Douglas Partners
Geotechnics / Environment / Groundwater

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SYDNEY NSW 2000

Project 35470.05
5 April 2016
35470.05.R.001.Rev0
DEM:ss

Attention: Mr Stephen Girdis

Dear Sir

Geotechnical Assessment and Report for
New Residential Development
967 Barrenjoey Road, Palm Beach

1. Introduction

This report presents the results of a geotechnical assessment carried out for a proposed new residential development 967 Barrenjoey Road, Palm Beach. The proposed work will include demolition of the existing dwelling and the construction of a new residence and swimming pool. The work was carried out at the request of Mr Stephen Girdis, on behalf of SMJ Investments Pty Ltd, owner of the property.

Douglas Partners Pty Ltd (DP) has previously undertaken investigation and construction inspections for the existing residence on 969 Barrenjoey Road, as well as assessment for previous proposed residential developments on 967 Barrenjoey Road in 2008 and 2013, neither of which proceeded.

The current assessment comprised re-inspection of the site as well as review of the available information. This assessment report is specific to the currently proposed development and aims to provide information on subsurface conditions for design and costing and for Development Application purposes, in accordance with requirements of Pittwater's Geotechnical Risk Management Policy (GRMP) of December 2009. The report includes comments relating to the geotechnical model of the inferred subsurface profile, identification, description and reporting of geotechnical hazards, as well as design parameters and construction practice.

This report also incorporates relevant information that was obtained during the previous site assessment and investigation (borehole logs etc.).

2. Site Description and Geology

The site is located at 967 Barrenjoey Road Palm Beach, on the low, western side of the road and extends downslope to the Pittwater foreshore (Drawing 1).

The allotment is an irregularly shaped area of 650 m^2 with a total frontage to Barrenjoey Road of approximately 24 m and a foreshore frontage of approximately 20 m. The subject site slopes steeply down to the Pittwater foreshore with a difference in elevation of approximately 18.7 m from the road kerb (21.0 AHD) to the paved terrace adjoining the timber deck at the foreshore (2.3 AHD).

The site is bounded by residential properties to the north (No.969) and south (No. 965). A drainage easement lies within a natural gully line beyond (north of) 969 Barrenjoey Road.

The site is occupied by a residence on the central part of the site with most of the site covered by the existing site developments. The existing structures comprises a dilapidated timber residence, steps, retaining walls and paved areas, with substantial sections of the site obscured by sandstone flagging. There is highly weathered, open jointed sandstone outcrop behind the timber boatshed at the foreshore. This outcrop extends upslope beside the pathway leading to the foreshore area. The outcrop also extends across slope at the foreshore level, behind the boatshed on the adjoining southern property (965 Barrenjoey Road) where the rock is moderately weathered, open jointed sandstone with detached joint blocks and some large floaters.

On 969 Barrenjoey Road there is a residence which was constructed in 2008. Inspections undertaken by DP during the construction of this residence indicated that the underlying bedrock comprises medium to high strength sandstone with some shaly beds. This underlying geology is also exposed in the base of the drainage easement on the northern side of 969 Barrenjoey Road.

Reference to the Sydney 1:100 000 Geological Series sheet indicates that the site is underlain by rocks of the Newport Formation which are the upper unit of the Narrabeen Group. These rocks are of Triassic age and typically comprise interbedded shale, laminite and lithic to quartz lithic sandstone.

3. Field Work and Site Observations

The field work upon which the current report is based comprised a re-inspection of the site on 22 March 2016, earlier inspections on 23 June 2015 and 8 July 2013, the work undertaken previously on 967 Barrenjoey Road in August 2008 (Project 35470.02; Bore 1) and drilling carried out in 2003 on 969 Barrenjoey Road (Project 35470; Bores 1 and 3).

The locations of the boreholes and selected site features are shown on Drawing 1. Copies of the borehole logs and core photos are included in Appendix A together with notes defining classification methods and descriptive terms.

The main site observations from the recent re-inspection of the site as well as the salient points from previous site inspections and work are:

- the site slopes steeply from Barrenjoey Road to the Pittwater foreshore at an average slope angle of 30^{o}. Across 967 Barrenjoey Road, the slope comprises a series of brick and stone retaining structures, paved pathways and sandstone flagging faced batters;
- the sandstone flagging on the slope above the residence has slumped against the rear of the residence (the failure has occurred sometime between July 2013 and June 2015);
- most, if not all, of the remaining structures on 967 Barrenjoey Road exhibit evidence of minor downslope creep movement and there has been on-going, additional movement since the previous inspection of the site. The structures include; the existing residence (the foundations of

which have moved with some pillars rotated), brick and sandstone garden retaining structures (which are cracked and rotated), paving (which has settled) and cracking of the sandstone flagging on the lower slope batters;

- large sandstone floaters are present at a number of locations on the site, including:
    - adjacent to the north-east corner of the 967 residence and about 5 m across slope to the north;
    - behind the boatshed at the common boundary with 969 Barrenjoey Road on the lower part of the site at the northern end of a low concrete block retaining wall;
- adjoining the northern side of 969 Barrenjoey Road, within the northern stormwater easement/drain, stress relief joints are evident dipping at approximately 45^{o} to the west in the upper level of rock. The upper most sandstone outcrop within the drain suggests that the stress relief joints rollover/merge into the natural, sub-horizontal bedding planes within the bedrock, similar to features observed during the excavation works for the residence on 969 Barrenjoey Road.

Previous subsurface investigation across 967 and 969 Barrenjoey Road comprised a total of five cored boreholes, three of which are considered to be relevant to the current proposed development on 967 Barrenjoey Road.

The three relevant bores were drilled to depth ranging from 6.7 m to 15.25 m depth. They encountered a highly variable profile reflecting the steeply sloping topography of the site and in summary the conditions encountered, comprise:

- **Filling**; ranging from 0.15 m to about 1.2 m depth, over
- **Colluvium**; sandy clay and clayey sand of variable thickness (typically stiff to very stiff orange-brown sandy clay) up to 3.2 m depth, over
- **Very Low strength Sandstone**; extremely low and very low strength clayey sandstone to up to 5.37 m depth; over
- **Sandstone Bedrock**; medium then high strength sandstone to the full depth of drilling/ investigation (ranging from 6.7 m to 15.25 m).

The rock core contained ironstained bedding planes with a number of ironstained 45^{o} joints also identified (refer to borehole logs and core photos).

4. Proposed Development

It is understood that the proposed development will comprise:

- demolition of existing residence;
- moderate site excavation to around 1 m to 2 m maximum depth, benching, piering and retention works (including a piered retaining wall to be located across site and upslope of the new residence);
- construction of a small, storey two bedroom dwelling and a concrete swimming pool;
- the dwelling will be predominantly constructed of timber, with some masonry with a metal roof;

- extensive landscaping of the site.

5. Comments

5.1 Geological Model

The interpreted geological model for the site comprises a steep slope with a surface mantle of colluvium and a residual clayey sand/sandy clay soil profile (typically ranging from less than 1 m to about 3 m deep, but locally deeper) underlain by very low then medium and high strength bedrock (which possibly steps down the slope). Refer to Drawing 2 for an inferred geological section through the site.

It is expected that bedrock will comprise sandstone and siltstone with some shale beds. Sandstone bedrock is present along parts of the lower foreshore area, within the drainage easement/gully to the north of the site, and was exposed during the construction of the existing residence on 969 Barrenjoey Road.

5.2 Stability and Slope Risk Assessment

Inspection of the general slope on the site indicated no evidence of significant natural slope instability in the recent past. There has however, been a slumping failure of the sandstone flagging covering the slope above the existing residence.

The presence of large floaters mid-slope on and adjoining the site indicate past detachment and movement of large sandstone joint blocks from further upslope (possibly from above Barrenjoey Road). However, it is considered that the likelihood of similar natural rock falls affecting the property in its existing condition is “rare to barely credible” for the life of the proposed structure.

There is evidence of ongoing settlement/consolidation of some areas of filling behind existing retaining structures, as well as ongoing creep of the upper level soils and colluvium, as evidenced by rotation of landscaping walls and cracking of sandstone flagging surfaces of the lower batters.

The site soils will be susceptible to erosion where disturbed and care will be required to ensure concentrated surface flows are not created. Recommendations for stormwater disposal are presented in Section 5.5.

The hazards above and on the site have been assessed for risk to property and life using the general methodology outlined by the Australian Geomechanics Society - Landslide Risk Management Subcommittee, 2007.

Identified hazards are summarised in Table 1, together with qualitative assessment of likelihood, consequence and slope instability risk to property after completion of construction (including appropriate engineering design and construction works).

Table 1: Property Slope Instability Risk Assessment for Proposed Development

Hazard	Likelihood	Consequence	Risk
Overflow of stormwater onto the site from Barrenjoey Road and surface erosion	Rare, following construction of proposed retaining/slope protection measures and adequate road maintenance	Property - Minor	Very Low
Failure of temporary shoring during construction	Unlikely, for properly designed and constructed structure	Property – Medium	Low
Failure of final excavation support	Rare for properly designed and constructed structure	Property – Medium	Low
On-going creep of colluvium and soils	Unlikely, following construction of appropriate retaining walls and other landscaping measures	Property – Minor to Medium	Very Low to Low

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

$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)}$

where:

$R_{(LoL)}$	*is the risk (annual probability of loss of life (death) of an individual)*
$P_{(H)}$	*is the annual probability of the hazardous event (erosion/ wall failure)*
$P_{(S:H)}$	*is the probability of spatial impact by the hazard (e.g. of the failure reaching the residence the taking into account the distance for a given event)*
$P_{(T:S)}$	*is the temporal probability (e.g. of the adjacent area being occupied by the individual) given the spatial impact*
V(D:T)	*is the vulnerability of the individual (probability of loss of life of the individual given the impact*

The assessed individual risk to life (person most at risk) resulting from slope instability is summarised in Table 2.

Table 2: Life Risk Assessment for Proposed Development

Hazard	$P_{(H)}$	$P_{(S:H)}$	$P_{(T:S)}$	$V_{(D:T)}$	Risk $R_{(LoL)}$
Overflow of stormwater onto the site from Barrenjoey Road and surface erosion	1×10^{-5}	0.5	0.5	0.05	1.25×10^{-7}
Catastrophic failure of final excavation support	1×10^{-6}	1.0	0.75	1.0	7.5×10^{-7}
Movement of retaining walls or foundations supporting proposed structures	5×10^{-5}	0.2	0.5	0.01	5×10^{-8}
On-going creep of colluvium and soils.	5×10^{-5}	0.2	0.5	0.01	5×10^{-8}

When compared to the requirements of the AGS, it is considered that the proposed development meets ‘Acceptable Risk Management’ criteria with respect to both property and life under current and foreseeable conditions.

Provided the construction is undertaken in accordance with the recommendations contained in this report, the construction would be expected to not adversely affect the overall stability of the site or negatively influence the geotechnical hazards identified in Tables 1 and 2.

5.3 Excavation Conditions

Inspection and investigation has indicated that the site is underlain by highly variable depths of filling and shallow soil/colluvium, ranging up to about 3.2 m, then extremely to highly weathered sandstone and clayey sandstone to 5.3 m depth, underlain by medium and high strength sandstone.

The subsurface conditions exposed during construction work on 969 Barrenjoey Road indicate that the bedrock profile steps down towards the west essentially matching the site topography.

The layout and architectural plans indicate that the development will require only a moderate amount of excavation for the proposed residence and for benching into the slope for the pool and landscaping.

The upper colluvium and soil materials, down to the level of low to medium strength sandstone, should be readily excavated using conventional earthmoving equipment; however, any large sandstone floaters encountered would most likely to require the use of rock breaking equipment to break the boulders down to a manageable size for removal from site. Medium and high strength sandstone bedrock, if encountered, would require the use of rock sawing, rotary milling head or rock breaking equipment to remove the rock.

The previous field work did not encounter any groundwater during auger drilling of the bores and the use of drilling fluid when coring thereafter precluded subsequent observation. However, it is anticipated that seepage will be present through the upper soils, at the upper soil/rock surface and from jointing within the bedrock. Seepage will be present both during the excavation work and for the life of the structure. During construction any seepage should be readily controlled by the use of strategically sited sumps and intermittent pumping.

Under current practice for the disposal of excavated materials, it is likely that environmental testing of the excavated material for waste classification purposes will be required to determine the suitability of the material for disposal at a licensed landfill, or for re-use on third party sites.

5.4 Excavation Vibration

The residence on the adjoining, southern property is located within about 4 m of the proposed excavation. If inappropriate excavation methods or excessively large rock breaking equipment are used excessive vibration could be generated, potentially adversely affecting the adjacent residence.

It is therefore possible that vibration monitoring may be required to ensure that vibrations generated during the proposed excavation are reduced to limit potential damage to the structure. It is suggested that a dilapidation survey of the adjacent residence be carried out to document the existing condition and any damage present before excavation commences. It was noted during the earlier field work that there are cracks in the render of the northern wall of the adjoining southern residence. Any dilapidation survey of adjacent structures which may be affected, should be carried out prior to commencement of site preparation, demolition and excavation works.

Provisional Allowed Vibration Limit

From current information, it is considered likely that the residence on the adjacent southern site can withstand vibration levels higher than those required to maintain the comfort of the occupants. A human comfort criterion is therefore indicated and the peak particle velocity in any direction i (PPVi), is proposed as the control parameter. It is recommended that a Provisional Allowed Vibration Limit of 8.0 mm/sec PPVi be set during normal working hours, measured at foundation level of the potentially affected building.

Excavation Plant

DP maintains a database of vibration trial results which can provide guidance for the selection of plant. Trial data is dependent on site conditions and equipment, hence actual vibration levels may differ from predictions and a specific trial is recommended at the commencement of rock excavation. The database suggests that buffer distances within the ranges shown below should be maintained between excavation plant and the adjacent buildings. These estimates should be examined in relation to the distances between adjacent building(s) and the proposed excavation footprint, in order to select suitable plant.

Table 3: Approximate Buffer Distances for Excavation Plant

Provisional Allowed Vibration Limit:	**8 mm/s PPVi**	
Excavation Plant	**Buffer Distance**[1]	
	(from trial maxima) [1]	**(from trial averages)**
Rock Saw on Excavator[2]	0.8 m	0.4 m
Ripper on 20t Excavator	2.5 m	0.9 m
Rock Hammer < 500 kg operating weight	5.6 m	2.2 m
Rock Hammer 501 - 1000 kg operating weight	6.3 m	2.6 m
Rock Hammer 1001 - 2000 kg operating weight	9.7 m	4.3 m

1. Smaller distances can generally be determined from individual trials, as indicated by those from trial averages.

2. Loading effects from buildings may reduce vibration levels, to enable boundary saw cuts with few exceedances.

5.5 Excavation Support and Retaining Structures

Investigation of the rock levels has indicated that, at the location of Bore 1 (Project 35470.02), the site is underlain by filling material to 1.2 m, sandy clay (probable colluvium) to 3.2 m depth, then extremely low and very low strength clayey sandstone to 5.37 m depth overlying medium then high strength sandstone.

It is therefore possible that full retention of the slope above the residence excavation will be required. Shoring would need to extend down to the level of the underlying medium and high strength sandstone, both as part of the excavation work and in the final wall structure. The drilling has also identified the possible presence of stress relief jointing in the sandstone and localised support of the upper section of sound sandstone may be required.

The nature of the support required will be determined by the adjoining structures and their sensitivity to movement and possible settlement. Where the adjoining structures are sensitive to movement, such as the adjoining southern residence, it will be necessary to provide positive lateral support designed for “at rest” (Ko) conditions.

Excavation support could be provided by the use of bored soldier piles and infill shotcrete panels with temporary anchors into the adjoining property and possibly the road reserve (as was undertaken for the construction on the adjoining northern property) with final lateral support being provided by the completed structure.

It may be possible to provide temporary cantilevered support to the excavation, however, this option may be limited or excluded by the proposed depth and extent of the excavation, the difficulty of drilling into the underlying high strength sandstone and possible lack of restraint of the toe of the piles (unless restrained by temporary anchors).

It is recommended that all proposed retaining walls be engineer designed in accordance with the following suggested parameters.

Table 4: Summary of Retaining Wall Design Parameters

Material	Coefficient of Active Earth Pressure (Ka) *	"At rest" Coefficient of Earth Pressure (Ko) *	Unit Weight (kN/m^3)
Filling - uncompacted - compacted	0.4 0.3	0.6 0.45	20
Colluvium/sandy clay	0.35	0.5	20
Extremely to Highly Weathered Bedrock - very low strength	0.2	0.3	22

* Allowance will need to be incorporated to accommodate the slope of the site and any additional surcharge loads.

All retaining structures will need to be designed taking into consideration additional loads due to any adjoining structures and any surcharges due to external loads. They should be founded on in situ bedrock and should be designed to incorporate free draining backfill material behind the structure and appropriate subsoil drainage to discharge all seepage and groundwater collected within the backfill material and to prevent water pressure building up behind the wall.

Previous investigations identified the presence of some stress relief jointing in the upper levels of intact sandstone bedrock. Such joints could affect the design of anchors and final bracing/support of retaining structures.

Where required, anchors should have a minimum bond length of 3 m, with the bond developed behind an "active" zone determined approximately by drawing a line at 45^{o} upwards from the level of medium strength sandstone bedrock (5.37 m in Bore 1) to intersect the ground surface behind the excavated face. Appropriate bond and anchor lengths can be estimated from the adhesion developed on the side of the anchorages based on a working bond stress of 600 kPa in medium and stronger sandstone for temporary load conditions. Permanent anchors, if required, should be designed for a working load stress of 350 kPa.

5.6 Foundations

Based on the results of the previous investigations, it is expected that the deepest section of the excavation into the hillside for the proposed residence will probably reach bedrock of at least very low to low strength.

It is recommended that all foundations be taken down and socketed into insitu bedrock of uniform strength to minimise the potential for differential settlement across the proposed structures and top resist downhill creep of the near surface soils.

Suggested design parameters for new footings are provided in Table 5 below.

Table 5: Recommended Design Parameters for Bored Piles and Spread Footings

Strata	Allowable (Serviceability)	
	End Bearing Pressure (kPa)	Shaft Adhesion (kPa)
Low strength bedrock	1500	150
Medium to high strength bedrock	3500	350

For uplift loads it is recommended that the shaft adhesion values given in Table 5 should be reduced by 0.75, and if short piles are used then a check should be made for a potential cone failure in uplift.

It is recommended that all foundation excavations be inspected by an experienced engineering geologist to confirm the actual conditions on site are in accordance with the interpretations and assumptions made in this report.

5.7 Drainage and Stormwater Control

It is recommended that the proposed works include stormwater and subsoil drainage control measures. Such measures are very important to the maintenance and improvement of the stability of the site, particularly of the upper colluvium and soils, as well as the amenity of below ground sections of the structure.

Appropriately sized grate-covered surface drainage should be installed with lined catch drains at the crest of slopes and batters with subsoil drains behind all retaining walls. All collected water should be directed by pipe-work to approved and controlled discharge points. All pipes and drainage lines should include inspection ports to permit periodic maintenance and cleanout by the owners.

It is important that Council adequately maintain the pavement drainage of Barrenjoey Road, to prevent the build-up of sediment in the roadside drain, the blocking of the stormwater pipes and potential overflow into the property.

6. Conditions Relating to Design and Construction Monitoring

To comply with Pittwater Council conditions and to enable the completion of Pittwater Forms 2b and 3 (which are required as part of the construction, building and post-construction certificate requirements of the GRMP), it will be necessary for DP to:

- review the geotechnical content of all structural drawings (Form 2b requirement);
- progressively inspect all new footing excavations and bulk excavations into the slope to confirm compliance to design with respect to allowable bearing pressure and stability, and inspect retaining wall drainage measures (Form 3 requirement).

7. Design Life and Requirement for Future Geotechnical Assessments

Douglas Partners Pty Ltd interprets the reference to design life requirements specified within the GRMP to refer to structural elements designed to retain the subject slope and maintain the risk of instability within acceptable limits.

Specific structures that may affect the maintenance of site stability in relation to the proposed development on this site are considered to comprise:

- existing (and any proposed) stormwater surface drains and buried pipes leading to the stormwater disposal system;
- existing and proposed retaining walls on the site.

In order to attain a structural life of 100 years as required by the Council Policy, it will be necessary for the structural engineer to incorporate appropriate construction detailing and for the property owner to adopt and implement a maintenance and inspection program. A typical program for developments on sloping sites is given in Table 6.

Table 6: Recommended Maintenance and Inspection Program

Structure	Maintenance/Inspection Task	Frequency
Drainage lines	Inspect to ensure line is flowing and not blocked.	Every 2 years or following each significant rainfall event.
Drainage pits	Inspect to ensure that pits are free of debris and sediment build-up. Clear surface grates of vegetation/litter build-up.	During normal grounds maintenance and following each significant rainfall event.
Retaining walls	Inspect walls for the presence of cracking or rotation from vertical, or as-constructed condition	Every 5 years or following each significant rainfall event.
General slopes	Inspect slopes and batters for indications of movement which may comprise tension cracks, backscarps of freshly exposed soil.	Every 2 years or following each significant rainfall event.

Where changes to site conditions are identified during the maintenance and inspection program, reference should be made to a relevant professional (e.g. structural engineer or geotechnical engineer).

8. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for this project at 967 Barrenjoey Road, Palm Beach in accordance with the email request received from Mr Stephen Girdis of SMJ Investments Pty Ltd on 1 March 2016. The work was carried out under DP Conditions of Engagement and this report is provided for the exclusive use of SMJ Investments Pty Ltd for the specific project and purpose as described in the report. It should not be used by or relied upon for other projects or purposes on the same or another site or by a third party.

The results provided in the report are considered to be indicative of the sub-surface conditions on the site only to the depths observed, and only at the time the work was carried out. DP's advice is based on observations, measurements and derived interpretations. The accuracy of the advice provided by DP in this report is limited by unobserved features and variations in ground conditions across and beyond the site boundaries or by variations with time. The advice may be limited by restrictions in the observations which were able to be carried out, as well as by the amount of data that could be collected given the project and site constraints.

Actual ground conditions and materials behaviour observed or inferred may differ from those which may be encountered elsewhere on the site. If variations in subsurface conditions are encountered, then additional advice should be sought from DP and, if required, amendments made.

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 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.

This report must be read in conjunction with the attached notes "About This Report" and any other attached explanatory notes and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions from review by others of this report or test data, which are not otherwise supported by an expressed statement, interpretation, outcome or conclusion stated in this report. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

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.

We trust that these comments are sufficient for your present requirements. If further assistance is required, please do not hesitate to contact the undersigned.

Yours faithfully
Douglas Partners Pty Ltd

Reviewed by

Michael Thom

David Murray
Senior Associate/Senior Engineering Geologist

Michael J Thom
Principal

Attachments:	Notes "About this Report" Drawings 1 and 2 Selected Field Work Results Projects 35470 and 35470.02 AGS Appendix C and G "Landslide Risk Management Concepts and Guidelines" Australian Geoguides LR3 to LR8 inclusive Pittwater Council Geotechnical Forms 1 and 1A

About this Report

Douglas Partners

Introduction

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

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

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

Borehole and Test Pit Logs

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

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

Groundwater

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

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

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

Reports

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

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

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

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

Site Anomalies

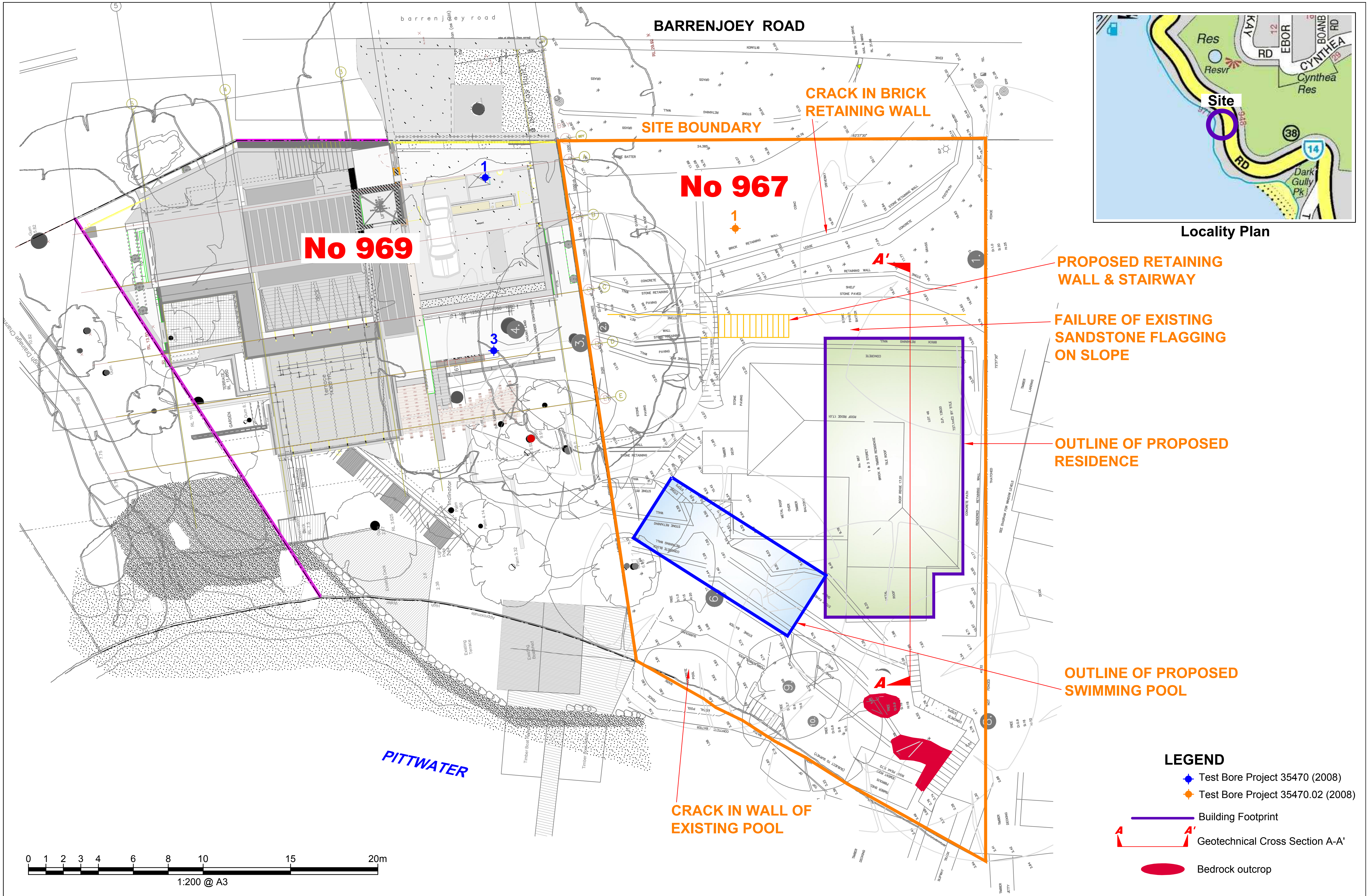
In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later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

Information for Contractual Purposes

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

Site Inspection

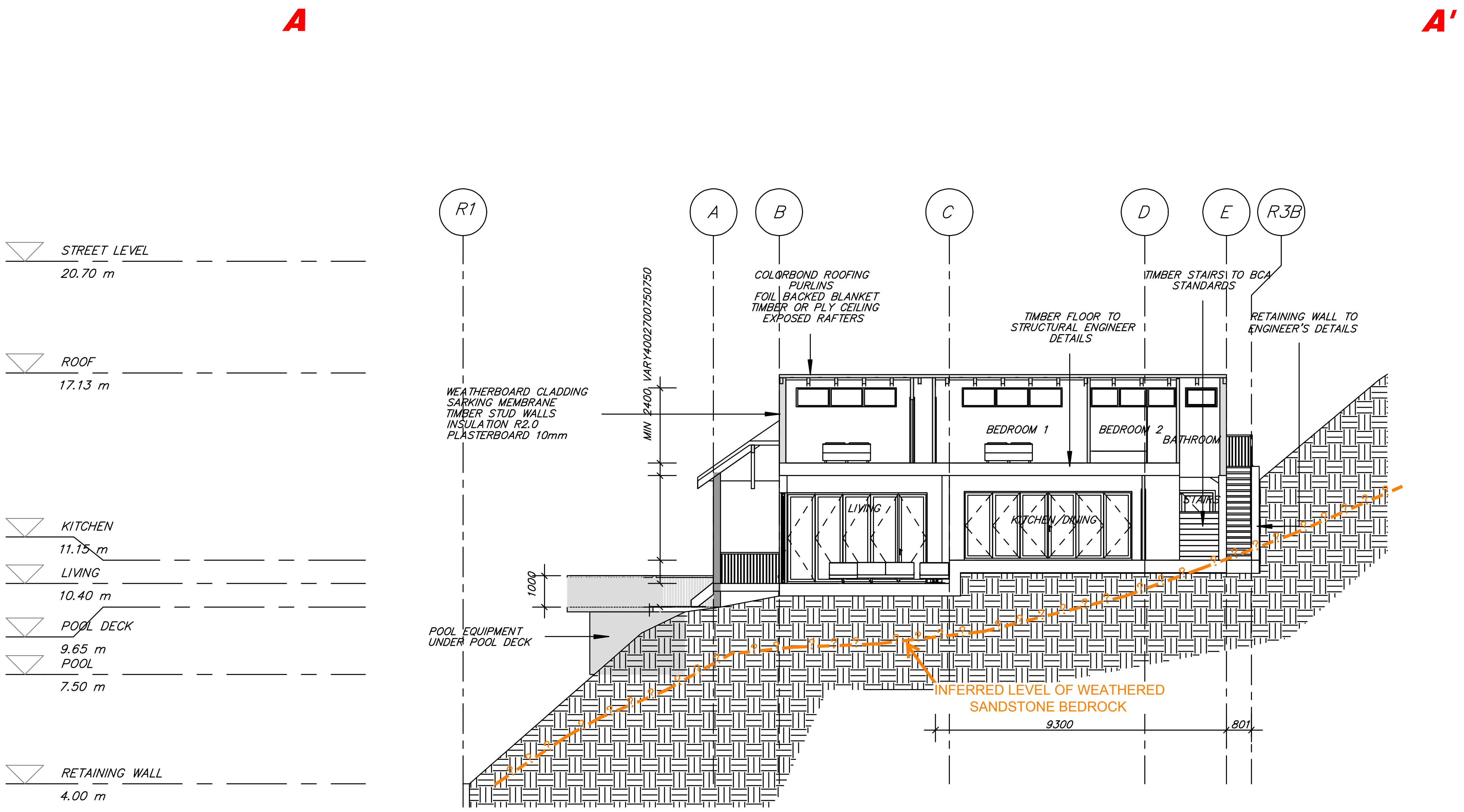
The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.



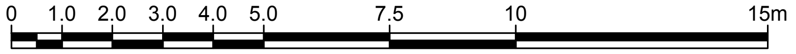
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Mr Stephen Girdis		TITLE:	**Location of Tests and Site Features** **Proposed Residential Development** **967 Barrenjoey Road, PALM BEACH**
OFFICE: Sydney	DRAWN BY: PSCH		
SCALE: As shown	DATE: 30.3.2016		

PROJECT No: 35470.05
DRAWING No: 1
REVISION: 0



NOTE:
1: Base drawing from Blue Sky Building Design Pty Ltd
(Dwg A-103, dated 22.2.2016)
2: See Dwg 1 for location of Cross Section A-A'



1:150 @ A3

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Mr Stephen Girdis
OFFICE: Sydney
DRAWN BY: PSCH
SCALE: As shown
DATE: 30.3.2016

TITLE: **Cross Section A-A'**
Proposed Residential Development
967 Barrenjoey Road, PALM BEACH

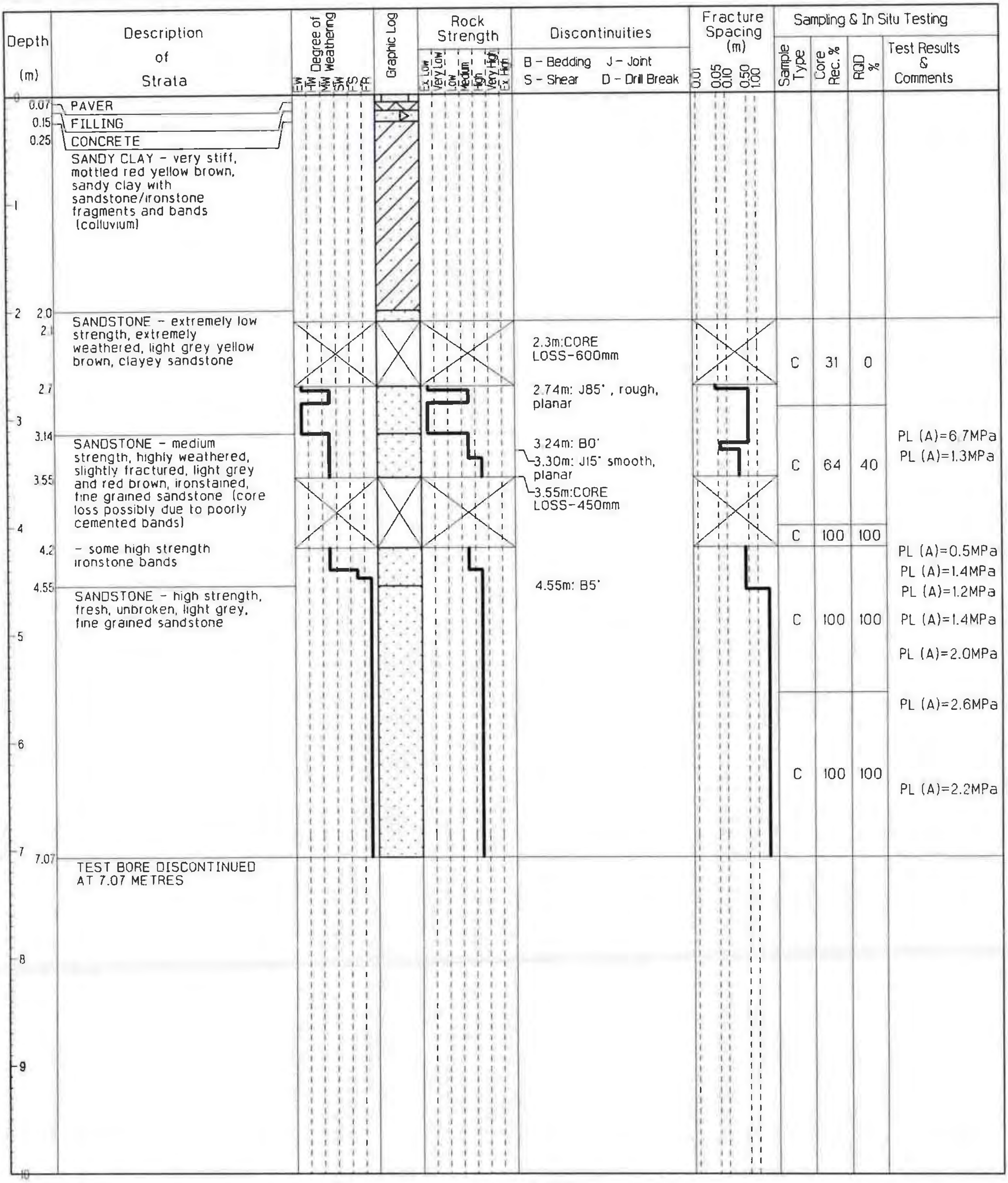
PROJECT No: 35470.05
DRAWING No: 2
REVISION: 0

TEST BORE REPORT

BORE No: 1 & 1A
DATE: 23 SEPTEMBER 02
SHEET 1 **OF** 1
AZIMUTH:

CLIENT: MR S GIRDIS
PROJECT: PROPOSED NEW RESIDENCE
LOCATION: 969 BARRENJOEY RD, PALM BEACH

PROJECT No: 35470
SURFACE LEVEL: 17.5 AHD
DIP OF HOLE: 90˚



Depth (m)	Description of Strata	Discontinuities
0.07	PAVER	
0.15	FILLING	
0.25	CONCRETE	
	SANDY CLAY - very stiff, mottled red yellow brown, sandy clay with sandstone/ironstone fragments and bands (colluvium)	
2.0	SANDSTONE - extremely low strength, extremely weathered, light grey yellow brown, clayey sandstone	
2.1		2.3m:CORE LOSS-600mm
2.7		2.74m: J85˚, rough, planar
3.14	SANDSTONE - medium strength, highly weathered, slightly fractured, light grey and red brown, ironstained, fine grained sandstone (core loss possibly due to poorly cemented bands)	3.24m: B0˚ 3.30m: J15˚ smooth, planar
3.55		3.55m:CORE LOSS-450mm
4.2	- some high strength ironstone bands	
4.55	SANDSTONE - high strength, fresh, unbroken, light grey, fine grained sandstone	4.55m: B5˚
7.07	TEST BORE DISCONTINUED AT 7.07 METRES	

Sampling & In Situ Testing

Sample Type	Core Rec. %	RQD %	Test Results & Comments
C	31	0	
C	64	40	PL (A)=6.7MPa PL (A)=1.3MPa
C	100	100	
C	100	100	PL (A)=0.5MPa PL (A)=1.4MPa PL (A)=1.2MPa PL (A)=1.4MPa PL (A)=2.0MPa
C	100	100	PL (A)=2.6MPa PL (A)=2.2MPa

RIG: PORTABLE **DRILLER:** L COOPER **LOGGED:** JARDINE **CASING:** SL TO 2.1m

TYPE OF BORING: HAND AUGER-1.4m ROTARY-2.1 NMLC-CORING TO 7.07m

WATER OBSERVATIONS: NO FREE GROUNDWATER OBSERVED WHILST AUGERING

REMARKS: LOGS FOR BORE 1 AND 1A COMBINED INTO SINGLE LOG

SAMPLING & IN SITU TESTING LEGEND

A auger sample	PL point load strength I_s (50)MPa
B bulk sample	S standard penetration test
C core drilling	Ux x mm dia. tube
pp pocket penetrometer (kPa)	V Shear Vane (kPa)

CHECKED:
Initials: RM
Date: 16/10

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DOUGLAS PARTNERS PTY LTD
NEW RESIDENCE – PALM BEACH
BORE 1
PROJECT 35470
SEP 2002
2
2.1
3
4
2.10 – 5.00M

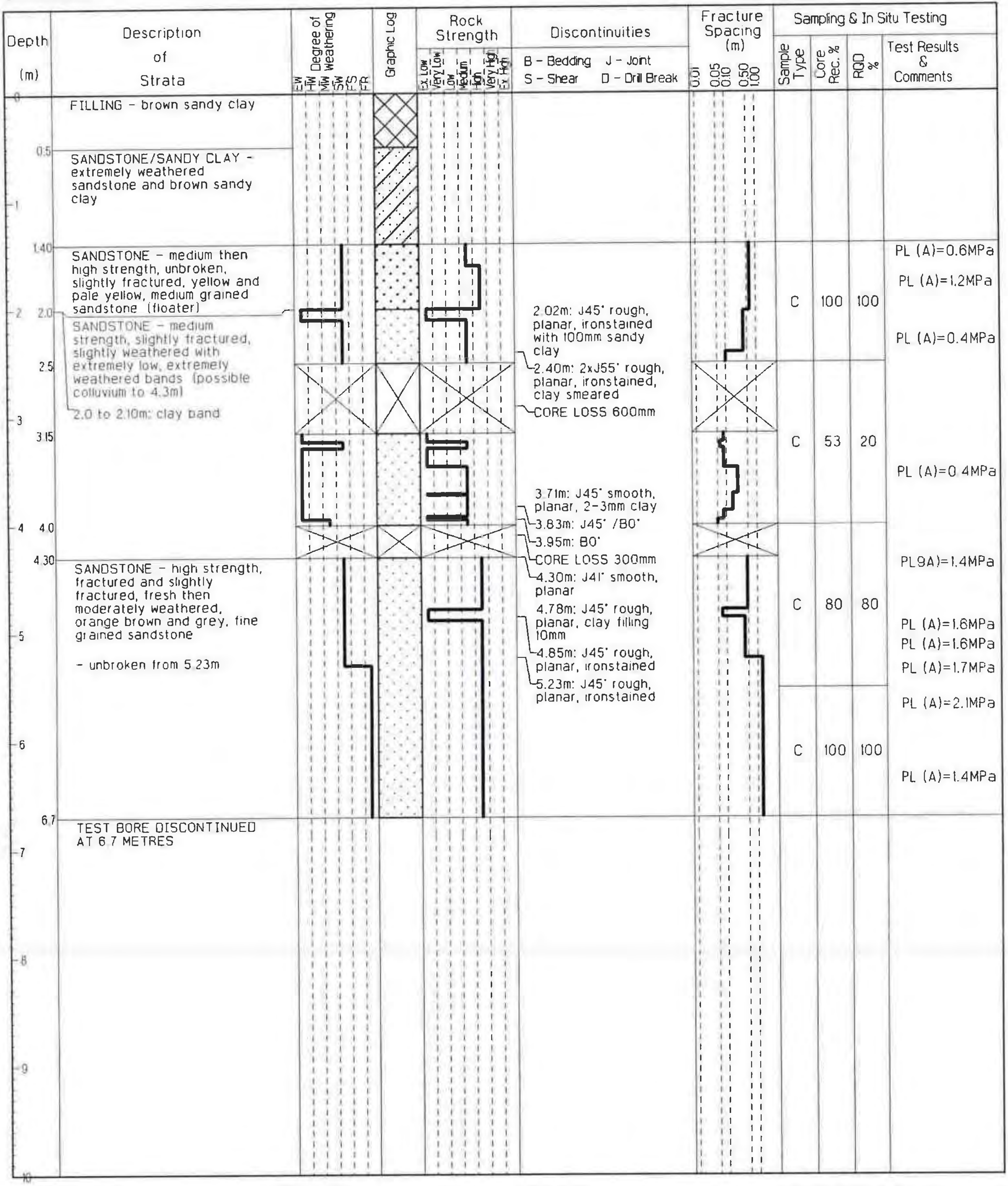

DOUGLAS PARTNERS PTY LTD
NEW RESIDENCE – PALM BEACH
BORE 1A
PROJECT 35470
SEP 2002
4
35470 START
4·2M
5
6
7
END 7·07M
4.20 – 7.07 M

TEST BORE REPORT

BORE No: 3
DATE: 23-24 SEPT 02
SHEET 1 **OF** 1
AZIMUTH:

CLIENT: MR S GIRDIS
PROJECT: PROPOSED NEW RESIDENCE
LOCATION: 969 BARRENJOEY RD, PALM BEACH

PROJECT No: 35470
SURFACE LEVEL: 13.45 AHD
DIP OF HOLE: 90°



Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear D - Drill Break	Sample Type	Core Rec. %	RQD %	Test Results & Comments
0	FILLING - brown sandy clay					
0.5	SANDSTONE/SANDY CLAY - extremely weathered sandstone and brown sandy clay					
1.40	SANDSTONE - medium then high strength, unbroken, slightly fractured, yellow and pale yellow, medium grained sandstone (floater)		C	100	100	PL (A)=0.6MPa PL (A)=1.2MPa
2.0	SANDSTONE - medium strength, slightly fractured, slightly weathered with extremely low, extremely weathered bands (possible colluvium to 4.3m) 2.0 to 2.10m: clay band	2.02m: J45° rough, planar, ironstained with 100mm sandy clay				PL (A)=0.4MPa
2.5		2.40m: 2xJ55° rough, planar, ironstained, clay smeared CORE LOSS 600mm				
3.15		3.71m: J45° smooth, planar, 2-3mm clay	C	53	20	PL (A)=0 4MPa
4.0		3.83m: J45° /B0° 3.95m: B0° CORE LOSS 300mm				
4.30	SANDSTONE - high strength, fractured and slightly fractured, fresh then moderately weathered, orange brown and grey, fine grained sandstone - unbroken from 5.23m	4.30m: J41° smooth, planar 4.78m: J45° rough, planar, clay filling 10mm 4.85m: J45° rough, planar, ironstained 5.23m: J45° rough, planar, ironstained	C	80	80	PL9A)=1.4MPa PL (A)=1.6MPa PL (A)=1.6MPa PL (A)=1.7MPa
			C	100	100	PL (A)=2.1MPa PL (A)=1.4MPa
6.7	TEST BORE DISCONTINUED AT 6.7 METRES					

RIG: PORTBLE
DRILLER: L COOPER
LOGGED: JARDINE
CASING: SL TO 1.4m
TYPE OF BORING: HAND AUGER-0.5m ROTARY-1.4m NMLC-CORING-6.7m
WATER OBSERVATIONS: NO FREE GROUNDWATER OBSERVED DURING AUGERING
REMARKS:

SAMPLING & IN SITU TESTING LEGEND

A auger sample	PL point load strength I_s (50)MPa
B bulk sample	S standard penetration test
C core drilling	Ux x mm dia tube
pp pocket penetrometer (kPa)	V Shear Vane (kPa)

CHECKED:
Initials: RM
Date: 16/10

Douglas Partners
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DOUGLAS PARTNERS PTY LTD
NEW RESIDENCE – PALM BEACH
BORE 3
PROJECT 35470
SEP 2002
1M
35470 B13 STARTS 1.4
2M
3M
4M
5M
1.40 – 6.00 M

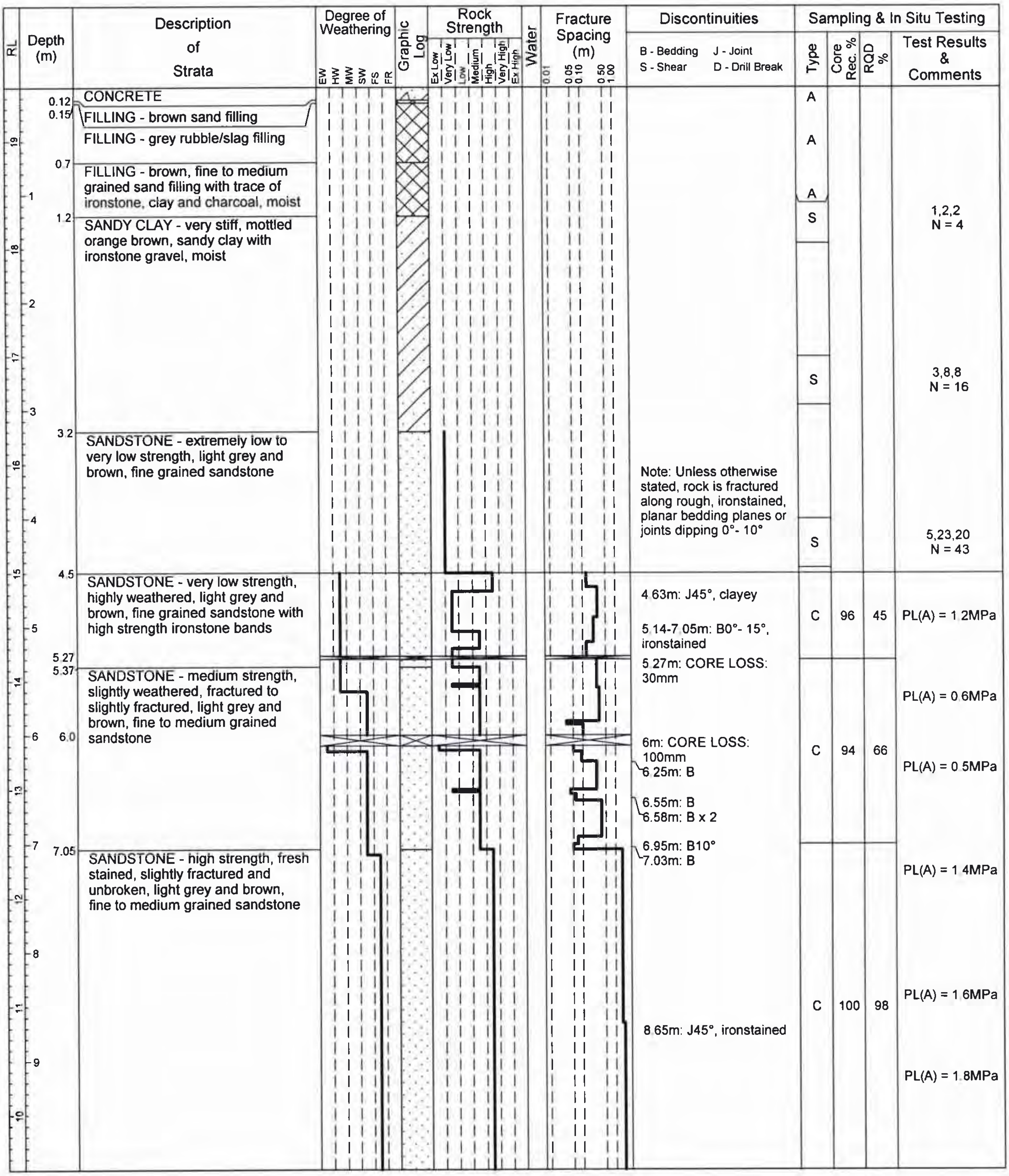

DOUGLAS PARTNERS PTY LTD
NEW RESIDENCE – PALM BEACH
BORE 3
PROJECT 35470
SEP 2002
6M
ENDS 6·7m
6.00 – 6.70 M

BOREHOLE LOG

CLIENT: SMJ Holdings Pty Ltd
PROJECT: New Residence and Swimming Pool
LOCATION: 967 Barrenjoey Road, Palm Beach

SURFACE LEVEL: 19.5 ~AHD*
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 35470.02
DATE: 05 Aug 08
SHEET 1 **OF** 2



Depth (m)	Description of Strata	Discontinuities	Type	Core Rec. %	RQD %	Test Results & Comments
0.12	CONCRETE		A			
0.15	FILLING - brown sand filling					
	FILLING - grey rubble/slag filling		A			
0.7	FILLING - brown, fine to medium grained sand filling with trace of ironstone, clay and charcoal, moist		A			
1.2	SANDY CLAY - very stiff, mottled orange brown, sandy clay with ironstone gravel, moist		S			1,2,2 N = 4
			S			3,8,8 N = 16
3.2	SANDSTONE - extremely low to very low strength, light grey and brown, fine grained sandstone	Note: Unless otherwise stated, rock is fractured along rough, ironstained, planar bedding planes or joints dipping 0°- 10°	S			5,23,20 N = 43
4.5	SANDSTONE - very low strength, highly weathered, light grey and brown, fine grained sandstone with high strength ironstone bands	4.63m: J45°, clayey 5.14-7.05m: B0°- 15°, ironstained	C	96	45	PL(A) = 1.2MPa
5.27		5.27m: CORE LOSS: 30mm				
5.37	SANDSTONE - medium strength, slightly weathered, fractured to slightly fractured, light grey and brown, fine to medium grained sandstone					PL(A) = 0.6MPa
6.0		6m: CORE LOSS: 100mm 6.25m: B 6.55m: B 6.58m: B x 2 6.95m: B10° 7.03m: B	C	94	66	PL(A) = 0.5MPa
7.05	SANDSTONE - high strength, fresh stained, slightly fractured and unbroken, light grey and brown, fine to medium grained sandstone					PL(A) = 1.4MPa
		8.65m: J45°, ironstained	C	100	98	PL(A) = 1.6MPa
						PL(A) = 1.8MPa

RIG: Bobcat **DRILLER:** Steve **LOGGED:** SI/DH **CASING:** HW to 2.5m
TYPE OF BORING: Diatube to 0.12m; Solid flight auger to 2.5m; Rotary to 4.5m; NMLC-Coring to 15.25m
WATER OBSERVATIONS: No free groundwater observed whilst augering
REMARKS: 80% water loss at 11.0m to 12.0m. *Level interpolated from survey plan

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U,	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ⊻ Water level

CHECKED
Initials: RW
Date: 11/8

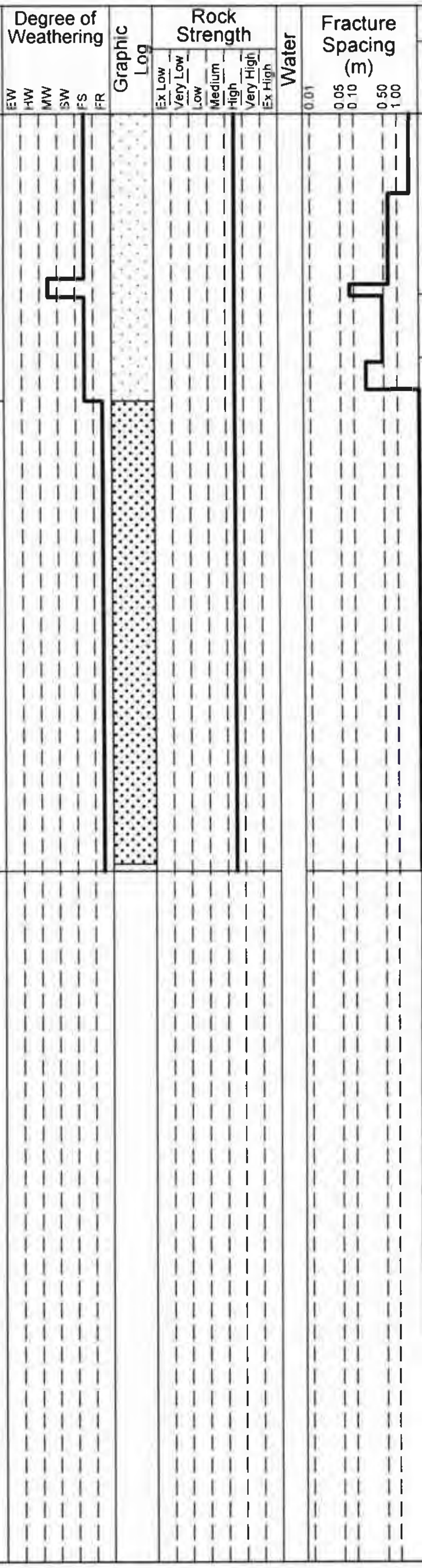
Douglas Partners
Geotechnics · Environment · Groundwater

BOREHOLE LOG

CLIENT: SMJ Holdings Pty Ltd
PROJECT: New Residence and Swimming Pool
LOCATION: 967 Barrenjoey Road, Palm Beach

SURFACE LEVEL: 19.5 ~AHD*
EASTING:
NORTHING:
DIP/AZIMUTH: 90°/--

BORE No: 1
PROJECT No: 35470.02
DATE: 05 Aug 08
SHEET 2 **OF** 2



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear D - Drill Break	Type	Core Rec. %	RQD %	Test Results & Comments
9		SANDSTONE - high strength, fresh stained, slightly fractured and unbroken, light grey and brown, fine to medium grained sandstone *(continued)*	10.55m: B0°, ironstained				PL(A) = 1.6MPa
8	11		11.19m: B15°, ironstained 11.26m: J20°, ironstained 11.7m: B, ironstained	C	100	100	PL(A) = 1.7MPa
7	12 12.0	SANDSTONE - high strength, fresh, unbroken, light grey, medium grained sandstone	11.92m: J30°, ironstained				PL(A) = 1.7MPa
6	13	- some siltstone laminations below 13.3m	>>				PL(A) = 1.7MPa
5	14			C	100	100	PL(A) = 1.6MPa
4	15 15.2	15.2-15.25m: dark grey laminite					PL(A) = 1.8MPa
	15.25	Bore discontinued at 15.25m					
3	16						
2	17						
1	18						
0	19						

RIG: Bobcat **DRILLER:** Steve **LOGGED:** SI/DH **CASING:** HW to 2.5m

TYPE OF BORING: Diatube to 0.12m; Solid flight auger to 2.5m; Rotary to 4.5m; NMLC-Coring to 15.25m

WATER OBSERVATIONS: No free groundwater observed whilst augering

REMARKS: 80% water loss at 11.0m to 12.0m. *Level interpolated from survey plan

SAMPLING & IN SITU TESTING LEGEND

A	Auger sample	pp	Pocket penetrometer (kPa)
D	Disturbed sample	PID	Photo ionisation detector
B	Bulk sample	S	Standard penetration test
U,	Tube sample (x mm dia.)	PL	Point load strength Is(50) MPa
W	Water sample	V	Shear Vane (kPa)
C	Core drilling	▷	Water seep ⊽ Water level

CHECKED
Initials:
Date: 11/8

Douglas Partners
Geotechnics · Environment · Groundwater


DOUGLAS PARTNERS PTY LTD
NEW RESIDENCE AND SWIMMING POOL – PALM BEACH
BORE 1
PROJECT
35470.02
AUG 2008
PALM BEACH 35470.20 BH-1 START 4.5m
5
CORE LOSS 0.03
6
CORE LOSS 0.1m
7
8
KODAK Color Control Patches
4.50 – 9.00 M
Gray Scale


DOUGLAS PARTNERS PTY LTD
NEW RESIDENCE AND SWIMMING POOL – PALM BEACH
BORE 1
PROJECT 35470.02
AUG. 2008
9
10
11
12
13
9.00 – 14.00 M
KODAK Color Control Patches
KODAK Gray Scale
C
Y
M


DOUGLAS PARTNERS PTY LTD
NEW RESIDENCE AND SWIMMING POOL – PALM BEACH
BORE 1
PROJECT
35470.02
AUG 2008
14
15
E.O.B 15.25 M
14.00 – 15.25 M
KODAK Color Control Patches
KODAK Gray Scale
C
Y
M

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 LR3 (LANDSLIDES IN SOIL)

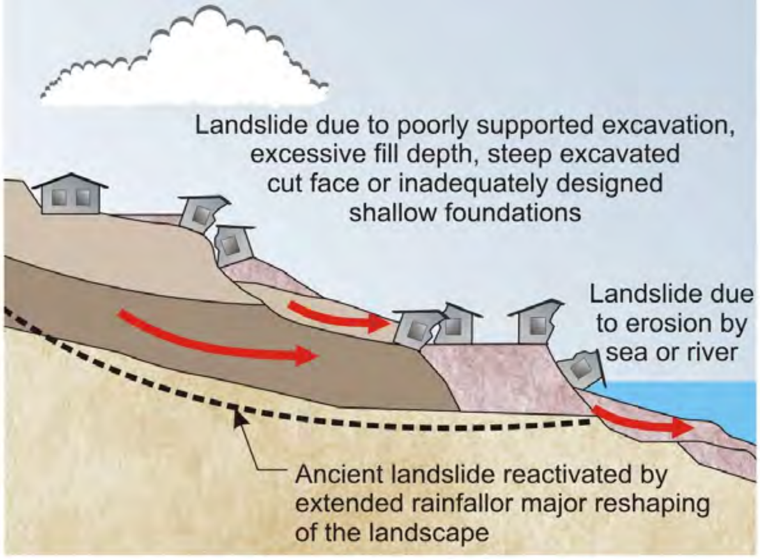


Figure 3

Some of the more common causes of landslides in soil are:

1) Falls of the parent material or residual soil from above, due to natural weathering processes (Figure 2).
2) Increased moisture content and consequent softening of the soil, or a rise in the water table. These can be due to excessive tree clearance, ill-considered soak-away drainage or septic systems, or heavy rainfall (Figure 2).
3) Excavation without adequate support, increased surface load from fill placement, or inadequately designed shallow foundations (Figure 3).
4) Natural erosion at the toe of the slope due to scour by a river or the sea (Figure 3).
5) Re-activation of an ancient landslide (Figure 3).

Most soil slopes appear stable, but they all achieved their present shape through a process of weathering and erosion and are often sensitive to minor changes in the factors that affect their stability. As a general rule, human activities only improve the situation if they have been designed to do so. Once this idea is understood, it is probably easy to see why the following basic rules are so important and should not be ignored without seeking site specific advice from a geotechnical practitioner:

- Do not clear trees unnecessarily.
- Do not cut into a slope without supporting the excavated face with an engineer designed structure.
- Do not add weight to a slope by placing earth fill or constructing buildings with inadequately designed shallow foundations (Note: in certain circumstances weight is added to the toe of a slope to inhibit landslide movement, but this must be carried out in accordance with a proper engineering design).
- Do not allow water from storm water drains, or from septic waste or effluent disposal systems to soak into the ground where it could trigger a landslide.

More information in relation to good and poor hillside construction practice is given in GeoGuide LR8. With appropriate engineering input it is often possible to reduce the likelihood, or consequences, of a landslide and so reduce the risk to property and to life. Such measures can include the construction of properly designed storm water and sub-soil drains, surface protection (GeoGuide LR5) and retaining walls (GeoGuide LR6). **Design should be undertaken by a geotechnical practitioner and will normally require local council approval.**

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- 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 LR3 (LANDSLIDES IN SOIL)

LANDSLIDES IN SOIL

Landslides occur on soil slopes and the consequences can include damage to property and loss of life. Soil slopes exist in all parts of Australia and can even occur in places where rock outcrops can be seen on the surface. If you live on, or below, a soil slope it is important to understand why a landslide might occur and what you can do to reduce the risk it presents.

It is always worth asking the question *"why is this slope here?"*, because the answer often leads to an understanding of what might happen in the future. Slopes are usually formed by weathering (breakdown) and erosion (physical movement) of the natural ground - the "parent material". Many factors are involved including rain, wind, chemical change, temperature variation, plant growth, animal activity and our own human enthusiasm for development. The general process is outlined in Figure 1.

The upper levels of the parent material progressively weather over thousands, or millions, of years, losing strength. This can result in a surface layer which looks similar to the parent material (although its colour has probably changed) but has the strength of a soil - this is called "residual soil". At some stage the weathered surface layer is exposed to the elements and fragments are transported down the slope. In this context a fragment could be a single sand grain, a boulder, or a landslide. The time scale could be anything from a few seconds to many thousands of years. The transported fragments often collect on the lower slopes and form a new soil layer that blankets the original slope - "colluvium". If material reaches a river or the sea it is deposited as "alluvium" or as a "marine deposit". With appropriate changes in river and sea level this material can again find itself on the surface to commence another cycle of weathering and erosion. In places often, but not only, near the coast, this can include sand sized fragments which form beaches and are sometimes blown back onto the land to form dunes.

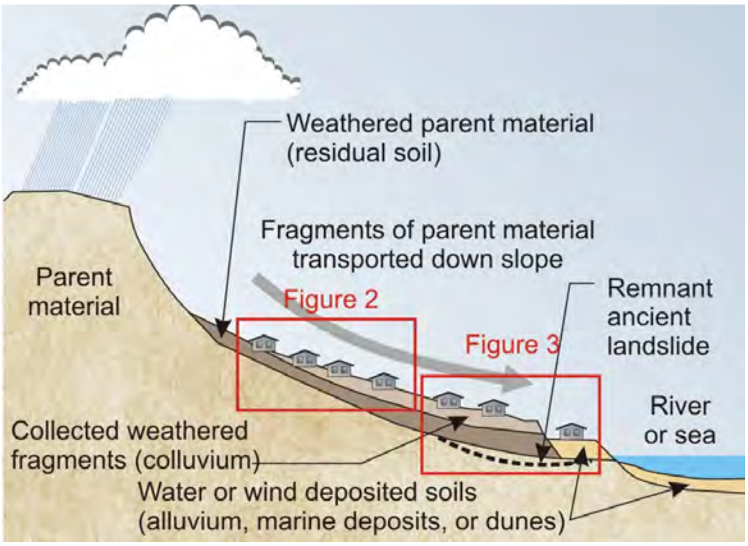


Figure 1

Landslides can occur almost anywhere on a soil slope. Slides can be rotational, translational, or debris flows (see GeoGuide LR2) and may have a number of causes.

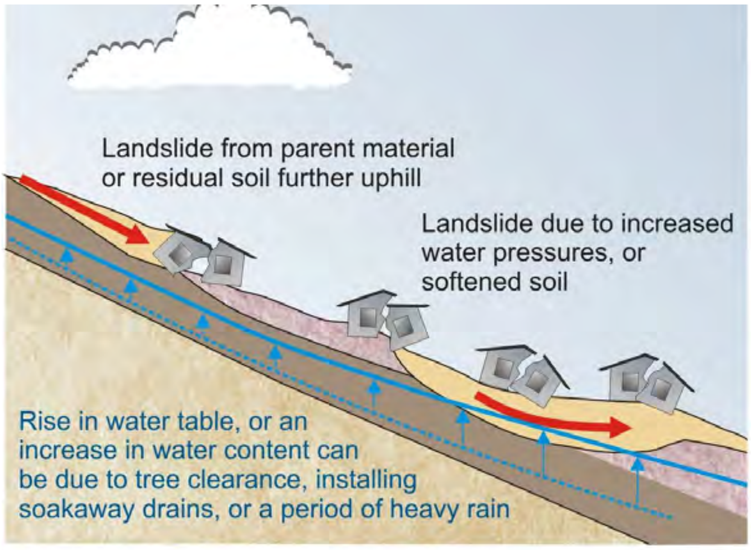


Figure 2

AUSTRALIAN GEOGUIDE LR4 (LANDSLIDES IN ROCK)

LANDSLIDES IN ROCK

Rocks have been formed by many different geological processes and may have been subjected to intense pressure, large scale distortion, extreme temperature and chemical change. As a result there are many different rock types and their condition varies enormously. Rock strength varies and is often significantly reduced by the presence of discontinuities (GeoGuide LR1). You may think that rock lasts forever, but in reality it weathers under the combined effects of water, wind, chemical change, temperature variation, plant growth and animal activity and erodes with time. Rock is often the parent material that ends up forming soil slopes (GeoGuide LR3). Inevitably different rocks have different physical and chemical characteristics and they weather and erode to form different types of soil.

Weathering can lead to landslides (GeoGuide LR2) on rock slopes. The type of landslide depends on the nature of rock, the way it has weathered and the presence or absence of discontinuities. It is hard to generalise, though normally a specific combination of discontinuities and material types will be the determining factor and these are often underground and out of sight. Typical examples are provided in the figures 1 to 4. A geotechnical practitioner can assess the landslide risk and propose appropriate maintenance measures. This often entails making geological observations over an area significantly larger than the site and a review of available background information, including records of known landslides and aerial photographs. Depending on the amount of information available, geotechnical investigation may or may not be needed. Every site is different and every site has to be assessed individually.

It is impossible to predict exactly when a landslide will occur on a rock slope, but failure is normally sudden and the consequences can be catastrophic.

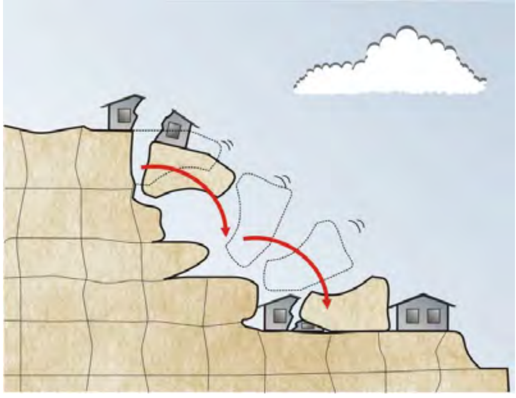


Figure 1 - Failure of an undercut block

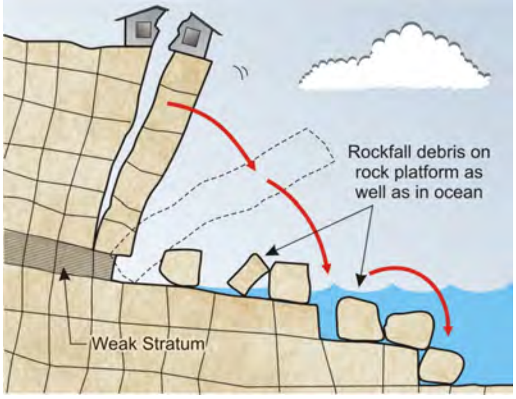


Figure 2 - Toppling failure

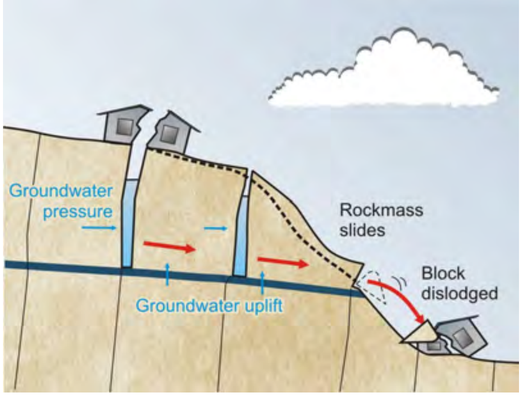


Figure 3 - Block slide on weak layer

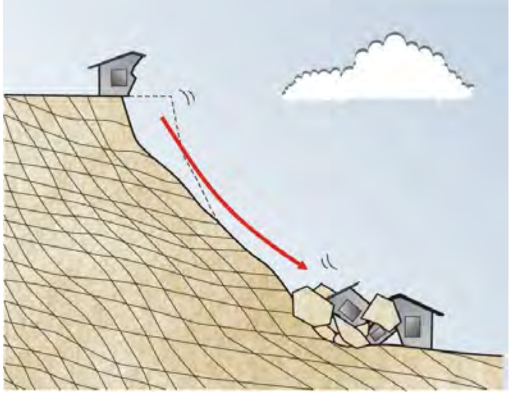


Figure 4 - Wedge failure along discontinuities

If the landslide risk is assessed as being anything other that Low, or Very Low, (GeoGuide LR7) it may be possible to carry out work aimed at reducing the level of risk.

The most common options are:

1) Trimming the slope to remove hazardous blocks of rock.
2) Bolting, or anchoring, to fix hazardous blocks in position and prevent movement.
3) Installation of catch fences and other rockfall protection measures to limit the impact of rockfalls.
4) Deep drainage designed to limit changes in the ground water table (GeoGuide LR5).

Although such measures can be effective, they need inspection and on-going maintenance (GeoGuide LR11) if they are to be effective for periods equivalent to the life of a house. **Design should be undertaken by a geotechnical practitioner and will normally require local council approval.** It should be appreciated that it may not be viable to carry out remedial works in all circumstances: for example where the landslide is on someone else's property, where the cost is out of proportion to the value of the property, or where the risk inherent in carrying out the work is actually greater than the risk of leaving things as they are. In situations such as these, development may be considered inappropriate.

ROCK SLOPE HAZARD REDUCTION MEASURES

Removal of loose blocks - may be effective but, depending on rock type, ongoing erosion can result in more blocks becoming unstable within a matter of years. Routine inspection, every 5 or so years, may be required to detect this.

Rock bolts and rock anchors (Figure 5) - can be installed in the ground to improve its strength and prevent individual blocks from falling. Rock bolts are usually tightened using a torque wrench, whilst rock anchors carry higher loads and require jacking. Both can be designed to be "permanent" using stainless steel, or sheathing, to inhibit corrosion, but the cost can be up to 10 times that of the "temporary" alternative. You should inspect rock bolts and rock anchors for signs of water seepage, rusting and deterioration around the heads at least once every 5 years. If you notice any of these warning signs, have them checked by a geotechnical practitioner. It is recommended that you keep copies of design drawings and maintenance records (GeoGuide LR11) for the anchors on your site and pass them on to the new owner should you sell.

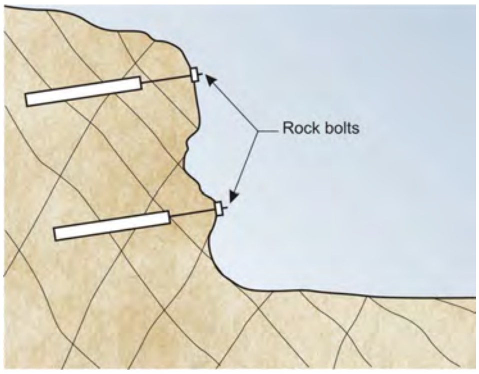


Figure 5

Rock fall netting, catch fences and catch pits (Figure 6) - are designed to catch or control falling rocks and prevent them from damaging nearby property. You should inspect them at least once every 5 years, and after major falls, and arrange for fallen and trapped rocks to be removed if they appear to be filling up. Check for signs of corrosion and replace steel elements and fixings before they lose significant strength.

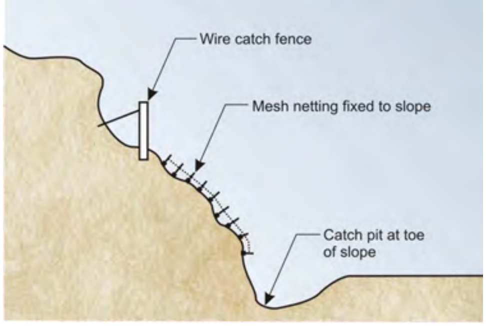


Figure 6

Cut-off drains (Figure 7) - can be used to intercept surface water run-off and reduce flows down the cliff face. Suitable drains are often excavated into the rock, or constructed from mounds of concrete, or stabilised soil, depending on conditions. Drains must be laid to a fall of at least 1% so they drain adequately. Frequent inspection is needed to ensure they are not blocked and continue to function as intended.

Clear trees and large bushes (Figure 7) - from slopes since roots can prize boulders from the face increasing the landslide hazard.

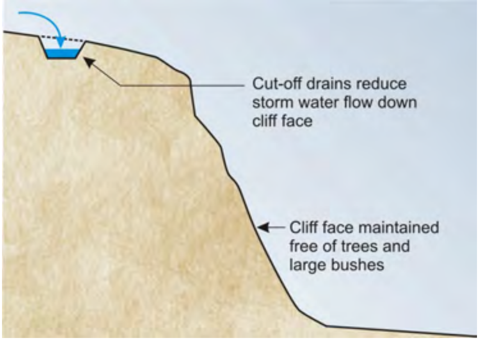


Figure 7

Natural cliffs and bluffs - often present the greatest hazard and yet are easily overlooked, because they have "been there forever". They can exist above a building, road, or beach, presenting the risk of a rock falling onto whatever is below. They also sometimes support buildings with a fine view to the horizon. Cliffs should be observed frequently to ensure that they are not deteriorating. You may find it convenient to use binoculars to look for signs of exposed "fresh" rock on the face, where a recent fall has occurred, or to go to the foot of the cliff from time to time to see if debris is collecting. A thorough inspection of a cliff face is often a major task requiring the use of rope access methods and should only be undertaken by an appropriately qualified professional. If tension cracks are observed in the ground at the top of a cliff take immediate action, since they could indicate imminent failure. **If you have any concerns at all about the possibility of a rock fall seek 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 LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
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AUSTRALIAN GEOGUIDE LR5 (WATER & DRAINAGE)

WATER, DRAINAGE & SURFACE PROTECTION

One way or another, water usually plays a critical part in initiating a landslide (GeoGuide LR2). For this reason, it is a key factor to be controlled on sites with more than a low landslide risk (GeoGuide LR7).

Groundwater and Groundwater Flow

The ground is permeable and water flows through it as illustrated in Figure 1. When rain falls on the ground, some of it runs along the surface ("surface water run-off") and some soaks in, becoming groundwater. Groundwater seeps downwards along any path it can find until it meets the water table: the local level below which the ground is saturated. If it reaches the water table, groundwater either comes to a halt in what is effectively underground storage, or it continues to flow downwards, often towards a spring where it can seep out and become surface water again. Above the water table the ground is said to be "partially saturated", because it contains both water and air. Suctions can develop in the partially saturated zone which have the effect of holding the ground together and reducing the risk of a landslide. Vegetation and trees in particular draw large quantities of water out of the ground on a daily basis from the partially saturated zone. This lowers the water table and increases suctions, both of which reduce the likelihood of a landslide occurring.

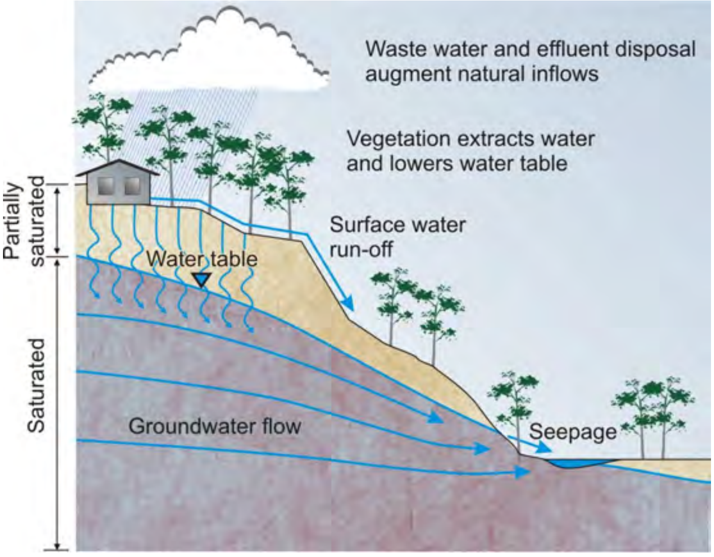

Figure 1 - Groundwater flow

Groundwater Flow and Landslides

The landslide risk in a hillside can be affected by increase in soak-away drainage or the construction of retaining walls which inhibit groundwater flow. The groundwater is likely to rise after heavy rain, but it can also rise when human interference upsets the delicate natural balance. Activities such as felling trees and earthworks can lead to:

- a reduction in the beneficial suctions in the partially saturated zone above the water table.
- increased static water pressures below the water table,
- increased hydraulic pressures due to groundwater flow,
- loss of strength, or softening, of clay rich strata,
- loss of natural cementing in some strata,
- transportation of soil particles.

Any of these effects, or a combination of them, can lead to landslides like those illustrated in GeoGuides LR2, LR3 and LR4.

Limiting the Effect of Water

Site clearance and construction must be carefully considered if changes in groundwater conditions are to be limited. GeoGuide LR8 considers good and poor development practices. Not surprisingly much of the advice relates to sensible treatment of water and is not repeated here. Adoption of appropriate techniques should make it possible to either maintain the current ground water table, or even cause it to drop, by limiting inflow to the ground.

If drainage measures and surface protection are relied on to keep the risk of a landslide to a tolerable level, it is important that they are inspected routinely and maintained (GeoGuide LR11).

The following techniques may be considered to limit the destabilising effects of rising groundwater due to development and are illustrated in Figure 2.

AUSTRALIAN GEOGUIDE LR5 (WATER & DRAINAGE)

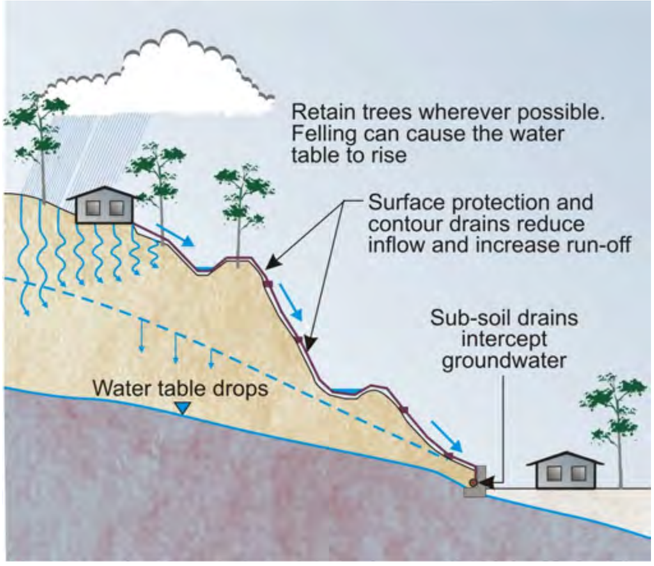

Figure 2 - Techniques used to control groundwater flow

Surface water drains (dish drains, or table drains) - are often used to prevent scour and limit inflow to a slope. Other than in rock, they are relatively ineffective unless they have an impermeable lining. You should clear them regularly, and as required, and not less than once a year. If you live in an area with seasonal rainfall, it is best to do this near the end of the dry season. If you notice that soil or rock debris is falling from the slope above, determine the source and take appropriate action. This may mean you have to seek advice from a geotechnical practitioner.

Surface protection - is sometimes used in addition to surface water drainage to prevent scour and minimise water inflow to a slope. You should inspect concrete, shotcrete or stone pitching for cracking and other signs of deterioration at least once a year. Make sure that weepholes are free of obstructions and able to drain. If the protection is deteriorating, you should seek advice from a geotechnical practitioner.

Sub-soil drains - are often constructed behind retaining walls and on hillsides to intercept groundwater. Their function is to remove water from the ground through an appropriate outlet. It is important that subsoil drains are designed to complement other measures being used. They should be laid in a sand, or gravel, bed and protected with a graded stone or geotextile filter to reduce the chance of clogging. Sub-soil drains should always be laid to a fall of at least 1 vertical on 100 horizontal. Ideally the high end should be brought to the surface, so it can be flushed with water from time to time as part of routine maintenance procedures.

Deep, underground drains - are usually only used in extreme circumstances, where the landslide risk is assessed as not being tolerable and other stabilisation measures are considered to be impractical. They work by permanently lowering the water table in a slope. They are not often used in domestic scale developments, but if you have any on your site be aware that professional maintenance is essential. If they are not maintained and stop working, the water table will rise and a landslide may even occur during normal weather conditions. Both an increase or a reduction in the normal flow from deep drains could indicate a problem if it appears to be unrelated to recent rainfall. If changes of this sort are observed, you should have the drains and your site checked by a geotechnical practitioner.

Documentation - design drawings and specifications for geotechnical measures intended to minimise landslide risk can be of great assistance to a geotechnical specialist, or structural engineer, called in to inspect and report on them. Copies of available documentation should be retained and passed to the new owner when the property is sold (GeoGuide LR11). You should also request details of an appropriate maintenance program for drainage works from the designer and keep that information with other relevant documentation and maintenance records.

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 LR6 - Retaining Walls
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AUSTRALIAN GEOGUIDE LR6 (RETAINING WALLS)

RETAINING WALLS

Retaining walls are used to support cuts and fills. Some are built in the open and backfill is placed behind them (gravity walls). Others are inserted into the ground (cast *in situ* or driven piles) and the ground is subsequently excavated on one side. Retaining walls, like all man-made structures, have a finite life. Properly engineered walls should last 50 years, or more, without needing significant repairs. However, not all walls fit this category. Some, particularly those built by inexperienced tradesmen without engineering input, can deflect and even fail because they are unable to withstand the pressures that develop in the ground around them or because the materials from which they are built deteriorate with time. **Design of retaining walls more than 900mm high should be undertaken by a geotechnical practitioner or structural engineer and normally require local council approval.**

Retaining walls have to withstand the weight of the ground on the high side, any water pressure forces that develop, any additional load (surcharge) on the ground surface and sometimes swelling pressures from expansive clays. These forces are resisted by the wall itself and the ground on the low side. Engineers calculate the forces that the retained ground, the water, and the surcharge impose on a wall (the disturbing force) as well as the maximum force that the wall and ground on the low side can provide to resist them (the restoring force). The ratio of the restoring force to the disturbing force is called the "factor of safety" (GeoGuide LR1). Permanent retaining walls designed in accordance with accepted engineering standards will normally have a factor of safety in the range 1.5 to 2.

Never add surcharge to the high side of a wall (e.g. place fill, erect a structure, stockpile bulk materials, or park vehicles) unless you know the wall has been designed with that purpose in mind.

Never more than lightly water plants on the high side of a retaining wall.

Never excavate at the toe of a retaining wall.

Any of these actions will reduce the factor of safety of the wall and could lead to failure. If in doubt about any aspect of an existing retaining wall, or changes you would like to make near one, seek advice from a geotechnical practitioner, or a structural engineer. This GeoGuide sets out basic inspection requirements for retaining walls and identifies some common signs that might indicate all is not well. GeoGuide LR11 provides information about records that should be kept.

GRAVITY WALLS

Gravity walls are so called because they rely on their own weight (the force of gravity) to hold the ground behind in place.

Formed concrete and reinforced blockwork walls (Figure 1) **-** should be built so the backfill can drain. They should be inspected at least once a year. Look for signs of tilting, bulging, cracking, or a drop in ground level on the high side, as any of these may indicate that the wall has started to fail. Look for rust staining, which may indicate that the steel reinforcement is deteriorating and the wall is losing structural strength ("concrete cancer"). Ensure that weep holes are clear and that water is able to drain at all times, as high water pressures behind the wall can lead to sudden and catastrophic failure.

Concrete "crib" walls (Figure 2) **-** should be filled with clean gravel, or "blue metal" with a nominated grading. Sometimes soil is used to reduce cost, but this is undesirable, from an engineering perspective, unless internal drainage is incorporated in the wall's construction. Without backfill drainage, a soil filled crib wall is likely to have a lower factor of safety than is required. Crib walls should be inspected as for formed concrete walls. In addition, you should check that material is not being lost through the structure of the wall, which has large gaps through it.

Timber "crib" walls - should be checked as for concrete crib walls. In addition, check the condition of the timber. Once individual elements show signs of rotting, it is necessary to have the wall replaced. If you are uncertain seek advice from a geotechnical practitioner, or a structural engineer.

Masonry walls: natural stone, brick, or interlocking blocks (Figure 3) - more than about 1m high, should be wider at the bottom than at the top and include specific measures to permit drainage of the backfill. They should be checked as for formed concrete walls. Natural stone walls should be inspected for signs of deterioration of the individual blocks: strength loss, corners becoming rounded, cracks appearing, or debris from the blocks collecting at the foot of the wall.

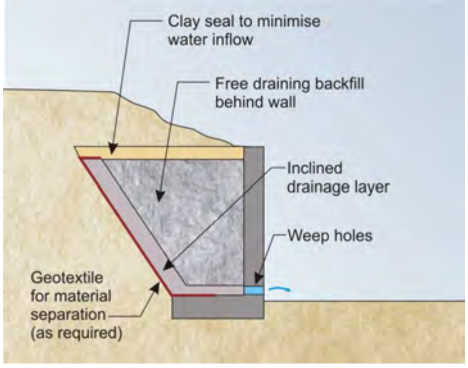

Figure 1- Typical formed concrete wall

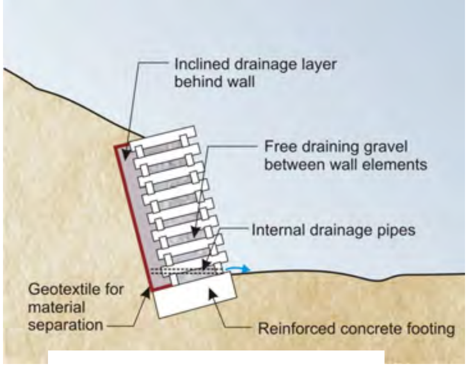

Figure 2 -Typical crib

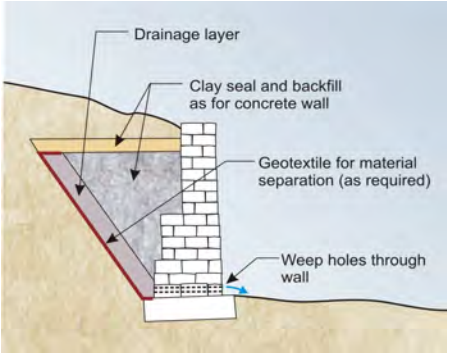

Figure 3 -Typical masonry wall

Old Masonry walls (Figure 4) - Many old masonry retaining walls have not been built in accordance with modern design standards and often have a low "factor of safety" (GeoGuide LR1). They may therefore be close to failure and a minor change in their condition, or loading, could initiate collapse. You need to take particular care with such structures and seek professional advice sooner rather than later. Although masonry walls sometimes deflect significantly over long periods of time collapse, when it occurs, is usually sudden and can be catastrophic. Familiarity with a particular situation can instil a false sense of confidence.

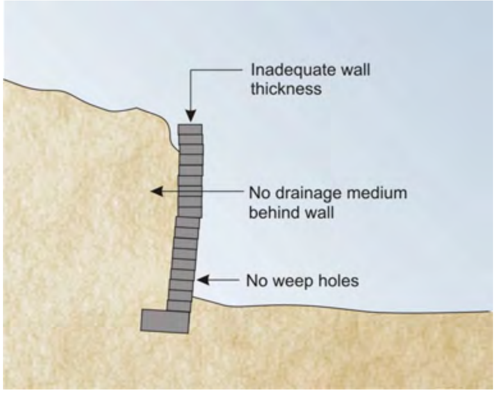

Figure 4 - Poorly built masonry wall

Reinforced soil walls (Figure 5) **-** are made of compacted select fill in which layers of reinforcement are buried to form a "reinforced soil zone". The reinforcement is all important, because it holds the soil "wall" together. Reinforcement may be steel strip, or mesh, or a variety of geosynthetic ("plastic") products. The facing panels are there to protect the soil "wall" from erosion and give it a finished appearance.

Most reinforced soil walls are proprietary products. Construction should be carried out strictly in accordance with the manufacturer's instructions. Inspection and maintenance should be the same as for formed concrete and concrete block walls. If unusual materials such as timber, or used tyres, are used as a facing it should be checked to see that it is not rotting, or perishing.

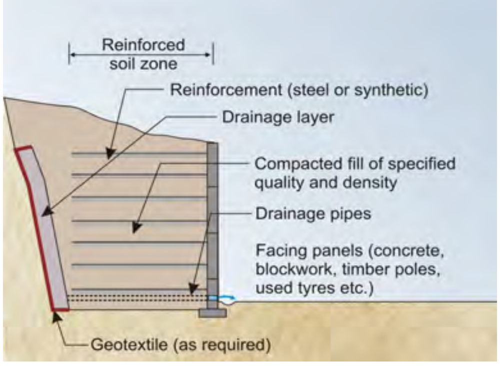

Figure 5 - Typical reinforced soil wall

OTHER WALLS

Cantilevered and anchored walls (Figure 6) **-** rely on earth pressure on the low side, rather than self-weight, to provided the restoring force and an adequate factor of safety. These walls may comprise:

- a line of touching bored piers (contiguous bored pile wall) or
- sprayed concrete panels between bored piers (shotcrete wall) or
- horizontal timber or concrete planks spanning between upright timber or steel soldier piles or
- steel sheet piles.

Depending on the form of construction and ground conditions, walls in excess of 3 m height normally require at least one row of permanent ground anchors.

INSPECTION

All walls should be inspected at least once a year, looking for tilting and other signs of deterioration. Concrete walls should be inspected for cracking and rust stains as for formed concrete gravity walls. Contiguous bored pile walls can have gaps between the piles - look for loss of soil from behind which can become a major difficulty if it is not corrected. Timber walls should be inspected for rot, as for timber crib walls. Steel sheet piles should be inspected for signs of rusting. In addition, you should make sure that ground anchors are maintained as described in GeoGuide LR4 under the heading "Rock bolts and rock anchors".

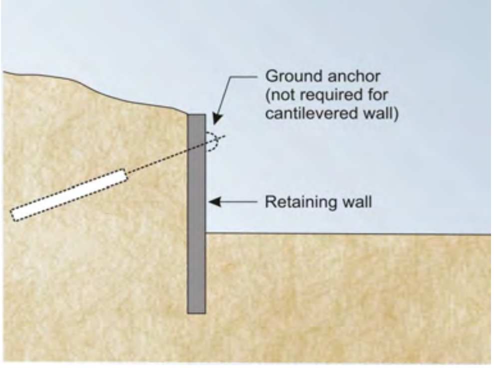

Figure 6 - Typical cantilevered or anchored wall

One of the most important issues for walls is that their internal drainage systems are operational. Frequently verify that internal drainage pipes and surface interception drains around the wall are not blocked nor have become inoperative.

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

- GeoGuide LR1 - Introduction
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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:

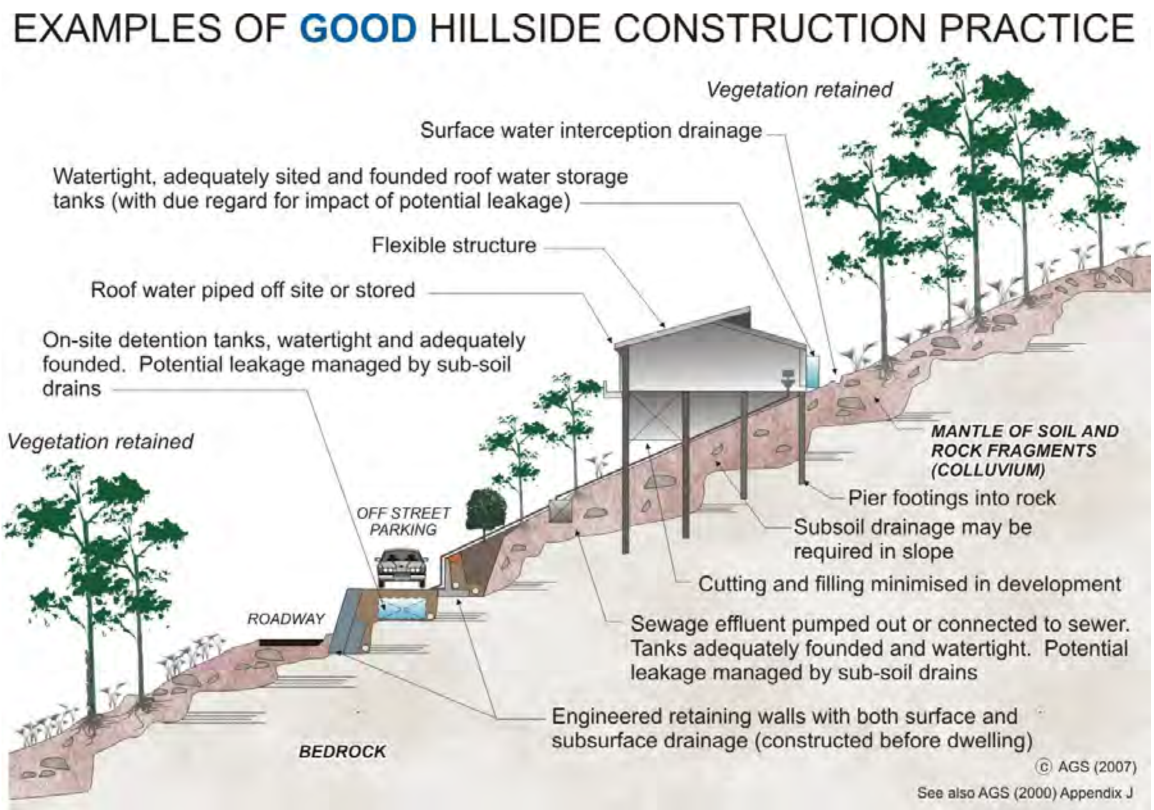
- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
  GeoGuide LR10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

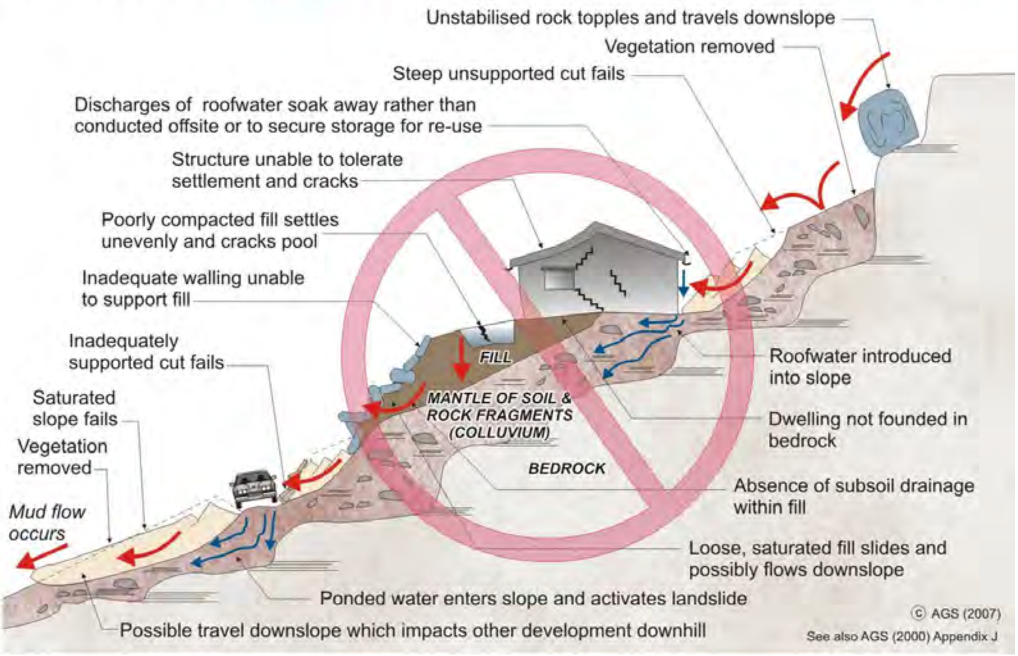
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

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- 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

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PITTWATER COUNCIL

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for ~~SMJ Investments Pty Ltd~~
Name of Applicant

Address of site 967 Barrenjoey Road, Palm Beach

Declaration made by geotechnical engineer or engineering geologist or coastal engineer (where applicable) as part of a geotechnical report

I, Michael Thom on behalf of Douglas Partners
(Insert Name) (Trading or Company Name)

on this the 5 April 2016 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $2million.
I have:

Please mark appropriate box

☐ Prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☑ I am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009

☐ Have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.

☐ Have examined the site and the proposed development/alteration in detail and am of the opinion that the Development Application only involves Minor Development/Alterations that do not require a Detailed Geotechnical Risk Assessment and hence my report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements for Minor Development/Alterations.

☐ Provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: Geotechnical Assessment and Report for New Residential Development
Report Date: 5 April 2016 Project 35470.05
Author: David Murray
Author's Company/Organisation: Douglas Partners

Documentation which relate to or are relied upon in report preparation:

Arch Dwgs A-100, A101, A101A, A-102, A103, A-104,
A105, A-106, A-107, A108, A-109, A-110, A-111, A-112, A-113
NN, by Blue Sky Building Design (all DA Issue)

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature Michael Thom
Name MICHAEL THOM
Chartered Professional Status F I E Aust
Membership No. 293608
Company DOUGLAS PARTNERS PTY LTD

PITTWATER COUNCIL

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER
FORM NO. 1(a) - Checklist of Requirements For Geotechnical Risk Management Report for Development Application

Development Application for SMJ Investments Pty Ltd
Name of Applicant
Address of site 967 Barrenjoey Road, Palm Beach

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Geotechnical Report. This checklist is to accompany the Geotechnical Report and its certification (Form No. 1).

Geotechnical Report Details:

Report Title: Geotechnical Assessment + Report for New Residential Development
Project 35470.05
Report Date: 5 April 2016
Author: David Murray
Author's Company/Organisation: Douglas Partners

Please mark appropriate box

☑ Comprehensive site mapping conducted 22/3/10, 2015, 2013, 2008, 2002
(date)
☑ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
☑ Subsurface investigation required
  ☐ No Justification ……………………………………………………
  ☑ Yes Date conducted ……2008 + 2002……………
☑ Geotechnical model developed and reported as an inferred subsurface type-section
☑ Geotechnical hazards identified
  ☑ Above the site
  ☑ On the site
  ☐ Below the site
  ☐ Beside the site
☑ Geotechnical hazards described and reported
☑ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
  ☑ Consequence analysis
  ☑ Frequency analysis
☑ Risk calculation
☑ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
☑ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
☑ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
☑ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
☑ Design Life Adopted:
  ☑ 100 years
  ☐ Other ………………………………………………
specify
☑ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
☑ Additional action to remove risk where reasonable and practical have been identified and included in the report.
☐ ~~Risk assessment within Bushfire Asset Protection Zone~~.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least 100 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature ……Michael Thom……
Name ……MICHAEL THOM……
Chartered Professional Status……FIE AUST……
Membership No. ……293 608……
Company……DOUGLAS PARTNERS PTY LTD