly occupied by an open grassed field and to a lesser extent by residential lots to the south and a temporary paved carpark to the west. The ground surface within this area generally dips down to the north-east towards the bushland and Coups Creek beyond. Generally, the ground surface dips at approximately 2 to 5 degrees within the paved carpark, increasing in steepness to approximately 10 degrees within the open grassed field, and becoming approximately 15 to 20 degrees along the north-eastern perimeter with the bushland. Photographs 7 to 12 in Appendix C show the current site conditions within the proposed playing field area.

There are some existing areas of cut and fill, typically between 1 m and 3 m high, as part of the existing developments on the sites, mainly associated with the buildings, a stormwater detention basin and existing carparks.

An aerial photograph showing the location of the site is included in Drawing 1 in Appendix B.

3. Geological Setting

The site location is shown on an extract of the Sydney 1:100,000 Series Geological Sheet on Drawing 2 in Appendix B. The geological mapping indicates that the south-eastern, higher part of the site adjacent to Fox Valley Road is underlain by Ashfield Shale with Hawkesbury Sandstone beneath the lower levels of the site.

Ashfield Shale typically comprises black to dark grey shale and laminite while Hawkesbury Sandstone typically comprises medium to coarse grained quartz sandstone with minor shale and laminite bands. The Ashfield Shale typically weathers to form clayey soils of medium to high plasticity and low permeability.

The Soil Conservation Service of NSW Acid Sulphate Soil Risk Map for Hornsby – Mona Vale indicates that there are no known occurrences of acid sulphate soils at the site. It is extremely unlikely that acid sulphate soils would be encountered at the site.

4. Previous Investigations

Douglas Partners has carried out previous geotechnical investigations on the site which are summarised as follows:

Project 28258 Proposed Day Care Centre (June 1999)
The Day Care centre is located on the western side of Fox Valley Road adjacent to the nurse's accommodation and south of the hospital buildings. The geological map showed the site was close to the geological boundary of Ashfield Shale and Hawkesbury Sandstone. Three boreholes drilled on this site encountered a thin layer of topsoil overlying firm to stiff sandy clay with very low to low strength sandstone at depths of 0.6 m to 1.1 m. Medium strength sandstone possibly occurred below 0.9 - 1.2 m depth.

Project 43899 Extensions to Former Laundry Building (May 2006)
The former laundry building is located to the west of the main hospital buildings. The investigation comprised three boreholes which encountered filling over sandy clay with sandstone encountered at depths ranging from 0.65 m to 1.65 m.

Project 45569 Proposed Redevelopment of Wahroonga Estate (November 2008)
A desktop study including a review of previous investigations in the area and a site walkover was undertaken for the proposed redevelopment of the Wahroonga Estate. The findings of the site walkover relevant to the current proposed development are summarised as follows:

Coups Creek

- There are numerous sandstone outcrops on the valley sides;
- Sandstone boulders and floaters (buried boulders) are plentiful in the creek valley; and
- Sandstone bedrock is exposed in the creek bed.

Hospital and Church Precinct

- There is some exposed weathered shale bedrock under the nurses accommodation building; and
- The car parking areas along the northern and western sides of the hospital appeared to have been formed by some cut and fill works. Most of the filling is on the Coups Creek side of the car parking area. In some instances the fill batters are relatively steep. In other areas, the batters have "grown" with the addition of more filling and also the dumping of grass cuttings. In most cases, filling is probably up to about 3 – 4 m deep.

5. Current Site Features

A walkover of the site was carried out on 29 October 2012. Extensive earthworks have been undertaken over the site in recent years including construction of a stormwater detention basin and temporary carparks. The major site features are noted as follows:

School Buildings and Basement Carpark Area

- The grassed playing field, playground area and outdoor areas along the northern side of the existing school have been constructed on raised fill areas (see Photos 1 and 2);

- A 0.5 m to 2.0 m high batter, sloping at approximately 2:1 (Horizontal:Vertical) extends along the northern side of the school grounds and unsealed gravel carpark. This batter face exposed filling, indicating past cut and fill earthworks to form current site levels (see Photos 3 and 5);
- Residual, stiff, red brown clay underlain by stiff, light grey clay with 'high strength' ironstone bands are exposed in the base and sidewalls of the detention basin immediately north of the site (see Photo 6).

Playing Fields Area

- A fill batter less than 1 m high and sloping at approximately 3:1 (H:V) extends along the northern perimeter of the paved carpark, indicating past placement of filling in this area;
- North of the paved carpark, a raised fill platform with a batter slope of approximately 3:1 (H:V) and approximately 3 m to 4 m high extends between the grassed field and the bushland below (see Photo 12);
- Cracks up to 20 mm wide and 150 mm deep are present in the surface filling near the crest of the batter (see Photo 11);
- Local stockpiles of woodchips and mixed soil, rock and concrete were present on top of the raised fill platform area (see Photos 9 and 10); and
- No sandstone outcrops were observed along the toe of the batter which extends between the grassed field and the bushland.

6. Proposed Development

The proposed Kindergarten to Year 12 school will be constructed as a four-staged development comprising:

- Three (Junior, Middle and Senior School) buildings of three and four-storey construction. It is understood that the school site will cover an area of approximately 7,050 m^2;
- A single-level basement carpark for approximately 124 car spaces beneath the school buildings;
- Three playing fields and a store room building located at the far north-eastern corner of the site. It is understood that the playing fields will cover an area of approximately 7,165 m^2; and
- A road providing vehicular access off Fox Valley Road to the school site.

7. Comments

7.1 General

The aim of this geotechnical assessment is to provide preliminary geotechnical information for the development and as part of a DA and EIS submission to The Department of Planning and Infrastructure. The following comments are based on a site inspection and desktop review of available information only. Therefore, the comments are preliminary in nature and intended as a guide to geotechnical constraints associated with the future development at the site.

For detailed design, comprehensive geotechnical investigations should be undertaken for specific locations and structures to provide information on the subsurface profile in order to more accurately determine the design issues and parameters.

7.2 Geological Model

There are two geological profiles which could be expected on the site; namely the Ashfield Shale and Hawkesbury Sandstone profiles.

The Ashfield Shale profile generally comprises a moderately to highly reactive, residual clay grading into Ashfield Shale at depth. The depth to shale is expected to be relatively shallow, possibly of the order of 1 – 3 m. The Ashfield Shale profile is expected to be found on the southern side of the site where higher ground levels exist around Fox Valley Road.

The Hawkesbury Sandstone profile generally comprises residual sandy clay over shallow sandstone generally within 1 – 3 m depth. It is expected to be found in the central and northern portion of the site where lower ground levels exist (i.e. further north of Fox Valley Road).

There are significant areas of existing cutting and filling on the site generally associated with previous development.

7.3 Excavation Conditions

It is anticipated that some cut and fill techniques will be required to achieve final ground levels across the site and excavation for the basement carpark is anticipated to be 2 m to 3 m deep, depending on current ground levels.

Review of existing information suggests that stiff clays may be encountered within the first 0.5 m to 1.5 m of excavations below original ground levels, however deeper excavations may encounter rock formation. The clays should be readily removed using hydraulic excavators and the excavation of rock is likely to require large rippers, rock hammers or rotary saws.

The permanent groundwater table is not expected to be encountered within the proposed excavation depths for the development, however some water seepage out of cut slopes should be expected especially after periods of prolonged rainfall.

7.4 Vibration Induced by Excavation Plant

Noise and vibration will be generated by excavation works in rock. Precautions, therefore will be required when excavating rock close to existing buildings. The level of acceptable vibration is dependent on various factors including the type of adjacent building structure (e.g. reinforced concrete, brick, etc.), its structural condition, the frequency range of vibrations produced by the construction equipment, the natural frequency of the building and the vibration transmitting medium. A vibration limit should be set following the detailed geotechnical investigation and inspection of adjacent vibration-sensitive structures.

7.5 Site Preparation

Excavated material from site may be suitable for reuse as engineered filling following further geotechnical assessment and contamination testing. Further reference should be made to DP's Phase 1 Contamination Desktop Review (Document 2) for reuse of site won materials. From a geotechnical perspective, engineered filling should be placed in layers and compacted in accordance with AS 3798-2007 "Guidelines on earthworks for commercial and residential developments". Filling should only be placed on areas which have been suitably prepared by removing any vegetation, organic topsoils and other unsuitable material and providing relatively level benched areas.

7.6 Slope Stability

There were no signs of slope instability observed on the site. There was some cracking observed along the crest of a filled batter but this is probably due to shrink-swell movements of reactive clays.

There are some steeper natural slopes in the bushland to the north-west of the site, but these are in areas underlain by Hawkesbury Sandstone where such steep overall slopes are common and slope instability is usually limited to block failures from cliffs.

To avoid slope instability being caused by the proposed development it is recommended that all permanent cut and fill batters be sloped at 2H:1V or flatter, with erosion protection provided as required. In addition, where new filling is to be placed over existing slopes, the existing slope should first be benched to form a series of near horizontal benches onto which the filling can be placed and compacted.

Some standard recommendations for building on slopes are given in the guidelines by the Australian Geomechanics Society which is provided in Appendix D.

7.7 Excavation Support and Retaining Walls

Any excavations through filling, natural soils and very low to low strength rock should be battered to no steeper than 1.5H:1V for temporary slopes and 2H:1V for permanent slopes. For any exposed permanent batter slopes, erosion protection will be required and slopes of 3H:1V allow for establishment and maintenance of grass covering. Steeper batters may be feasible in rock, however batter slopes should be reassessed when the basement layout is finalised and soil/rock conditions have been investigated. Where there is inadequate space for batters, retaining walls will be required and these should be designed by an engineer taking into account the slope behind the wall and any surcharge loading.

Where retaining walls are to be used on site, each case should be individually assessed and the type of wall adopted will depend on the height of the wall and whether deflections at the top of the wall are critical. Earth pressures acting on cantilevered, free-draining retaining walls can be calculated using a triangular pressure distribution based on an active earth pressure coefficient (K_a) of 0.3 for a level surface behind the wall and using an average bulk unit weight of 20 kN/m^3 for the filling and soil. The passive pressure provided below the toe of the wall will depend on the ground conditions present. An ultimate passive pressure (K_p) of 100 kPa for stiff clay and 400 kPa for very low strength sandstone or shale would be appropriate.

For smaller retaining walls, such as around landscaped garden beds etc., masonry type walls or crib walls may be appropriate.

7.8 Foundations

It is preferable to found footings for a structure on the same bearing stratum to reduce differential settlements. Given the anticipated shallow depth to rock over most of the site, it is suggested that all major structures are founded within rock. For support of the building loads, footing types could comprise shallow level pad and/or strip footings. Where the depth to rock increases or filling has been placed over the area, bored piers could be adopted. It is expected that the majority of the rock on site will be suitable for an allowable bearing pressure of 1000 kPa (i.e. at least very low strength sandstone or shale).

For lightly loaded structures (e.g. the store building at the playing fields), shallow footings founded on natural clays could be considered. If there is deep filling present, bored piers would be suitable. For preliminary design purposes footings founded on natural clay for a “Class H1” site classification as defined in Australian Standard for Residential Slabs and Footings AS2870, but this should be confirmed for detailed design. If greater than 0.4 m of clayey filling is present, then a “Class P” site classification would be appropriate, for which footings are designed on the basis of engineering principles.

7.9 Seismic Design

In accordance with the Australian Standard for Earthquake Loading AS1170.4-2007, the site has a hazard factor (z) of 0.08 and possibly a Site Sub-soil Class of Rock (B_e) if good rock is no more than 3 m deep. If a surface layer of soil/weathered rock of more than 3 m is present, then a Site Sub-soil Class of Shallow Soil (C_e) would be appropriate.

7.10 Roads

A road providing vehicular access off Fox Valley Road to the school site is proposed.

It is considered likely that the pavement may be founded on a subgrade comprising firm to stiff clay or sandy clay. For preliminary design purposes, a California bearing ratio (CBR) of 2% is suggested for the natural clays on site, but testing during detailed design investigations would provide a site specific design value.

In other areas, the roads may be constructed on filling. For filling under pavements, it is suggested that the filling is compacted to a maximum dry density ratio (MDDR) of 98% relative to standard compaction, with the final 500 mm depth below subgrade level compacted to an MDDR of 100% relative to standard compaction. The CBR for filling is dependent on the material used as filling. If the filling is derived from cuts elsewhere on site then a preliminary design CBR of 2% is suggested.

7.11 Further Investigation

Intrusive geotechnical investigation for the proposed development has not been carried out for this assessment but it is considered that boreholes will be required at the locations of the proposed structures to determine the actual subsurface conditions and soil properties prior to the detailed design.

8. Limitations

Douglas Partners (DP) has prepared this report for a proposed development at Fox Valley Road, Wahroonga, in accordance with DP's proposal (Syd120991) dated 8 October 2012, and acceptance received from Ms Caroline Hart of Stanton Dahl Architects on 24 October 2012, on behalf of the client, Seventh Day Adventist Church, Greater Sydney Conference. The report is provided for the exclusive use of Seventh Day Adventist Church, Greater Sydney Conference and their agents 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 this report are based on the sub-surface conditions encountered in previous investigations undertaken by DP and on the site conditions observed at the time of preparing this report. Sub-surface conditions can change abruptly due to variable geological processes and also as a result of man-made changes. Such changes may have occurred after the date of previous investigations and following observations of the current site conditions.

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

Douglas Partners Pty Ltd

Appendix A

About this Report

About this Report

Douglas Partners

Introduction

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

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

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

Borehole and Test Pit Logs

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

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

Groundwater

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

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

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

Reports

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

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

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

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

About this Report

Site Anomalies

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

Information for Contractual Purposes

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

Site Inspection

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

Appendix B

Drawing 1 – Site Plan
Drawing 2 – Geological Map

Aerial photograph sourced from Nearmap.com, photograph dated 24 October 2012

Douglas Partners Geotechnics / Environment / Groundwater	**Site Plan** **Wahroonga Adventist School** **Fox Valley Road, Wahroonga**	PROJECT	73244.00
		DWG No:	1
		REV:	0
	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

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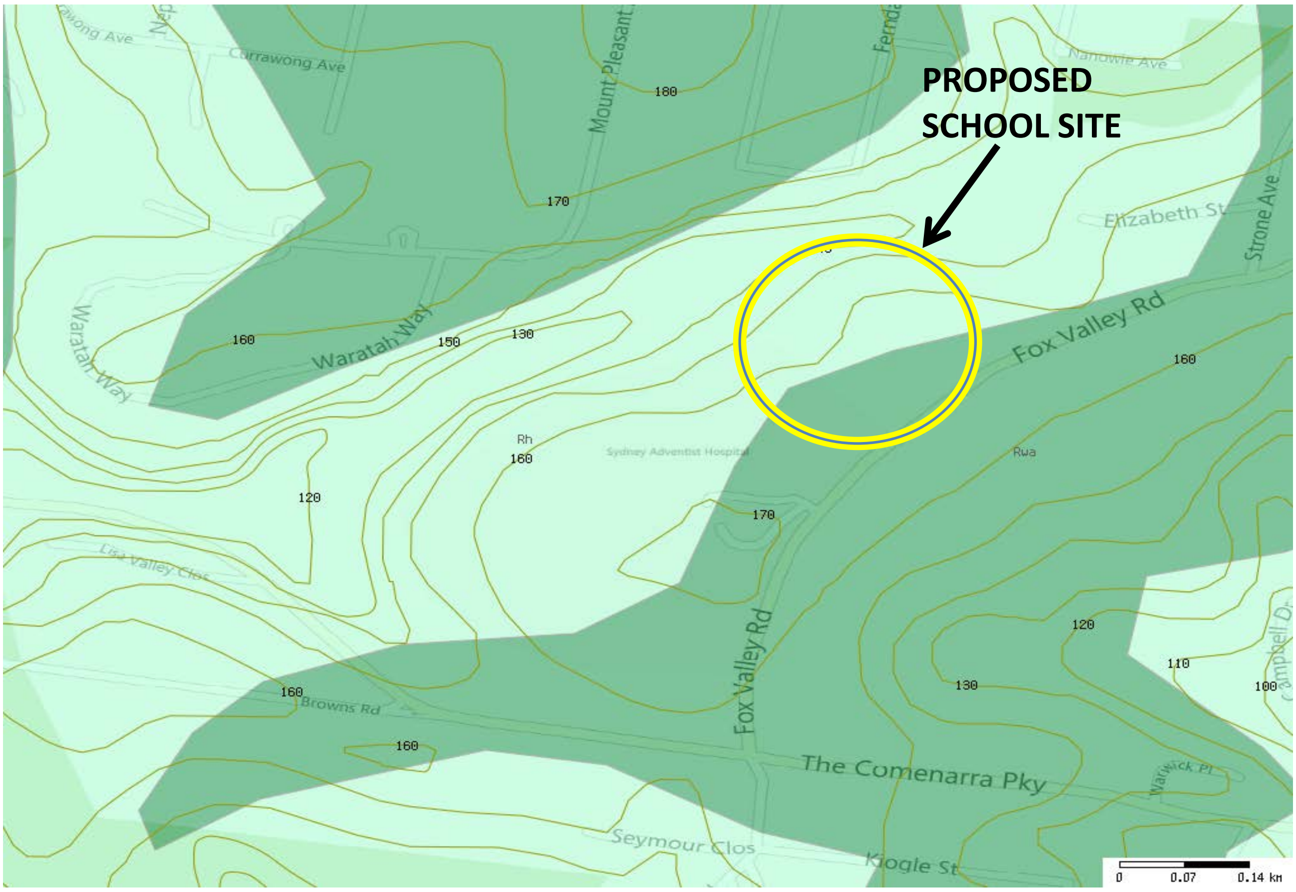

Legend:
Rwa = Ashfield Shale
Rh = Hawkesbury Sandstone

Douglas Partners — Geotechnics / Environment / Groundwater	**Geological Map**	PROJECT:	73244.00
	Wahroonga Adventist School	DWG No:	2
	Fox Valley Road, Wahroonga	REV:	0
	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

Appendix C

Photographs 1 to 12

Photo 1 – School Buildings and Grounds

Photo 2 – School Playing Field and Carpark

Douglas Partners Geotechnics / Environment / Groundwater	**Desktop Study**	PROJECT:	73244.00
	Wahroonga Adventist School	PLATE No:	1
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	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

Photo 3 – Sealed and unsealed carparks separated by 0.5m to 2m high soil batter (possible filling) within proposed school building/basement footprint

Photo 4 – Sealed carpark and school buildings within proposed school building/basement footprint

Douglas Partners Geotechnics / Environment / Groundwater	**Desktop Study**	PROJECT:	73244.00
	Wahroonga Adventist School	PLATE No:	2
	Fox Valley Rd, Wahroonga	REV:	0
	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

Photo 5 – Continuation of 2m high soil batter (possible filling) along northern side of school grounds and within proposed school building/basement footprint

Photo 6 – Stiff residual clay and ironstone bands exposed within stormwater detention basin north of proposed school building/basement footprint

Douglas Partners Geotechnics / Environment / Groundwater	**Desktop Study**	PROJECT:	73244.00
	Wahroonga Adventist School	PLATE No:	3
	Fox Valley Rd, Wahroonga	REV:	0
	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

Photo 7 – Residential properties south of proposed playing fields

Photo 8 – Southern side of proposed playing fields, stockpile of woodchips, possible filling beneath carpark

Douglas Partners Geotechnics / Environment / Groundwater	**Desktop Study**	PROJECT:	73244.00
	Wahroonga Adventist School	PLATE No:	4
	Fox Valley Rd, Wahroonga	REV:	0
	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

Photo 9 – Stockpile of mixed silty sand topsoil, clay, gravel, shale sandstone, concrete and organics on proposed playing fields

Photo 10 – Stockpile of woodchips on proposed playing fields

Douglas Partners Geotechnics / Environment / Groundwater	**Desktop Study**	PROJECT:	73244.00
	Wahroonga Adventist School	PLATE No:	5
	Fox Valley Rd, Wahroonga	REV:	0
	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

Photo 11 – Tension/shrinkage cracks up to 20mm wide and 150mm deep along crest of northern slope at proposed playing fields

Photo 12 – Ground surface slopes at approximately 3:1 (H:V) along northern side of proposed playing fields, possible filling in this area

Douglas Partners Geotechnics / Environment / Groundwater	**Desktop Study**	PROJECT:	73244.00
	Wahroonga Adventist School	PLATE No:	6
	Fox Valley Rd, Wahroonga	REV:	0
	CLIENT: Stanton Dahl Architects	DATE:	2-Nov-12

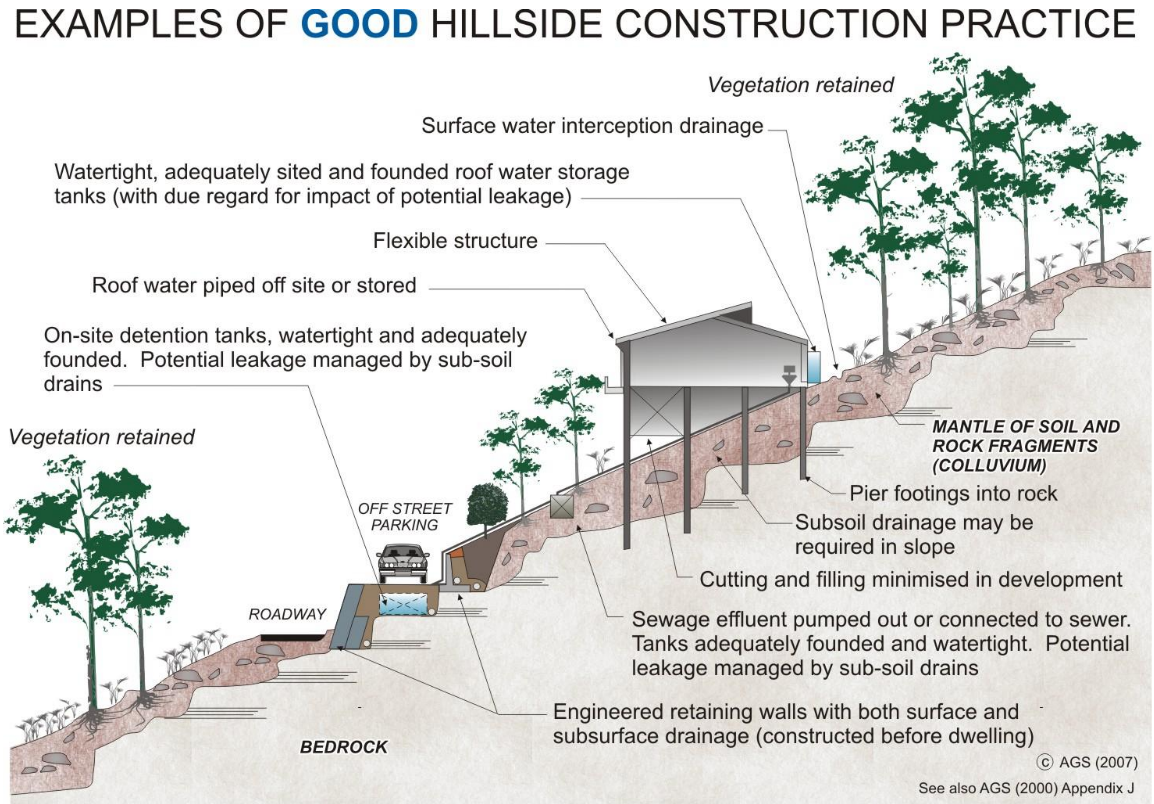
Appendix D

Australian Geoguide LR8 – Construction Practice

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.

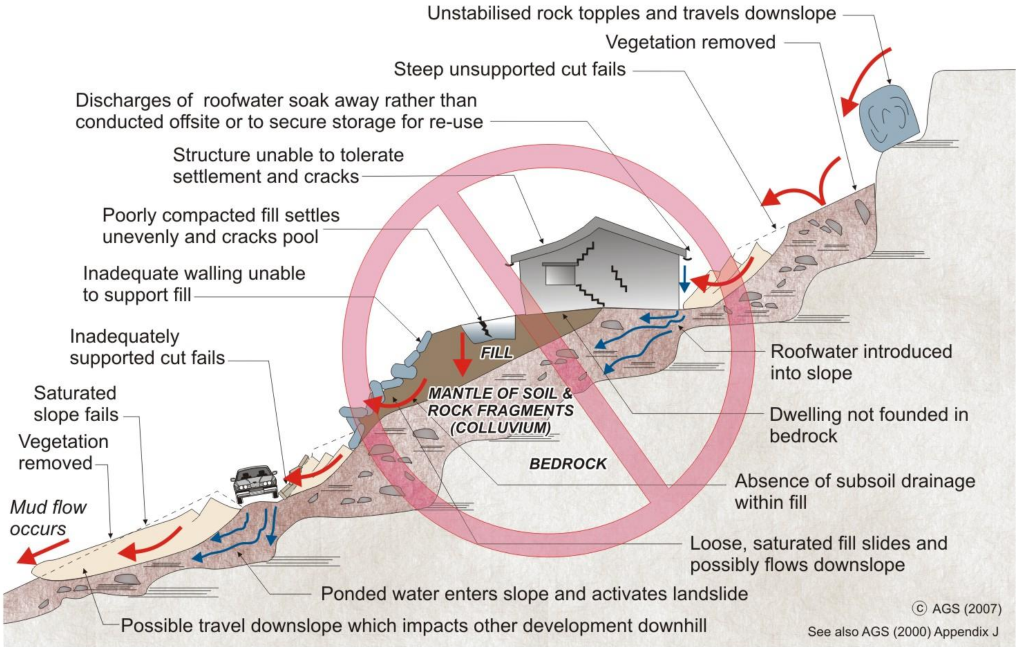
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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
- 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.