Douglas Partners
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Report on
Geotechnical Investigation

Proposed Residential Subdivision
32 Lovelle Street and 141 Yarrawa Road,
Moss Vale

Prepared for
Prime Moss Vale Pty Ltd

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Table of Contents

Report on Geotechnical Investigation
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1. Introduction

This report presents the results of a geotechnical investigation undertaken for a steep hillside in the northern part of a proposed residential subdivision (herein referred to as 'the site') at 32 Lovelle Street (Chelsea Gardens) and 141 Yarrawa Road (Coomungie), Moss Vale. The investigation was commissioned in an email dated 14 October 2019 by Prime Moss Vale Pty Ltd and was undertaken in accordance with Douglas Partners' Pty Ltd (DP) proposal WOL190315.P.001.Rev1, dated 4 October 2019.

The geotechnical investigation was carried out to provide information on the soil, rock and groundwater profile in the northern hillside to facilitate stability modelling and to assess potential remedial works and to provide development guidelines for future development of the steep hillside area.

The geotechnical investigation for the steep hillside comprised the drilling of seven cored boreholes and the excavation of four test pits followed by groundwater monitoring, laboratory testing, engineering analysis and reporting. Details of the work undertaken and the results obtained are given in the report, together with comments relating to the above items, development potential and construction practice.

The geotechnical investigation for the steep hillside was undertaken concurrently with a rock depth and quality survey, and a preliminary assessment of erosion and salinity potential. Both of these have been reported separately (40494.03.R.002 and 40494.03.R.003 respectively).

A draft report was provided dated 6 December 2019. This report supersedes all previous written correspondence and verbal advice.

2. Background

In 2006 Harvest Scientific Services (HSS) carried out a geotechnical classification of the site (HSS, 2006). In summary, the steep hillside in the northern part of the overall site was classified as High to Very High risk to property due to slope instability and no development was recommended without detailed geotechnical investigation.

In 2018 DP carried out a preliminary geotechnical investigation for the overall site including the steep hillside in the northern part of the site (DP, 2018). The preliminary investigation included eight test pits in the steep hillside and geotechnical mapping by an experienced engineering geologist. In summary, the assessment indicated that extensive slope instability affected, or had the potential to affect the steep hillside in the northern part of the site. This was considered to be a major constraint to development of the steep hillside and adjacent area without detailed subsurface investigation to assess options for remedial and slope stabilisation works, and any resulting potential for development in the area. The report recommended that detailed subsurface investigation and assessment be carried out for any proposed development extending into the High and Very High risk zones.

Information provided by the client for the current assessment included:

- Orion Consulting *'Bulk Earth Works Strategy'*, Project 19-34 Plans 000, 200 – 2023, 300 – 313, 401 and 501 – 508 Revision 1 dated 13 September 2019, which included concept lot and road layouts and sections through the steep northern hillside.

Relevant information from the above reports and plans has been considered, and where appropriate, included in the current assessment.

3. Site Description and Regional Geology

The overall site comprises Lot 12 in DP 866036, Lot 3 in DP 706194. The steep northern hillside, henceforth the **site**, is located in the northern part of Lot 12 (refer Drawing 1). It forms an irregular-shaped area of approximately 12 ha with maximum north-south and east-west dimensions of 410 m and 400 m, respectively. The site is accessed from Hill Road and Lovelle Street and is bounded to the north by low density residential lots and Hill Road, to the east by two water reservoirs and large rural-residential lots, to the south by undeveloped land and the remainder of the proposed subdivision, and to the west by Moss Vale Golf Course.

Within the site, the ground surface lies between approximately RL 689 and RL 752 relative to Australian Height Datum (AHD), with natural slopes typically in the range of approximately 4° to 45°.

Most of the site is grass covered with small isolated shrubs and trees, particularly in the south-eastern and north-western parts of the sites. A ephemeral creek line, oriented north-east south-west, runs down the hillside through the centre of the site. A small farm dam is located at the base of the hillside at the end of the ephemeral creek line.

Reference to the Moss Vale 1:100 000 Geological Series Sheet (NSW DISRD, 2016) indicates that the site is underlain, in descending stratigraphical order, by rocks of the Jurassic Volcanics and Bringelly Shale, and Quaternary residuum. The Jurassic Volcanics typically comprise dark, medium-grained dolerite, while the Bringelly Shale typically comprises light to dark grey, sideritic claystone to siltstone, dark grey carbonaceous claystone, sandstone to siltstone and quartz-lithic very fine- to medium-grained sandstone. Quaternary residuum typically comprises residual deposits of unconsolidated, clayey, coarse to fine grained sands to weakly consolidated sandy clay layers with poor to extensive soil development.

4. Field Work Methods

The field work for the current investigation, to supplement and provide additional information on the subsurface conditions within the steep hillside, comprised:

- The drilling of seven augered and diamond cored boreholes (Bores 101 – 107) to depths ranging from 4.3 m to 10.9 m. At the completion of drilling, piezometers were installed in each borehole. The boreholes included regular Standard Penetration Tests (SPTs) in the soil profile and were logged by a geotechnical engineer.
- The excavation by a JCB 3CX-4 backhoe, fitted with a 450 mm bucket, of four test pits (Pits 125 – 128) to depths ranging from 2.1 m to 2.5 m. The test pits were logged, photographed and sampled by a geotechnical engineer, then immediately backfilled.

Previous subsurface investigations and assessments used as part of this assessment comprised:

- Geological mapping by an experienced engineering geologist on 1 September 2018.
- The excavation by DP (2018) of nine test pits (Pits 1 – 8 and 22) in and adjacent to the current site to depths ranging from 0.5 m to 2.5 m.
- Geotechnical classification by Harvest Scientific Services (HSS, 2006).

The recent and previous test locations are shown on Drawing 1 in Appendix B. The surface levels to Australian Height Datum (AHD) and coordinates to Map Grid of Australia (MGA) of the current borehole locations were determined on site using a differential GPS unit for which an accuracy of ± 20 mm is typical.

5. Field Work Results

5.1 General

The subsurface conditions encountered in the current test pits and boreholes are given in the log sheets in Appendix B, together with the terms used to classify the strata in Appendix A. The details of the test pits previously excavated by DP are included in Appendix B.

5.2 Geological Mapping

The principal geotechnical and geological observations within and immediately adjacent to the site are summarised below with selected items shown on Drawing 1 and Photos 1 – 7 (refer Plates 1 – 2 in Appendix B).

- Irregular and hummocky slopes and soil terracing were observed in the slopes in the northern part of the site and include run-out of displaced material, possibly of historic landslides, to above approximately RL 696. These slopes include slumps, back scarps up to 1 m high, igneous cobbles and boulders on and embedded in the surface and inferred seepage (refer Photos 2 – 6). One active slump in the hillside is currently being driven by groundwater seepage from the hillside.

- Seepage was inferred at a number of location including a currently active scarp in the hillside in the northern part of the site (refer Photos 7 and 8) and from discrete areas of green grass in the same hillside.
- Bedrock comprising medium to high strength, slightly fracture dolerite is exposed at discrete locations in the steep to very steep hillside in the northern part of the site, below the existing water reservoirs (refer Photo 11).

5.3 Subsurface Investigation

The borehole and test pit logs are included in Appendix B and should be read in conjunction with the accompanying standard notes defining classification methods and descriptive terms.

The succession of strata is broadly summarised as follows:

Topsoil –clay, silty clay, sandy clay and clayey silt with root fibres to depths of 0.1 – 0.3 m;

Colluvium – present in Bores 101, 102, 104, 105 and 107, and Pits 1, 3 – 8, 126 and 127 comprising stiff to very stiff clay, silty clay and sandy clay with included gravel, cobbles and boulder-sized dolerite fragments to depths of up to 1.3 m in the middle and upper slopes and to depths of 4.4 m in the lower slope at the test locations. The colluvium ranged in thickness from less than 0.4 m to 4.4 m, directly overlying (and probably, in part, grading to) residual soil or weathered bedrock. At Pit 1 in an area of seepage, colluvium was initially of soft consistency.

Residual Soil –stiff to hard clay, silty clay, sandy clay and shaly clay grading into extremely weathered siltstone, sandstone, shale and dolerite. The profile ranged in thickness from 0.1 m to in excess of 3.1 m, described in Bores 101 – 107 and Pits 1, 3, 4, 8, and 125 – 128 but absent in the remaining pits.

Bedrock – comprising variously very low to very high strength, siltstone, sandstone, shale and dolerite in all boreholes and pits, intersected at depths ranging from 0.1 m (Pit 2) to 8.0 m (Bore 105). Dolerite was observed above RL 711 to RL 732 with the level increasing towards the east.

6. Groundwater

The following groundwater observations were made during the current investigation:

- Groundwater was encountered during auger drilling at depths of 4.0 m (Bore 101) and 7.7 m (Bore 107);
- Groundwater was measured in standpipe piezometers installed in the current boreholes at depths of 2.2 m (Bore 101), 5.6 m (Bore 102) and 7.9 m (Bore 105) on 6 November 2019. No groundwater was observed within the depth of the standpipe piezometers at the remaining locations.

Seepage was previously observed during DP's preliminary investigation in September 2018 in Pit 1 in an active area of slumping in the steep hillside. Seepage was also inferred during mapping and from a review of aerial photography:

- Between RL 694 to RL 709 in the lower hillside in the central and western parts of the site (refer Drawing 1); and
- About previous slumping near Pit 1.

Groundwater levels are dependent on preceding climatic conditions and soil permeability, and can therefore vary with time. It is noted that the current field work was carried out following a below average period of rainfall.

7. Laboratory Testing

Selected samples from previous and current boreholes and test pits from the overall site were tested in the laboratory for measurement of field moisture content, Atterberg limits and linear shrinkage. The detailed test report sheets are included in Appendix C, with the results summarised in Table 1.

Table 1: Results of Laboratory Testing – Plasticity

Test Location	Depth (m)	W_F (%)	W_L (%)	W_P (%)	PI (%)	Material Description
1	0.4 – 0.5	38.8	48	15	33	Silty clay (Colluvium)
19	0.4 – 0.5	17.0	54	15	39	Silty clay (Residual)
101	3.5 – 3.95	18.5	38	18	20	Clay (Colluvium)
104	1.5 – 1.95	23.5	37	15	22	Clay (Residual)
125	0.5	17.6	36	18	18	Clay (Residual)
127	1.5	12.5	40	18	22	Clay (Residual)

Where:
W_F = Field moisture content
W_P = Plastic limit
PI = Plasticity Index
W_L = Liquid Limit

The results indicate that the samples tested are of generally intermediate plasticity, with one sample (Pit 19 at 0.4 – 0.5 m) being of high plasticity. The results are summarised in a modified Casagrande chart in Figure1 (following page).

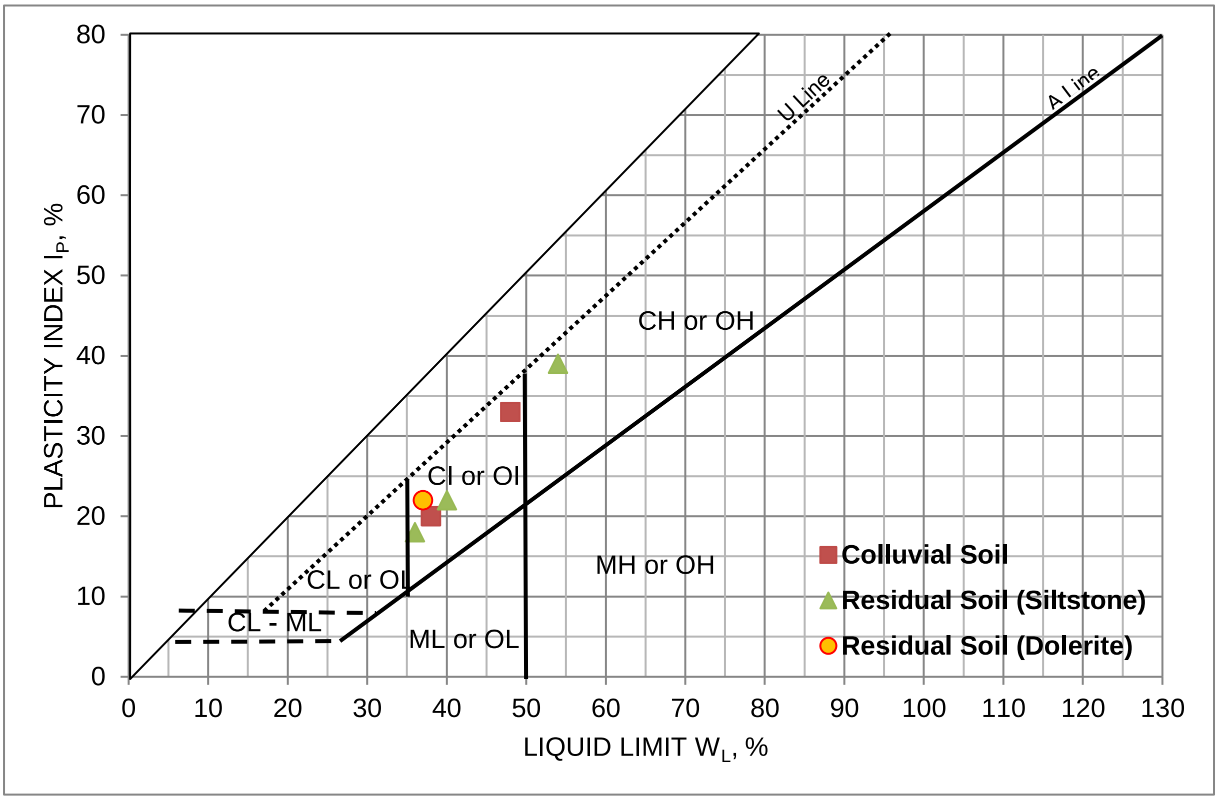


Figure 1: Results of plasticity testing plotted on a Modified Casagrande Chart.

8. Proposed Development

The concept plan for development of the steep hillside (refer Figure 2, following page), dated September 2019, includes proposed residential lots of varying sizes, access roads, areas for public recreation and environmental conservation. Access for the proposed subdivision will be developed from the overall subdivision to the south, with a few lots at the crest of the steep hillside accessed from Hill Road.

At the time of preparing this report, concept bulk earthworks plans had been provided for the proposed development of the lower hillside only (refer Figure 3, following page). The plans indicated cut and fill in the order of 3 m in the lower hillside. The extent of potential earthworks in the middle and upper slopes of the northern hillside will be guided by the recommendations of this report.

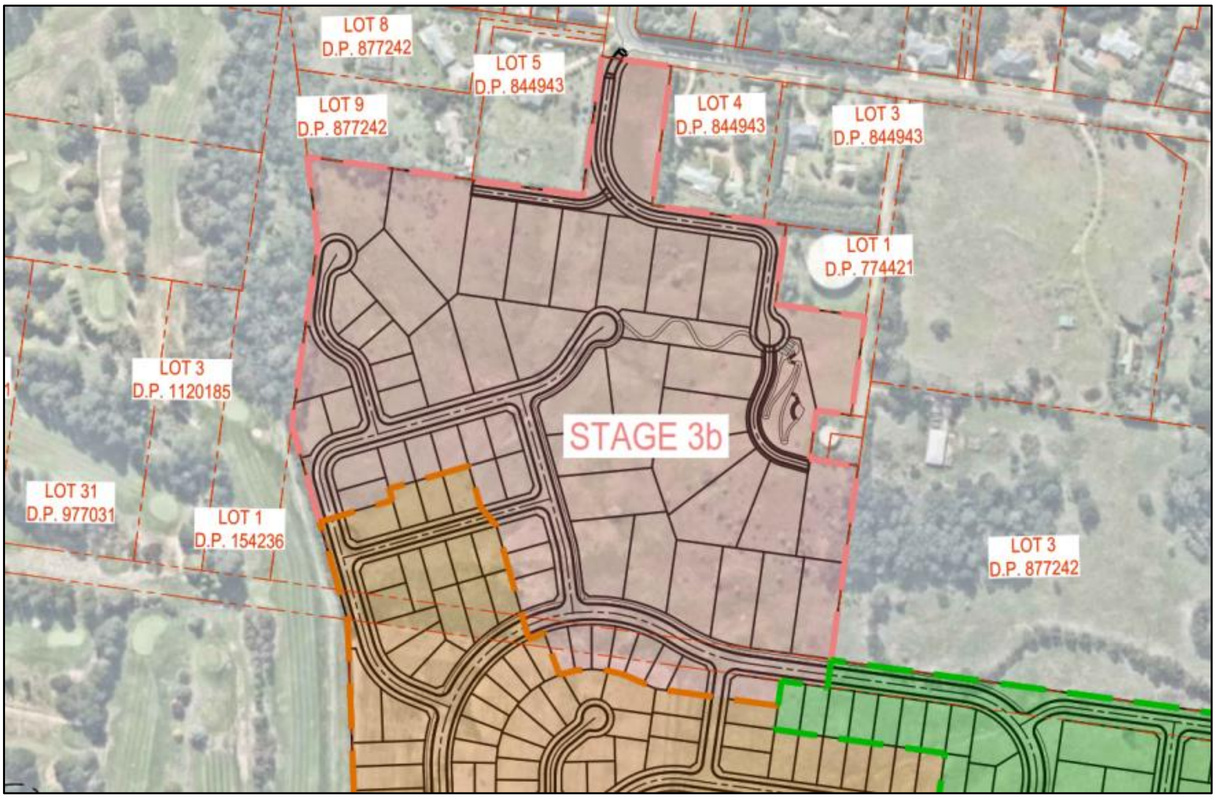


Figure 2: Excerpt of the concept plan for development of the steep hillside.

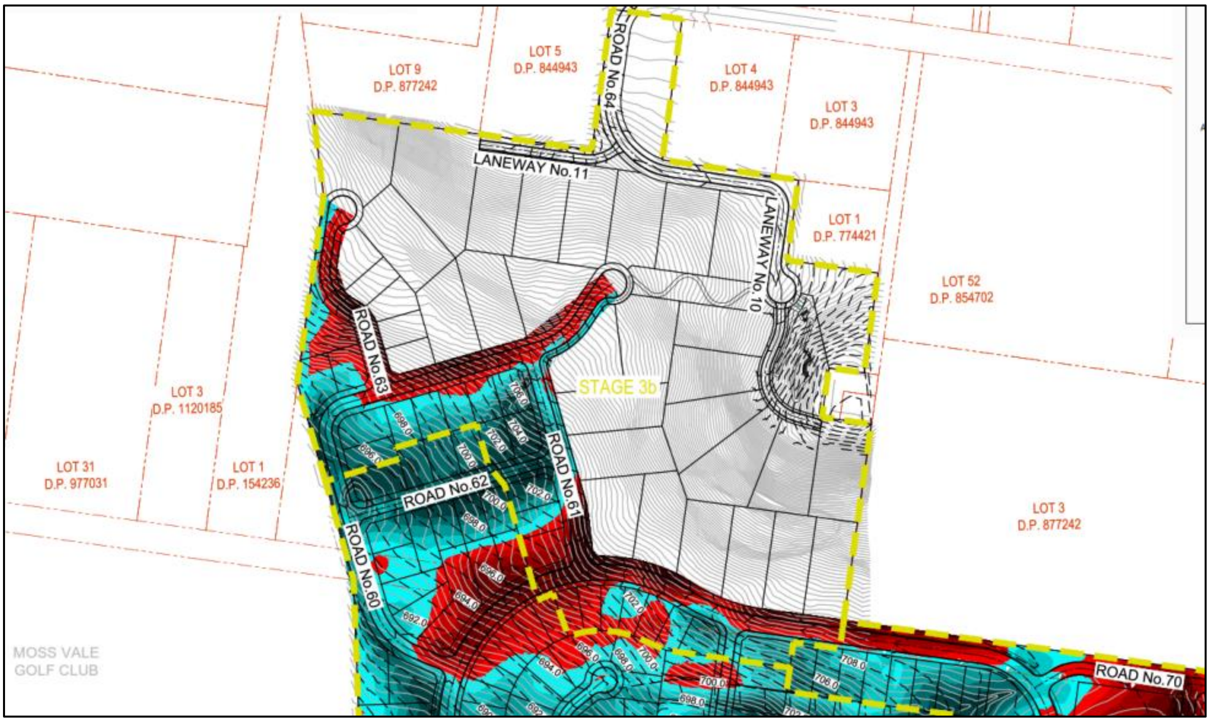


Figure 3: Excerpt of the bulk earthworks plan for the steep hillside.

9. Comments

9.1 General

The following comments are based on the surface and subsurface profiles encountered during the DP's current and previous investigations and on the results of laboratory testing of selected samples.

Comments are provided on development constraints related to geotechnical and geological factors to assist in the conceptual planning of the proposed development. The comments given must also be considered as being preliminary, as detailed design for the steep hillside in the northern part of the site is incomplete. Once details are available, they must be forwarded to DP for assessment to determine whether comments given in this report require revision.

9.2 Geotechnical Site Model

The inferred geological model for the site includes:

- Bedrock, of the Bringelly Shale, comprising weathering-prone shales, claystone, siltstone and laminite with more resistant sandstone bands in the lower and middle slopes of the steep hillside.
- Bedrock, of the Jurassic Volcanics, comprising dolerite, in the middle and upper slopes of the steep hillside in the northern part of the site.
- Preferential weathering of the finer grained rock results in over-steepening of the slopes below volcanic rocks with resulting susceptibility for slumping of residual and accumulated colluvial materials in the adjacent slopes.
- Open joints in the volcanic rock allowing infiltration of rainfall leading to a build-up in groundwater pressure in the higher elevation slump areas during periods of high rainfall which can initiate flow sliding.
- Groundwater flow through thinner sandstone bands at lower elevations within the hillside may also trigger slumping at both new and previous slump and flow debris locations.
- Additional slumping and creep flow is also likely to be facilitated by tension cracks and internal drainage within previously slumped debris, together with the scarp geometry which provides for concentration of stormwater and infiltration. At residual shear strength parameters, groundwater levels above slide planes need only reach ground level to trigger movement, particularly on moderate or steep slopes.
- A variable thickness of colluvial cover over much of the hillside as the result of the combination of direct deposition by ancient landslide activity during slope retreat, historical landslide activity probably facilitated by land clearing and/or the transport of eroded debris (colluvium) downslope by sheet stormwater flow. It should be noted that the on-going erosion and/or deposition of colluvial materials may hide older (relict) landslide features within the lower elevations of the site.
- Infilling of some drainage paths by water-logging susceptible colluvium derived mainly from the steep slopes in the northern part of the site.

The site geological model has been divided into two terrain units (Terrain Units A and B) and the inferred boundaries of which are given on Drawing 2 in Appendix B. Descriptions of each of the terrain units and limitations for development of the units are given in the following sections.

Terrain Unit A
Comprises the steep and very steep slopes in the middle and upper hillside and is typically located above RL708 to RL710. This terrain unit comprises soil terracing and inferred lobes of movement-affected materials and is characterised by shallow cover of soil, generally less than 2 m thick overlying the bedrock.

Terrain Unit B
Comprises the lower slopes of the hillside and the area downslope where colluvium has accumulated and is typically located below RL708 to RL710. This terrain unit is characterised by more than 3 m of soil cover including movement-affected material in the southern central and western parts of the site and by a ‘thinner’ cover of colluvium and residual soil in the south-eastern part of the site.

9.3 Stability Assessment

9.3.1 Slope Instability Risks

While the site is not within an area that has been broadly mapped for slope instability, the Wianamatta Group (ie including the Bringelly Shale), and to a limited extent the Robertson Basalt (located in the vicinity of the site), are both geological strata in which slope instability has occurred within the area and wider region. It is further noted that survey of the steep and very steep slopes in the northern part of the site has, in places, irregular contours indicative of historic slope instability.

DP (2018) assessed the overall site for current and inferred susceptibility for slope instability based on the distribution of geological, topographical and drainage features identified during the investigation together with slope angles at slump and flow termination locations and consideration of potential or identified hidden slope instability features. The steep hillside in the northern part of the site was assessed by DP (and others) to have a High to Very High risk to property due to slope instability in its current state.

9.3.2 Slope Instability Risk Assessment Methodology

The subject site has been assessed following the methods of the Australian Geomechanics Society (AGS 2007), relevant extracts of which are included in Appendix D. The methodology for description and assessment of risk levels associated with landslides, rock falls and soil slumps is based upon inputs including:

- Identification of landslide susceptibility, landslide hazards including potential triggers (eg erosion, undercutting, saturation, earthquake), and frequency (or likely range of frequencies) of occurrence.
- Probability of the effects of a hazard on the element at risk (ie property, services or site including occupants), requiring assessment of the translational mode of landsliding (rate of movement and run out distance).
- Probability of occupation of the element of risk at the time of the event.
- Vulnerability, the probability and cost of damage of the property or loss of life given the impact of the particular hazard.

9.3.3 Slope Instability Hazards

Based on the results of the previous and current assessments and intrusive investigation the slope instability hazards assessed as affecting or potentially affecting the site in its current profile and the adjacent areas are considered to be:

- Extremely slow soil creep affecting the colluvial or residual soils developed on the steep slopes. Creep movement is most likely to occur due to a combination of saturation by direct infiltration of the soils in the gently sloping depression base and by development of groundwater pressure in the underlying weathered rock during periods of prolonged wet weather;
- Rapid, surficial soil slump and shallow rotational failures affecting the colluvial soils and potentially the residual soils, particularly initiating in the very steep sections of the hillside and running out below the toe of the steep slope;
- Rockfall from embedded blocks dislodging from the very steep slopes, particularly during bulk earthworks and site-specific construction activities; and
- Slow, intermediate to deep-seated failure affecting the colluvial, residual soils and potentially the weathered rock of low strength on steep slope of the hillside.

Potential hazards during development include the mobilisation of undetected, old landslide-affected materials by inappropriate excavation or change of drainage characteristics. It should be noted that deposition of colluvium (slopewash) has masked most of the surface in the northern part of the site.

9.3.4 Stability Analysis

Stability analyses were carried out using Slope/W slope stability programme distributed by Geo-slope International Ltd. Slope/W uses limit equilibrium methods (the Morgenstern-Price Method) for the analysis of circular and non-circular failure surfaces. The method calculates a factor of safety (FoS) as the ratio of the restoring moment and the overturning moment. Typically an acceptable FoS for slope stability for a new development in the long-term would be 1.5.

The model was initially calibrated using the geological model detailed in Section 9.2, the geometry shown in site models (refer Drawings 3, 6 and 9), and then run for various groundwater scenarios. Material parameters adopted for the various strata are summarised in Table 2. The modelling also assumed that slope failure cannot occur through medium strength or better rock.

Table 2: Material Parameters Selected for Analyses

Material	Bulk Density, γ' (kN/m^3)	Internal Friction Angle, ϕ' (°)	Cohesion, c' (kPa)
Colluvium	20	20 – 24	0 – 2
Residual clay	20	20 – 24	2
VL – L Rock	22	20	10 – 20
M or better Rock	Impenetrable		

Where: VL = Very low strength L = Low strength
M = Medium strength

Selected results of the analyses are shown on Drawings 3 – 11 in Appendix B and are summarised in Table 3.

Table 3: Summary of Stability Analysis Results

Scenario	Calculated Factor of Safety
Calibration: Existing geometry and observed groundwater – shallow and intermediate depth failures	1.04* – 1.36
Groundwater level at the surface, original geometry – shallow and intermediate depth failures	≤ 1.00
Following remedial workings including subsurface drainage and removal and replacement of movement-affected material	> 1.5

Notes: * While the calculated FoS is low for the existing conditions, it probably has additional cohesion provided to the slope by unsaturated conditions which develop during period of 'low' and/or 'normal' groundwater levels.

In summary, the results indicate that the existing slope is sensitive to variations in groundwater water levels, particularly the movement-affected material. Based on these results it should be feasible to increase the long term factor of safety by implementing the hazard reduction measures detailed in Section 9.3.5.

9.3.5 Remedial and Precautionary Works for Proposed Development

Based on the results of the detailed stability analyses (refer Section 9.3.4), the following items should be included in the engineering design and subsequent construction phases of the subdivision:

- Removal of all movement-affected materials from the steep slopes in Terrain Unit A including cobbles and boulders embedded in the slopes.
- The installation of subsurface drains in the lower hillside to intercept seepage previously observed, together with any additional seepage zones identified during site preparation.
- The installation of subsurface drains in the middle and upper hillside along lot boundaries and in the road easement to intercept seepage through the dolerite.
- Limit cut and fills in the steep hillside to a maximum height of 1 m above or below the existing ground surface. Cut and fill that exceed this requirement must be subject to geotechnical review and approval of earthworks methodology and retaining structural details.
- Cut and fill is possible in the lower slope provided drainage is placed below the level of fill and controlled fill is placed with Level 1 supervision and testing in accordance with Australian Standard AS 3798:2007 *Guidelines for Earthworks for Commercial and Residential Developments*. Cut surfaces should be tapered to direct groundwater flow along the base of the fill into subsurface drainage lines.
- Improvement of surface drainage by re-contouring the hillside and adjacent areas to collect overland stormwater flows (ie from upslope).
- Improve soil stabilisation in public recreation and environmental conservations areas on hillside slopes by planting local, native, deep-rooted shrubs or trees.

It is noted that it may not be possible to continue remedial works to the east of the site (ie outside the site boundary) without permission from the adjacent landholders. As there is some inherent risk that slope instability affecting this section of the hillside may run-out into the site, the inclusion of an earth bund as a precautionary measure is also recommended adjacent to this area (refer Drawing 2).

Geotechnical constraints will also apply to residential development on the steep slopes. While these details will be finalised following lot classification, likely requirements may include:

- Foundations design by a qualified structural engineer for Class P (ie hillside sites) in accordance with Australian Standard AS 2870 *Residential Slabs and Footings*.
- A requirement for footings to rock for hillside lots.
- Design to accommodate creep movements.
- Stormwater collection and discharge from individual sites in a controlled manner.
- Ongoing site maintenance, particularly for drainage but also for retaining structures and slopes.
- Review of design plans by a geotechnical engineer to ensure that the geotechnical requirements of the site are accommodated in the design.
- Design compliance to be confirmed following inspection by a suitably qualified engineer during construction.

9.3.6 Slope Instability Risk Assessment

A summary of the assessed risk to property, after the methods of the Australian Geomechanics Society Practice Note Guidelines for Landslide Risk Management (AGS 2007, refer Appendix D), from instability affecting the development of the steep hillside is given in Table 4.

The assessment assumes that:

- The site layout is reviewed and approved by DP prior to finalisation.
- Remedial and precautionary works are carried out in accordance with the recommendations included in this report.
- Owners (serially) of the lots will implement inspection and maintenance programs relevant to the maintenance of slope stability.
- Where any significant changes in slope or condition of structures such as retaining walls, houses, footpaths etc are identified during inspections by owners, these changes are brought promptly to the attention of relevant professionals (eg geotechnical or structural engineers).

Table 4: Risk to Property for Development After Remedial and Precautionary Measures

Hazard	Likelihood	Consequence to Property	Risk
Extremely slow soil creep	Likely but minimised after site development including the removal of movement-affected material and the installation of surface and subsurface drainage	Insignificant for engineered structures provided that they are designed for creep loadings	Low
Rapid, surficial soil slump and shallow rotational failures	Unlikely but minimised after site development including the removal of movement-affected material and the installation of surface and subsurface drainage	Minor due to part of the site requiring reinstatement/ stabilisation works	Low
Rapid, rockfall from dislodged blocks embedded in the very steep slopes	Possible during earthworks for individual structures.	Minor, limited damage to part of structure	Moderate
Slow, intermediate to deep-seated rotational failure	Rare after site development including the removal of movement-affected material and the installation of surface and subsurface drainage	Catastrophic	Moderate

It is considered that the development of the steep hillside is feasible provided that the remedial and precautionary works detailed in this report are carried out in order to reduce the risk to property from slope instability to at least a tolerable level (taken as *Moderate Risk* for the purpose of this assessment based on current geotechnical practice).

Semi-quantitative risk assessments, incorporating the indicated annual probability of the hazard events given in Table 5, have been used to determine the annual probability of loss of life to an individual ($P_{(LoL)}$) for residential structures within the steep hillside. The risk assessment, by necessity, includes assessment of the temporal probability of residents, velocity and magnitude of hazards together with the structural capacity of the residential structures if struck by a landslip or debris flow.

The probability of loss of life to an individual ($P_{(LoL)}$) is the product of:

$P_{(H)}$ = the annual probability of the hazard event (as indicated in Table 4);
$P_{(S:H)}$ = the probability of spatial impact
$P_{(T:S)}$ = the temporal probability of the person most at risk being within the potential failure or debris zone
$V_{(D:T)}$ = the vulnerability of the individual (refer AGS Appendix F, copy included in Appendix D for guidance).

A summary of the assessment is given in Table 5

Table 5: Risk to Life for Development Following Remedial and Precautionary Measures

Hazard	Likelihood $P_{(H)} \times P_{(S:H)}$	Temporal Probability $(P_{(T:S)})$	Vulnerability $(V_{(D:T)})$	Loss of life $(P_{(LoL)})$
Rapid, surficial soil slump and shallow rotational failures	10^{-4}	5×10^{-2}	1×10^{-2}	5×10^{-8}
Very rapid rockfall from blocks dislodge embedded in the very steep slopes	10^{-3}	2×10^{-2} (building penetrated)	5×10^{-2} (building does not collapse)	1×10^{-6}
Slow, intermediate to deep-seated rotational failure	10^{-5}	1×10^{-2} (evacuation generally possible)	0.9 (part of building may collapse)	9×10^{-8}
Extremely slow soil creep in building areas	10^{-2}	$<10^{-3}$	5×10^{-2} (remediation before life threatening damage)	5×10^{-7}

Based on assessed parameters, the assessed annualised $P_{(LoL)}$ (refer Table 3) for development including the recommendations of this report is calculated to be 10^{-6} or less. This annualised $P_{(LoL)}$ is consistent with an “acceptable” risk level for new slopes as suggested in the AGS Guidelines.

9.4 Development Guidelines

9.4.1 Earthworks

The following guidelines are provided for remedial earthworks in and adjacent to the steep hillside in the northern part of the site:

- The stripping out of movement-affected materials to expose residual soil and/or weathered bedrock in the steep and lower slopes. Strip inspections by the geotechnical consultant to confirm movement-affected materials have been removed and to determine subsurface drainage requirements.
- The placement of drainage below fill (refer Section 9.4.2 *Subsurface Drainage*).
- The placement of all new fill on the benched surface in near-horizontal layers not exceeding 300 mm loose thickness with compaction to a minimum of 98% of the maximum dry density obtained in the laboratory standard compaction test (AS 1289 5.1.1) with clayey materials being placed within -2% to +2% of Standard optimum moisture content (OMC). Where filling is to be within the upper 500 mm of road embankments, the compaction level should be increased to 100% of the maximum dry density at the moisture contents noted above. Under no circumstances should the compaction levels exceed 104% standard.

- Control testing progressively during the course of earthworks to ensure quality control with respect to the material type and compaction. The testing should be carried out in accordance with Australian Standard AS 3798:2007 *Guidelines for Earthworks for Commercial and Residential Developments* and re-vegetated as soon as possible after construction to minimise soil erosion.
- Re-contour the design surface at a maximum batter of 3:1 (H:V).
- The provision of lined drains along the crest and toes of natural slopes and man-made batter slopes.
- The sequencing of site activities such that areas upslope of any excavation are not subject to instability.

9.4.2 Subsurface Drainage

The subsurface drainage lines to be installed should be constructed by extending trenches upslope from RL696 at a grade of at least 2%. Trenches should be as deep as practicable with a nominal depth of 4 m. Trenches can be tapered from termination locations marked on Drawing 2 into the subdivision's stormwater system. The spacing between subsurface drains should not exceed 15 m. Additional spur lines may be required to drain previously identified areas of seepage and seepage identified during construction. Where it is practical, subsurface drains could be located along property boundaries. The subsurface drain layouts must be approved by DP.

The trenches for the subsurface drains should be a minimum 450 mm wide and include dual 100 mm diameter perforated pipes set into geo-textile wrapped, free-draining aggregate extending to approximately 1 m below the surface. The dual 100 mm diameter perforated pipes should be located at the base of the trench. The upper 1 m of the trench must be backfilled with selected clayey material compacted in layers to provide a surface seal. Typically the trenching would commence from the downslope end and be progressively laid to minimise the length of trench open at one time. If significant groundwater inflow is encountered at the trench head, it may be necessary to allow drainage of the upslope soil material prior to continuing the trenching, minimising the risk of trench collapse. If unsatisfactory excavation or drainage conditions are encountered, if may be also necessary to construct pressure relief bores by drilling below the base of the drainage trenches. Temporary trench support, such as shoring may also be required, given the required depth of the excavation by conventional measures and the proximity to site boundaries. Reinstatement with controlled filling will be required to minimise the potential for erosion scouring.

Aggregate for drainage must comprise durable material that is not prone to leaching and/or subsequent mineral growth or deposition. An appropriate aggregate would be crushed basalt or other durable volcanic rock. Crushed concrete or slag is not appropriate for use as a drainage layer.

The drain should be finished with permanent structures including flushing points and a discharge point protected from damage and constructed to provide flushing access. Erosion control measure must also be implemented at the discharge points, such as piping flows into concrete collection pits, to ensure that erosion does not occur at discharge points.

Standpipe piezometers installed during the current investigation should be maintained on the site, where possible, during remedial works, to allow monitoring of groundwater levels during drain construction and subsequently on a regular basis, to assess groundwater response to drain construction, response to major rainfall events and to provide warning of potential adverse groundwater conditions.

9.4.3 Drainage and Stormwater Control

The aim of any drainage should be to minimise or prevent soil saturation, as well as to reduce the risk of soil erosion. Under no circumstances is stormwater to be directed into remedial subsurface drainage works. Drainage should be provided to contain and control stormwater, which should be directed into lined drains or pipework and removed from the site. Any such drains should be aligned downslope or diagonally across the slope. Drains which run parallel to the ground contours (ie along a slope) should be avoided or be fully lined.

Subsurface drainage connected to the stormwater system should be provided in the areas where there is seepage. These areas should be identified by inspection following clearing of areas to be developed.

9.4.4 Inspection and Maintenance Program

As recommended by the AGS (2007) guidelines, there should be definition of which parties will be responsible for the maintenance, particularly with respect to site drainage measures.

Drainage and any retaining structures should be designed and maintained for the design life of the proposed structures, which in our experience, is normally taken to be in the order of 60 years. In order to ensure acceptable site performance over the design life of structures and likely extension beyond that period, the structural engineer should include within the design, suitable observation and cleaning access points in the subsurface drainage system and document appropriate structural inspection requirements for the individual property owners who should in-turn adopt and implement a maintenance and inspection program. A suggested maintenance and inspection program is given in Table 5.

Table 5: Suggested Maintenance and Inspection Program

Structure	Maintenance/Inspection Task	Frequency
Drainage Lines	Inspect to ensure line is flowing and not blocked and is not cracked. Repair cracks if necessary.	Every 5 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 ground maintenance and following each significant rainfall event.
Retaining Walls and Detention Structure	Inspect walls for deviation from as-constructed condition.	Every 5 years or following each significant rainfall event.
General slopes	Inspect for possible tension cracks	Every 2 years or following each significant rainfall event.

10. Summary

A geotechnical investigation and stability assessment has been carried out to assess the geotechnical requirements for development of the steep hillside in the northern part of the site. The investigation comprised borehole drilling and test pitting to further define the subsurface soil, rock and groundwater conditions.

The steep hillside is mantled by a relatively thin blanket of colluvium from past slope instability while the toe of the hillside typically has a considerable depth of accumulated colluvium. The measurement of groundwater levels has been carried out following an extended period of below average rainfall. Nevertheless, groundwater was identified within areas of previously seepage in the lower hillside.

Slope stability modelling indicated that while the steep slopes currently have a marginal factor of safety, following an extended period of wet weather and saturation of site soils, further slope instability is likely. Modelling was also carried out following the implementation of hazard reduction and precautionary works including the installation of subsurface drainage, to lower groundwater levels and reduce pore water pressures, and the removal and/or the replacement of movement-affected soils. The modelling indicated that an acceptable factor of safety and tolerable risk to property of slope instability can be achieved.

It is considered that provided remedial works are carried out in accordance with the recommendations of this report and with good practice for hillside construction, that the steep hillside in the northern part of the site can be developed.

11. References

AGS (2007), *Practice Note Guidelines for Landslide Risk Assessment*, Australian Geomechanics Society Landslide Taskforce, Australian Geomechanics, Vol 42, No 1.

DP (2018), Report on Preliminary Geotechnical Investigation, Proposed Residential Subdivision, 141 Yarrawa Road and 32 Lovelle Street, Moss Vale, Douglas Partners Pty Ltd, Project 40494.01.R.001.Rev1.

HS (2006), Soil, Groundwater, Agricultural Capability, Geotechnical Classification, Mineral Potential and Preliminary Contamination Report for the Proposed “Chelsea Gardens Development Site”, Harvest Scientific Services, Job Reference 200677.

NSW DECC (2008) *Soil and Land Resources of the Hawkesbury-Nepean Catchment*, Natural Resources Information Unit, Department of Environment and Climate Change NSW, Parramatta.

NSW DISRD (2016) *Moss Vale 1:100 000 Geological Sheet 8928*, Geological Survey, NSW Department of Industry, Skills and Regional Development.

AS 2870:2011, *Residential Slabs and Footings*, Standards Australia.

AS 3798:2007, *Guidelines for Earthworks for Commercial and Residential Developments*, Standards Australia.

12. Limitations

Douglas Partners (DP) has prepared this report for this project at 32 Lovelle Street and 141 Yarrawa Road, Moss Vale in accordance with DP's proposal WOL190315.P.001.Rev0 dated 4 October 2019 and acceptance received from Prime Moss Vale Pty Ltd dated 14 October 2019. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Prime Moss Vale Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or be relied upon for other projects or purposes on the same or another site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

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

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

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

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

The scope for work for this investigation/report did not include the assessment of surface or sub-surface materials or groundwater for contaminants, within or adjacent to the site. Should evidence of filling of unknown origin be noted in the report, and in particular the presence of building demolition materials, it should be recognised that there may be some risk that such filling may contain contaminants and hazardous building materials.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires a risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life. This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report

Introduction

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

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

Copyright

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

Borehole and Test Pit Logs

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

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

Groundwater

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

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

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

Reports

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

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

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

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

Site Anomalies

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

Information for Contractual Purposes

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

Site Inspection

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

Sampling

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

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

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

Test Pits

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

Large Diameter Augers

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

Continuous Spiral Flight Augers

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

Non-core Rotary Drilling

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

Continuous Core Drilling

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

Standard Penetration Tests

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

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

The test results are reported in the following form.

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

  4,6,7
  N=13

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

  15, 30/40 mm

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

Dynamic Cone Penetrometer Tests / Perth Sand Penetrometer Tests

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

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

Soil Descriptions

Description and Classification Methods

The methods of description and classification of soils and rocks used in this report are based on Australian Standard AS 1726-1993, Geotechnical Site Investigations Code. In general, the descriptions include strength or density, colour, structure, soil or rock type and inclusions.

Soil Types

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

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

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

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

The proportions of secondary constituents of soils are described as:

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

Definitions of grading terms used are:

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

Cohesive Soils

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

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

Cohesionless Soils

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

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

Soil Descriptions

Soil Origin

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

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

Transported soils may be further subdivided into:

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

Rock Descriptions

Rock Strength

Rock strength is defined by the Point Load Strength Index ($Is_{(50)}$) and refers to the strength of the rock substance and not the strength of the overall rock mass, which may be considerably weaker due to defects. The test procedure is described by Australian Standard 4133.4.1 - 2007. The terms used to describe rock strength are as follows:

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

* Assumes a ratio of 20:1 for UCS to $Is_{(50).}$ It should be noted that the UCS to $Is_{(50)}$ ratio varies significantly for different rock types and specific ratios should be determined for each site.

Degree of Weathering

The degree of weathering of rock is classified as follows:

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

Degree of Fracturing

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

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

Rock Descriptions

Rock Quality Designation

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

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

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

Stratification Spacing

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

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

Symbols & Abbreviations

Introduction

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

Drilling or Excavation Methods

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

Water

▷	Water seep
▽	Water level

Sampling and Testing

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

Description of Defects in Rock

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

Defect Type

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

Orientation

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

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

Coating or Infilling Term

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

Coating Descriptor

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

Shape

cu	curved
ir	irregular
pl	planar
st	stepped
un	undulating

Roughness

po	polished
ro	rough
sl	slickensided
sm	smooth
vr	very rough

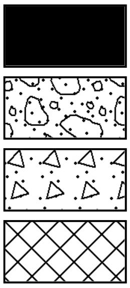
Other

fg	fragmented
bnd	band
qtz	quartz

Symbols & Abbreviations

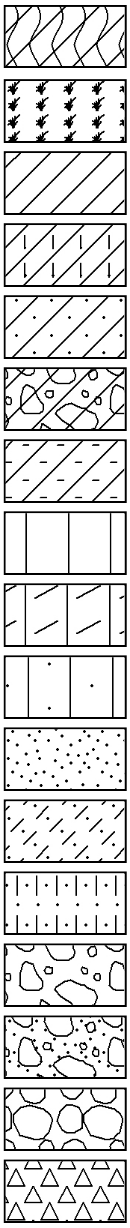
Graphic Symbols for Soil and Rock

General



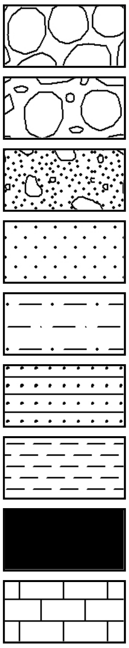
- Asphalt
- Road base
- Concrete
- Filling

Soils



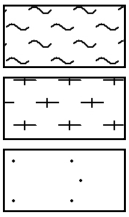
- Topsoil
- Peat
- Clay
- Silty clay
- Sandy clay
- Gravelly clay
- Shaly clay
- Silt
- Clayey silt
- Sandy silt
- Sand
- Clayey sand
- Silty sand
- Gravel
- Sandy gravel
- Cobbles, boulders
- Talus

Sedimentary Rocks



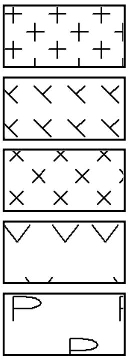
- Boulder conglomerate
- Conglomerate
- Conglomeratic sandstone
- Sandstone
- Siltstone
- Laminite
- Mudstone, claystone, shale
- Coal
- Limestone

Metamorphic Rocks



- Slate, phyllite, schist
- Gneiss
- Quartzite

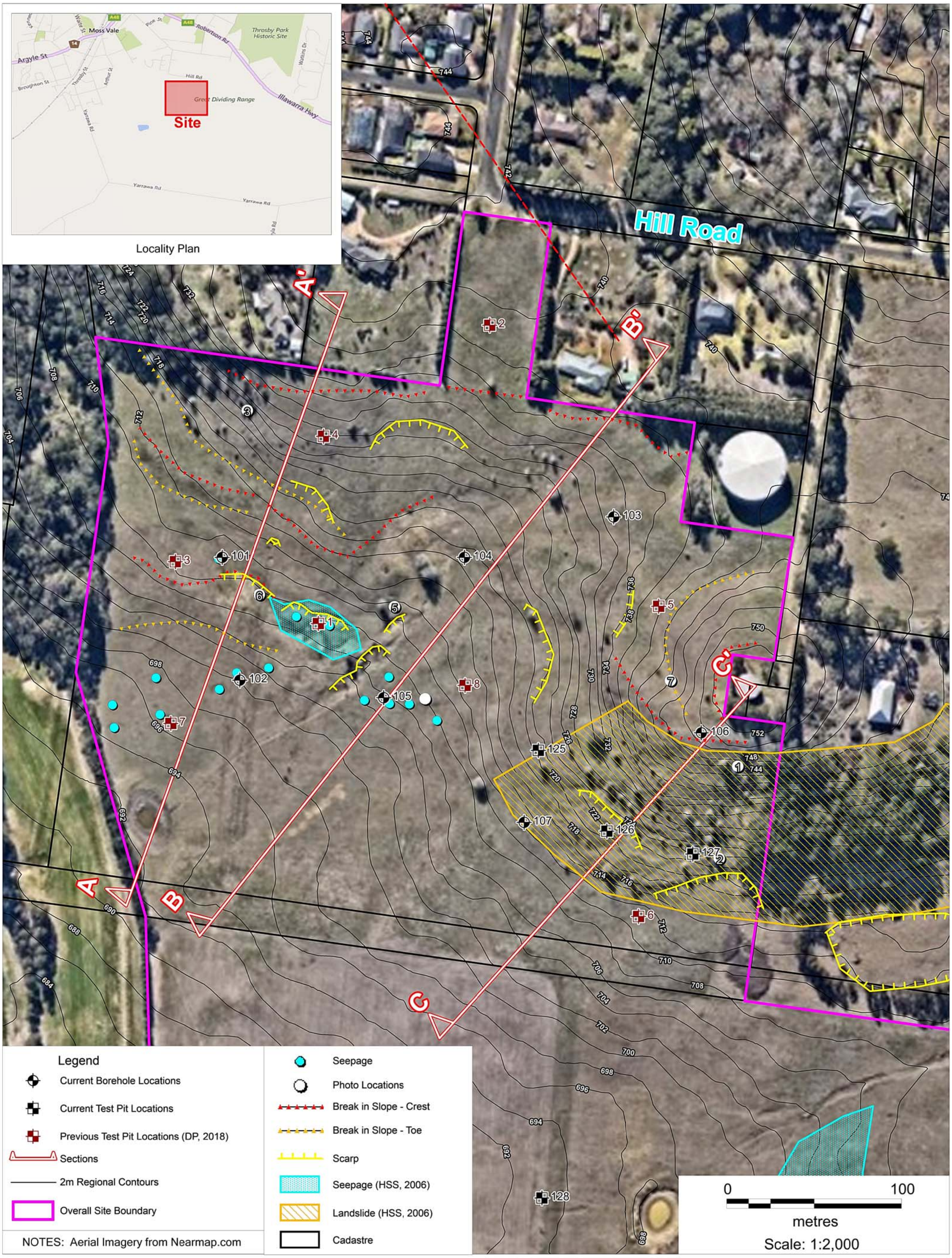
Igneous Rocks



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

Appendix B

Drawing 1 - 11
Results of Current Field Work (Bores 101 – 107 & Pits 125 – 128)
Results of Previous Field Work (Pits 1 – 8 & 22)
Photos 1 – 7 (Plates 1 – 2)



Legend

⊕	Current Borehole Locations	●	Seepage
▣	Current Test Pit Locations	○	Photo Locations
▣	Previous Test Pit Locations (DP, 2018)	▲▲▲	Break in Slope - Crest
⊓	Sections	▲▲▲	Break in Slope - Toe
—	2m Regional Contours	⊥⊥⊥	Scarp
☐	Overall Site Boundary	▨	Seepage (HSS, 2006)
		▨	Landslide (HSS, 2006)
		☐	Cadastre

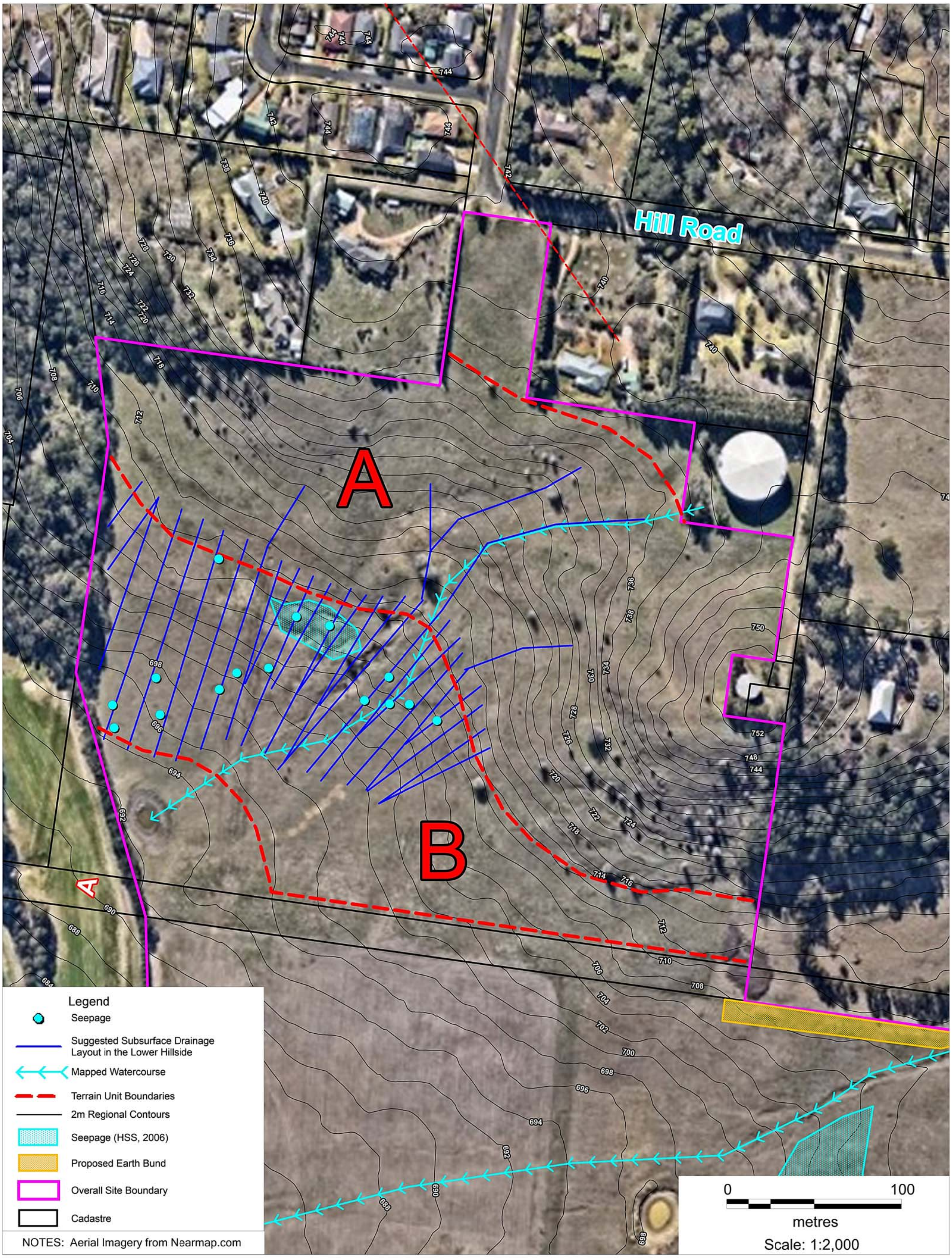
NOTES: Aerial Imagery from Nearmap.com

0 100
metres
Scale: 1:2,000

Douglas Partners
Geotechnics / Environment / Groundwater

TITLE: **Test Locations - Steep Hillside** **Proposed Residential Subdivision** **32 Lovelle St & 141 Yarrawa Rd, Moss Vale**	N MGA	OFFICE: Wollongong DRAWN BY: RJH DATE: 06 Dec 2019

CLIENT: Prime Moss Vale Pty Ltd	PROJECT No: 40494.03	DRAWING No: 1	REVISION: 0	SCALE: 1:2000 @ A3



NOTES: Aerial Imagery from Nearmap.com

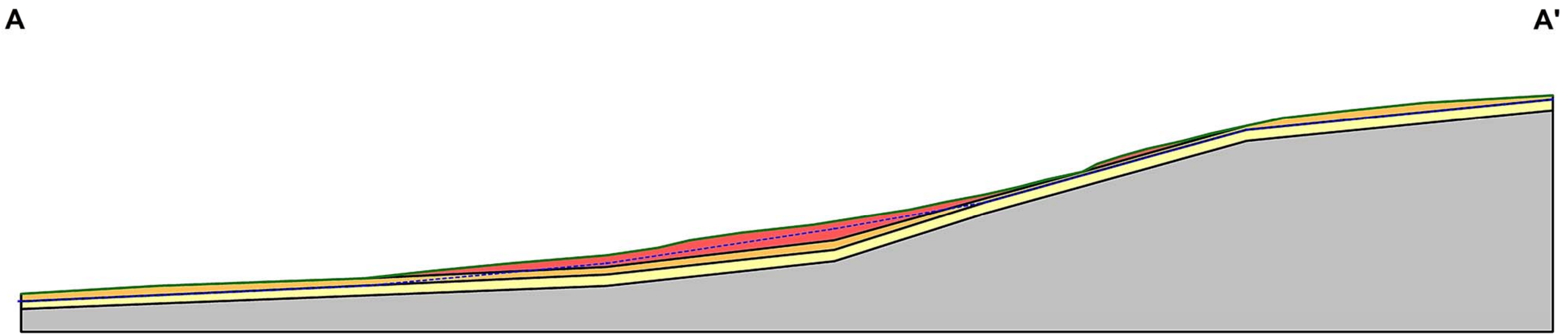
Douglas Partners
Geotechnics | Environment | Groundwater

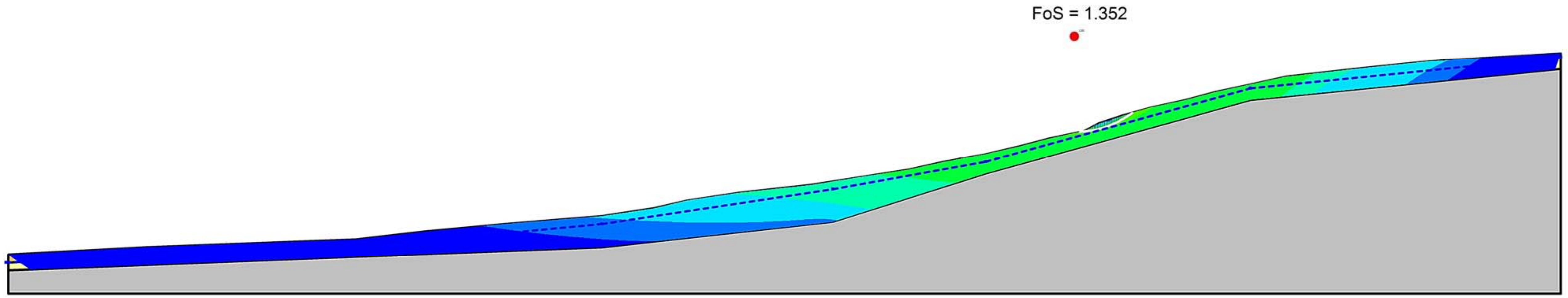
TITLE: **Terrain Units & Remedial Works**
Proposed Residential Subdivision
32 Lovelle St & 141 Yarrawa Rd, Moss Vale

N
MGA

OFFICE: Wollongong
DRAWN BY: RJH
DATE: 06 Dec 2019

CLIENT: Prime Moss Vale Pty Ltd
PROJECT No: 40494.03
DRAWING No: 2
REVISION: 0
SCALE: 1:2000 @ A3





Factor of Safety

🟥	≤ 0.900 - 1.000
🟧	1.000 - 1.100
🟨	1.100 - 1.200
🟩	1.200 - 1.300
🟩	1.300 - 1.400
🟩	1.400 - 1.500
🟩	1.500 - 1.600
🟦	1.600 - 1.700
🟦	1.700 - 1.800
🟦	≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	2	20	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	2	20	1
🟨	VL-L Rock	Mohr-Coulomb	22	10	20	1

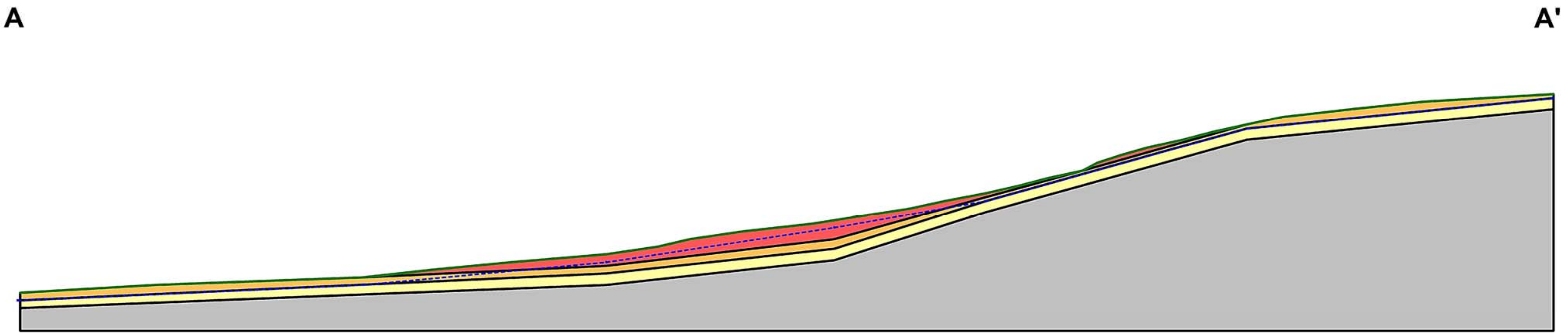
NOTE: Refer Drawing 1 for Location of Section A - A'

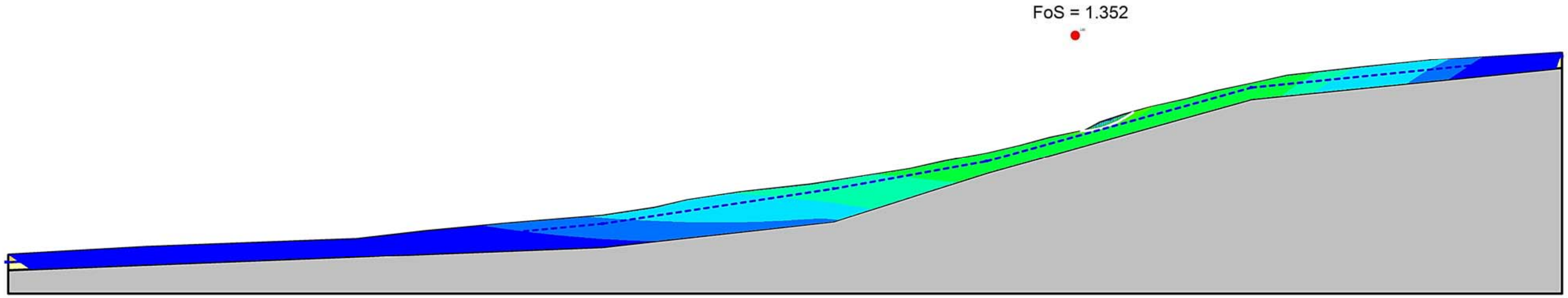
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:1200 @ A3
DATE: 28 Nov 2019

TITLE: **Stabilty Analysis: Section A - Model and Baseline**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 2
REVISION: 0





Factor of Safety
- 🟥 ≤ 0.900 - 1.000
- 🟧 1.000 - 1.100
- 🟨 1.100 - 1.200
- 🟩 1.200 - 1.300
- 🟩 1.300 - 1.400
- 🟩 1.400 - 1.500
- 🟩 1.500 - 1.600
- 🟦 1.600 - 1.700
- 🟦 1.700 - 1.800
- 🟦 ≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	2	20	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	2	20	1
🟨	VL-L Rock	Mohr-Coulomb	22	10	20	1

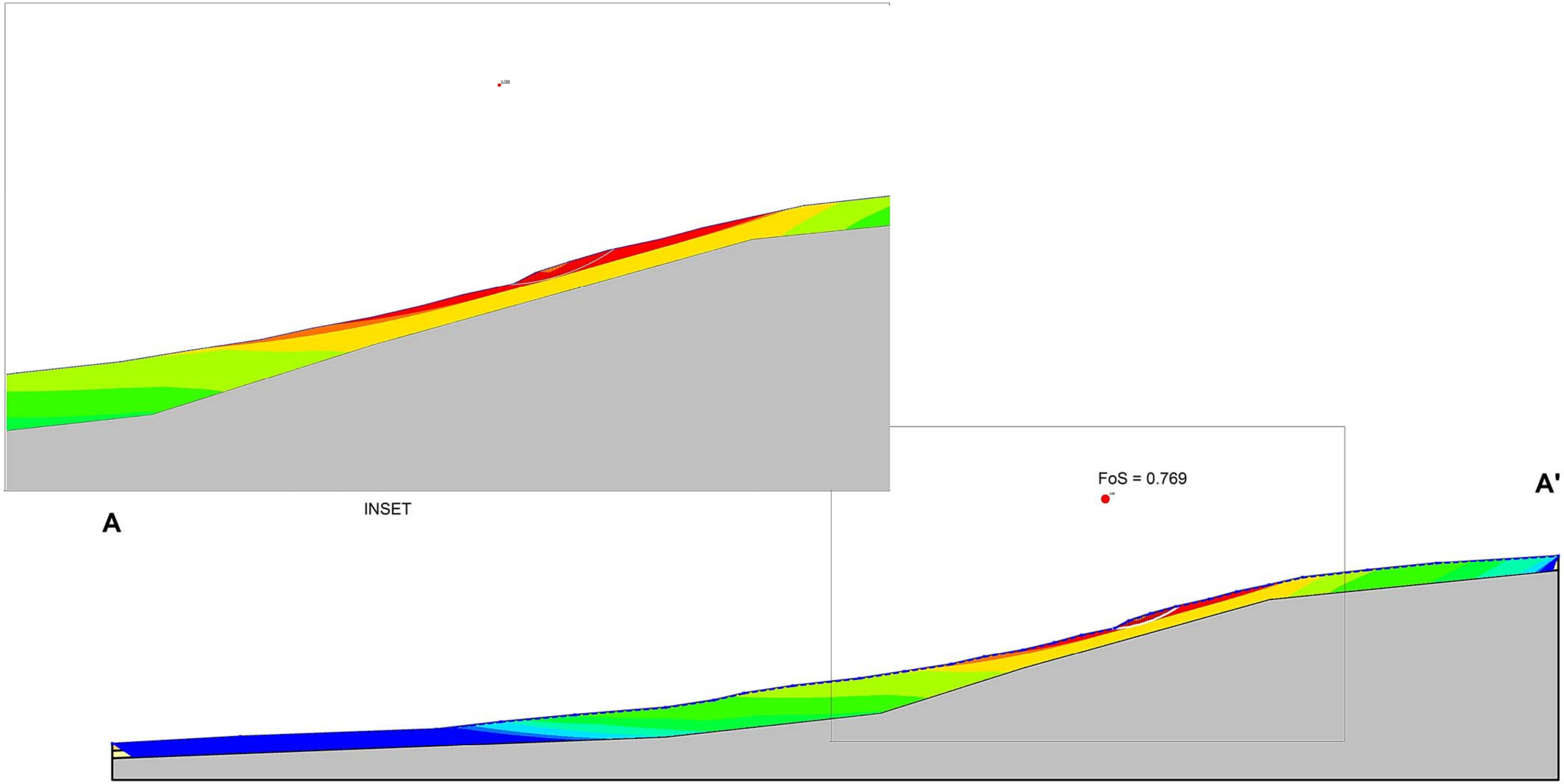
NOTE: Refer Drawing 1 for Location of Section A - A'

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:1200 @ A3
DATE: 28 Nov 2019

TITLE: **Stabilty Analysis: Section A - Model and Baseline**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 3
REVISION: 0



Factor of Safety

🟥	≤ 0.900 - 1.000
🟧	1.000 - 1.100
🟨	1.100 - 1.200
🟩	1.200 - 1.300
🟩	1.300 - 1.400
🟩	1.400 - 1.500
🟩	1.500 - 1.600
🟦	1.600 - 1.700
🟦	1.700 - 1.800
🟦	≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	2	20	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	2	20	1
🟨	VL-L Rock	Mohr-Coulomb	22	10	20	1

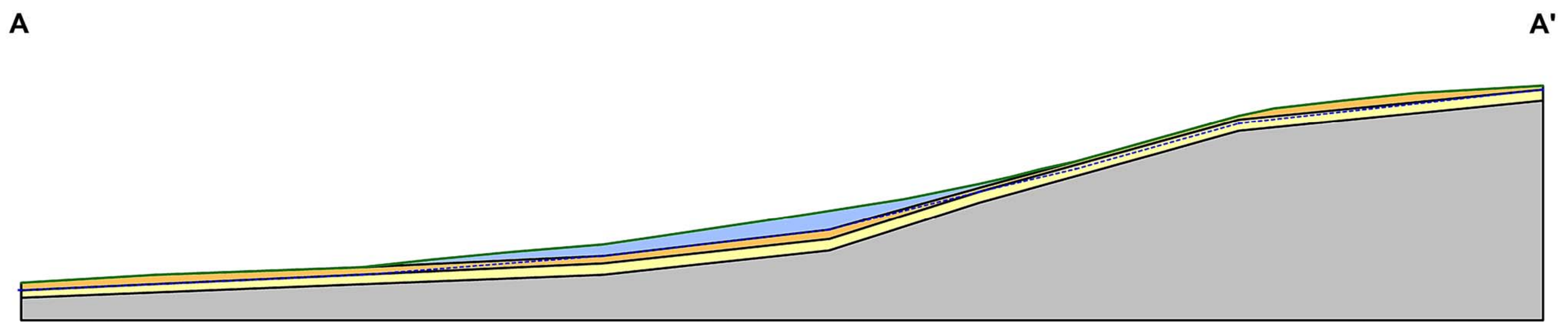
NOTE: Refer Drawing 1 for Location of Section A - A'

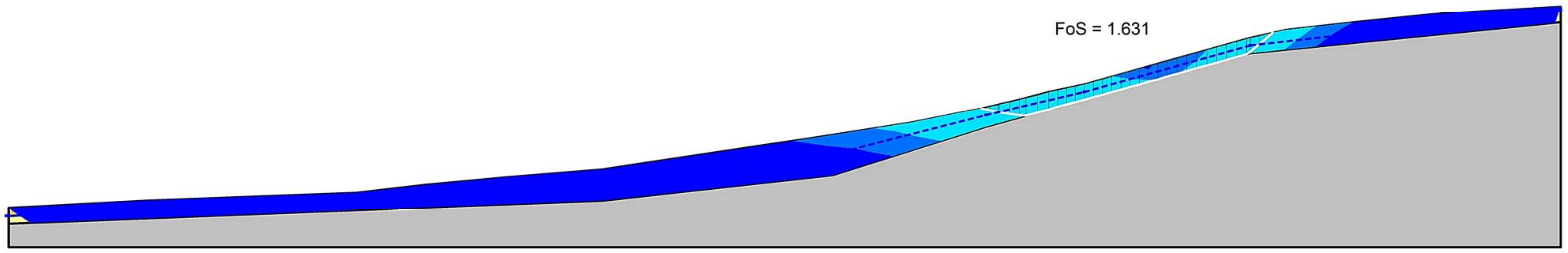
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:1200 @ A3
DATE: 28 Nov 2019

TITLE: **Stabilty Analysis: Section A - Raised Water Level**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 4
REVISION: 0





Factor of Safety
🟥 ≤ 0.900 - 1.000
🟧 1.000 - 1.100
🟨 1.100 - 1.200
🟩 1.200 - 1.300
🟩 1.300 - 1.400
🟩 1.400 - 1.500
🟩 1.500 - 1.600
🟦 1.600 - 1.700
🟦 1.700 - 1.800
🟦 ≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟦	Level 1 Fill	Mohr-Coulomb	20	10	20	1
▩	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	2	20	1
🟨	VL-L Rock	Mohr-Coulomb	22	10	20	1

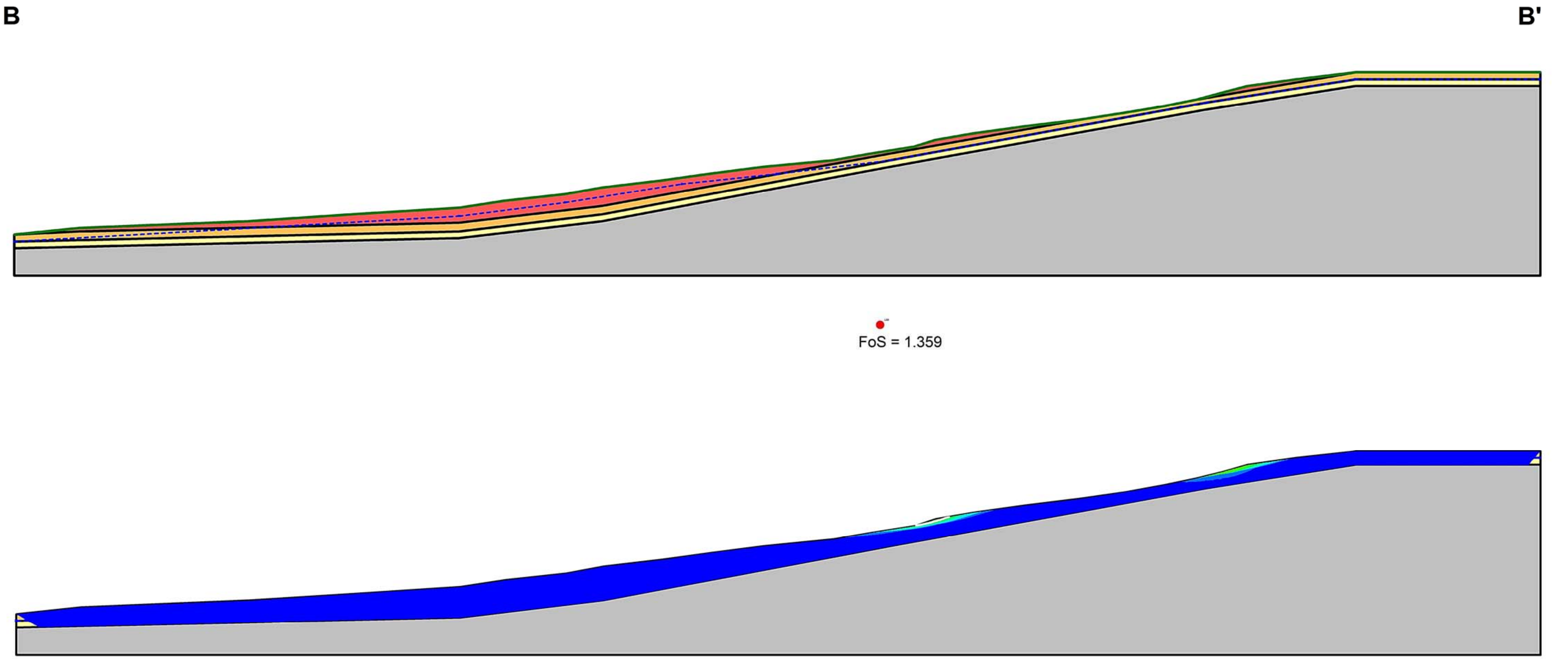
NOTE: Refer Drawing 1 for Location of Section A - A'

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:1200 @ A3
DATE: 04 Dec 2019

TITLE: **Stabilty Analysis: Section A - Remedial Works**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 5
REVISION: 0



Factor of Safety
- 🟥 ≤ 0.900 - 1.000
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- 🟨 1.100 - 1.200
- 🟩 1.200 - 1.300
- 🟩 1.300 - 1.400
- 🟩 1.400 - 1.500
- 🟩 1.500 - 1.600
- 🟦 1.600 - 1.700
- 🟦 1.700 - 1.800
- 🟦 ≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	0	20	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	2	20	1
🟨	VL-L Rock	Mohr-Coulomb	22	10	20	1

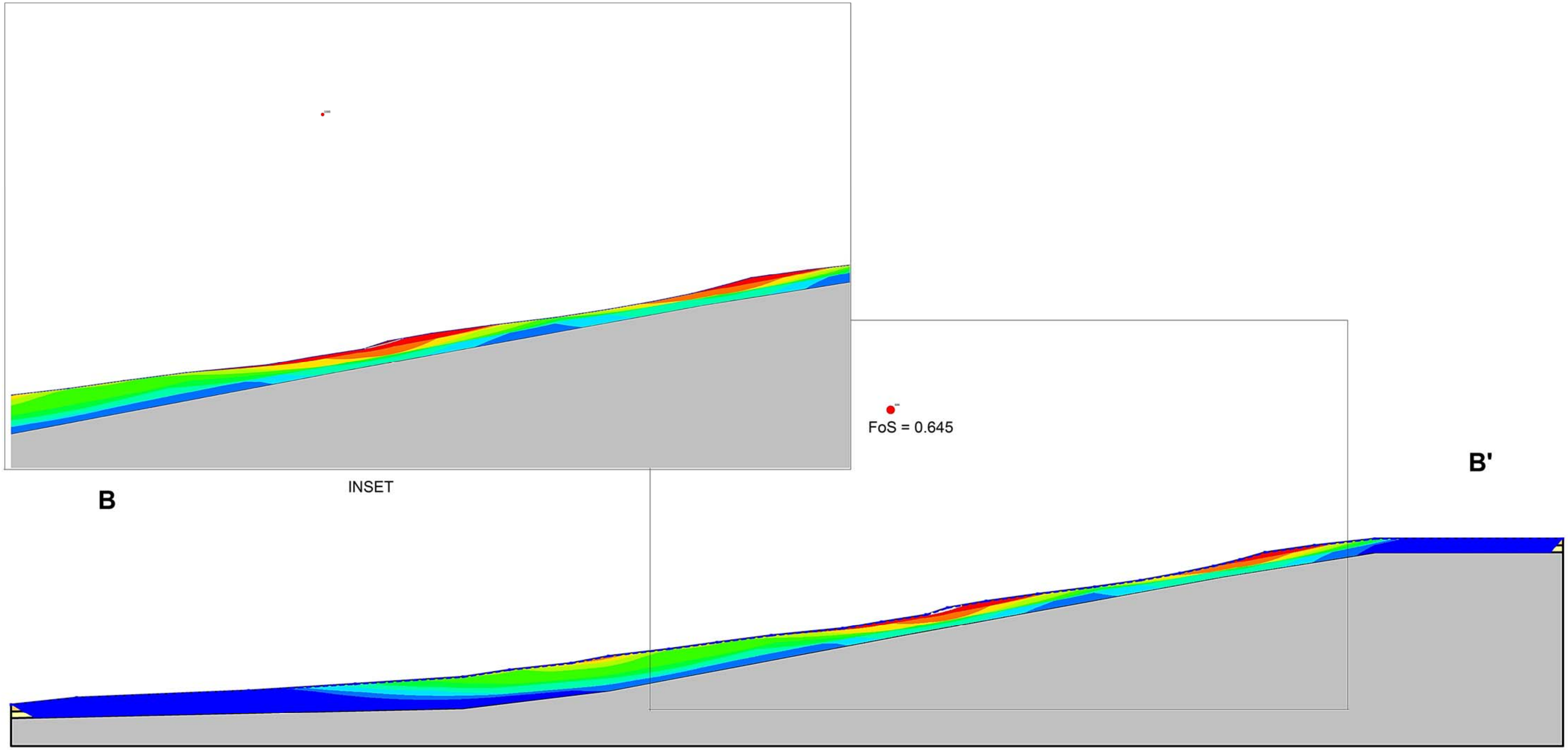
NOTE: Refer Drawing 1 for Location of Section B - B'

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:1200 @ A3
DATE: 27 Nov 2019

TITLE: **Stabilty Analysis: Section B - Model and Baseline**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 6
REVISION: 0



Factor of Safety
- 🟥 ≤ 0.900 - 1.000
- 🟧 1.000 - 1.100
- 🟨 1.100 - 1.200
- 🟩 1.200 - 1.300
- 🟩 1.300 - 1.400
- 🟩 1.400 - 1.500
- 🟩 1.500 - 1.600
- 🟦 1.600 - 1.700
- 🟦 1.700 - 1.800
- 🟦 ≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	0	20	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	2	20	1
🟨	VL-L Rock	Mohr-Coulomb	22	10	20	1

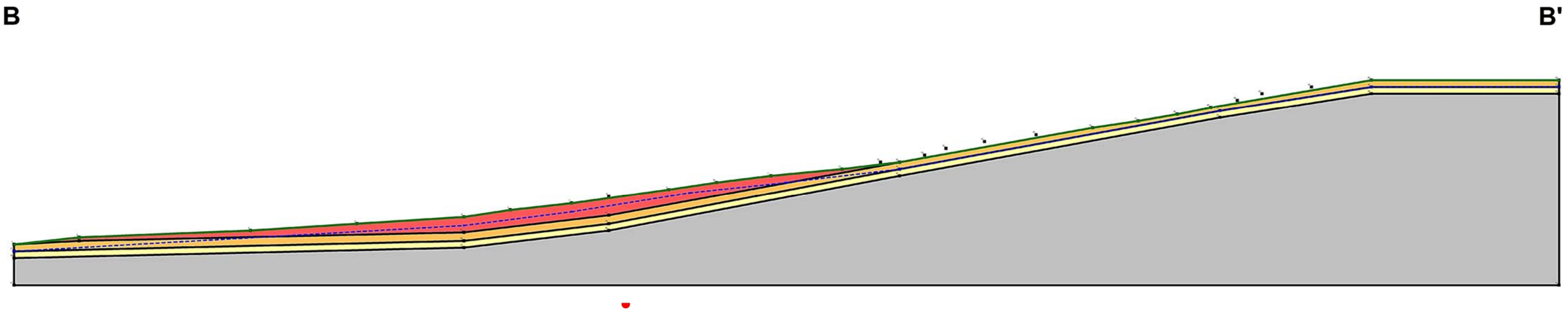
NOTE: Refer Drawing 1 for Location of Section B - B'

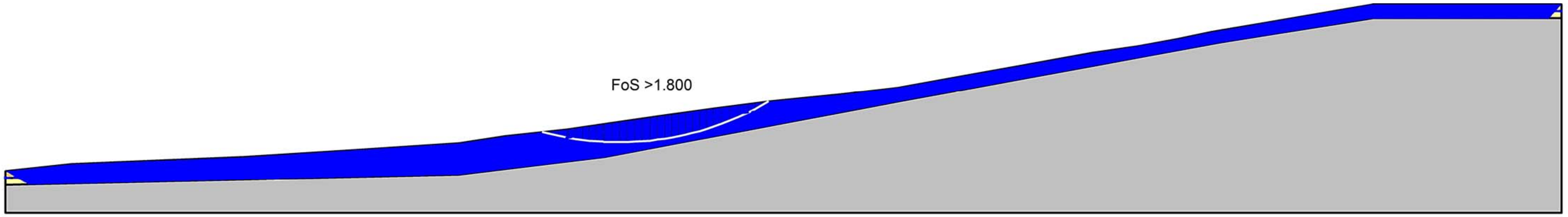
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:1200 @ A3
DATE: 28 Nov 2019

TITLE: **Stabilty Analysis: Section B - Raised Water Level**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 7
REVISION: 0





Factor of Safety
- 🟥 ≤ 0.900 - 1.000
- 🟧 1.000 - 1.100
- 🟨 1.100 - 1.200
- 🟩 1.200 - 1.300
- 🟩 1.300 - 1.400
- 🟩 1.400 - 1.500
- 🟩 1.500 - 1.600
- 🟦 1.600 - 1.700
- 🟦 1.700 - 1.800
- 🟦 ≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	0	20	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	2	20	1
🟨	VL-L Rock	Mohr-Coulomb	22	10	20	1

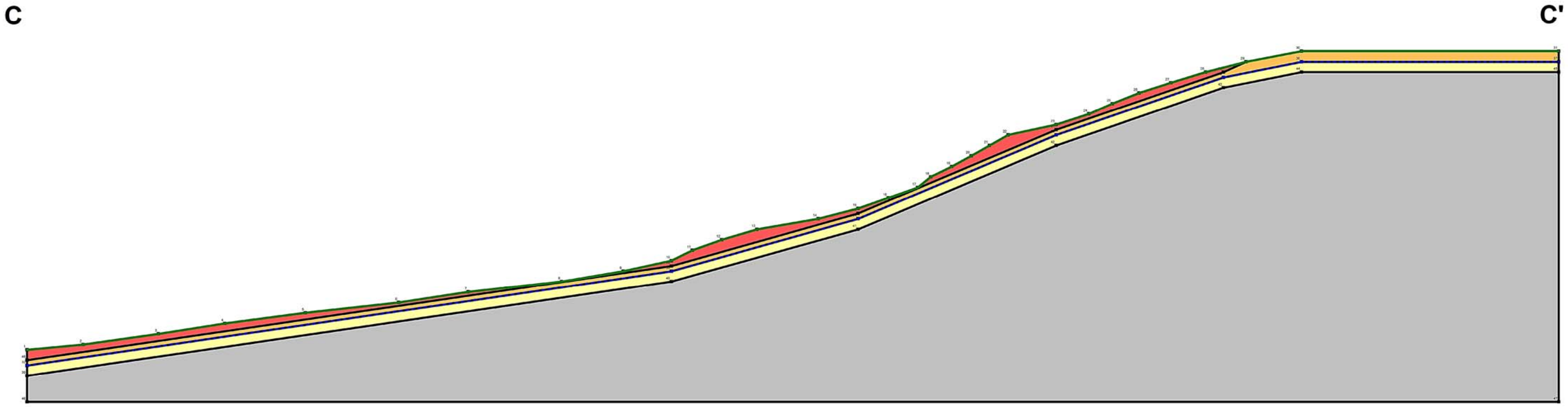
NOTE: Refer Drawing 1 for Location of Section B - B'

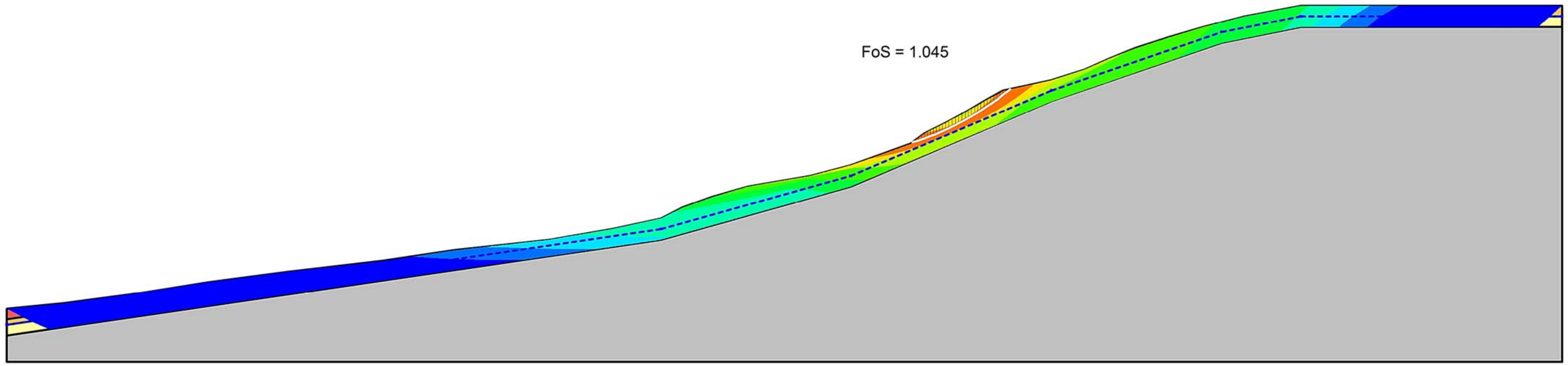
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:1200 @ A3
DATE: 05 Dec 2019

TITLE: **Stabilty Analysis: Section B - Remediated**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 8
REVISION: 0





Factor of Safety

■	≤ 0.900 - 1.000
■	1.000 - 1.100
■	1.100 - 1.200
■	1.200 - 1.300
■	1.300 - 1.400
■	1.400 - 1.500
■	1.500 - 1.600
■	1.600 - 1.700
■	1.700 - 1.800
■	≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	2	24	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	3	24	1
🟨	VL-L Rock	Mohr-Coulomb	22	20	20	1

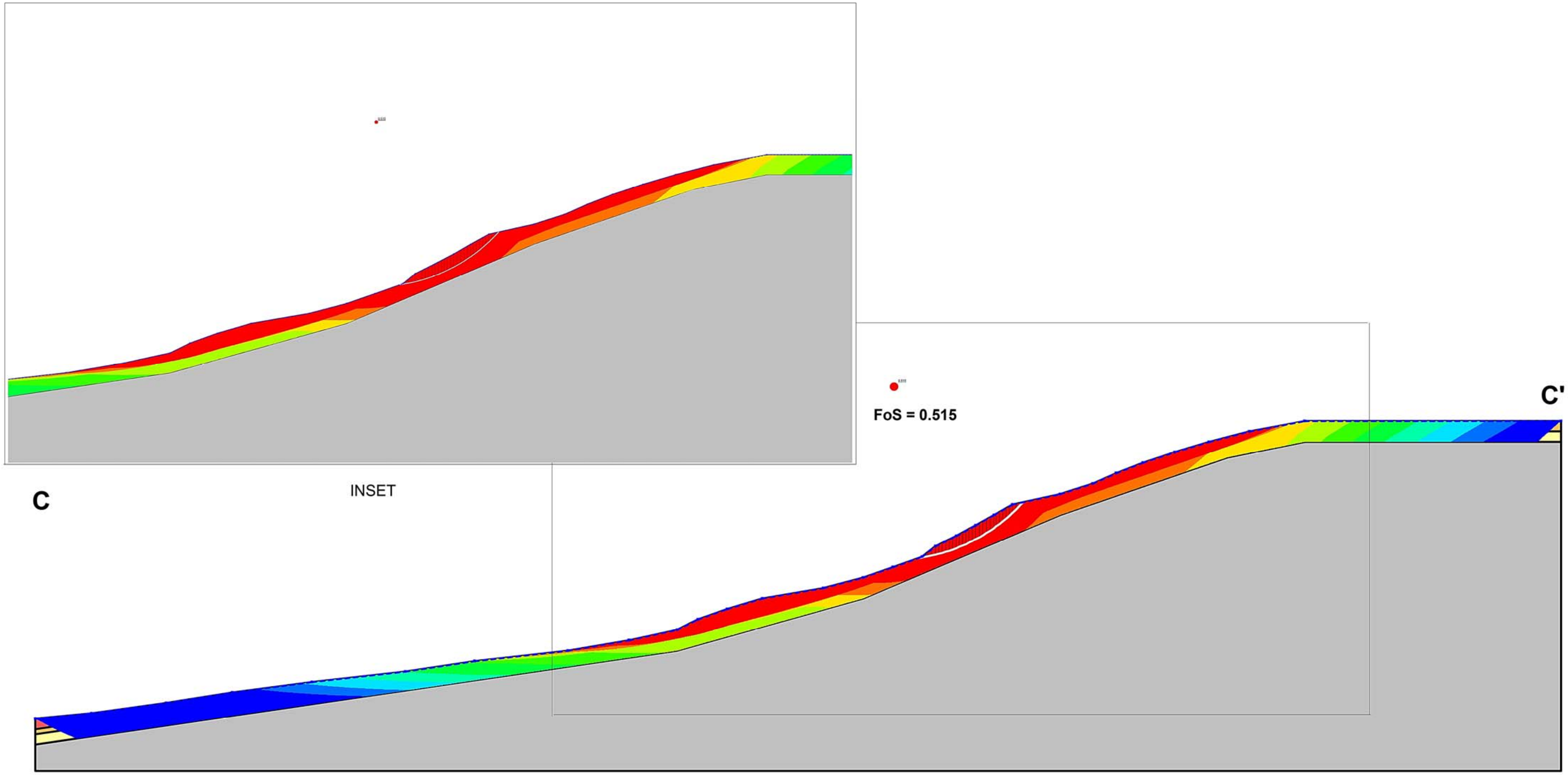
NOTE: Refer Drawing 1 for Location of Section C - C'

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:800 @ A3
DATE: 26 Nov 2019

TITLE: **Stabilty Analysis: Section C - Model and Baseline**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 9
REVISION: 0



Factor of Safety

🟥	≤ 0.900 - 1.000
🟧	1.000 - 1.100
🟨	1.100 - 1.200
🟩	1.200 - 1.300
🟩	1.300 - 1.400
🟩	1.400 - 1.500
🟩	1.500 - 1.600
🟦	1.600 - 1.700
🟦	1.700 - 1.800
🟦	≥ 1.800

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	2	24	1
⬜	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	3	24	1
🟨	VL-L Rock	Mohr-Coulomb	22	20	20	1

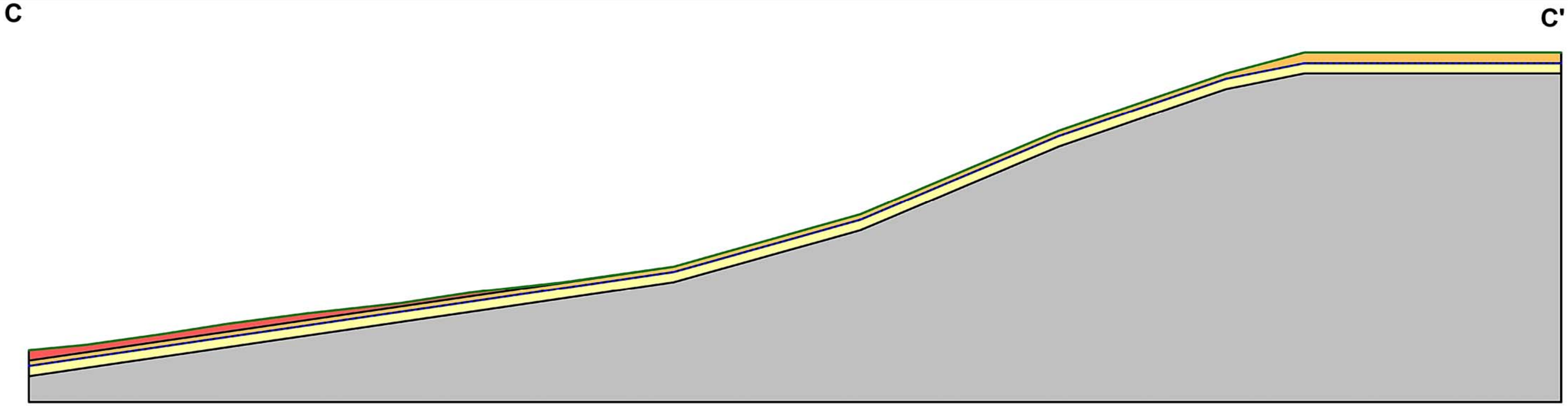
NOTE: **Refer Drawing 1 for Location of Section C - C'**

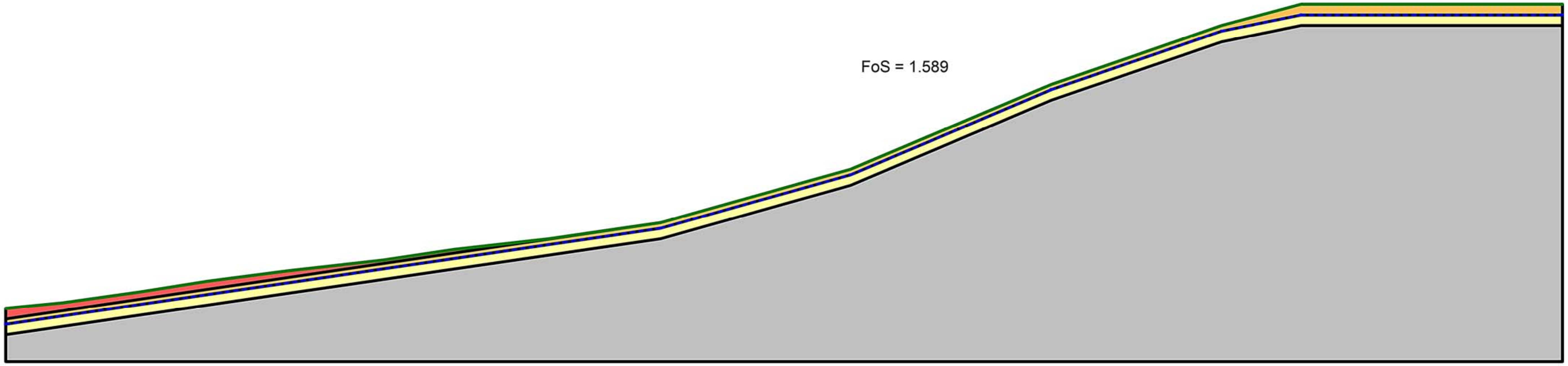
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:800 @ A3
DATE: 28 Nov 2019

TITLE: **Stabilty Analysis: Section C - Raised Water Level**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 10
REVISION: 0





Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Piezometric Line
🟥	Colluvium	Mohr-Coulomb	20	2	24	1
▨	M or better Rock	Bedrock (Impenetrable)				1
🟧	Residual Clay	Mohr-Coulomb	20	3	24	1
🟨	VL-L Rock	Mohr-Coulomb	22	20	20	1

NOTE: Refer Drawing 1 for Location of Section C - C'

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: 1:800 @ A3
DATE: 06 Dec 2019

TITLE: **Stabilty Analysis: Section C - Remedial Works**
Proposed Residentual Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
DRAWING No: 11
REVISION: 0

DOUGLAS PARTNERS PTY LTD
PROPOSED RESIDENTIAL SUBDIVISION
32 LOVELLE STREET & 141 YARRAWA ROAD, MOSS VALE

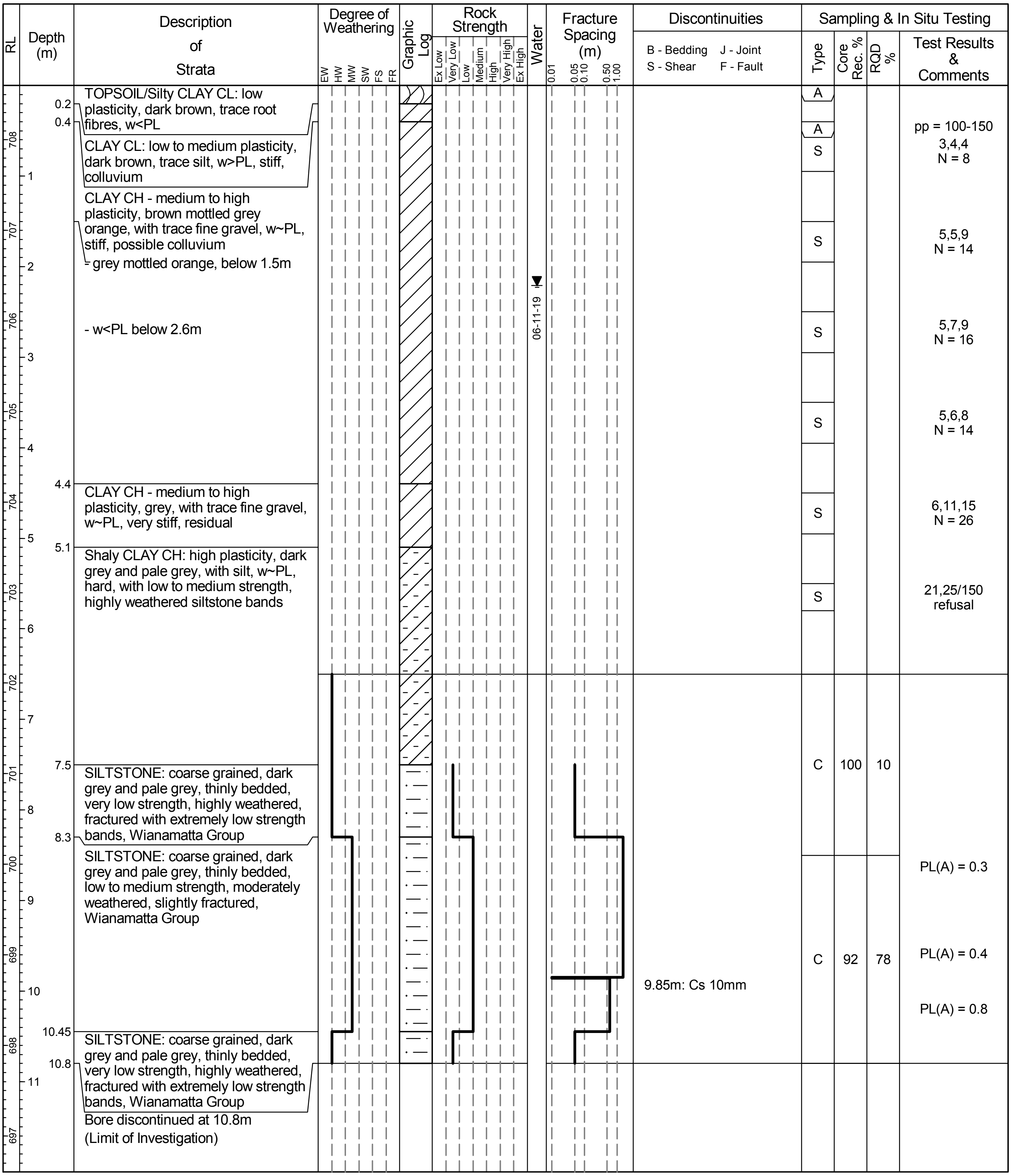
BORE: 101 DEPTH: 6.50 – 11.00 m PROJECT: 40494.03 Oct 2019

BOREHOLE LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 708.6 AHD
EASTING: 259542
NORTHING: 6172772
DIP/AZIMUTH: 90°/--

BORE No: 101
PROJECT No: 40494.03
DATE: 24/10/2019
SHEET 1 OF 1



Depth (m)	Description of Strata	Water	Discontinuities	Type	Core Rec. %	RQD %	Test Results & Comments
				A			
0.2	TOPSOIL/Silty CLAY CL: low plasticity, dark brown, trace root fibres, w<PL						
0.4	CLAY CL: low to medium plasticity, dark brown, trace silt, w>PL, stiff, colluvium			A			pp = 100-150
				S			3,4,4 N = 8
	CLAY CH - medium to high plasticity, brown mottled grey orange, with trace fine gravel, w~PL, stiff, possible colluvium - grey mottled orange, below 1.5m			S			5,5,9 N = 14
		06-11-19					
	- w<PL below 2.6m			S			5,7,9 N = 16
				S			5,6,8 N = 14
4.4	CLAY CH - medium to high plasticity, grey, with trace fine gravel, w~PL, very stiff, residual			S			6,11,15 N = 26
5.1	Shaly CLAY CH: high plasticity, dark grey and pale grey, with silt, w~PL, hard, with low to medium strength, highly weathered siltstone bands			S			21,25/150 refusal
7.5	SILTSTONE: coarse grained, dark grey and pale grey, thinly bedded, very low strength, highly weathered, fractured with extremely low strength bands, Wianamatta Group			C	100	10	
8.3	SILTSTONE: coarse grained, dark grey and pale grey, thinly bedded, low to medium strength, moderately weathered, slightly fractured, Wianamatta Group						PL(A) = 0.3
				C	92	78	PL(A) = 0.4
			9.85m: Cs 10mm				PL(A) = 0.8
10.45	SILTSTONE: coarse grained, dark grey and pale grey, thinly bedded, very low strength, highly weathered, fractured with extremely low strength bands, Wianamatta Group						
10.8	Bore discontinued at 10.8m (Limit of Investigation)						

RIG: Hanjin **DRILLER:** Total Drilling **LOGGED:** FH/IKA **CASING:** HWT to 5.6m

TYPE OF BORING: 110mm solid flight auger 'TC bit' to 5.8m, coring 'NMLC' from 6.5m to 10.8m

WATER OBSERVATIONS: Groundwater observed between 4.0m and 4.5m during drilling

REMARKS: Location coordinates are in MGA94 Zone 56.

SAMPLING & IN SITU TESTING LEGEND

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

Douglas Partners
Geotechnics / Environment / Groundwater

DOUGLAS PARTNERS PTY LTD
PROPOSED RESIDENTIAL SUBDIVISION
32 LOVELLE STREET & 141 YARRAWA ROAD, MOSS VALE

BORE: 102 DEPTH: 4.55 – 7.50 m PROJECT: 40494.03 Oct 2019

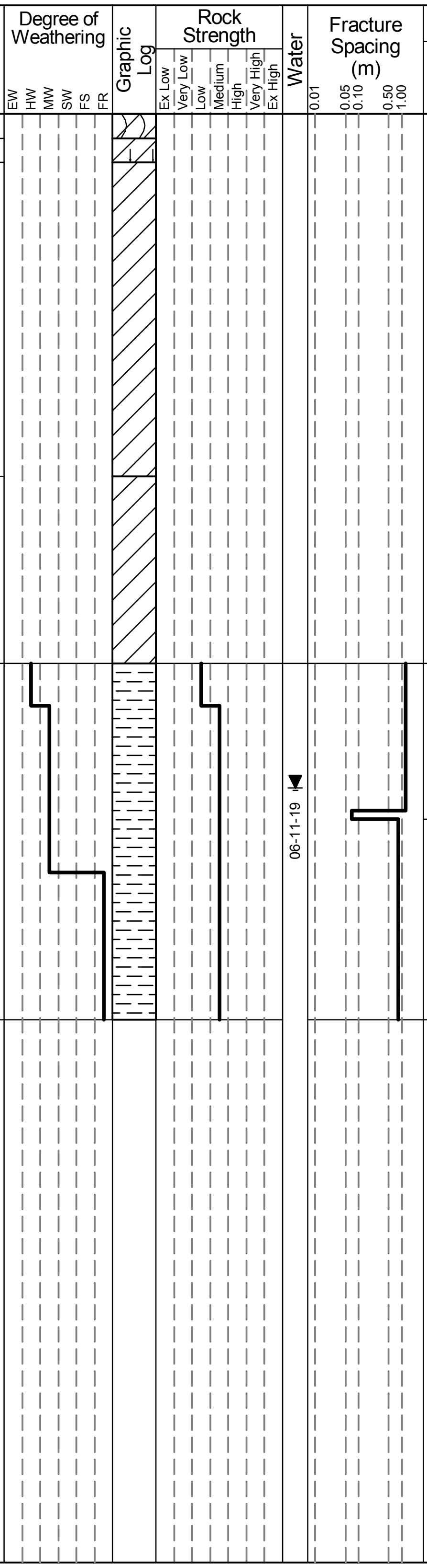
BOREHOLE LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 700.5 AHD
EASTING: 259552
NORTHING: 6172702
DIP/AZIMUTH: 90°/--

BORE No: 102
PROJECT No: 40494.03
DATE: 24/10/2019
SHEET 1 OF 1

Depth (m)	Description of Strata	Discontinuities	Type	Core Rec. %	RQD %	Test Results & Comments
0.2	TOPSOIL/Silty CLAY CL - low plasticity, dark brown, with root fibres, w<PL		A			
0.4	Silty CLAY CL: low to medium plasticity, brown mottled dark brown, trace root fibres, hard, colluvium		A			
			S			pp = 500 4,5,7 N = 12
	CLAY CL - medium to high plasticity, brown, trace fine gravel, stiff, probable colluvium - brown mottled orange below 1.5m		S			4,6,9 N = 15
	- very stiff, trace fine sand below 2.5m		S			5,10,11 N = 21
3.0	CLAY CL - medium to high plasticity, grey mottled orange, trace fine gravel, very stiff, residual		S			7,11,17 N = 28
4.55	SHALE - fine grained, brown, thinly laminated to laminated, low strength then medium strength, highly then moderately weathered, slightly fractured, Wianamatta Group - dark grey and fresh below 6.28m	5.77m: B 0° pl, ro, cly 5.84m: J 75° pl, ro, cln 6.66m: J 65° pl, ro, cln	C	100	72	PL(A) = 0.4 PL(A) = 0.6 PL(A) = 0.9 PL(A) = 0.6
7.5	Bore discontinued at 7.5m (Limit of Investigation)					



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

RL: 700, 699, 698, 697, 696, 695, 694, 693, 692, 691, 690, 689
Depth: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

RIG: Hanjin **DRILLER:** Total Drilling **LOGGED:** FH **CASING:** HWT to 4.6m
TYPE OF BORING: 110mm solid flight auger TC bit from 0.0m to 4.5m, coring 'NMLC' from 4.55m to 7.5m
WATER OBSERVATIONS: No free groundwater observed
REMARKS: Location coordinates are in MGA94 Zone 56.

SAMPLING & IN SITU TESTING LEGEND

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

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DOUGLAS PARTNERS PTY LTD
PROPOSED RESIDENTIAL SUBDIVISION
32 LOVELLE STREET & 141 YARRAWA ROAD, MOSS VALE

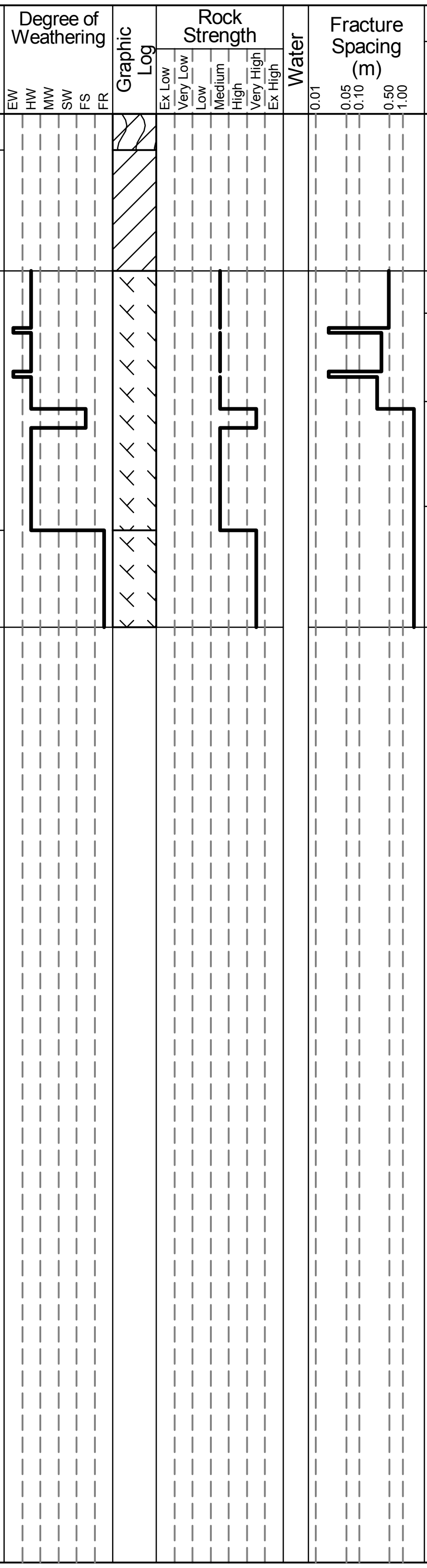
BORE: 103 DEPTH: 1.30 – 4.25 m PROJECT: 40494.03 Oct 2019

BOREHOLE LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 732.1 AHD
EASTING: 259765
NORTHING: 6172795
DIP/AZIMUTH: 90°/--

BORE No: 103
PROJECT No: 40494.03
DATE: 24/10/2019
SHEET 1 OF 1



RL	Depth (m)	Description of Strata	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
732		TOPSOIL/Silty CLAY CL: low plasticity, dark brown, trace root fibres, w<PL		A			
731	0.3 1	CLAY CL: Low to medium plasticity, dark brown mottled brown, w<PL, very stiff, residual - brown mottled orange, trace fine grained sand below 0.5m	Note: Unless otherwise stated rock is fractured along curved, rough, iron stained, healed, joint	A S			pp = 350 18,25/100 refusal
730 729	1.3 2 3	DOLERITE: medium to coarse grained, dark grey, green and pale grey, medium strength, highly weathered, slightly fractured, Jurassic Volcanics	1.43m: 2J 25-35° discing 1.65m: J 80-85° 1.95m: J 80-85° 2.25m: 2J 15-25° 2.38m: J 75-80° 2.64m: 2J 75-85° 3.06m: 2J 85-90° discing 3.25m: J 75°	C C	100 100	92 96	PL(A) = 0.5 PL(A) = 0.4
728	3.45 4	DOLERITE: medium to coarse grained, pale grey, very high strength, fresh, slightly fractured, Jurassic Volcanics	3.65m: J 65°	C	100	100	PL(A) = 7.4
	4.25	Bore discontinued at 4.25m (Limit of Investigation)					
727	5						
726	6						
725	7						
724	8						
723	9						
722	10						
721	11						

RIG: Hanjin **DRILLER:** Total Drilling **LOGGED:** FH **CASING:** HWT to 1.3m

TYPE OF BORING: 110mm solid flight auger TC bit from 0.0m to 1.3m, coring 'NMLC' from 1.3m to 4.25m

WATER OBSERVATIONS: No free groundwater observed

REMARKS: Location coordinates are in MGA94 Zone 56.

SAMPLING & IN SITU TESTING LEGEND

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

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DOUGLAS PARTNERS PTY LTD
PROPOSED RESIDENTIAL SUBDIVISION
32 LOVELLE STREET & 141 YARRAWA ROAD, MOSS VALE

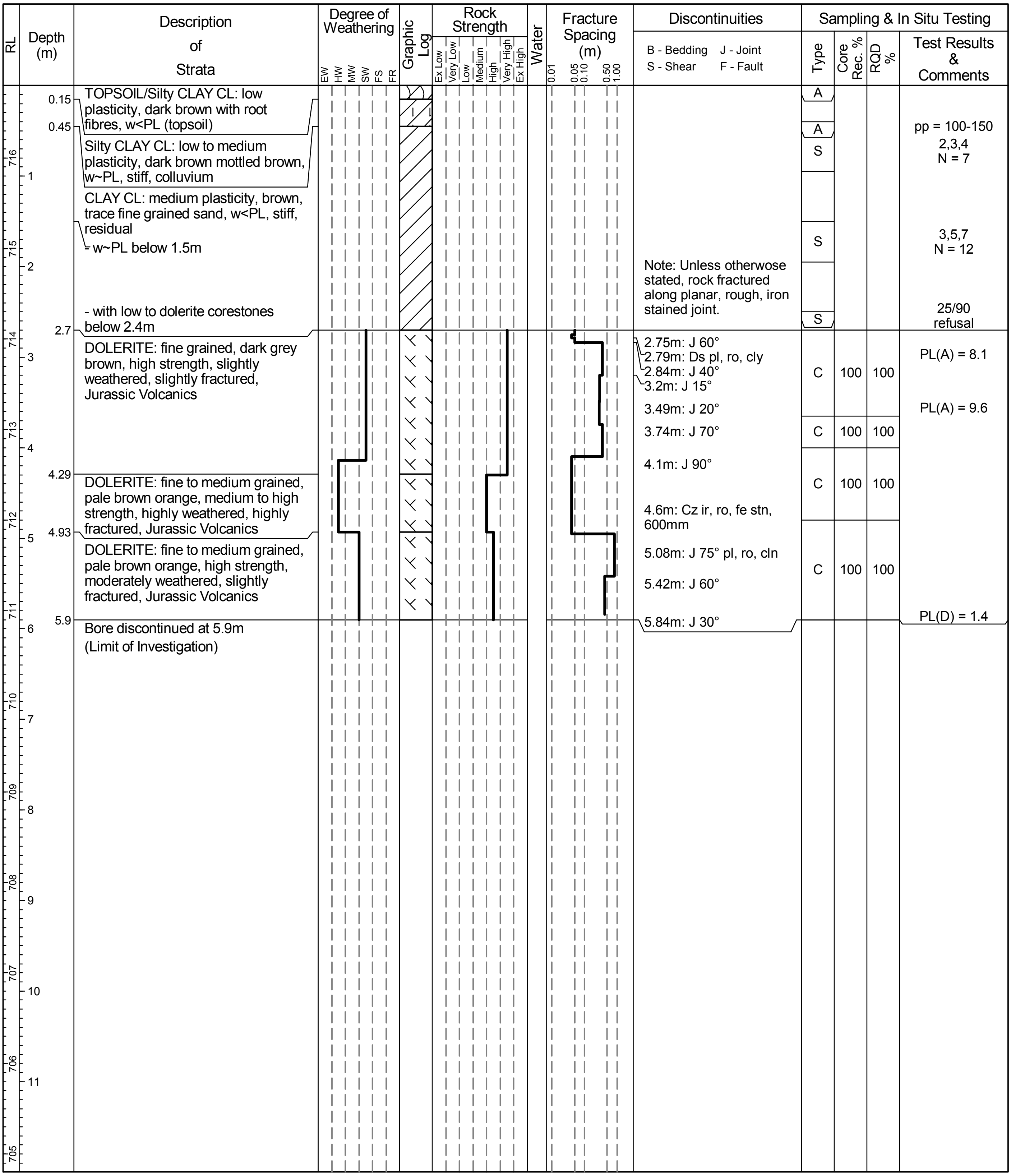
BORE: 104 DEPTH: 2.70 – 5.90 m PROJECT: 40494.03 Oct 2019

BOREHOLE LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 716.8 AHD
EASTING: 259680
NORTHING: 6172772
DIP/AZIMUTH: 90°/--

BORE No: 104
PROJECT No: 40494.03
DATE: 23/10/2019
SHEET 1 OF 1



Depth (m)	Description of Strata
0.15	TOPSOIL/Silty CLAY CL: low plasticity, dark brown with root fibres, w<PL (topsoil)
0.45	Silty CLAY CL: low to medium plasticity, dark brown mottled brown, w~PL, stiff, colluvium
	CLAY CL: medium plasticity, brown, trace fine grained sand, w<PL, stiff, residual - w~PL below 1.5m - with low to dolerite corestones below 2.4m
2.7	DOLERITE: fine grained, dark grey brown, high strength, slightly weathered, slightly fractured, Jurassic Volcanics
4.29	DOLERITE: fine to medium grained, pale brown orange, medium to high strength, highly weathered, highly fractured, Jurassic Volcanics
4.93	DOLERITE: fine to medium grained, pale brown orange, high strength, moderately weathered, slightly fractured, Jurassic Volcanics
5.9	Bore discontinued at 5.9m (Limit of Investigation)

Discontinuities

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

Note: Unless otherwose stated, rock fractured along planar, rough, iron stained joint.

2.75m: J 60°
2.79m: Ds pl, ro, cly
2.84m: J 40°
3.2m: J 15°
3.49m: J 20°
3.74m: J 70°
4.1m: J 90°
4.6m: Cz ir, ro, fe stn, 600mm
5.08m: J 75° pl, ro, cln
5.42m: J 60°
5.84m: J 30°

Sampling & In Situ Testing

Type	Core Rec. %	RQD %	Test Results & Comments
A			
A			pp = 100-150
S			2,3,4 N = 7
S			3,5,7 N = 12
S			25/90 refusal
C	100	100	PL(A) = 8.1 PL(A) = 9.6
C	100	100	
C	100	100	
C	100	100	PL(D) = 1.4

RIG: Hanjin **DRILLER:** Total Drilling **LOGGED:** FH **CASING:** HWT to 5.9m
TYPE OF BORING: 110mm solid flight auger TC bit from 0m to 2.5m, coring 'NMLC' from 2.7m to 5.9m
WATER OBSERVATIONS: No free groundwater observed
REMARKS: Location coordinates are in MGA94 Zone 56.

SAMPLING & IN SITU TESTING LEGEND

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

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DOUGLAS PARTNERS PTY LTD
PROPOSED RESIDENTIAL SUBDIVISION
32 LOVELLE STREET & 141 YARRAWA ROAD, MOSS VALE

BORE: 105 DEPTH: 8.00 – 10.90 m PROJECT: 40494.03 Oct 2019

BOREHOLE LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 705.5 AHD
EASTING: 259634
NORTHING: 6172692
DIP/AZIMUTH: 90°/--

BORE No: 105
PROJECT No: 40494.03
DATE: 23/10/2019
SHEET 1 OF 1

Depth (m)	Description of Strata	Water	Discontinuities (B - Bedding, J - Joint, S - Shear, F - Fault)	Type	Core Rec. %	RQD %	Test Results & Comments
0.2	TOPSOIL/CLAY CL: low plasticity, dark brown, with trace silt and fine grained sand, w<PL (topsoil)			A			
	CLAY CL: low to medium plasticity, dark brown, w<PL, stiff to very stiff, probable colluvium - brown mottled dark brown, trace fine sand - dark brown below 1.5m			A			pp = 350-400
				S			3,4,5 N = 9
				S			4,7,9 N = 16
	- with trace fine grained sand below 2.3m			S			7,10,12 N = 22
3.3	CLAY CH: medium to high plasticity, grey/dark grey mottled orange, w~PL, stiff to very stiff, probable colluvium			S			3,6,9 N = 15
				S			3,5,8 N = 13
5.5	CLAY CH: medium to high plasticity, grey/dark grey mottled orange, with trace fine grained sand, w~PL, stiff to very stiff, residual			S			6,8,11 N = 19
	- with trace fine gravel, stiff below 6.5m			S			5,7,8 N = 15
	- with ironstone gravel below 7.7m	▼ 06-11-19		S			5,9,25 N = 34
8.0	SHALE: fine grained, grey brown, thinly laminated to laminated, medium strength, slightly weathered, slightly fractured to unbroken, Wianamatta Group			C	100	84	PL(A) = 0.6
			9.88m: J 40° pl, ro, cln 9.89m: J 40° pl, ro, cln 10.13m: J 55° pl, ro, cln 10.43m: J 55° pl, ro, cln				PL(A) = 0.6
	- high strength below 10.3m						PL(A) = 1.4
10.9	Bore discontinued at 10.9m (Limit of Investigation)						

RIG: Hanjin **DRILLER:** Total Drilling **LOGGED:** FH **CASING:** HWT to 7.6m

TYPE OF BORING: 110mm solid flight auger TC bit from 0-7.6m, coring 'NMLC' from 8.0m-10.9m

WATER OBSERVATIONS: wet zone at ~7.7m

REMARKS: Location coordinates are in MGA94 Zone 56.

SAMPLING & IN SITU TESTING LEGEND

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

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DOUGLAS PARTNERS PTY LTD
PROPOSED RESIDENTIAL SUBDIVISION
32 LOVELLE STREET & 141 YARRAWA ROAD, MOSS VALE

BORE: 106 DEPTH: 2.60 – 6.45 m PROJECT: 40494.03 Oct 2019

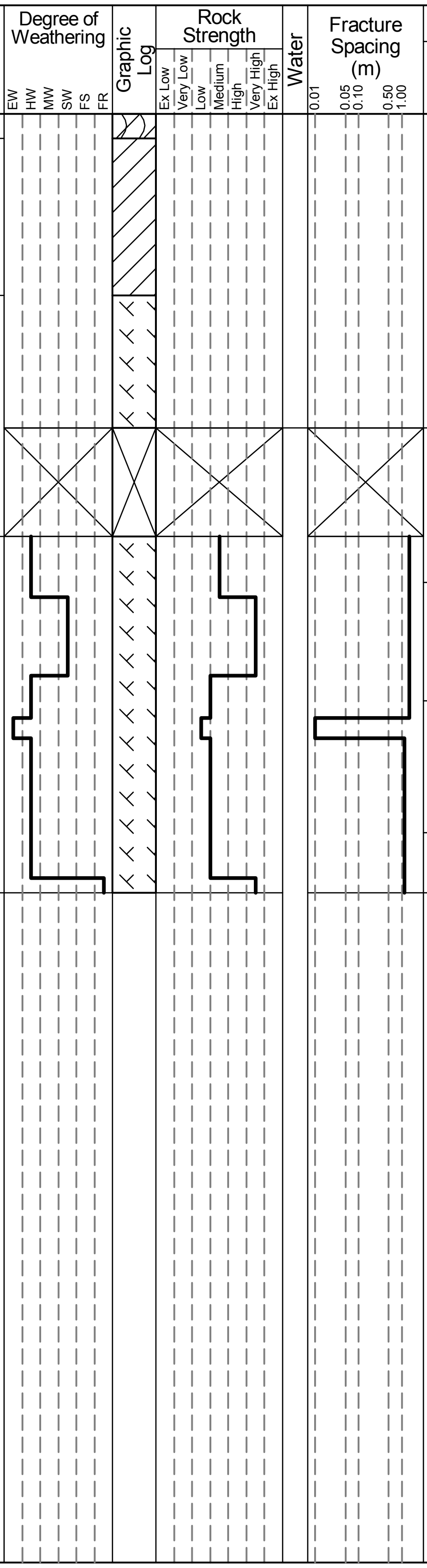
BOREHOLE LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 748.5 AHD
EASTING: 259815
NORTHING: 6172672
DIP/AZIMUTH: 90°/--

BORE No: 106
PROJECT No: 40494.03
DATE: 24/10/2019
SHEET 1 OF 1

Depth (m)	Description of Strata	Discontinuities (B - Bedding, J - Joint, S - Shear, F - Fault)	Type	Core Rec. %	RQD %	Test Results & Comments
0.2	TOPSOIL/Silty Clay CL: low plasticity, brown, trace gravel, w<PL		A			
1.5	CLAY CL - medium plasticity, red brown, with trace fine grained sand, w<PL, very stiff to hard, residual - pale brown mottled grey, very stiff below 0.5m		A S			pp = 400-500 7,11,13 N = 24
	DOLERITE: fine to medium grained, pale brown grey, very low strength, highly weathered, Jurassic Volcanics	Note: Unless otherwise stated rock is fractured along curved, rough, iron stained, healed, joint	S			25/130 refusal
3.5	- core loss probable very low strength dolerite	2.6m: CORE LOSS: 900mm	C	64	100	
6.45	DOLERITE: medium to coarse grained, dark grey green and pale grey, medium strength, highly to slightly weathered, slightly fractured, Jurassic Volcanics - very high strength corestone 4.00-4.65m	3.75m: 2J 70-85° discing 3.88m: 3J 20-30° 4.3m: J 65-70°				PL(A) = 0.4
		4.7m: 2J 75-85° discing 4.86m: 3J 50-70°	C	100	86	PL(A) = 6.8
	- very high strength (possible corestone) below 6.33m	5.32m: J 80-85° 5.58m: J 80-90° 5.83m: J 75-85° 5.95m: 3J 20-25° 6.21m: 4J 70-85° discing	C	100	100	PL(A) = 0.2
	Bore discontinued at 6.45m (Limit of Investigation)					



RL: 748, 747, 746, 745, 744, 743, 742, 741, 740, 739, 738, 737
Depth (m): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11

RIG: Hanjin **DRILLER:** Total Drilling **LOGGED:** FH **CASING:** HWT to 2.55m

TYPE OF BORING: 110mm solid flight auger TC bit from 0.0m to 2.5m, coring 'NMLC' from 2.5m to 6.45m

WATER OBSERVATIONS: No free groundwater observed

REMARKS: Location coordinates are in MGA94 Zone 56.

SAMPLING & IN SITU TESTING LEGEND

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

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DOUGLAS PARTNERS PTY LTD
PROPOSED RESIDENTIAL SUBDIVISION
32 LOVELLE STREET & 141 YARRAWA ROAD, MOSS VALE

BORE: 107 DEPTH: 2.20 – 5.20 m PROJECT: 40494.03 Oct 2019

BOREHOLE LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 712.2 AHD
EASTING: 259714
NORTHING: 6172621
DIP/AZIMUTH: 90°/--

BORE No: 107
PROJECT No: 40494.03
DATE: 24/10/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Degree of Weathering EW HW MW SW FS FR	Graphic Log	Rock Strength Ex Low Very Low Low Medium High Very High Ex High	Water	Fracture Spacing (m) 0.01 0.05 0.10 0.50 1.00	Discontinuities B - Bedding J - Joint S - Shear F - Fault	Type	Core Rec. %	RQD %	Test Results & Comments
712	0.3	TOPSOIL/Clayey SILT ML: brown, trace medium grained sand, w<PL							A			
	0.5	Silty CLAY CL: low plasticity, brown grey, w<PL, stiff, colluvium							A			
711	1.5	CLAY CL - low to medium plasticity, brown mottled grey orange, w<PL, very stiff, residual							S			7,9,15 N = 24
710	2.2	SANDSTONE: fine grained, pale grey, very low to medium strength, highly to moderately weathered, Wianamatta Group							S			6,25/130 refusal
709, 708, 707	5.2	SANDSTONE - fine to medium grained, pale grey, medium strength, slightly weathered to fresh stained, slightly fractured, Wianamatta Group - with laminated siltstone bands from 4.81m to 4.91m						4.6m: B 0° sm-ro, pl, fe stn	C	100	100	PL(A) = 0.5 PL(A) = 0.5 PL(A) = 0.5
706, 705, 704, 703, 702, 701		Bore discontinued at 5.2m (Limit of Investigation)						5.2m: B 0° sm-ro, pl, fe stn				

RIG: Hanjin **DRILLER:** Total Drilling **LOGGED:** FH **CASING:** HWT to 2.2m

TYPE OF BORING: 110mm solid flight auger TC bit from 0.0m to 2.2m, coring 'NMLC' from 2.2m to 5.2m

WATER OBSERVATIONS: No free groundwater observed

REMARKS: Location coordinates are in MGA94 Zone 56.

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 720.0 AHD
EASTING: 259722
NORTHING: 6172662

PIT No: 125
PROJECT No: 40494.03
DATE: 22/10/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
720		TOPSOIL/Silty CLAY CL: low plasticity, brown, with root fibres, w<PL		D	0.1				
	0.15	Silty CLAY CL: low to medium plasticity, brown, with trace root fibres, w<PL, hard, residual		D	0.5		pp >600		
719	1 1.0	SILTSTONE: brown, very low strength, highly weathered, with clay seams, Wianamatta Group - becoming low to medium strength, moderately weathered below 1.3m		D D	1.0 1.5				1
	1.8	SANDSTONE: fine grained, orange brown, low to medium strength, moderately weathered, Wianamatta Group		D	2.0				
718	2								2
	2.1	Pit discontinued at 2.1m (Refusal on medium strength sandstone)							
717	3								3
716	4								4
715	5								5

RIG: JCB 3CX-4 Backhoe with 450mm toothed bucket **LOGGED:** FH **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 720.6 AHD
EASTING: 259761
NORTHING: 6172616

PIT No: 126
PROJECT No: 40494.03
DATE: 22/10/2019
SHEET 1 OF 1

Depth (m)	Description of Strata	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
0.1	TOPSOIL/Silty CLAY CL: low plasticity, brown, with root fibres, w<PL	D	0.1			
	Silty CLAY CL: low to medium plasticity, brown, with cobbles and boulders, w<PL, hard, colluvium	D	0.5		pp >600	
		D	1.0		pp = 350-400	
1.3	Silty CLAY CL: low to medium plasticity, dark grey mottled brown, w<PL,very stiff, residual - with bands of very low strength, highly weathered siltstone below 1.4m	D	1.5			
1.9	SILTSTONE: grey brown, very low strength, highly weathered, with clay seams, Wianamatta Group	D	2.0			
2.5	Pit discontinued at 2.5m (Refusal on medium strength siltstone)	D	2.5			

Dynamic Penetrometer Test (blows per mm)

RIG: JCB 3CX-4 Backhoe with 450mm toothed bucket **LOGGED:** FH **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 722.9 AHD
EASTING: 259810
NORTHING: 6172603

PIT No: 127
PROJECT No: 40494.03
DATE: 22/10/2019
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water	Dynamic Penetrometer Test (blows per mm) 5 10 15 20
	0.15	TOPSOIL/Silty CLAY CL: low plasticity, brown, with root fibres, cobbles and boulders, w<PL		D	0.1				
		Silty CLAY CL: low to medium plasticity, red brown, with cobbles, boulders and trace fine grained sand, w<PL, very stiff, colluvium		D	0.5				
	0.75	Silty CLAY CL: low to medium plasticity, dark grey mottled brown, w<PL, hard, residual							
722	1			D	1.0		pp >600		1
		- extremely low strength, residual soil siltstone bands below 1.3m		D	1.5				
721	2 / 2.0	SILTSTONE: pale grey brown, very low strength, moderately weathered, with clay seams, Wianamatta Group		D	2.0				2
	2.15	Pit discontinued at 2.15m (Refusal on low to medium strength siltstone)							
720	3								3
719	4								4
718	5								5
717									

RIG: JCB 3CX-4 Backhoe with 450mm toothed bucket
LOGGED: FH
SURVEY DATUM: MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

CLIENT: Prime Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 32 Lovelle Street & 141 Yarrawa Road, Moss Vale

SURFACE LEVEL: 693.2 AHD
EASTING: 259724
NORTHING: 6172407

PIT No: 128
PROJECT No: 40494.03
DATE: 22/10/2019
SHEET 1 OF 1

Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
0.1	TOPSOIL/Silty CLAY CL: low plasticity, pale brown, with root fibres, w<PL	D	0.1			
	CLAY CH: medium to high plasticity, brown mottled orange, w<PL, hard, residual					
	- becoming grey mottled orange below 0.5m	D	0.5		pp >500	
		D	1.0		pp >500	
		D	1.5		pp >600	
		D	2.0		pp >600	
	- with trace fine sand below 2.4m	D	2.5		pp = 600	
3.0	- becoming very stiff below 2.8m	D	3.0		pp = 300-400	
	Pit discontinued at 3.0m (Limit of investigation)					

Dynamic Penetrometer Test (blows per mm)

RIG: JCB 3CX-4 Backhoe with 450mm toothed bucket **LOGGED:** FH **SURVEY DATUM:** MGA94 Zone 56

WATER OBSERVATIONS: No free groundwater observed

REMARKS:

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

SAMPLING & IN SITU TESTING LEGEND

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

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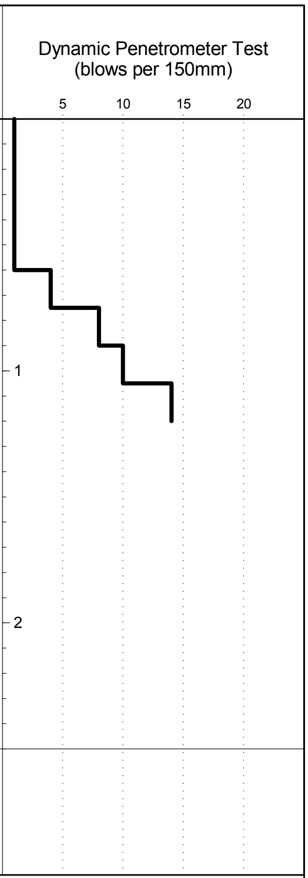
TEST PIT LOG

CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 707.4 AHD
EASTING: 259597
NORTHING: 6172734

PIT No: 1
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - dark brown mottled grey and red brown, silty clay, moist, FMC~PL						
	0.1	SILTY CLAY - soft, dark grey mottled green grey and orange brown, silty clay, moist, FMC>PL (COLLUVIUM)		D	0.1			
707				D	0.5		pp = 0-50	
	0.6	SILTY CLAY - stiff to hard, dark grey mottled brown, silty clay with iron indurations, moist, FMC<PL (POSSIBLE COLLUVIUM)						
	1			D	1.0			
706				D	1.5			
	1.6	SILTY CLAY - hard, grey mottled orange brown, silty clay with some extremely low strength, extremely weathered siltstone bands, moist, FMC<PL (RESIDUAL)						
	2			D	2.0			
	2.1	SILTSTONE - very low strength, moderately weathered, grey with orange brown bands siltstone with some extremely low strength, extremely weathered bands						
705								
	2.5	Pit discontinued at 2.5m (Limit of Investigation)		D	2.5			▷



Pit 1 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket **LOGGED:** IKA/FH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: Ground water ingress at 2.5m

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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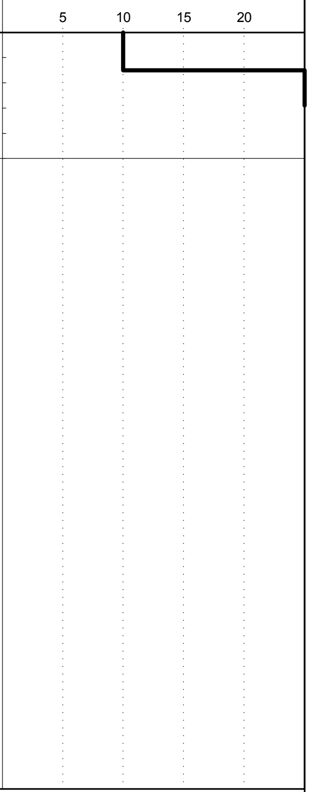
TEST PIT LOG

CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 739.3 AHD
EASTING: 259694
NORTHING: 6172904

PIT No: 2
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per 150mm)
				Type	Depth	Sample	Results & Comments		
	0.1	TOPSOIL - dark brown, silty clay with some sandstone cobbles, moist, FMC<PL		D	0.1				
739		DOLERITE - medium strength, moderately weathered, grey brown dolerite							
	0.5	Pit discontinued at 0.5m (Refusal on medium strength dolerite)		D	0.5				



Pit 2 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket

LOGGED: IKA/FH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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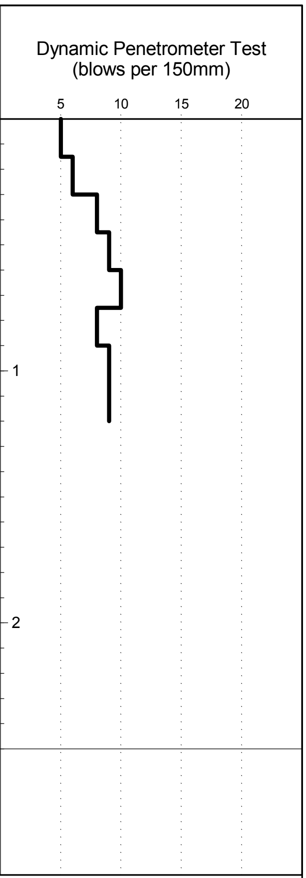
TEST PIT LOG

CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 708.2 AHD
EASTING: 259515
NORTHING: 6172770

PIT No: 3
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
		TOPSOIL - brown grey, silty clay, moist, FMC<PL		D	0.01			
708	0.1	SILTY CLAY - stiff to hard, grey mottled orange brown, silty clay, moist, FMC<PL (COLLUVIUM)		B D	0.4 0.5 0.6		pp = 400-500	
	1 — 1.0	SILTY CLAY - very stiff, grey mottled orange brown, silty clay with some gravel-sized ironstone fragments, moist, FMC<PL (RESIDUAL)		D	1.0			
707	1.1	SILTSTONE - very low strength, moderately weathered, dark grey siltstone with extremely low strength, extremely weathered bands		D D	1.5 2.0			
706	2							
	2.5	- becoming extremely low strength, extremely weathered, grey with orange brown bands siltstone with very low strength bands below 2.4m		D	2.5			
		Pit discontinued at 2.5m (Limit of Investigation)						



Pit 3 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket
LOGGED: IKA/FH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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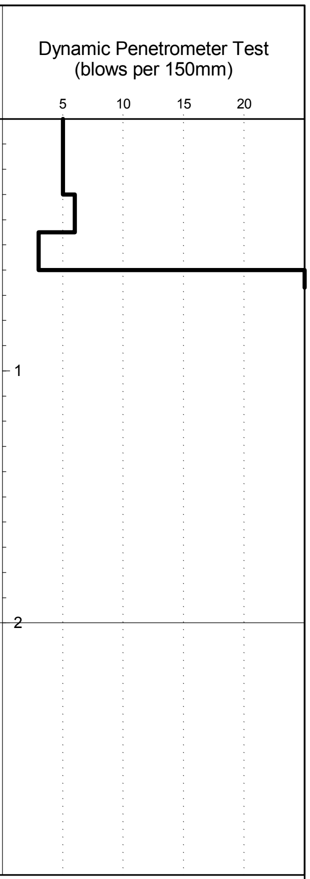
TEST PIT LOG

CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 729.7 AHD
EASTING: 259600
NORTHING: 6172841

PIT No: 4
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing Type	Depth	Sample	Results & Comments	Water
	0.05	TOPSOIL - brown, sandy clay with some boulders (dolerite), moist, FMC<PL (COLLUVIUM)		D	0.1			
		SANDY CLAY - stiff, brown orange, friable, sandy clay, moist, FMC<PL (COLLUVIUM)		D	0.5			
729								
	0.8	SANDY CLAY - stiff, orange brown, sandy clay with iron indurations, moist, FMC<PL (RESIDUAL)		D	1.0			
	1							
	1.1	DOLERITE - very low strength, highly weathered, orange brown dolerite with extremely low strength, extremely weathered bands		D	1.5			
728		- becoming low strength, moderately weathered brown orange with very low strength, highly weathered bands below 1.2m						
	2 2.0	Pit discontinued at 2.0m (Refusal on medium strength dolerite)		D	2.0			



Pit 4 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket

LOGGED: IKA/FH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

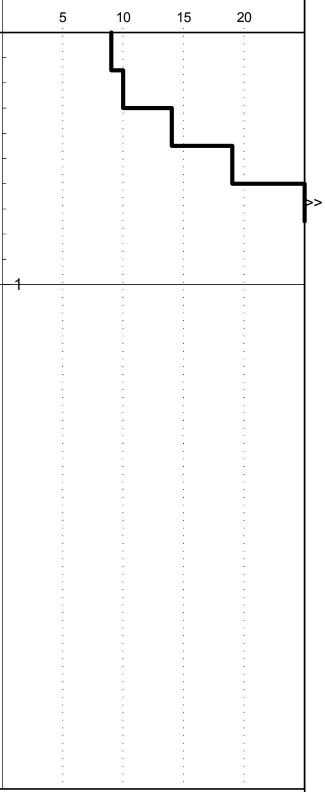
CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 738.7 AHD
EASTING: 259791
NORTHING: 6172744

PIT No: 5
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.05	TOPSOIL - brown, silty clay, moist, FMC<PL						
	0.4	SANDY CLAY - stiff to hard, brown mottled orange brown, sandy clay with some cobbles (dolerite) and iron indurations, moist, FMC<PL (COLLUVIUM)		D	0.1			
738		DOLERITE - very low strength, highly weathered, brown orange dolerite with some ironstone and extremely low strength, extremely weathered bands		D	0.5			
	1 1.0	Pit discontinued at 1.0m (Refusal on medium strength dolerite)		D	1.0			

Dynamic Penetrometer Test (blows per 150mm)



Pit 5 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket **LOGGED:** IKA/FH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

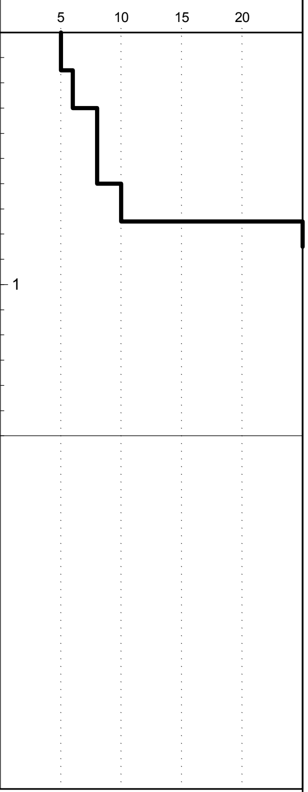
CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 710.7 AHD
EASTING: 259779
NORTHING: 6172567

PIT No: 6
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water
				Type	Depth	Sample	Results & Comments	
		TOPSOIL - brown, silty clay, moist, FMC<PL		D	0.1			
	0.2	SILTY CLAY - very stiff to hard, brown, silty clay, moist, FMC<PL (COLLUVIUM)		D	0.5		pp >600	
710		- becoming orange brown with iron indurations and some cobbbles (dolerite) below 0.7m						
	1			D	1.0			
	1.2	SILTSTONE - low strength, moderately weathered, grey siltstone with extremely low strength, extremely weathered bands		D	1.5		pp >600	
	1.6	Pit discontinued at 1.6m (Refusal on medium strength siltstone)						

Dynamic Penetrometer Test (blows per 150mm)



Pit 6 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket

LOGGED: IKA/FH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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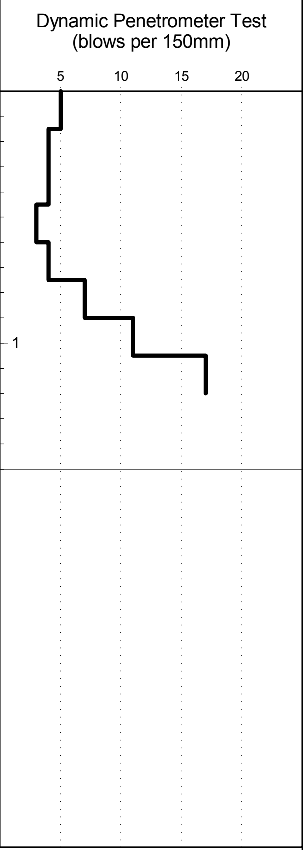
TEST PIT LOG

CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 696.5 AHD
EASTING: 259513
NORTHING: 6172677

PIT No: 7
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing: Type	Depth	Sample	Results & Comments	Water
	0.1	TOPSOIL - brown, silty clay, moist, FMC<PL						
		SILTY CLAY - stiff, dark brown, silty clay, moist, FMC<PL (POSSIBLE COLLUVIUM/SLOPEWASH)		D	0.1			
696				D	0.5		pp >600	
	1	- becoming very stiff to hard, grey mottled orange brown below 0.8m		D	1.0		pp >600	
	1.2	SILTSTONE - low to medium strength, moderately weathered, brown grey siltstone with very low strength, highly weathered bands						
695	1.5	Pit discontinued at 1.5m (Refusal on medium strength siltstone)		D	1.5			



Pit 7 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket
LOGGED: IKA/FH
SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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Geotechnics / Environment / Groundwater

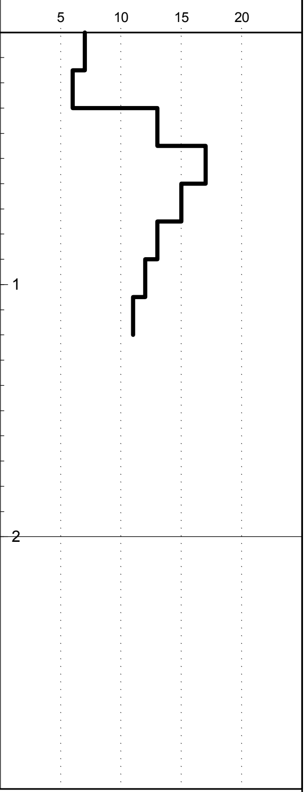
TEST PIT LOG

CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 712.3 AHD
EASTING: 259680
NORTHING: 6172699

PIT No: 8
PROJECT No: 40494.01
DATE: 18/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Graphic Log	Sampling & In Situ Testing				Water	Dynamic Penetrometer Test (blows per 150mm)
				Type	Depth	Sample	Results & Comments		5 10 15 20
		TOPSOIL- brown, silty clay, moist, FMC<PL		D	0.1				
712	0.2	SILTY CLAY - hard, dark brown, silty clay with some ironstone gravel, moist, FMC<PL (COLLUVIUM)		D	0.5		pp >600		
	0.8	SILTY CLAY - very stiff to hard, brown mottled grey and orange brown, silty clay with some sandy clay bands and sub-rounded to rounded gravel, moist, FMC<PL (COLLUVIUM)		D	1.0		pp >600		1
711	1.3	SILTY CLAY - very stiff to hard, grey mottled orange brown, moist, FMC<PL (RESIDUAL)		D	1.5		pp >600		
	1.6	SANDSTONE - low to medium strength, moderately weathered, grey, brown and orange brown, fine to medium-grained sandstone							
	2.0	Pit discontinued at 2.0m (Refusal on medium strength sandstone)		D	2.0				2



Pit 8 excavation.

RIG: Yanmar 5T excavator- 600mm toothed bucket **LOGGED:** IKA/FH **SURVEY DATUM:** MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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TEST PIT LOG

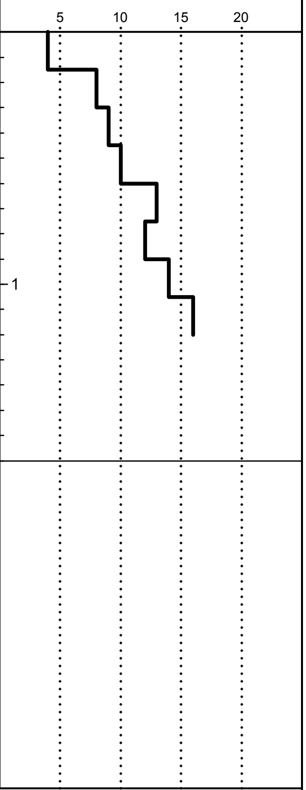
CLIENT: Moss Vale Pty Ltd
PROJECT: Proposed Residential Subdivision
LOCATION: 141 Yarrawa Road and 32 Lovelle Street, Moss Vale

SURFACE LEVEL: 684.4 AHD
EASTING: 259546
NORTHING: 6172361

PIT No: 22
PROJECT No: 40494.01
DATE: 17/9/2018
SHEET 1 OF 1

RL	Depth (m)	Description of Strata	Type	Depth	Sample	Results & Comments	Water
		TOPSOIL- brown, silty clay, moist, FMC<PL					
	0.1	SILTY CLAY - very stiff, dark brown grey, silty clay, moist, FMC<PL (POSSIBLE ALLUVIUM)	D	0.1			
684		- becoming very stiff to hard below 0.5m	D	0.5		pp >600	
		- becoming grey mottled with orange below 0.7m (RESIDUAL)					
	1		D	1.0		pp >600	
683							
	1.5	SANDSTONE - low to medium strength, slightly weathered, grey and orange brown, fine-grained sandstone with some ironstone bands	D	1.5			
	1.7	Pit discontinued at 1.7m (Refusal on medium strength sandstone)					

Dynamic Penetrometer Test (blows per 150mm)



Pit 22 excavation.

RIG: Backhoe 3CX-4-550mm toothed bucket

LOGGED: IKA/FH

SURVEY DATUM: MGA94

WATER OBSERVATIONS: No free groundwater observed

REMARKS: FMC = field moisture content; PL = plastic limit

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

SAMPLING & IN SITU TESTING LEGEND

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

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Photo 1: View looking south across the central part of the site from the very steep hillside in the northern part of the site.

Photo 2: View looking north at the smaller of the two water reservoirs at the top of the hill iadjacent to the northern part of the site.

Photo 3: View looking southeast across the steep to very steep hillside in the northern part of the site.

Photo 4: View looking northwest across the active scarp in the lower-middle part of the hillside in the northern part of the site.

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CLIENT: Prime Moss Vale Pty Ltd
OFFICE: Wollongong
DRAWN BY: RJH
SCALE: NTS
DATE: 11 Sep 2018

Site Photographs 1 to 4
Proposed Residential Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No: 40494.03
PLATE No: 1
REVISION: -

Photo 5: View looking northeast across the active scarp in the lower-midlle part of the hillside in the northern part of the site. Note: the igneous boulders lying on the surface.

Photo 6: View looking at slumping in a drainage depression in the steep to very steep hillside in the northern part of the site.

Photo 7: View looking at bedrock exposed near the crest of the steep to very steep hillside near the small water reservoir in the northern part of the site.

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CLIENT:	Prime Moss Vale Pty Ltd		
OFFICE:	Wollongong	DRAWN BY:	RJH
SCALE:	NTS	DATE:	11 Sep 2018

Site Photographs 5 to 7
Proposed Residential Subdivision
32 Lovelle Street and 141 Yarrawa Road, Moss Vale

PROJECT No:	40494.03
PLATE No:	2
REVISION:	-

Appendix C

Results of Laboratory Testing

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Unanderra Laboratory
Unit 1/1 Luso Drive Unanderra NSW 2526
Phone: (02) 4271 1836
Fax: (02) 4271 1897
Email: anes.ibricic@douglaspartners.com.au

Report Number:	**40494.03-1**
Issue Number:	1
Date Issued:	25/11/2019
Client:	Prime Moss Vale Pty Ltd Suite 30.02, Level 30, 420 George Street, Sydney NSW 2000
Project Number:	40494.03
Project Name:	Proposed Residential Subdivision
Project Location:	32 Lovelle Street & 141 Yarawa Road, Moss Vale
Work Request:	5001
Sample Number:	WO-5001M
Date Sampled:	22/10/2019
Dates Tested:	07/11/2019 - 21/11/2019
Sample Location:	**101 (3.5 - 3.95m)**
Material:	Clay

Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Anes Ibricic
Laboratory Manager

NATA Accredited Laboratory Number: 828

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	38		
Plastic Limit (%)	18		
Plasticity Index (%)	**20**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	18.5

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater
Douglas Partners Pty Ltd
Unanderra Laboratory
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Accredited for compliance with ISO/IEC 17025 - Testing

Approved Signatory: Anes Ibricic
Laboratory Manager
NATA Accredited Laboratory Number: 828

Report Number:	**40494.03-1**
Issue Number:	1
Date Issued:	25/11/2019
Client:	Prime Moss Vale Pty Ltd Suite 30.02, Level 30, 420 George Street, Sydney NSW 2000
Project Number:	40494.03
Project Name:	Proposed Residential Subdivision
Project Location:	32 Lovelle Street & 141 Yarawa Road, Moss Vale
Work Request:	5001
Sample Number:	WO-5001N
Date Sampled:	22/10/2019
Dates Tested:	07/11/2019 - 21/11/2019
Sample Location:	**104 (1.5 - 1.95m)**
Material:	Clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	37		
Plastic Limit (%)	15		
Plasticity Index (%)	**22**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	23.5

Material Test Report

Douglas Partners
Geotechnics / Environment / Groundwater

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Report Number: **40494.03-1**
Issue Number: 1
Date Issued: 25/11/2019
Client: Prime Moss Vale Pty Ltd
Suite 30.02, Level 30, 420 George Street, Sydney NSW 2000
Project Number: 40494.03
Project Name: Proposed Residential Subdivision
Project Location: 32 Lovelle Street & 141 Yarawa Road, Moss Vale
Work Request: 5001
Sample Number: WO-5001O
Date Sampled: 22/10/2019
Dates Tested: 07/11/2019 - 21/11/2019
Sample Location: **125 (0.5m)**
Material: Clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	36		
Plastic Limit (%)	18		
Plasticity Index (%)	**18**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	17.6

Material Test Report

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Client: Prime Moss Vale Pty Ltd
Suite 30.02, Level 30, 420 George Street, Sydney NSW 2000
Project Number: 40494.03
Project Name: Proposed Residential Subdivision
Project Location: 32 Lovelle Street & 141 Yarawa Road, Moss Vale
Work Request: 5001
Sample Number: WO-5001P
Date Sampled: 22/10/2019
Dates Tested: 07/11/2019 - 22/11/2019
Sample Location: **127 (1.5m)**
Material: Clay

Atterberg Limit (AS1289 3.1.2 & 3.2.1 & 3.3.1)		Min	Max
Sample History	Oven Dried		
Preparation Method	Dry Sieve		
Liquid Limit (%)	40		
Plastic Limit (%)	18		
Plasticity Index (%)	**22**		

Moisture Content (AS 1289 2.1.1)	
Moisture Content (%)	12.5

This document shall not be reproduced except in full without approval of the laboratory.
Results relate only to the items tested/sampled.

Appendix D

AGS Extracts

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.

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}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
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%	100%	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
60%	40%	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
20%	10%	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
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
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.

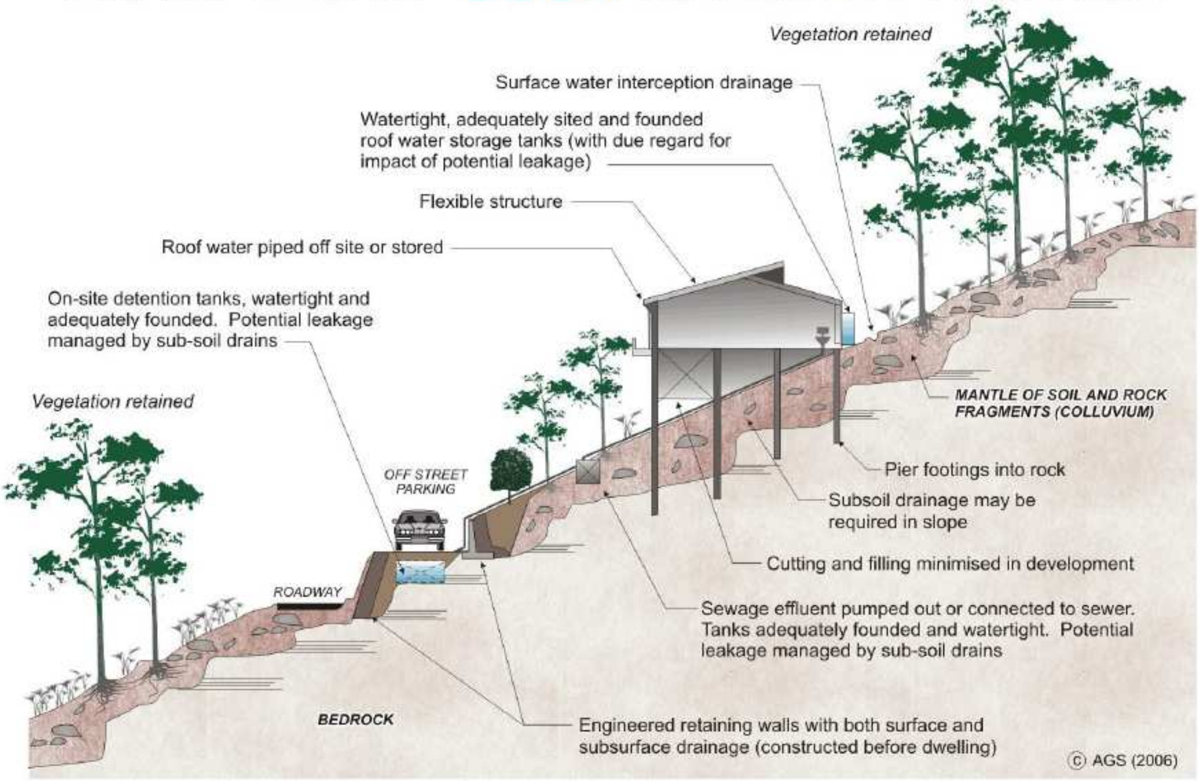
(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional 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

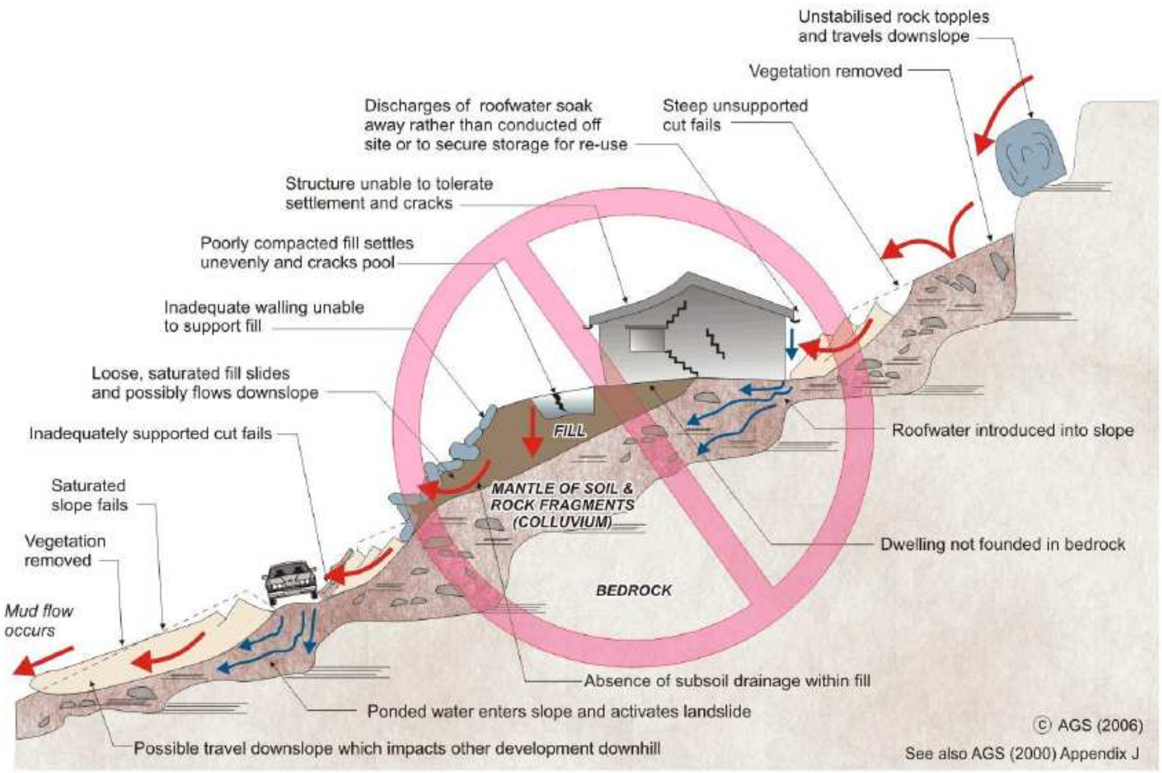
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

LANDSLIDES

What is a Landslide?

Any movement of a mass of rock, debris, or earth, down a slope, constitutes a "landslide". Landslides take many forms, some of which are illustrated. More information can be obtained from Geoscience Australia, or by visiting its Australian Landslide Database at www.ga.gov.au/urban/factsheets/landslide.jsp. Aspects of the impact of landslides on buildings are dealt with in the book "Guideline Document Landslide Hazards" published by the Australian Building Codes Board and referenced in the Building Code of Australia. This document can be purchased over the internet at the Australian Building Codes Board's website www.abcb.gov.au .

Landslides vary in size. They can be small and localised or very large, sometimes extending for kilometres and involving millions of tonnes of soil or rock. It is important to realise that even a 1 cubic metre boulder of soil, or rock, weighs at least 2 tonnes. If it falls, or slides, it is large enough to kill a person, crush a car, or cause serious structural damage to a house. The material in a landslide may travel downhill well beyond the point where the failure first occurred, leaving destruction in its wake. It may also leave an unstable slope in the ground behind it, which has the potential to fail again, causing the landslide to extend (regress) uphill, or expand sideways. For all these reasons, both "potential" and "actual" landslides must be taken very seriously. They present a real threat to life and property and require proper management.

Identification of landslide risk is a complex task and must be undertaken by a geotechnical practitioner (GeoGuide LR1) with specialist experience in slope stability assessment and slope stabilisation.

What Causes a Landslide?

Landslides occur as a result of local geological and groundwater conditions, but can be exacerbated by inappropriate development (GeoGuide LR8), exceptional weather, earthquakes and other factors. Some slopes and cliffs never seem to change, but are actually on the verge of failing. Others, often moderate slopes (Table 1), move continuously, but so slowly that it is not apparent to a casual observer. In both cases, small changes in conditions can trigger a landslide with serious consequences. Wetting up of the ground (which may involve a rise in ground water table) is the single most important cause of landslides (GeoGuide LR5). This is why they often occur during, or soon after, heavy rain. Inappropriate development often results in small scale landslides which are very expensive in human terms because of the proximity of housing and people.

Does a Landslide Affect You?

Any slope, cliff, cutting, or fill embankment may be a hazard which has the potential to impact on people, property, roads and services. Some tell-tale signs that might indicate that a landslide is occurring are listed below:

- open cracks, or steps, along contours
- ground water seepage, or springs
- bulging in the lower part of the slope
- hummocky ground
- trees leaning down slope, or with exposed roots
- debris/fallen rocks at the foot of a cliff
- tilted power poles, or fences
- cracked or distorted structures

These indications of instability may be seen on almost any slope and are not necessarily confined to the steeper ones (Table 1). Advice should be sought from a geotechnical practitioner if any of them are observed. Landslides do not respect property boundaries. As mentioned above they can "run-out" from above, "regress" from below, or expand sideways, so a landslide hazard affecting your property may actually exist on someone else's land.

Local councils are usually aware of slope instability problems within their jurisdiction and often have specific development and maintenance requirements. **Your local council is the first place to make enquiries if you are responsible for any sort of development or own or occupy property on or near sloping land or a cliff.**

TABLE 1 - Slope Descriptions

Appearance	Slope Angle	Maximum Gradient	Slope Characteristics
Gentle	0° - 10°	1 on 6	Easy walking.
Moderate	10°- 18°	1 on 3	Walkable. Can drive and manoeuvre a car on driveway
Steep	18°- 27°	1 on 2	Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car.
Very Steep	27°- 45°	1 on 1	Can only climb slope by clutching at vegetation, rocks etc.
Extreme	45°- 64°	1 on 0.5	Need rope access to climb slope
Cliff	64°- 84°	1 on 0.1	Appears vertical. Can abseil down.
Vertical or Overhang	84° - 90±°	Infinite	Appears to overhang. Abseiler likely to lose contact with the face.

Some typical landslides which could affect residential housing are illustrated below:

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

Rotational or circular slip failures (Figure 1) - can occur on moderate to very steep soil and weathered rock slopes (Table 1). The sliding surface of the moving mass tends to be deep seated. Tension cracks may open at the top of the slope and bulging may occur at the toe. The ground may move in discrete "steps" separated by long periods without movement. More rapid movement may occur after heavy rain.

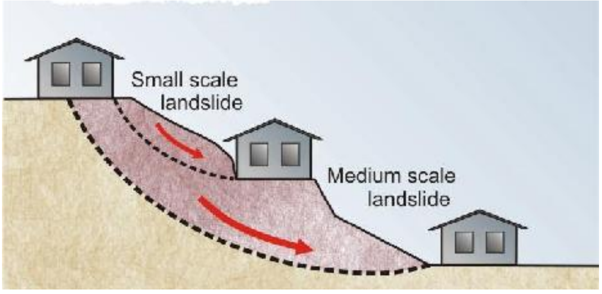


Figure 1

Translational slip failures (Figure 2) - tend to occur on moderate to very steep slopes (Table 1) where soil, or weak rock, overlies stronger strata. The sliding mass is often relatively shallow. It can move, or deform slowly (creep) over long periods of time. Extensive linear cracks and hummocks sometimes form along the contours. The sliding mass may accelerate after heavy rain.

Figure 2

Wedge failures (Figure 3) - normally only occur on extreme slopes, or cliffs (Table 1), where discontinuities in the rock are inclined steeply downwards out of the face.

Rock falls (Figure 3) - tend to occur from cliffs and overhangs (Table 1).

Cliffs may remain apparently unchanged for hundreds of years. Collections of boulders at the foot of a cliff may indicate that rock falls are ongoing. Wedge failures and rock falls do not "creep". Familiarity with a particular local situation can instil a false sense of security since failure, when it occurs, is usually sudden and catastrophic.

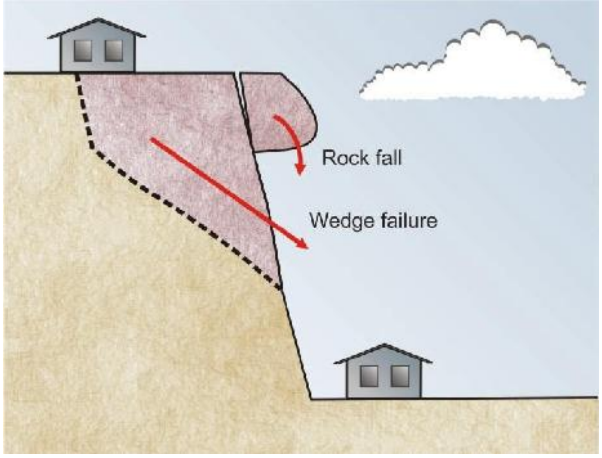


Figure 3

Debris flows and mud slides (Figure 4) - may occur in the foothills of ranges, where erosion has formed valleys which slope down to the plains below. The valley bottoms are often lined with loose eroded material (debris) which can "flow" if it becomes saturated during and after heavy rain. Debris flows are likely to occur with little warning; they travel a long way and often involve large volumes of soil. The consequences can be devastating.

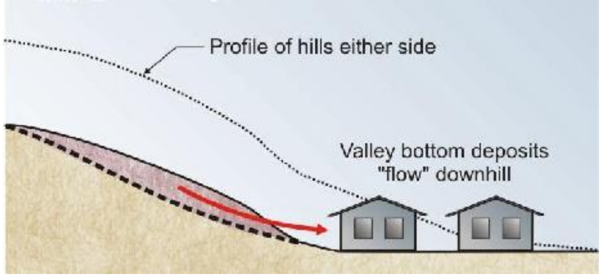


Figure 4

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

- GeoGuide LR1 - Introduction
- GeoGuide LR3 - Soil Slopes
- GeoGuide LR4 - Rock Slopes
- 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.

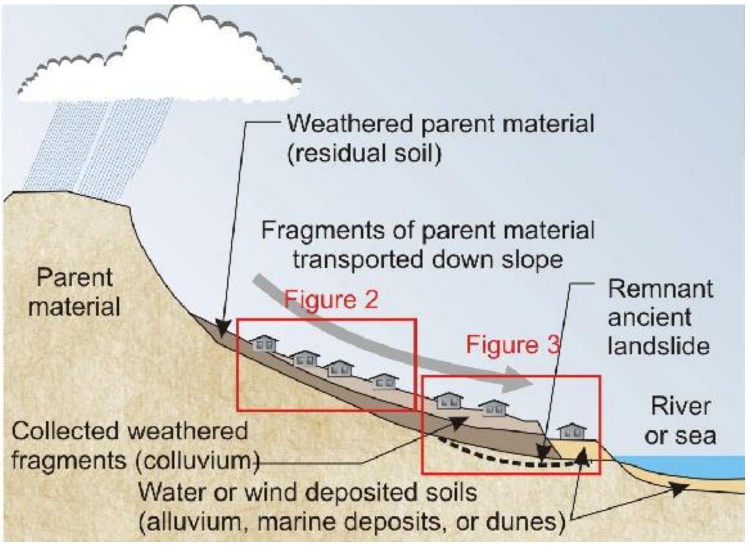


Figure 1

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.

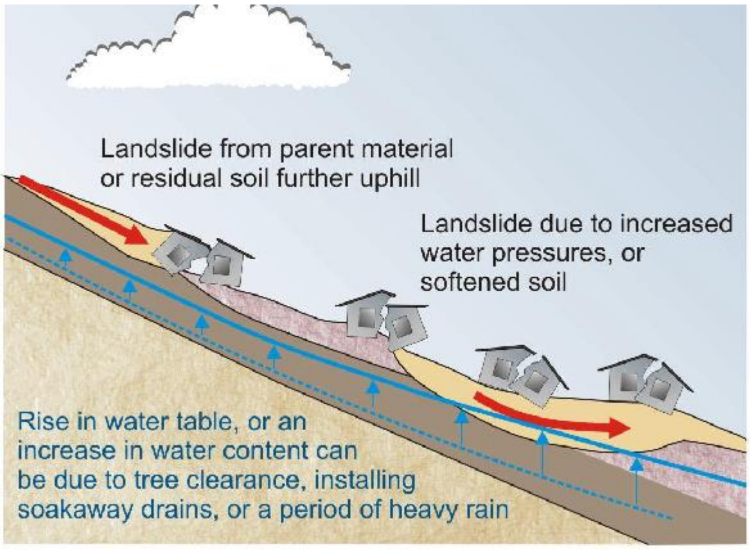


Figure 2

AUSTRALIAN GEOGUIDE LR3 (LANDSLIDES IN SOIL)

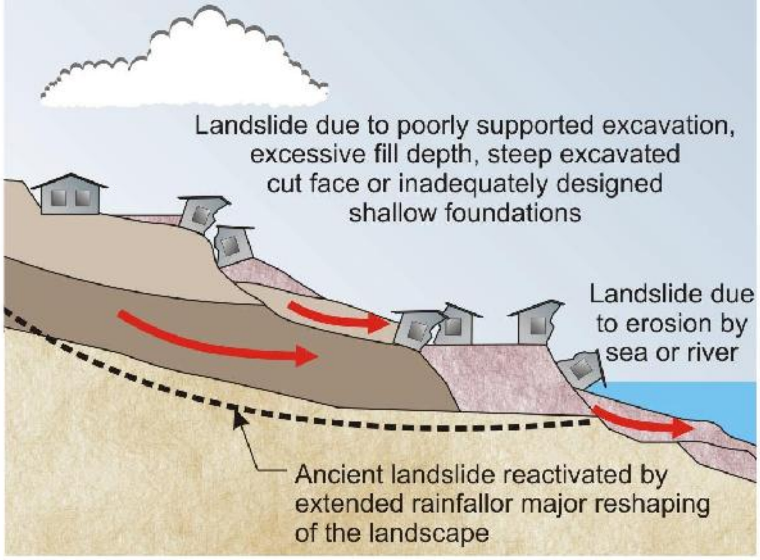


Figure 3

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

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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.

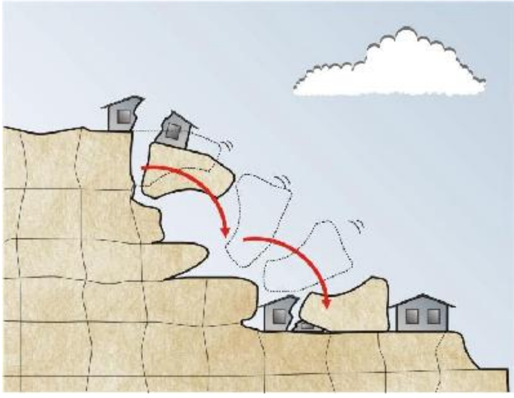

Figure 1 - Failure of an undercut block

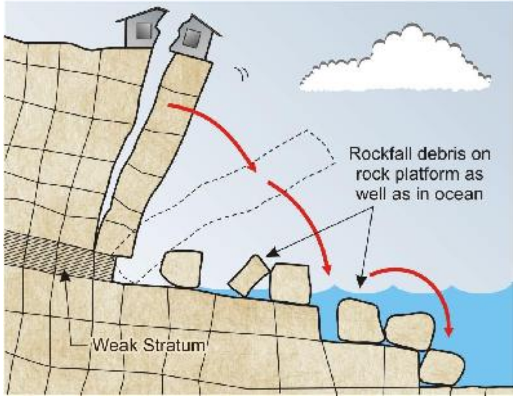

Figure 2 - Toppling failure

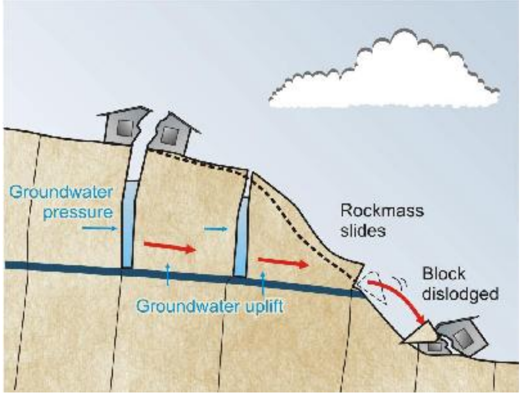

Figure 3 - Block slide on weak layer

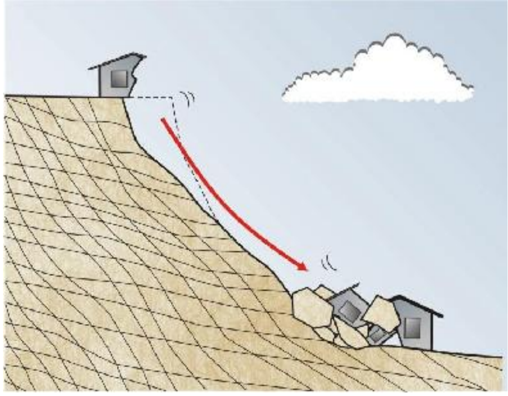

Figure 4 - Wedge failure along discontinuities

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.

AUSTRALIAN GEOGUIDE LR4 (LANDSLIDES IN ROCK)

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.

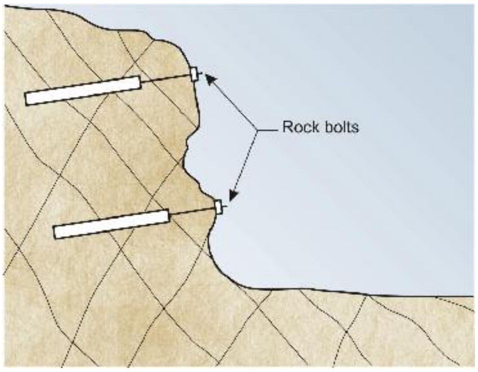

Figure 5

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.

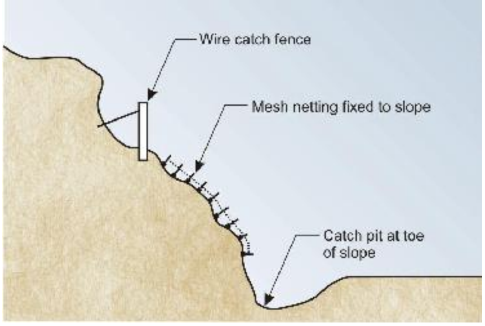

Figure 6

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.

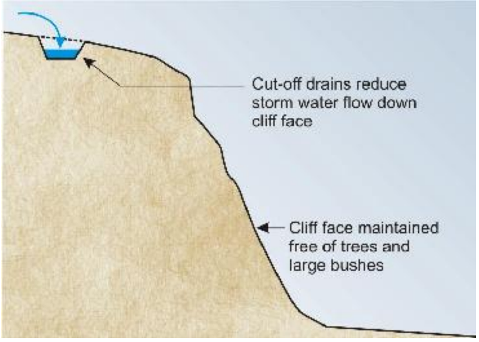

Figure 7

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. **<u>If you have any concerns at all about the possibility of a rock fall seek advice from a geotechnical practitioner.</u>**

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
- GeoGuide LR11 - Record Keeping

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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.

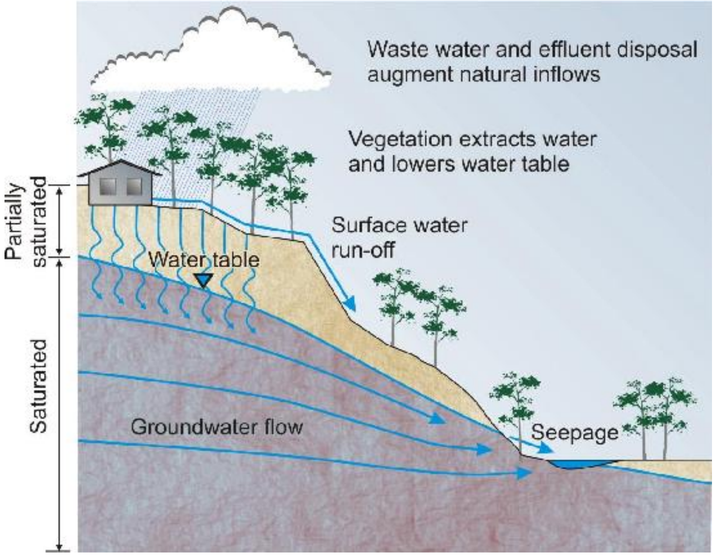

Figure 1 - Groundwater flow

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)

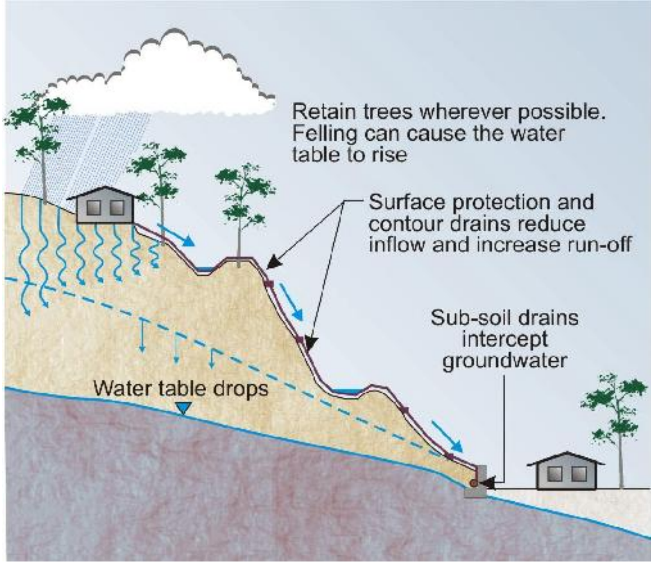

Figure 2 - Techniques used to control groundwater flow

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:

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- GeoGuide LR4 - Landslides in Rock
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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.

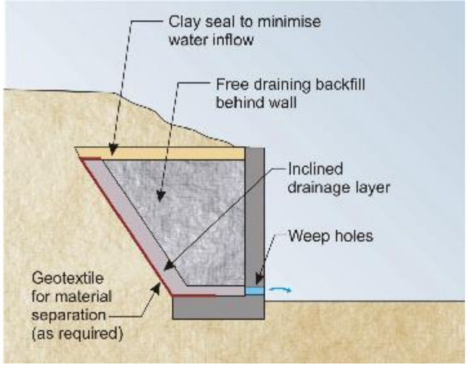

Figure 1- Typical formed concrete wall

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.

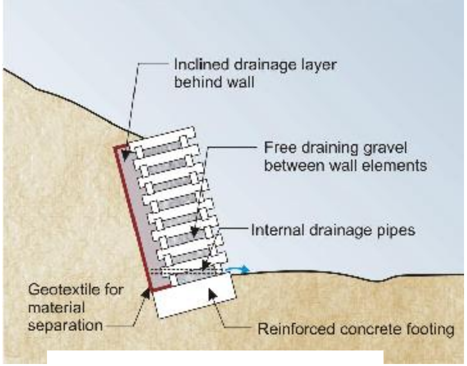

Figure 2 -Typical crib

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.

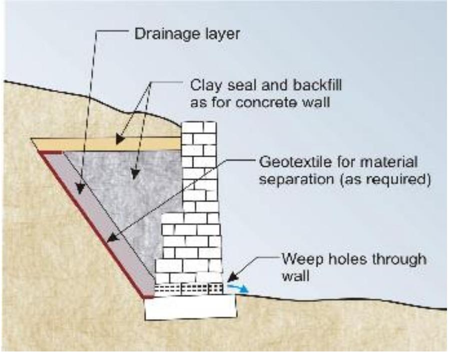

Figure 3 -Typical masonry wall

AUSTRALIAN GEOGUIDE LR6 (RETAINING WALLS)

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.

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.

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".

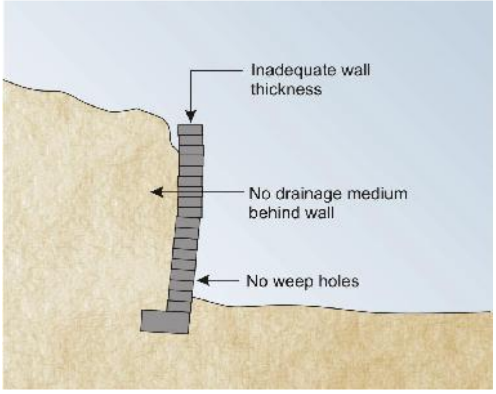

Figure 4 - Poorly built masonry wall

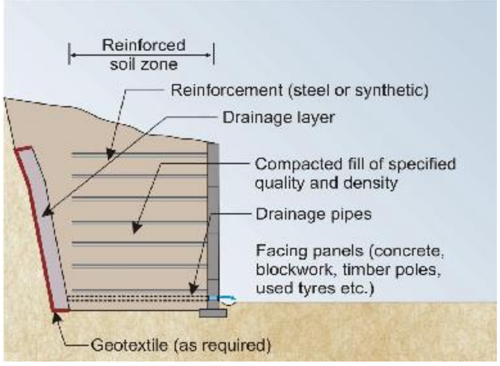

Figure 5 - Typical reinforced soil wall

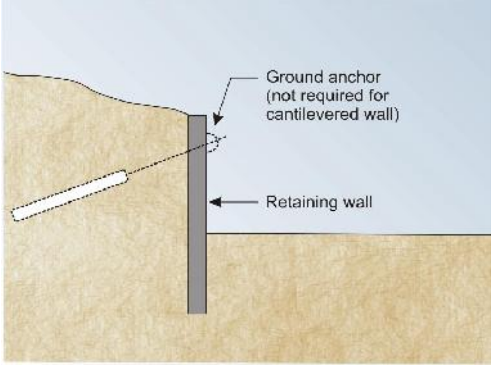

Figure 6 - Typical cantilevered or anchored wall

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.

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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:

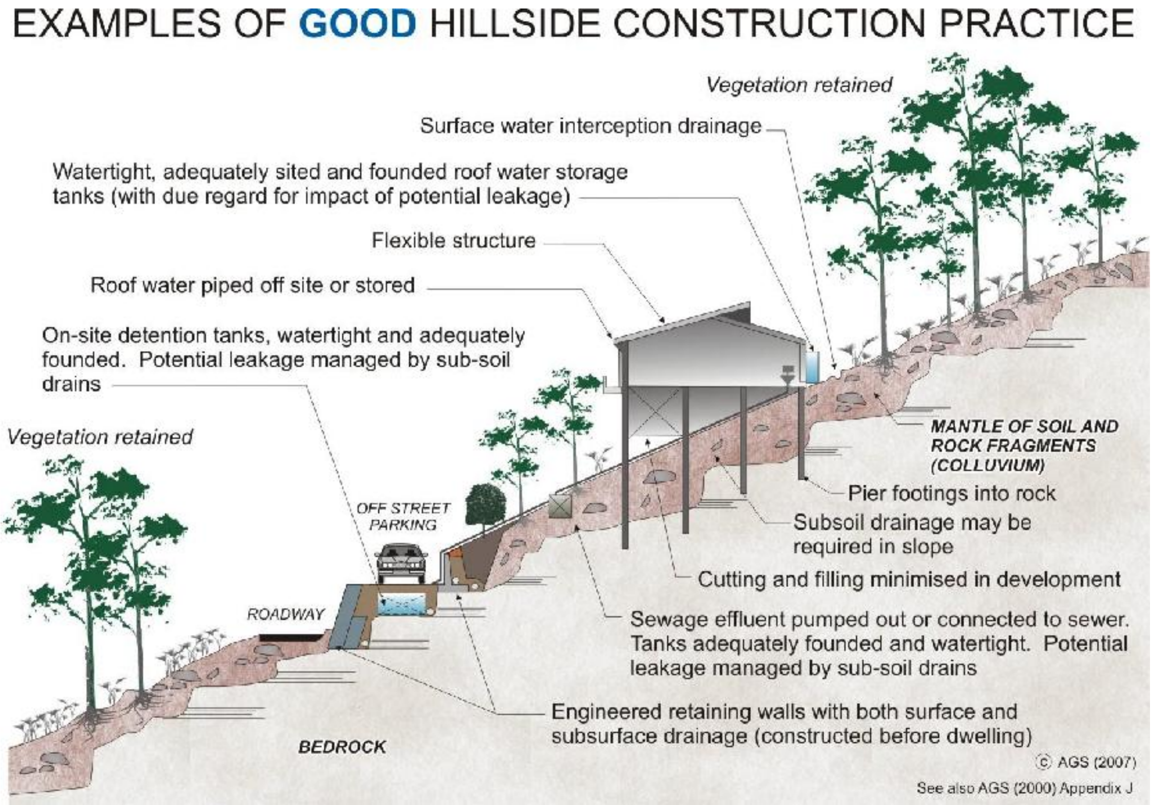
- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
GeoGuide LR10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

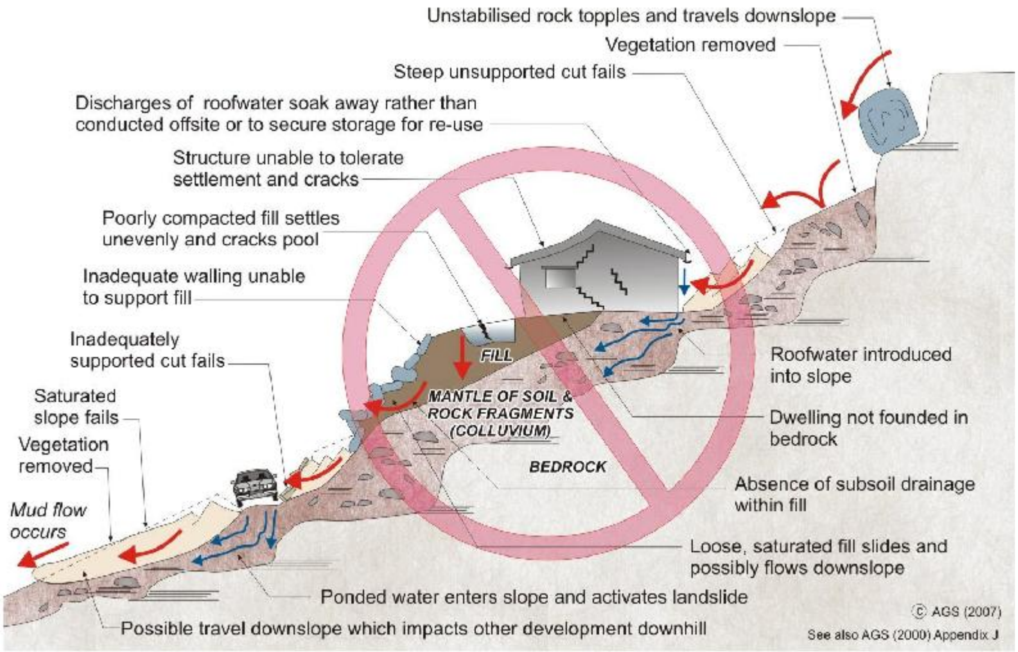
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing 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 LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal

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