Geotechnical Investigation Report
Landslip Remediation

32A Nareen Parade, North Narrabeen, NSW

Submitted to:

Silver Wolf Projects

Prepared By:

GeoReports Pty Ltd

PO Box 893, Newport Beach, NSW 2106

Project No.: 210083

Date: 13 November 2022

Table of Contents

1.0 INTRODUCTION

This geotechnical investigation report has been prepared by GeoReports to inform landslip remedial works at the subject site, which is located at 32A Nareen Parade, North Narrabeen, NSW (#32, the subject site). The remedial works are anticipated to involve the reinstatement of a failed slope and retaining walls and installation of drainage improvements following landslip near the southern boundary of the site Nareen Parade, which failed during a significant rainfall event in early March 2022.

We understand that Silver Wolf Projects Pty Ltd (Silver Wolf) have been engaged to design remedial works as part of a Northern Beaches Council Development Application. To assist with this process, GeoReports Pty Ltd was initially engaged in May 2022 to undertake a preliminary geotechnical assessment (GeoReports Report Ref. 210083-001), then undertake more detailed investigations involving drilling and probing, as reported herein. This most recent phase of work has been undertaken in general accordance with our proposal Ref. P220083-002-Rev0, dated 27 September 2022 and following your acceptance of the same date.

1.1 Background Information

The following information was reviewed as part of this study:

- Report on Geotechnical Assessment – Landslip Damage, by GeoReports Ref. 210083-001-Rev0, dated 10 May 2022 (referred to herein as 'GeoReports 2022a').
- Building/Engineering Report for 32A Nareen Parade, North Narrabeen NSW 2101, Ref. SWP-SIR-2205292 Rev.A, dated 13 May 2022.
- Site Survey by Detailed Surveys, Drawing No.1, Ref. 089/20, dated 23 Feb 2022.
- Site Survey by Complete Precision Surveys, Drawing Ref. 220039 Rev1, dated 23 Sept 2022.
- Mobile phone video and stills footage of overland surface water flows at/near the subject site, as follows:
  - 11 March 2022, 3:50 pm from neighbouring upslope property
  - 31 March 2022, 1:09 pm from subject site towards Nareen Pde
  - 6 April 2022, 12:30 pm towards adjacent property at 30 Nareen Pde

1.2 Scope of Work

The scope of investigation and reporting work has been undertaken in general accordance with our proposal, relevant Australian Standards and Council guidelines, as follows:

- Field investigation consisting of drilling of two boreholes (BH-01, BH-02) and seven Dynamic Cone Penetrometers (DCP-01 to 07) to observe and document the type and consistency of subsurface materials in the proposed works area;
- Surface mapping of site features and conditions;
- A Quantitative Risk Assessment (QRA) to evaluate acceptability of identified slope related hazards; and
- Reporting of the above in general accordance with Council reporting requirements (Geotechnical Risk Management Policy (GRMP) for Pittwater, No. 178) and provision of geotechnical recommendations to inform design and construction.

The scope of this report is limited to stability assessment and remedial design within the surveyed property boundary of #32A (the subject site). Related erosion and landslip affecting neighbouring properties and the adjoining communal driveway easement, which were triggered the same rainfall event in March 2022, are excluded from remedial upgrade, however, it is noted that these hazards could potentially impact access to, or cause damage to the subject site.

2.0 SITE DESCRIPTION

2.1 Site Location, Topography

The subject site is located between Elanora Heights and Lake Narrabeen on the southern flank of an extensive sandstone ridge about 50 to 60m high, as shown in Figure 1. The steeply sloping block is located on the lower part of the ridge slope above Nareen Parade with an average slope gradient of 28º across the whole length of the block. The lower portion of the block below the residence is locally steeper and contains terraced steel post and timber panel retaining walls with an overall slope gradient of about 40º.

The central/upper part of the block contains 2 storey, split level timber frame and weatherboard residence supported on timber poles and square section timber posts which are understood to be founded on concrete piles socketed into rock. The block is accessible via a shared concrete driveway from Nareen Parade from below the block. The driveway cuts diagonally across the ridge slope and switches back towards a private driveway and garage above the residence of #32A.

Survey plans and site observations show eight post and panel retaining walls terraced up the slope and one gravel-filled timber crib wall and shotcrete faced cutting along the slope fall-line at the common boundary with 30 Nareen Parade, where a double car-parking bay has been excavated into the slope. At the time of inspection, four levels of terraced post-and-panel retaining walls and timber steps below the subject residence were partly destroyed by landslip at the subject site, and other retaining walls within the site (e.g. upslope of the residence) showed evidence of movement, some of which is anecdotally historic movement which may have been arrested by more recent upgrades to existing walls.

Evidence of landslip, slope movement and erosion is also visible on neighbouring sites, resulting in damage to nearby assets including:

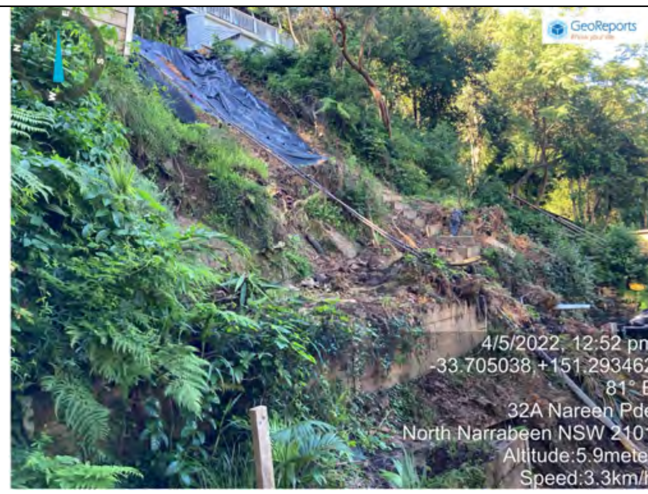
- Extensive cracking, movement and in places undercutting of the shared concrete driveway due to multiple landslips and erosion above and below the driveway.
- A 150-250m^3 landslip immediately above Nareen Parade in the adjoining blocks of 34 and 36 Nareen Parade which partly affects the shared driveway serving #32A.
- Damage and erosion of post and panel, mid-level retaining structures supporting paved areas at 30 Nareen Parade, including some evidence that water flows have crossed from that site into the slip area at the subject site.
- Deteriorating condition of the timber crib wall along the common boundary at the low car parking bay between #30 & #32A Nareen Parade. This old gravel-filled timber crib wall is up to about 5m high and is near the end of its service life, with loose / detached rib elements, bulging and decaying timbers.

As indicated previously, the scope of proposed remedial works at #32A are anticipated to exclude treating the above hazards, which exist on neighbouring land. However, because these issues could potentially impact the subject site, they have necessarily been incorporated into quantitative slope stability risk assessment discussed below in this report.

A summary of typical site images is presented in Figures 2a to d, below, as presented previously in GeoReports (2022a).

Figure 1 – Site Location (Source: Mecone Mosaic)

a) View upslope from below residence



b) View across slip area

c) Timber crib wall adj. to 30 Nareen Pde

d) Landslip below shared driveway (outside property boundary)

Figure 2 – Typical Site Images

2.2 Geology

The 1:100,000 scale Geological Survey Map of the Sydney region (Map sheet 9130[1]) indicates that the Subject Site is located above the Narrabeen Group sedimentary rock formation. Further reference to the more detailed NSW Seamless Geology data package (version 1.1[2]), shown in Figure 3, also confirms this lithology.

Narrabeen Group rocks contain a more variable and interbedded sequence of sedimentary rocks including laminate, shale and quartz to lithic quartz sandstone. Erosion of these rocks has produced steep slopes with relatively narrow terraces, infilled and outcropping rock benches as observed on site.

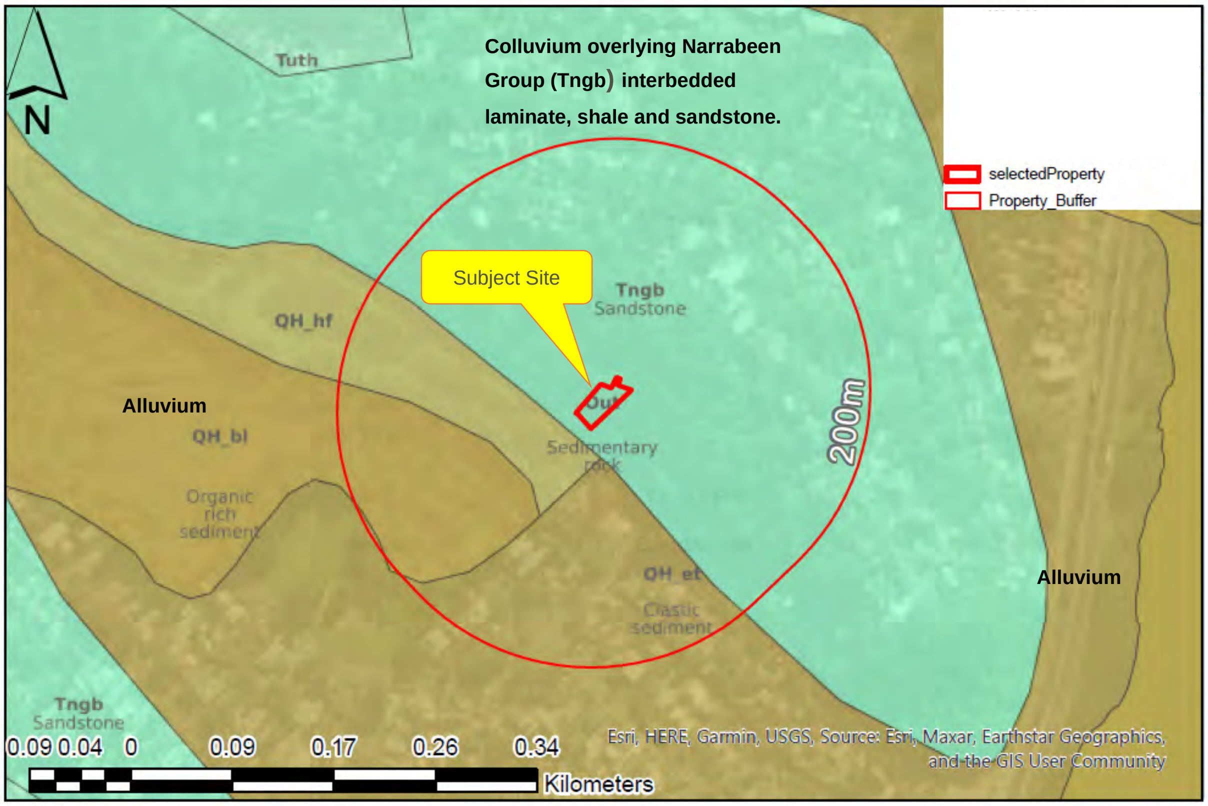


Figure 3 – Published Geology (Source: Geoscience NSW)

2.3 Soil Landscape

Soils developed on over bedrock near the residence at the Subject Site are largely associated with the Watagan soil landscape unit (See Figures 4 & 5). Terrain consists of rolling to very steep hills on fine-grained Narrabeen Group sediments. Local relief 60–120 m, slopes >25%. Landform comprises narrow, convex crests and ridges, steep colluvial side slopes with occasional sandstone boulders and benches. Soils are typically 30–200 cm deep stony, brownish-black, clayey and silty sands. Known issues include: mass movement hazard, steep slopes, severe soil erosion hazard, occasional rock outcrop.

[1] Herbert, C., West, J.L., 1983, Sydney, New South Wales,1:100 000 geological series map sheet 9130. 1st edition.

[2] Colquhoun G.P., Hughes K.S., Deyssing L., Ballard J.C., Phillips G., Troedson A.L., Folkes C.B. & Fitzherbert J.A. 2019. New South Wales Seamless Geology dataset, version 1.1, Geological Survey of New South Wales, NSW Department of Planning and Environment, Maitland.

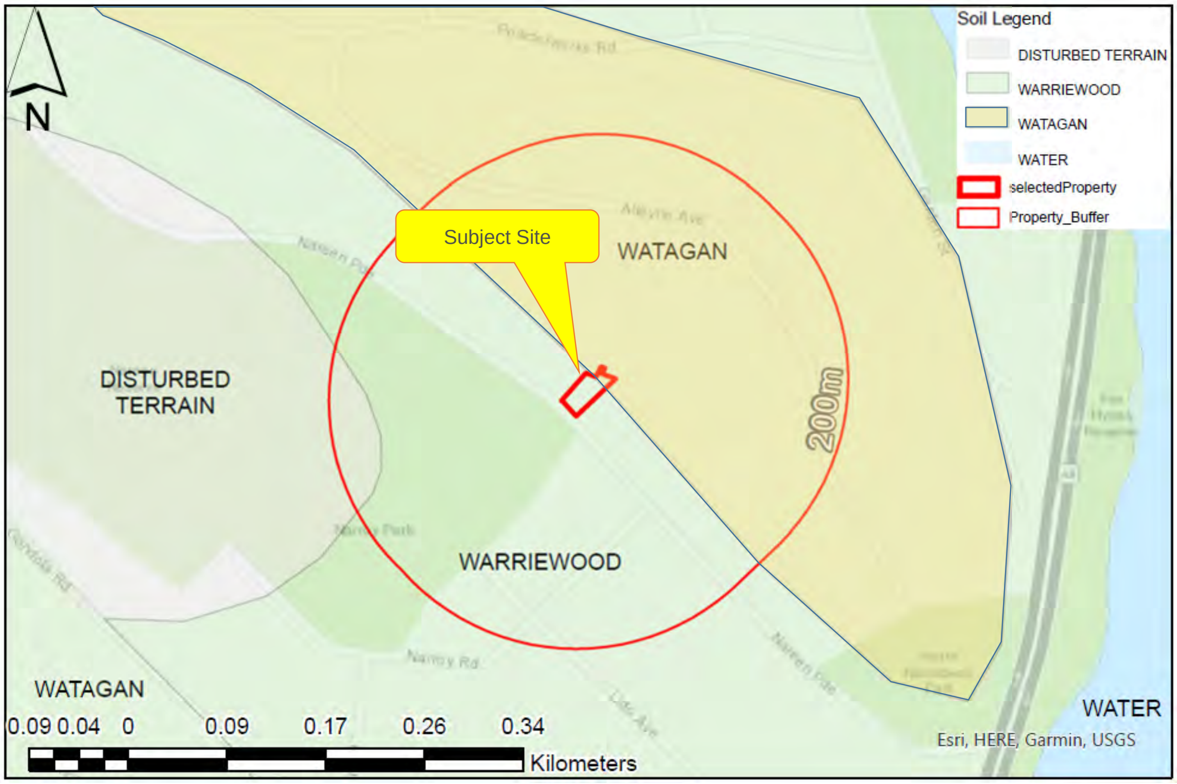
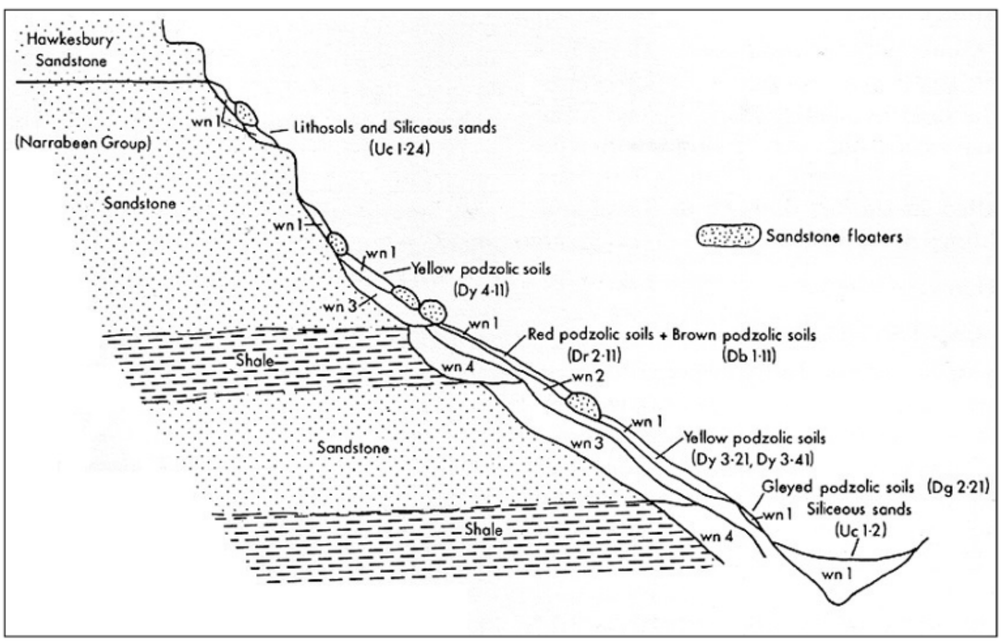


Figure 4: Soil Landscape (Source: Office of Environment and Heritage)



Schematic cross-section of Watagan soil landscape illustrating the occurrence and relationship of the dominant soil materials.

Figure 5 – Schematic Section through Watagan Soil Landscape (Source: Office of Environment and Heritage)

Reference to published Acid Sulfate Soils (ASS) maps indicates that ASS prone soils are unlikely to occur at this elevation.

2.4 Landslip Hazard Mapping

Residential developments in the locality of the subject site have historically involved modification of the slopes by excavation into the talus and clayey colluvium and localised filling and retaining above these materials. The occurrence of landslides in the Pittwater and Elanora area has been recognised since the 1970's when a number of homes were damaged or destroyed by landslides. The then Warringah Council first introduced a landslide zoning scheme in 1977 and this has evolved into the land categorisation system and online mapping zones presented on the Northern Beaches online mapping tool (https://nb-icongis.azurewebsites.net/).

A check of this mapping tool (reproduced in Figure 6), identifies that the subject site is zoned within the most adverse category of Geotechnical Hazard Zone H1, as defined in the Geotechnical Risk Management Policy for Pittwater Policy (DCP 21, Appendix 5). Sites which are in Geotechnical Hazard Zone H1 are associated with those having an elevated risk of landslip and are subject to the most strict controls relating to geotechnical investigation, design and construction stage management.

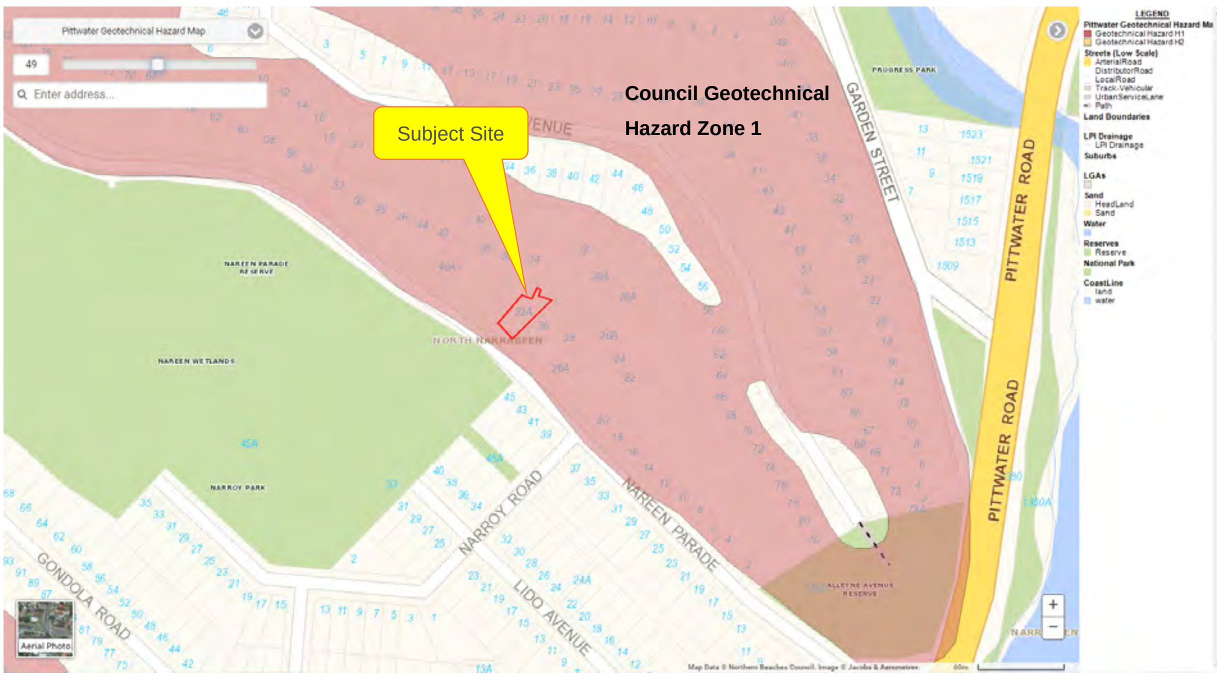


Figure 6 – Landslip Hazard Zoning Map – Northern Beaches Council
(Source: NB Council)

Reference has also been made to the proprietary landslip database compiled by GeoReports which includes the Australian Landslide Database (2012) as provided by Geoscience Australia. This has more than 3,000 entries detailing landslides and sets of landslides since 1842 throughout Australia. The resulting 'landslip heatmap' presented in Figure 7 has been filtered to exclude human-induced landslides. As described above, this landslip heatmap confirms that this locality is prone to landslip instability.

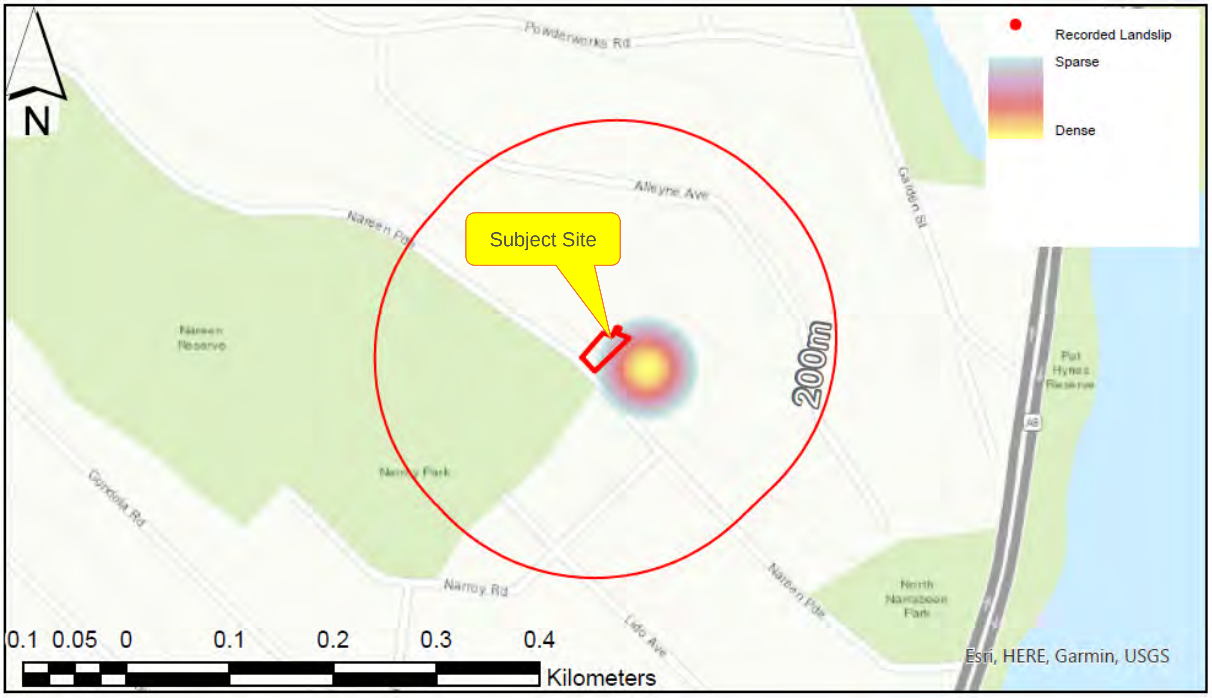


Figure 7 – Landslip Heatmap
(Source: GeoReports/Geoscience Australia)

3.0 GEOTECHNICAL INVESTIGATIONS

3.1 Investigation Scope and Methodology

A preliminary site inspection was undertaken by GeoReports on 4 May 2022 followed by investigation fieldwork on 5 October 2022, during moderately heavy rainfall.

Inspection, fieldwork and logging of subsurface profiles was carried out by an experienced Geotechnical Engineer from GeoReports. The borehole locations were set out by steel tape from site boundaries, and coordinates were also obtained using a hand-held GPS device. Ground surface elevations at investigation collar levels was interpolated from client-supplied survey plans. Investigation locations are shown in plan on Figure A1, attached and borehole logs are included in Appendix A together with explanatory notes. DCP logs are attached in Appendix B.

Fieldwork comprised site observations and a geotechnical investigation, involving the following:

- Site walkover, photography, documentation of geological and topographic features in the vicinity of the subject site;
- Drilling of two boreholes (BH-01 and BH-02) to allow subsurface characterisation and logging of soil samples. BH02 in the upper slope area terminated at 0.6m depth in Very Stiff to Hard residual soil and BH03 in the lower slope area also terminated at 0.6m depth but within fill on a buried obstruction; and,
- Probing using seven Dynamic Cone Penetration tests (DCP01 to 07), which were completed adjacent to each borehole and across the width and length of the sloping site to characterise soil consistency and strength. Probing was undertaken to practical refusal at depths of between 0.8m to 4.0m below the existing surface level. It is possible that DCPs 02 and 03 skidded off steeply inclined buried rock surfaces (as evidenced by bent steel rods on retrieval.

Geotechnical logging of soil samples recovered from boreholes in general accordance with AS1726 (2017) and DCP tests were undertaken in general accordance with AS1289.6.3.2-1997. No physical or chemical laboratory testing of soil samples was undertaken as this was not in the scope of the current investigation. Following drilling, boreholes were backfilled with excavated spoil and the site restored as close as practicable to pre-existing conditions.

4.0 INVESTIGATION FINDINGS AND RECOMMENDATIONS

4.1 Subsurface Conditions

Probing, drilling and mapping identified a variable distribution of mixed granular and cohesive topsoil, fill and colluvium fill varying from about 0.5m to 1.5 thick. Near surface materials mainly comprised sandy soil in the uppermost 1m and these soils were thickest in backfill areas behind terraced retaining structures. These materials overlie predominantly stiff but relatively thin and discontinuous natural residual clay soils. The underlying rock comprises benched sandstone which was also observed as rounded outcrops intermittently exposed at ground surface in the lower portion of the block. Detached rock 'floaters' and exfoliation 'onion skin' weathering is likely near the edge of bench rock terraces.

Depth to rock at the site varies from nil (at outcrops) to potentially 4m, but more typically 1m to 3m, noting the potential for steeply inclined and/or rounded buried rock benches up to about 3m high. These observations are consistent with expected conditions based on our review of published mapping data and local experience.

The landslip has an estimated volume of about 80-100m^3 and has resulted in removal of the uppermost 0.5m to 1.5m of topsoil across the landslip footprint. Extensive damage has occurred to multiple retaining walls as fluidised debris flows (inferred to be mainly re-worked colluvium) cascaded down the slope. The majority of the slip mass and broken wall materials have been removed off-site.

Plans and cross sections showing relevant features and interpreted distribution of subsurface materials are provided in Figures A1 to A4, attached. Further details of subsurface conditions encountered at each borehole location are described on the borehole log sheets, attached in Appendix A.

4.2 Groundwater, Drainage

A search of nearby groundwater bores (also known as wells, monitoring wells) on the WaterNSW Groundwater Bore database did not reveal any known wells within about 200m of the subject site. However, based on local experience, groundwater in this environment is likely to occur as localised and periodic perched groundwater tables concentrated above changes in lithology and especially above relatively impermeable horizons such as shale / siltstone interbeds.

Persistent seepage was identified near the toe of the slip and adjacent boundary crib wall, flowing towards the upslope verge of Nareen Parade, which was wet and waterlogged near the site. Minor residual groundwater seepage was also observed along and across the shared driveway near the switch-back area at mid-slope height. Various stormwater and sewer pipes, pits and rising pipes are scattered on the slope below the residence and near the shared driveway, some of which may require repair and protection. A circular steel stormwater detention tank is also positioned immediately downslope and west of the residence and appears stable and operational.

During borehole drilling, no significant free groundwater flow was encountered, although it is possible that groundwater inflows would have occurred if the boreholes had been left open for a longer period than was possible in the available timeframe of investigation.

Groundwater in the vicinity of the subject site, is expected to occur as persistent seepage zones near the soil/rock interface during and following wet weather events. Seepage is also likely from defects (bedding and joints) in the weathered rock mass following rainfall. These flows and perched groundwater systems would need to be managed using appropriate drainage measures incorporated into any remedial retaining structures, noting that groundwater levels can fluctuate with location, and over time due to the effects of rainfall, seasonally and due to longer term climate effects.

4.3 Geotechnical Design Parameters

Based on the observed subsurface observations and inferred consistency of materials identified during investigations and calibrated through back-analysis of the failed slope, the geotechnical design parameters shown in Table 1 are considered appropriate. Refer to Cross Sections in Figures A2 and A4 for the interpreted distribution of these materials.

Table 1 – General Geotechnical Design Parameters

Geotechnical Unit	Material type	Bulk Unit Weight (kN/m³)	Undrained Shear Strength (kN/m²)	Drained Cohesion (kN/m²)	Friction Angle (ϕ, Deg)	Youngs Modulus (MN/m²)
Fill	Topsoil over mainly Silty/Clayey SAND, Loose	18	-	1	30-32	8
Colluvial Soil (Granular)	Silty/Clayey SAND, Very Loose to Med. Dense	20	-	0	32	10
Colluvial Soil (Cohesive)	Sandy CLAY, Firm to Stiff	20	35	2	30	20
Residual Soil	Sandy/Silty CLAY, Stiff to Hard	22	60	5	28	30
Rock (VL-L strength)	Sandstone bedrock (Assumed Class V Sandstone equivalent, after Pells, 1998)	24	300	50	45	100

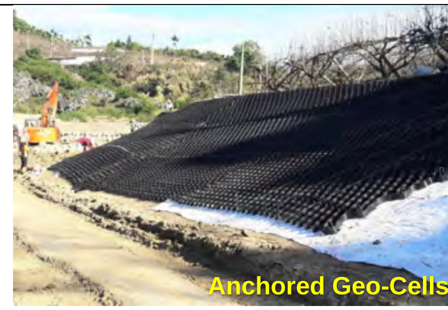
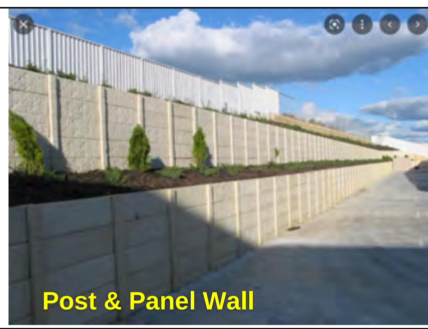
4.4 Remedial Works - Overview

It is anticipated that remedial works will likely consist of a combination of upgraded post-and-panel retaining wall structures, local stabilisation of soil slopes and drainage improvements (surface and subsurface). Suitable design options may be chosen according to the permanent remediated slope gradient as described below:

- **Slopes no steeper than 2H:1V:** Erosion treatment and surface stabilisation using coir logs, pinned geotextiles. Any re-profiling earthworks must be placed in accordance with Sections 4.5 and 4.6, below. Anchors and stakes must installed with erosion treatment supplier specifications;
- **Slopes steeper than 2H:1V, up to 1.5H:1V:** Anchored mesh or cellular confinement systems such as 'geo-cells' or similar. As above, for earthworks and anchoring.
- **Overall finished profiles steeper than 1.5H:1V:** Retaining structures (e.g. post & panel wall socketed at suitable depth into sandstone bedrock). Refer to Section 4.7 for further design recommendations.

Examples of suitable treatments are shown in Table 2.

Table 2 – Treatment options

Slope	Options	
No steeper than 2H:1V		
Between 2H:1V and 1.5H:1V		
Steeper than 1.5H:1V		

4.5 Cut and Fill Slopes

Slope re-profiling operations may be required where local slumping has occurred, behind retaining structures and for local excavations temporary works platforms. Excavations for the proposed retaining structure will likely require cutting through mixed fill and colluvium which may be locally waterlogged (especially during and following wet periods). Cut and fill slopes will either need to be battered back to suitable slope angles or be supported using suitably stiff temporary shoring. For unsupported cut and fill slopes, suitable limiting temporary and permanent batter slope angles are summarised in Table 3.

Table 3: Limiting Overall Slope Batter Angles

Material	Temporary Slopes*	Permanent Slopes**
Fill, colluvium, residual soil (stiff), to max 2m height	1.5H:1V	2H:1V
Residual soil (Very Stiff to Hard) and weathered rock, to max 3m height	1H:1V	1.5H:1V

Notes:
*- Benching may be required to reduce overall slope angle for slopes higher than the limiting height specified. Cuts must be appropriately drained, be outside the zone of influence of existing footings and be protected from rainfall / run-off and monitored for any evidence of local instability.
**- Permanent slopes require suitable surface treatment for erosion control and diversion of surface run-off away from slope crests.

Stockpiles of construction materials, spoil and mobile equipment should be kept well clear of the batter crests to avoid surcharging the crest of excavations. In the absence of case-specific stability analyses for unsupported slopes, a minimum offset (crest of slope to toe of any stockpile) at least equal to the slope height is recommended.

Where temporary slopes are required to be steeper than shown above, they must be supported by appropriately designed shoring or temporary retaining systems such as shoring or soldier piles and lagging designed as cantilevered or braced structural elements. Open cut excavations within the zone of influence of existing footings must be avoided, where the zone of influence may be taken as an envelope extending down at 1H:1V from the outermost point below the underside of any existing footing or loaded area at this site which is sensitive to ground movement.

4.6 Earthworks

Earthworks for re-profiling or wall backfilling are to be prepared in accordance with this report where applicable, or otherwise AS3798 (2007) Guidelines on Earthworks for commercial and residential developments. Specifically, the following recommendations apply:

- Any footings or paved areas not on rock must be founded below any uncontrolled fill or deleterious materials.
- Prior to forming footings or placement of site-won filling, any soft, organic or deleterious material must be removed to expose homogeneous, natural residual soil (very stiff clay) or rock.
- All fills or earthworks should be founded on strata of uniform stiffness to reduce the risk of risk of differential movements. As indicated above, we recommend that permanent retaining walls (or any building structures) are founded on uniform bedrock.
- Where required, suitable site-won backfill fill material should be placed in loose horizontal layers not exceeding 150mm in thickness, screened to remove oversize particles greater than 75mm size.
- All fills supporting structures and paved areas must be uniformly compacted in layers as per AS3798 (2007) guidelines.
- Compaction equipment is to be limited within 2m offset from retaining structures to a maximum of 125kg vibrating plate mass and an appropriate allowance allowed in structural design for compaction induced earth pressures.

For non-structural areas supporting flexible pathways and landscaping we recommend compacting suitable general fill in maximum 150mm loose layer thickness to a minimum 98% standard maximum dry density ratio to within 2% of optimum moisture content. Suitably screened and conditioned existing fill or site-won fill may be reconditioned for use as general fill provided it complies with the quality, grading and compaction requirements set out in AS3798 (2007) Guidelines on Earthworks for Commercial and Residential Developments.

In lieu of any specified compaction testing requirements expressed as standard maximum dry density testing, (involving validation of field density testing by nuclear gauge or sand/water replacement tests), it will be necessary to undertake field probing using Dynamic Cone Penetrometer (DCP) in accordance with AS 1289.6.3.2 (1997) to validate required as-placed soil consistency and strength with depth. The earthworks test frequency should be as nominated for Type 4 sites as in Table 8.1 of AS3798 (2007).

4.7 Retaining Structures and Piled Footings

Any slopes formed steeper than the profiles shown in Table 3 (above) will need to be supported by temporary or permanent bracing or retaining walls, as appropriate. Temporary support options include:

- Shotcrete and soil nails installed in a top-down sequence.
- Lightweight aluminium shoring shields – typically for depths and widths up to about 2.4m, these involve driving in perimeter panels of corrugated aluminium then installing internal bracing progressively at appropriate depth intervals during excavation.
- Soldier piles with timber/steel lagging – This would involve initial installation of steel ‘H’ soldier piles to a suitable depth followed by progressive installation of timber lagging or concrete elements (for combined temporary and permanent structures) between piles as excavation proceeds. This approach would require appropriate design of piles to act as cantilevered, braced or anchored structural elements.

For design of temporary and permanent wall structures, we recommend following earth pressure distributions and parameters:

- For relatively flexible walls such as soldier pile or some gravity walls, a triangular earth pressure distribution may be used. Where site boundaries, structures or utilities are offset from the excavation crest within a distance closer than the excavation depth, some degree of deformation is likely to occur and would need to be acceptable to those assets. Assuming that there are no other constraints on tolerable ground movements, and where crest movements for rotating walls in sand are >0.1% of the retained height they may be designed based on active (Ka) pressures (Refer Figure 8), taking due account of sloping ground.
- In areas where structures or property boundaries are close to the excavation (i.e. where offset distance from cut crest is less than or equal to the cut depth), or for cases where lower ground displacements are required or where crest movements for rotating walls in sand are >0.1% retained height, then higher "at rest" (Ko) pressures where Ko = 1-sinϕ from Table 1 and factored for the effects of sloping ground according to Figure 8).
- For rigid or propped walls, a rectangular earth pressure distribution with a pressure of 6H (kPa) for level soil may be used, depending on the amount of movement that can be tolerated, where 'H' is the effective vertical height of the wall in metres. Where sloping ground exists (no steeper than 2H:1V) or where movement sensitive structures or buried services lie close to the wall crest, then the uniform rectangular earth pressure distribution should be increased to 8H kPa.

All retaining structures must be designed and constructed in accordance with AS4678 (2002), which also contains further advice on wall movements associated with 'active' and 'at rest' pressure coefficients. The following recommendations also apply:

- The above earth pressures assume that effective drainage is provided behind or through the walls. If drainage cannot be provided to alleviate water pressure on retaining walls, an appropriate allowance for hydrostatic pressure should also be included, considering both the long-term groundwater level and potentially transient (higher) groundwater conditions which intermittently may rise above the base of the wall. Retaining wall panels and subsurface drains should be lined with a robust non-woven geotextile fabric, such as Bidim A34, to act as a filter against subsoil erosion. The subsoil drains should discharge into the stormwater system and be designed to allow for future maintenance flushing.
- Appropriate surface drainage must be provided to intercept and divert run-off above the existing slip area and resulting remediation area and also above each of level of terraced retaining wall so as to prevent ingress of run-off into retaining wall backfill.
- Any applicable surcharges (e.g. nearby footings, compaction stresses, construction loads etc) should be added to the soil pressures, using the Ka or Ko values nominated, as appropriate to wall rigidity and/or the permitted deformation condition. Refer to AS4678 (2002) Appendix J for further guidance on compaction induced stresses.
- The preferred wall design will require detailed consideration of global stability, bearing, overturning and sliding mechanisms in addition to serviceability requirements.
- The retaining wall and backfill geometry, drainage details, backfill specifications and compaction requirements would need to comply with the requirements of AS4678 (2002) and be documented on suitable design drawings.

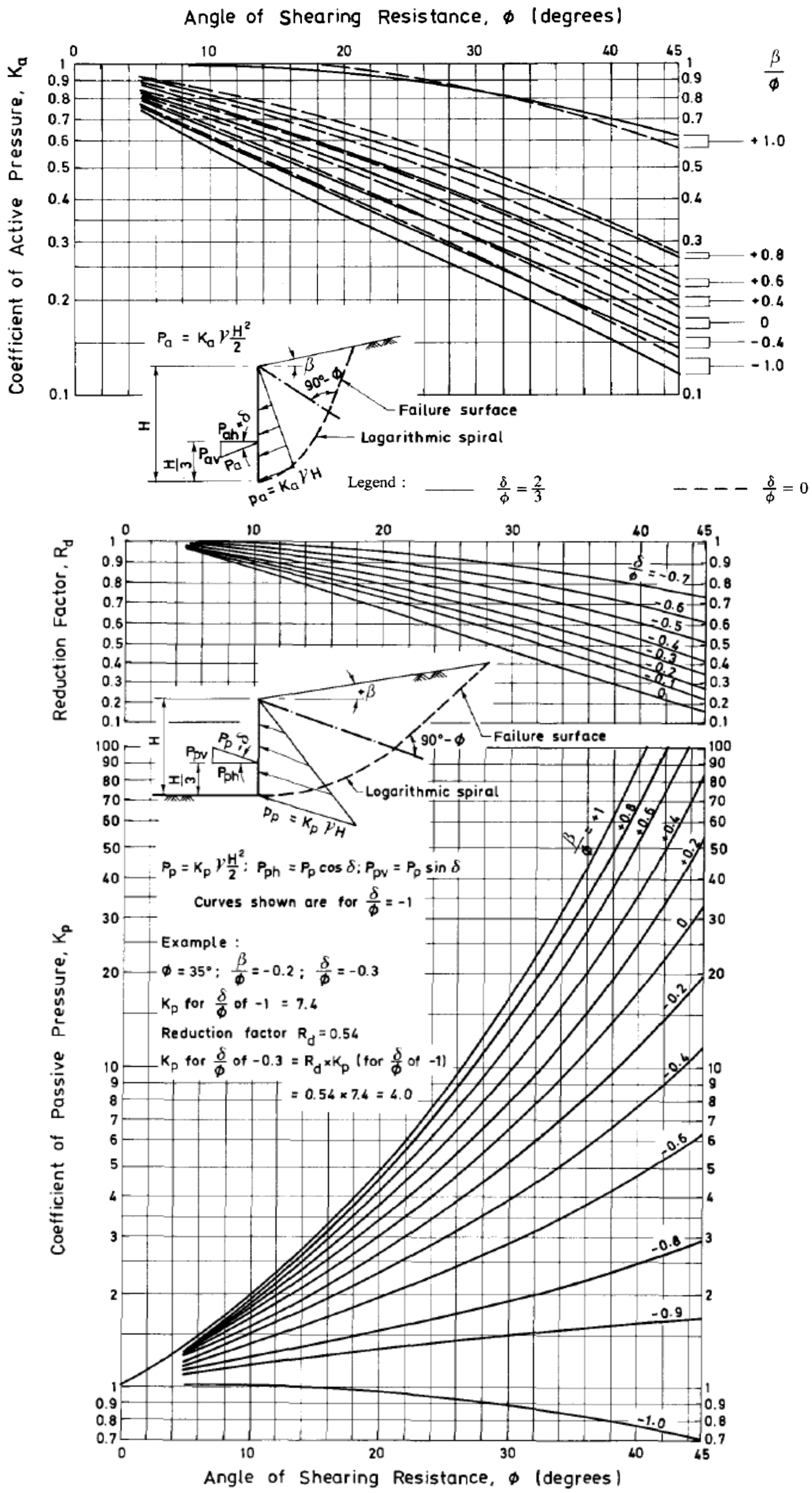


Figure 8: Earth Pressure Coefficients (Source: NAVFAC)

Additional design parameters specific to design of piled foundations are summarised below in Table 4.

Table 4 – Pile Design Parameters

Geotechnical Unit	Material type	Typical Unconfined Compressive Strength (MN/m^2)	Ultimate limit state (ULS)			Serviceability limit state (SLS)[2]	
			End bearing resistance[3] (kN/m^2)	Axial shaft resistance[1,3] (kN/m^2)	Lateral capacity[3] (kN/m^2)	End bearing resistance (kN/m^2)	Horizontal subgrade reaction, kh ($MN/m^2/m$)
Fill, Colluvium, Fluvial soils	Mixed fill and mainly sandy colluvium / fluvial soils	N/A	N/A	N/A	N/A	N/A	5
Residual Soil	Stiff to Hard CLAY	<0.3	N/A	20	150	N/A	10
Weathered Rock (VL-L strength)[4]	Siltstone/claystone (Class V shale equivalent, after Pells (1998))	0.3-1	2,000	75	300	800	50

Notes:

(1) Existing fill and colluvium is of variable consistency and potentially settlement-prone. Shaft resistance should be ignored in this unit.

(2) Serviceability end bearing pressure typically result in settlements in the order of 1% of the pile diameter. Consideration should be given by the designer to the acceptable lateral pile deformation, considering also the deflection/rotation of any cantilevering elements above the embedded pile.

(3) Adopt strength reduction factor (ϕ_g) of 0.4 and ensure that pile shafts in rock are free of smear and debris with Class R2 roughness. For uplift loads, reduce values of shaft friction to 80% of the values given in this table. Where uplift resistance is required, the uplift capacity should be checked against a cone pull-out failure mode assuming a cone angle of 60° considering the submerged weight of the soil or rock and adopting a reduction factor of 0.5 on pull-out mass. Shaft resistance in overlying soils should be ignored as rock shaft resistance would be fully mobilised before displacement required to mobilise resistance in soil occurs.

(4) Rock strength is the cautious rock mass range adopted for foundation design. Higher strength zones of rock are likely to exist and should be accounted for in the selection of appropriate piling equipment.

Where piled footings are used for retaining structures, there is a risk that they may be located at or near the edge of benched sandstone which may include jointed, unstable or overhanging rock. As such, it will be necessary to increase the minimum socket depth required to achieve reliable vertical and lateral resistance of piled sockets as compared to sites with relatively level rock terrain. At this site, a minimum pile rock socket penetration of 2m is recommended.

As shown in the attached cross sections, weathered bedrock is typically estimated to be about 1 to 3m depth below existing ground level and is likely to be highly irregular and benched. Due to the presence of steep rock surfaces identified during investigation probing by GeoReports, there is a high risk that during drilling of piles, augers could skid along steep rock surfaces, resulting in an inclined socket in soil, rather than penetrate the rock surface to form the required vertical socket in rock. Options to help mitigate this issue include adapting the design to use cored/hammered micropiles and/or using smaller diameter pilot holes. Construction stage inspections by a suitably qualified and experienced geotechnical engineer will also be required to validate that piled rock sockets achieve the design intent.

The structural engineer is required to assess all relevant temporary and permanent structural systems required to satisfy retaining wall serviceability and ultimate limit state conditions and make appropriate detailed provisions for wall and surface drainage and durability requirements.

It will be necessary to undertake careful construction staging to manage the risk of additional landslip and to protect buried services, the upslope structure (understood to be piered) and neighbouring property at the subject site. Details of foundations (size, depth, reinforcement, etc) are to be documented on structural drawings and a representative number of footings are to be inspected by a geotechnical engineer during construction.

All piled footings must be thoroughly cleaned free of smear and debris, dry and concreted as soon as practicable following excavation. In the case that water ponding occurs at the base of footings, footings should be pumped dry and then re-excavated to remove all loose and any water-softened materials. Details of these requirements and other specifications (size, depth, reinforcement, etc) are to be documented on structural drawings. For all types of footing, a concrete blinding layer must be placed on the same day as excavation and following inspection of final excavation surface.

4.8 Landslip Considerations

As required by the Northern Beaches Council Geotechnical Risk Management Policy (GRMP), selection of appropriate remedial works would be required to achieve improve the currently unacceptable (active) landslip risk to property to and 'Acceptable'/'Low' risk or better as defined by the Australian Geomechanics Society (AGS) Practice Note Guidelines for Landslide Risk Management (LRM), 2007[3] which provides a recognised framework for the characterisation, risk classification and treatment of landslip affected sites in Australia.

The AGS LRM process involves desktop and site assessment, hazard identification, assessment of probability risk to property and life by considering likelihood and consequence of the hazards identified. Based on the site assessment described above, relevant hazards have been identified in Appendix C (with risk calculations) and summarised in Table 4 and Appendix C. An extract from the AGS LRM is shown in Appendix D of this report, defining the relationship between likelihood, consequence and resultant risk, along with definitions for risk terminology used.

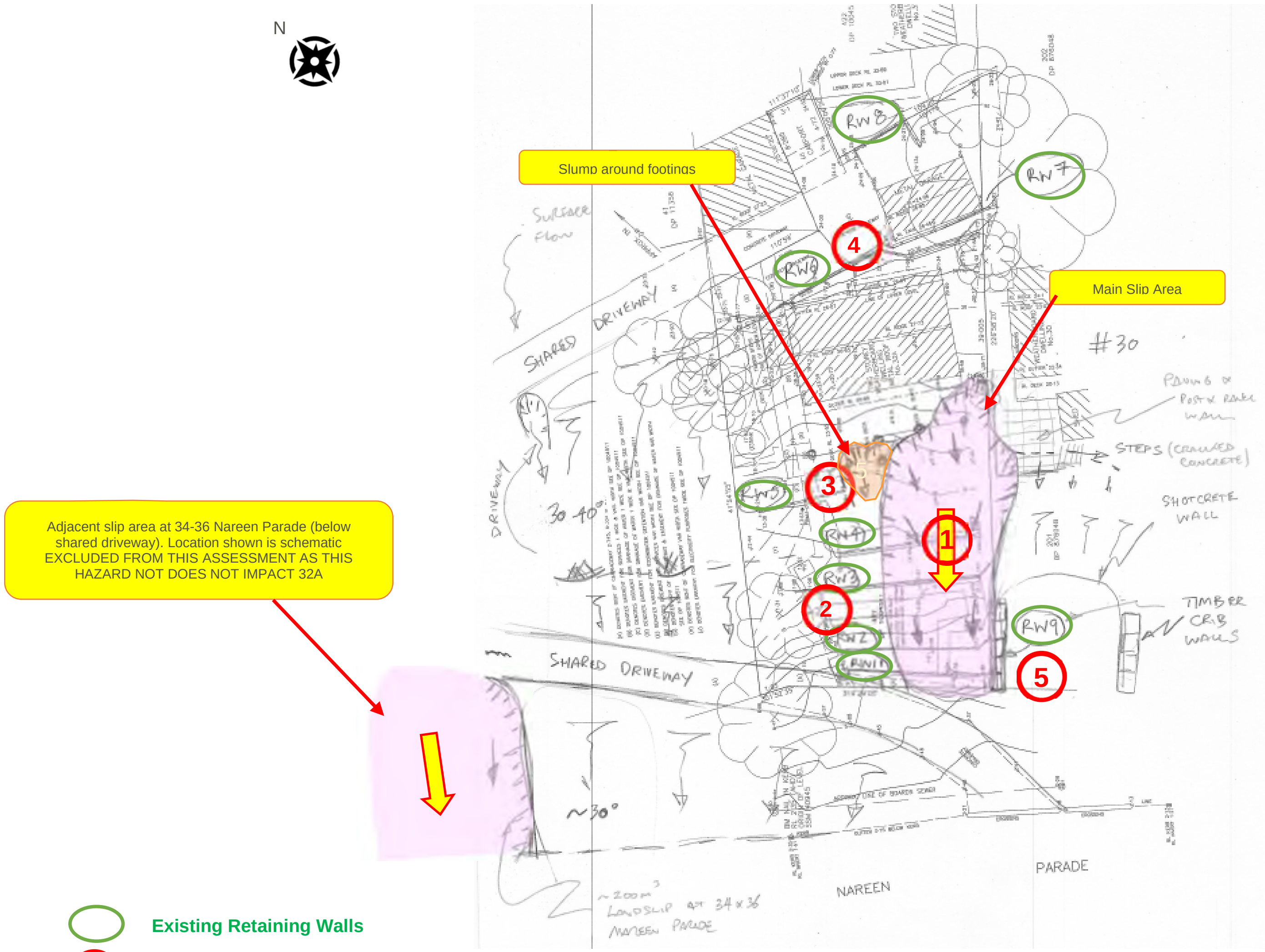
The itemised geotechnical hazards referred to in Table 5 are located as shown in Figures 9 & 10 overleaf.

Table 5 – QRA, Risk Summary and Recommendations

Hazard / Element #	Current Risk* to…		Comment / Recommended Mitigation Measure	Following Mitigation, Residual Risk* to…	
	Property	Life		Property	Life
1. Large scale global instability impacting multiple retaining structures (>50m^3 volume).	High to Very High	Unacceptable (R_{lol}>1x10^{-4})	Remediate existing slip area by demolishing remaining walls, removing debris and installing suitably upgraded replacement walls, slope and drainage in accordance with recommendations in report and as per AS4678. Inspect, maintain (periodically flush drainage), manage erosion.	Low	Acceptable (R_{lol}<1x10^{-5})
2. Small scale wall / bench instability impacting multiple single retaining structure (5-20m^3 volume).	Moderate to High	Tolerable (R_{lol}<1x10^{-4})	Remediate existing slope by demolishing remaining walls, removing debris and installing suitably upgraded replacement walls. Scale unstable rock above driveway. Inspect, maintain (periodically flush drainage), divert surface and groundwater water away from walls.	Low	Acceptable (R_{lol}<1x10^{-5})
3. Local instability of soil slope (3-10m^3 volume).	Moderate to High	Tolerable (R_{lol}<1x10^{-4})	Provide surface stabilisation using coir logs, pinned geotextiles, anchored mesh or geo-cells according to slope angle). Monitor, maintain, manage erosion. Divert surface and groundwater water away from slope/wall. Maintain small scale root-binding vegetation at crest and on slope. Optionally replace and upgrade section of post-and-panel retaining walls.	Low	Acceptable (R_{lol}<1x10^{-5})
4. Failure of RW6A/B/C impacting house (Up to approx. 20m^3 volume).	Moderate to High	Tolerable (R_{lol}<1x10^{-4})	Remediate existing existing deforming walls by either installing suitably upgraded replacement walls, or shotcrete and soil nails through existing wall(s). Improve surface and subsurface drainage in accordance with recommendations in report and as per AS4678.	Low to Mod.**	Tolerable to Acceptable**
5. Failure of RW9 on Bdy impacting subject site (Up to approx. 20m^3 volume).	Moderate	Acceptable (R_{lol}<1x10^{-5})	Treat & Manage as per Hazard #4. Optionally engage / collaborate with owners of #30 to agree on upgrade to mitigate risk.	Low to Mod.**	Acceptable (R_{lol}<1x10^{-5})

* A guide to risk AGS LRM terminology is attached in Appendix D. R_{lol} is the assessed annualised risk pertaining to loss of life.
**Replacement of structures would achieve 'Low' / 'Acceptable'. It may be possible to identify a 'repair / strengthen' solution (rather than 'replace' option which achieves 'Low Risk' (i.e. 'Acceptable') outcome. Improving existing risk to 'Low' outcome is a Council requirement for DA approval. if side retaining walls within about 5m of southern boundary are replaced and upgraded.

[3] Australian Geomechanics Journal 42(1):63-109 · March 2007



Existing Retaining Walls

Refer to Table 5 for Numbered Hazards

Figure 9 – Plan of Slope Risk Hazards

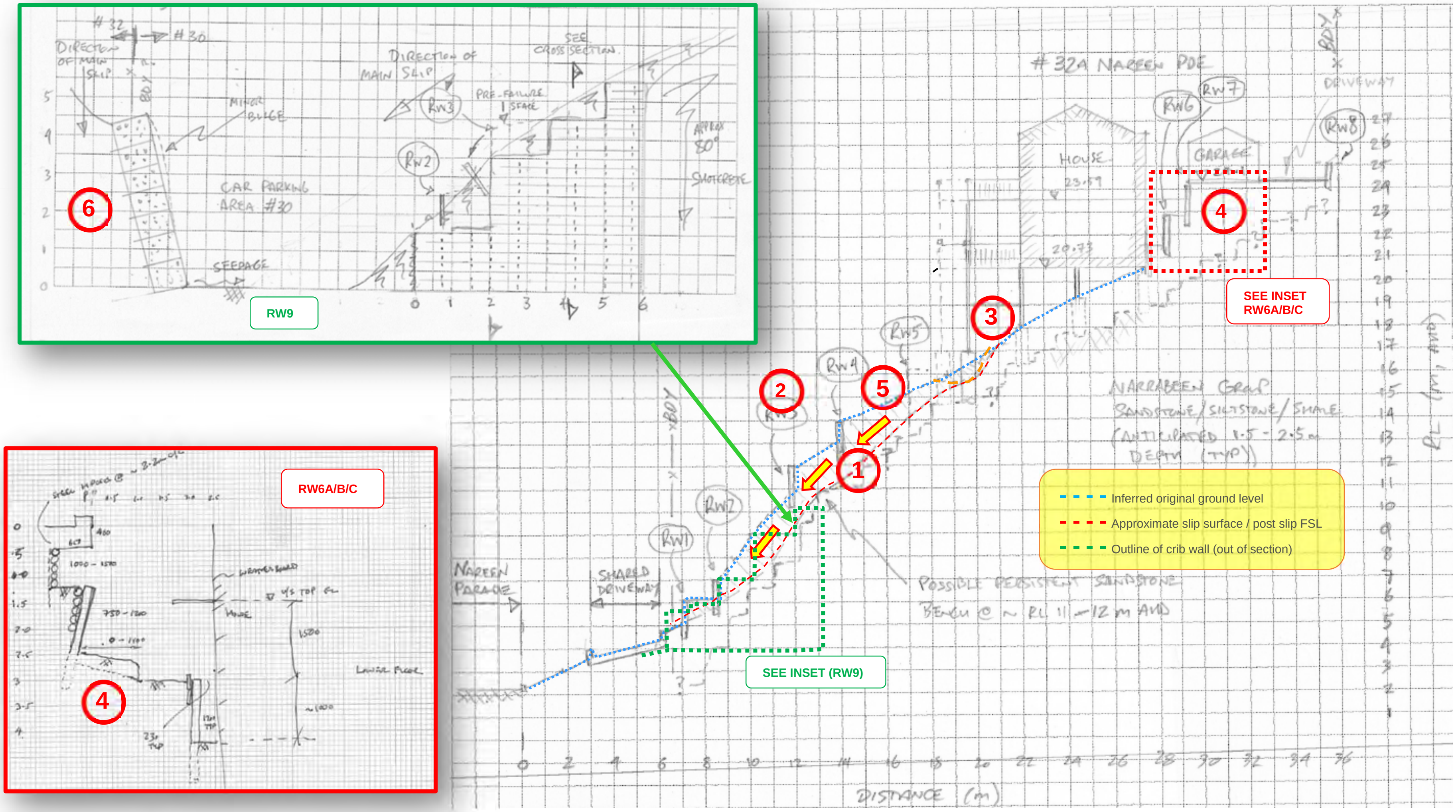


Figure 10 – Schematic Cross Section Showing Slope Risk Hazards

Based on Appendix the AGS LRM Guideline, 'Low' risk to property is defined as '*Usually acceptable to regulators*'. Ongoing inspection and visual monitoring of slope and retaining wall performance is required as part of routine maintenance. Additional general recommendations for good construction practice on sloping sites is provided in Appendix D.

Consideration has been given to the Council's GRMP requirements, as appropriate for the remedial works described above, and it is our opinion, having examined the site, undertaken investigations and assessed the proposed development and geotechnical risks in detail, that the geotechnical aspects of design can achieve the Council "Acceptable Risk Management" criteria provided that all recommendations stated in this report are adopted. On this basis, Council Forms 1A/1B have been completed and are attached as Appendix E.

4.9 Further Work Requirements

Following selection, design and documentation of the preferred remedial design by a suitably qualified and experienced (chartered) civil/structural engineer, design review and inspections will be by a suitably qualified geotechnical engineer as follows:

- Construction Certificate / IFC drawings: Geotechnical review of civil/structural drawings documenting remedial works (wall, earthworks, drainage) anticipating that drawings will include:
    - Dimensioned detailed of remedial works (slope treatments and retaining structures), finished slope geometry, drainage details, fill material types, specifications and construction stage testing requirements;
    - Suitable foundation material requirements (material type, preparation requirements, minimum allowable bearing pressure requirements);
    - Suitable details for any temporary and permanent retaining walls (complying with AS4678-2002 Australian Standard for Earth-retaining structures); and
    - Temporary excavation support and/or drainage requirements in accordance with this report.

- Construction stage: Inspection and approval to confirm that:
    - Installed temporary and permanent treatments and support details meet the requirements set out in this report and on approved drawings; and
    - Foundation preparation and allowable bearing capacity for all new structural footings meets requirements shown on approved structural drawings; and

5.0 LIMITATIONS

This assessment is limited in scope and coverage and is not designed or capable of identifying all subsurface conditions, which can vary even over short distances and with time. The advice given in this report is based on the assumption that the investigation and test results are representative of the overall ground conditions. However, it should be noted that actual conditions in some parts of the site might differ from those found. If excavations reveal ground conditions significantly different from those shown in our findings, GeoReports must be consulted.

The scope and the coverage of services are described in the report and are subject to restrictions and limitations. GeoReports has not performed a complete assessment of all possible conditions or circumstances that may exist at the site. If a service or issue is not expressly indicated as being considered, then do not assume it has been addressed. If a matter is not addressed, do not assume that any determination has been made by GeoReports with regards to it.

Where data has been supplied by the client or a third party, it is assumed that the information is correct unless otherwise stated. No responsibility is accepted by GeoReports for incomplete or inaccurate data supplied by others. Any drawings or figures presented in this report should be considered only as pictorial evidence of our work. Therefore, unless otherwise stated, any dimensions should not be used for accurate calculations or dimensioning.

6.0 REFERENCES

- Colquhoun G.P., Hughes K.S., Deyssing L., Ballard J.C., Phillips G., Troedson A.L., Folkes C.B. & Fitzherbert J.A. 2019. New South Wales Seamless Geology dataset, version 1.1, Geological Survey of New South Wales, NSW Department of Planning and Environment, Maitland.
- Office of Environment and Heritage, 2019, Soil Landscapes of Central and Eastern NSW - v2, NSW Office of Environment and Heritage, Sydney.
- AS 1726-2017 Geotechnical Site Investigations
- AS 3798-2007 Guidelines on Earthworks for Commercial and Residential Development
- AS 4678-2002 Earth Retaining Structures
- Landslide Risk Management Concepts and Guidelines, Australian Geomechanics Journal, March 2000
- NAVFAC (1986a). “Design Manual 7.1, Soil Mechanics,” U.S. Department of the Navy, Naval Facilities Engineering Command, 200 Stovall Street, Alexandria, VA 22332.
- Pells, P.J.N., Mostyn, G. & Walker, B.F. 1998. Foundations on Sandstone and Shale in the Sydney Region. Australian Geomechanics Journal, 33 Part 3.
- Foundation Maintenance and Footing Performance: A Homeowner's Guide, CSIRO Publishing published November 2012, ISBN BTF18PRT.
- Australian Geomechanics Journal Landslide Risk Management (LRM) Guidelines, Vol 42, No.1, March 2007.
- NSW - Department of Environment and Heritage (2010) Acid Sulfate Soil Risk Data. Bioregional Assessment Source Dataset.
- Macgregor, Patrick & Walker, Bruce & Fell, Robin & Leventhal, Andrew. (2007). Assessment of landslide likelihood in the Pittwater Local Government Area. 42.

7.0 CLOSURE

Please feel free to contact Philip Davies on 0409 33 22 34 to discuss any aspect of this report.

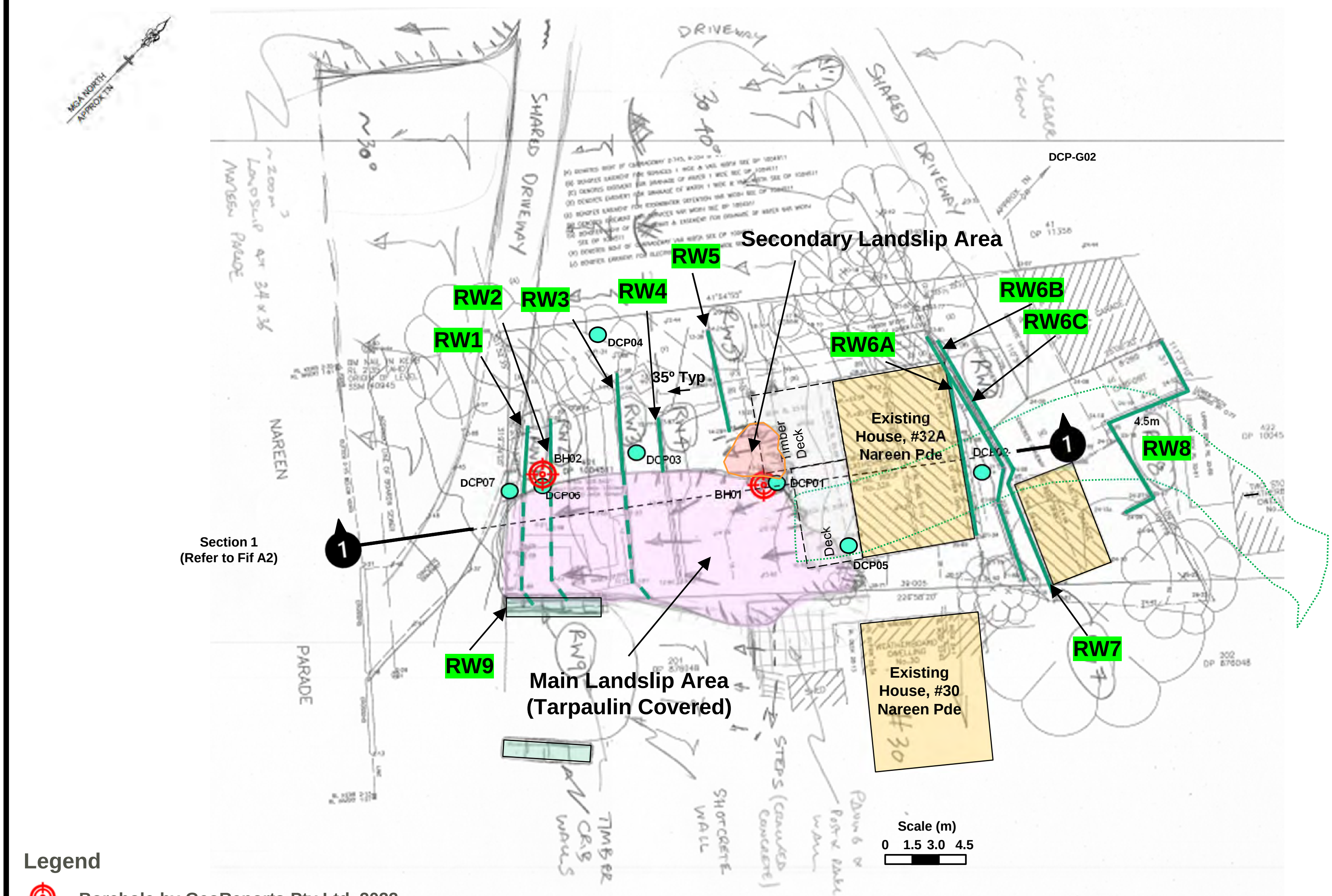
On behalf of GeoReports Pty Ltd,

Philip Davies

Principal Geotechnical Engineer, Director
(BEng (Hons), MSc, DIC, CPEng, MIEAust, NER)

Attached:

Appendix A: Borehole Logs, Explanatory Terms
Appendix B: DCP Logs
Appendix C: Quantitative Slope Risk Assessment
Appendix D: Australian Geoguide – Notes on Hillside Construction Practice
Appendix E: Northern Beaches Council DA Form 1/1A

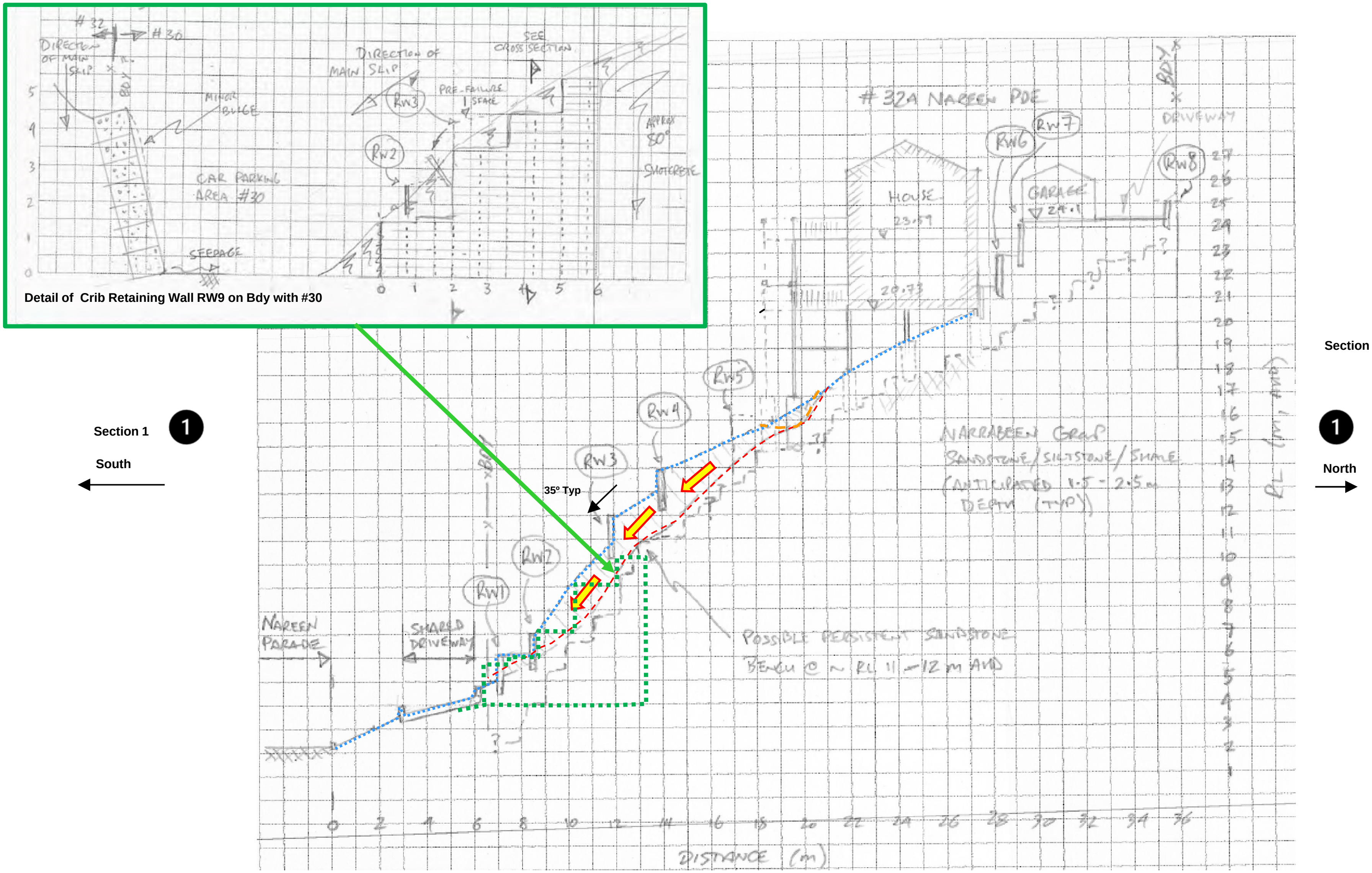


Source Dwg: Site Survey by Detailed Surveys, Drawing No.1, Ref. 089/20, dated 23 Feb 2022.

Legend

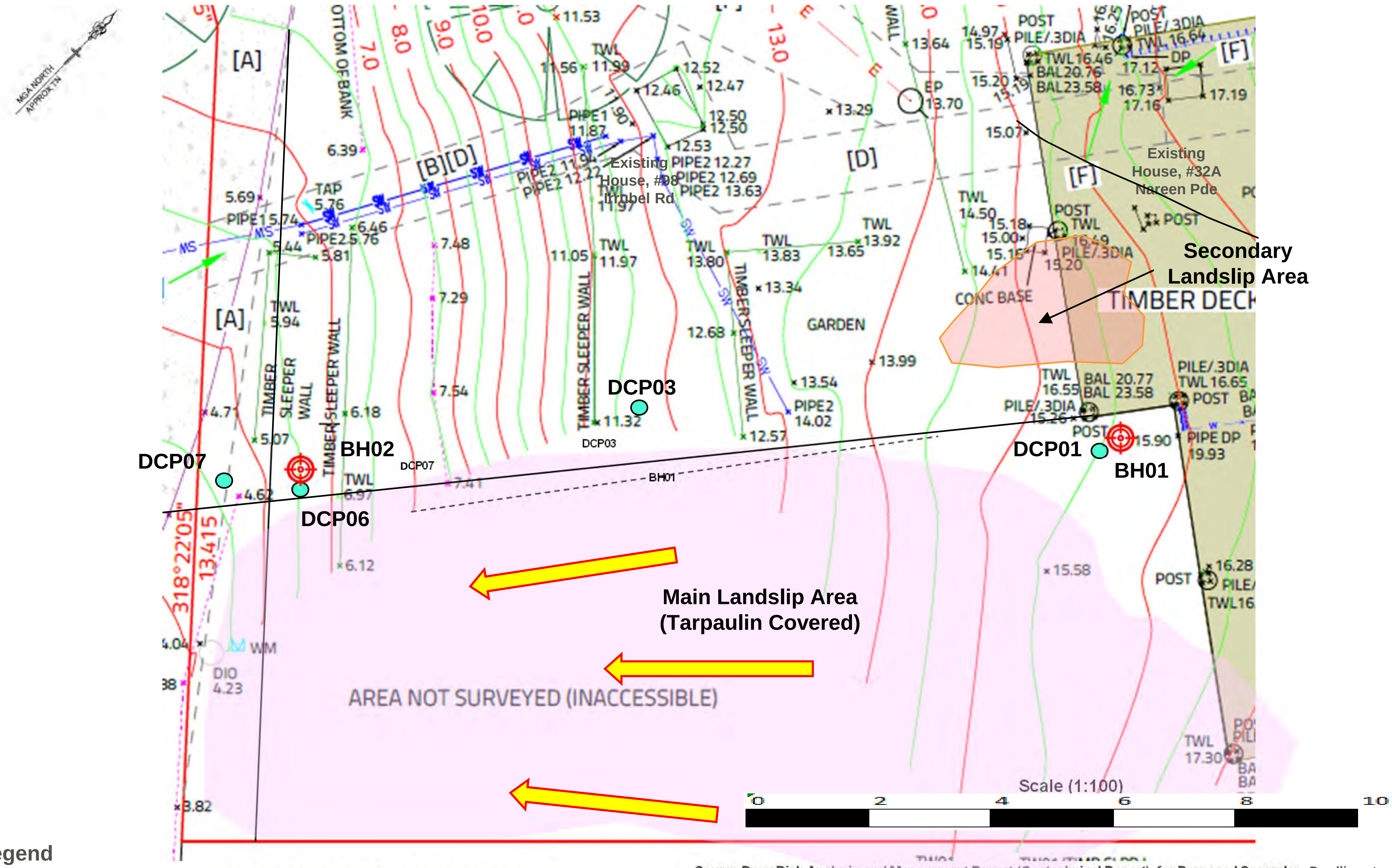
- Borehole by GeoReports Pty Ltd, 2022
- Dynamic Cone Penetrometer (DCP) by Jack Hodgson Pty Ltd, 2016
- Approximate extent of landslip, 2022
- Existing Retaining Walls

GeoReports	CLIENT: Silver Wolf Projects Pty Ltd	PROJECT: 32A Nareen Parade, Narrabeen	A4
	DRAWN: PD; DATE: 06/10/2022	TITLE: Plan Showing Key Features	
	CHECKED: HD; DATE: 07/10/2022		
	SCALE: As shown (1:350)	PROJECT No: 2200103; Reference: 2200103-001; 2100103-001	FIGURE: A1



- - - Inferred original ground level
- - - Approximate slip surface / post slip FSL
- - - Outline of crib wall (out of section)

GeoReports	CLIENT: Silver Wolf Projects Pty Ltd		PROJECT: 32A Nareen Parade, Narrabeen	A4
	DRAWN: PD	DATE: 06/10/2022	TITLE: Cross Section 1 – Overall Site	
	CHECKED: HD	DATE: 07/10/2022		
	SCALE: As shown		PROJECT No: 2200103 / Reference: 2200103-001	FIGURE: A2

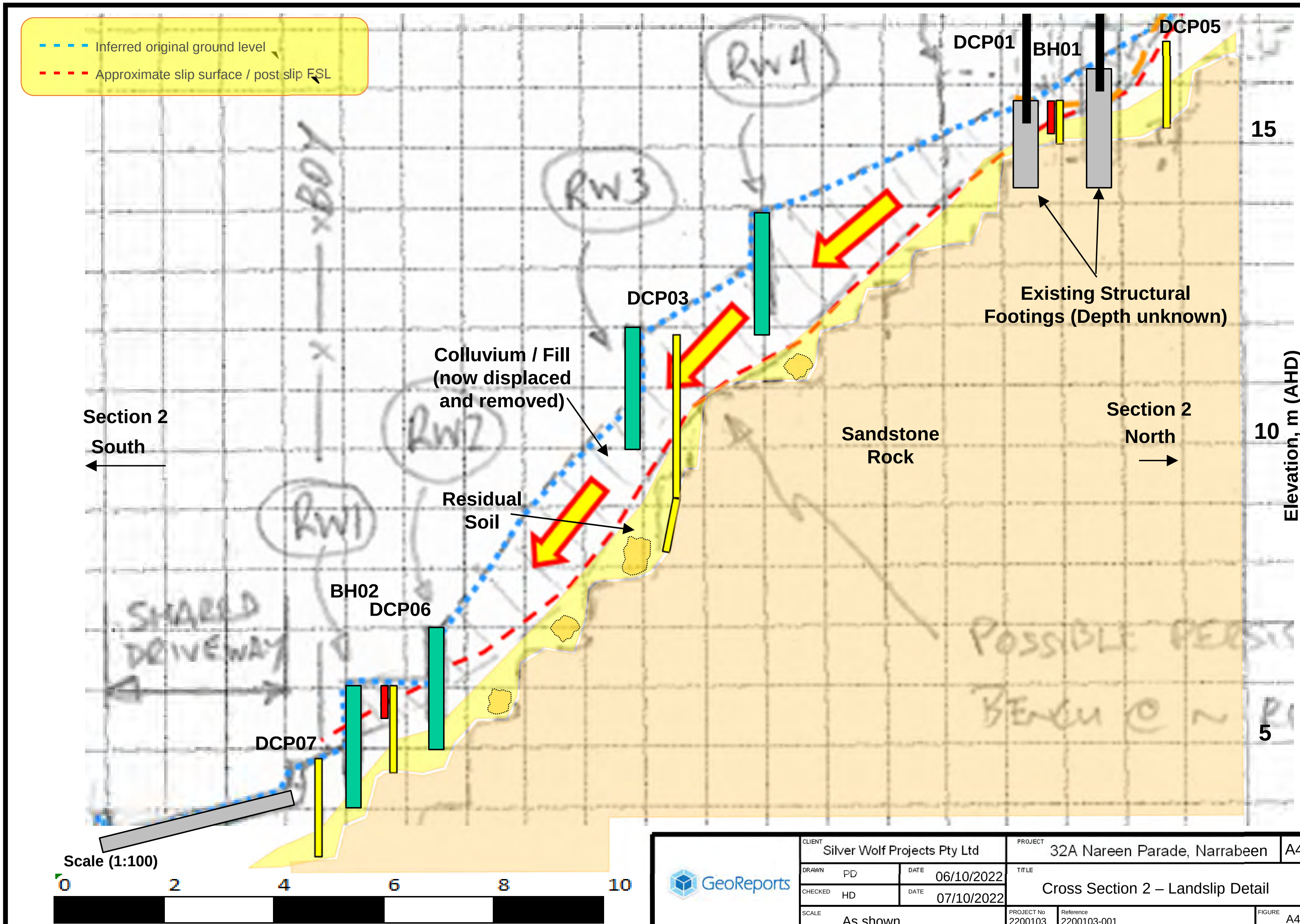


Legend

- Dynamic Cone Penetrometer (DCP) by GeoReports Pty Ltd, 2022
- Borehole by GeoReports Pty Ltd, 2022
- Dynamic Cone Penetrometer (DCP) by Jack Hodgson Pty Ltd, 2016
- Approximate extent of landslip, 2022
- Existing Retaining Walls

Source Dwg: Risk Analysis and Management Report (Geotechnical Report), for Proposed Secondary Dwelling at 100 Irrubel Road, Newport by Jack Hodgson Consultants Pty Ltd, Ref. MR30806, dated 6 September 2016

GeoReports	CLIENT Silver Wolf Projects Pty Ltd		PROJECT 32A Nareen Parade, Narrabeen			A4
	DRAWN PD	DATE 06/10/2022	TITLE Plan Showing Key Features			
	CHECKED HD	DATE 07/10/2022				
	SCALE As shown (1:350)		PROJECT No 2200103	Reference 2200103-001	2100103-001	FIGURE A3



GeoReports

CLIENT Silver Wolf Projects Pty Ltd		PROJECT 32A Nareen Parade, Narrabeen	A4
DRAWN PD	DATE 06/10/2022	TITLE Cross Section 2 – Landslip Detail	
CHECKED HD	DATE 07/10/2022		
SCALE As shown		PROJECT No 2200103 / Reference 2200103-001	FIGURE A4

APPENDIX A

Borehole Logs, Explanatory Terms

GeoReports

EXPLANATION OF NOTES, ABBREVIATIONS & TERMS USED ON BOREHOLE AND TEST PIT REPORTS

DRILLING/EXCAVATION METHOD

AS*	Auger Screwing	RD	Rotary blade or drag bit	NQ	Diamond Core - 47 mm
AD*	Auger Drilling	RT	Rotary Tricone bit	NMLC	Diamond Core - 52 mm
*V	V-Bit	RAB	Rotary Air Blast	HQ	Diamond Core - 63 mm
*T	TC-Bit, e.g. ADT	RC	Reverse Circulation	HMLC	Diamond Core – 63mm
HA	Hand Auger	PT	Push Tube	BH	Tractor Mounted Backhoe
ADH	Hollow Auger	CT	Cable Tool Rig	EX	Tracked Hydraulic Excavator
DTC	Diatube Coring	JET	Jetting	EE	Existing Excavation
WB	Washbore or Bailer	NDD	Non-destructive digging	HAND	Excavated by Hand Methods

PENETRATION/EXCAVATION RESISTANCE

L **Low resistance.** Rapid penetration possible with little effort from the equipment used.

M **Medium resistance.** Excavation/possible at an acceptable rate with moderate effort from the equipment used.

H **High resistance** to penetration/excavation. Further penetration is possible at a slow rate and requires significant effort from the equipment.

R **Refusal or Practical Refusal.** No further progress possible without the risk of damage or unacceptable wear to the digging implement or machine.

These assessments are subjective and are dependent on many factors including the equipment power, weight, condition of excavation or drilling tools, and the experience of the operator.

WATER

▽	Water level at date shown	◁	Partial water loss
▷	Water inflow	◀	Complete water loss

GROUNDWATER NOT OBSERVED — The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

GROUNDWATER NOT ENCOUNTERED — The borehole/test pit was dry soon after excavation. However, groundwater could be present in less permeable strata. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING AND TESTING

SPT	Standard Penetration Test to AS1289.6.3.1-2004
4,7,11 N=18	4,7,11 = Blows per 150mm. N = Blows per 300mm penetration following 150mm seating
30/80mm	Where practical refusal occurs, the blows and penetration for that interval are reported
RW	Penetration occurred under the rod weight only
HW	Penetration occurred under the hammer and rod weight only
HB	Hammer double bouncing on anvil
DS	Disturbed sample
BDS	Bulk disturbed sample
G	Gas Sample
W	Water Sample
FP	Field permeability test over section noted
FV	Field vane shear test expressed as uncorrected shear strength (s_v = peak value, s_r = residual value)
PID	Photoionisation Detector reading in ppm
PM	Pressuremeter test over section noted
PP	Pocket penetrometer test expressed as instrument reading in kPa
U63	Thin walled tube sample - number indicates nominal sample diameter in millimetres
WPT	Water pressure tests
DCP	Dynamic cone penetration test
CPT	Static cone penetration test
CPTu	Static cone penetration test with pore pressure (u) measurement

Ranking of Visually Observable Contamination and Odour (for specific soil contamination assessment projects)

R = 0	No visible evidence of contamination	R = A	No non-natural odours identified
R = 1	Slight evidence of visible contamination	R = B	Slight non-natural odours identified
R = 2	Visible contamination	R = C	Moderate non-natural odours identified
R = 3	Significant visible contamination	R = D	Strong non-natural odours identified

ROCK CORE RECOVERY

TCR = Total Core Recovery (%)

$$= \frac{\text{Length of core recovered}}{\text{Length of core run}} \times 100$$

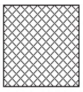
SCR = Solid Core Recovery (%)

$$= \frac{\sum \text{Length of cylindrical core recovered}}{\text{Length of core run}} \times 100$$

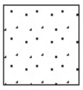
RQD = Rock Quality Designation (%)

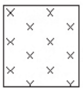
$$= \frac{\sum \text{Axial lengths of core} > 100\text{ mm}}{\text{Length of core run}} \times 100$$

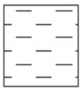
METHOD OF SOIL DESCRIPTION USED ON BOREHOLE AND TEST PIT REPORTS

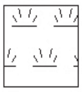

FILL

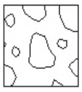

GRAVEL (GP or GW)


SAND (SP or SW)


SILT (ML or MH)


CLAY (CL, CI or CH)


ORGANIC SOILS (OL or OH or Pt)


COBBLES or BOULDERS

Combinations of these basic symbols may be used to indicate mixed materials such as sandy clay.

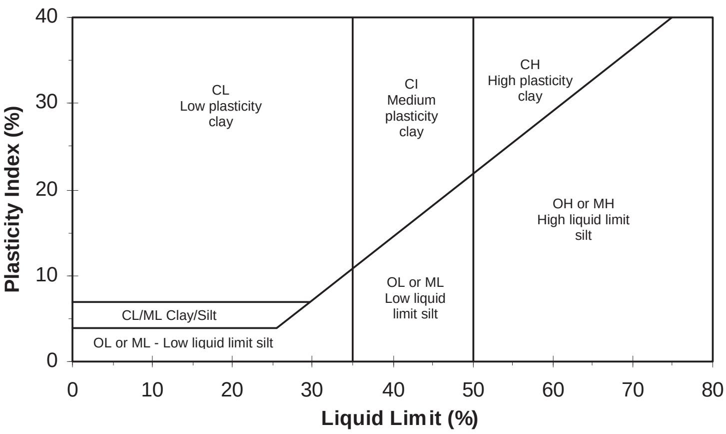
CLASSIFICATION AND INFERRED STRATIGRAPHY

Soil and Rock is classified and described in Reports of Boreholes and Test Pits using the preferred method given in AS1726 – 2017, Appendix A. The material properties are assessed in the field by visual/tactile methods.

Particle Size

Major Division	Sub Division	Particle Size
BOULDERS		> 200 mm
COBBLES		63 to 200 mm
GRAVEL	Coarse	20 to 63 mm
	Medium	6.0 to 20 mm
	Fine	2.0 to 6.0 mm
SAND	Coarse	0.6 to 2.0 mm
	Medium	0.2 to 0.6 mm
	Fine	0.075 to 0.2 mm
SILT		0.002 to 0.075 mm
CLAY		< 0.002 mm

Plasticity Properties



MOISTURE CONDITION

AS1726 - 2017

Symbol	Term	Description
D	Dry	Sands and gravels are free flowing. Clays & Silts may be brittle or friable and powdery.
M	Moist	Soils are darker than in the dry condition & may feel cool. Sands and gravels tend to cohere.
W	Wet	Soils exude free water. Sands and gravels tend to cohere.

CONSISTENCY AND DENSITY

AS1726 - 2017

Symbol	Term	Undrained Shear Strength
VS	Very Soft	0 to 12 kPa
S	Soft	12 to 25 kPa
F	Firm	25 to 50 kPa
St	Stiff	50 to 100 kPa
VSt	Very Stiff	100 to 200 kPa
H	Hard	Above 200 kPa

Symbol	Term	Density Index %	SPT “N” #
VL	Very Loose	Less than 15	0 to 4
L	Loose	15 to 35	4 to 10
MD	Medium Dense	35 to 65	10 to 30
D	Dense	65 to 85	30 to 50
VD	Very Dense	Above 85	Above 50

In the absence of test results, consistency and density may be assessed from correlations with the observed behaviour of the material.

SPT correlations are not stated in AS1726 – 2017, and may be subject to corrections for overburden pressure and equipment type.

GeoReports

TERMS FOR ROCK STRENGTH & WEATHERING AND ABBREVIATIONS FOR DEFECT DESCRIPTIONS

STRENGTH

Symbol	Term	Point Load Index, $Is_{(50)}$ (MPa)	Field Guide
EL	Extremely Low	< 0.03	Easily remoulded by hand to a material with soil properties.
VL	Very Low	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30 mm can be broken by finger pressure.
L	Low	0.1 to 0.3	Easily scored with a knife; indentations 1 mm to 3 mm show in the specimen with firm blows of pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.
M	Medium	0.3 to 1	Readily scored with a knife; a piece of core 150 mm long by 50 mm diameter can be broken by hand with difficulty.
H	High	1 to 3	A piece of core 150 mm long by 50 mm diameter cannot be broken by hand but can be broken with pick with a single firm blow; rock rings under hammer.
VH	Very High	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.
EH	Extremely High	>10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.

ROCK STRENGTH TEST RESULTS

▼ Point Load Strength Index, $I_s(50)$, Axial test (MPa)

◀ Point Load Strength Index, $I_s(50)$, Diametral test (MPa)

Relationship between $I_s(50)$ and UCS (unconfined compressive strength) will vary with rock type and strength, and should be determined on a site-specific basis. UCS is typically 10 to 30 x $I_s(50)$, but can be as low as 5.

ROCK MATERIAL WEATHERING

Symbol		Term	Field Guide
RS		Residual Soil	Soil developed on extremely weathered rock; the mass structure and substance fabric are no longer evident; there is a large change in volume but the soil has not been significantly transported.
EW		Extremely Weathered	Rock is weathered to such an extent that it has soil properties - i.e. it either disintegrates or can be remoulded, in water.
DW	HW	Distinctly Weathered	Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to deposition of weathering products in pores. In some environments it is convenient to subdivide into Highly Weathered and Moderately Weathered, with the degree of alteration typically less for MW.
	MW		
SW		Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength relative to fresh rock.
FR		Fresh	Rock shows no sign of decomposition or staining.

ABBREVIATIONS FOR DEFECT TYPES AND DESCRIPTIONS

Defect Type

B	Bedding parting
X	Foliation
C	Contact
L	Cleavage
J	Joint
SS/SZ	Sheared seam/zone (Fault)
CS/CZ	Crushed seam/zone (Fault)
DS/DZ	Decomposed seam/zone
IS/IZ	Infilled seam/zone
S	Schistosity
V	Vein

Coating or Infilling

Cn	Clean
Sn	Stain
Vr	Veneer
Ct	Coating or Infill

Planarity

Pl	Planar
Un	Undulating
St	Stepped

Roughness

Sl	Slickensided
Sm	Smooth
Ro	Rough

Vertical Boreholes – The dip (inclination from horizontal) of the defect is given.
Inclined Boreholes – The inclination is measured as the acute angle to the core axis.

GeoReports.com.au
Know your site

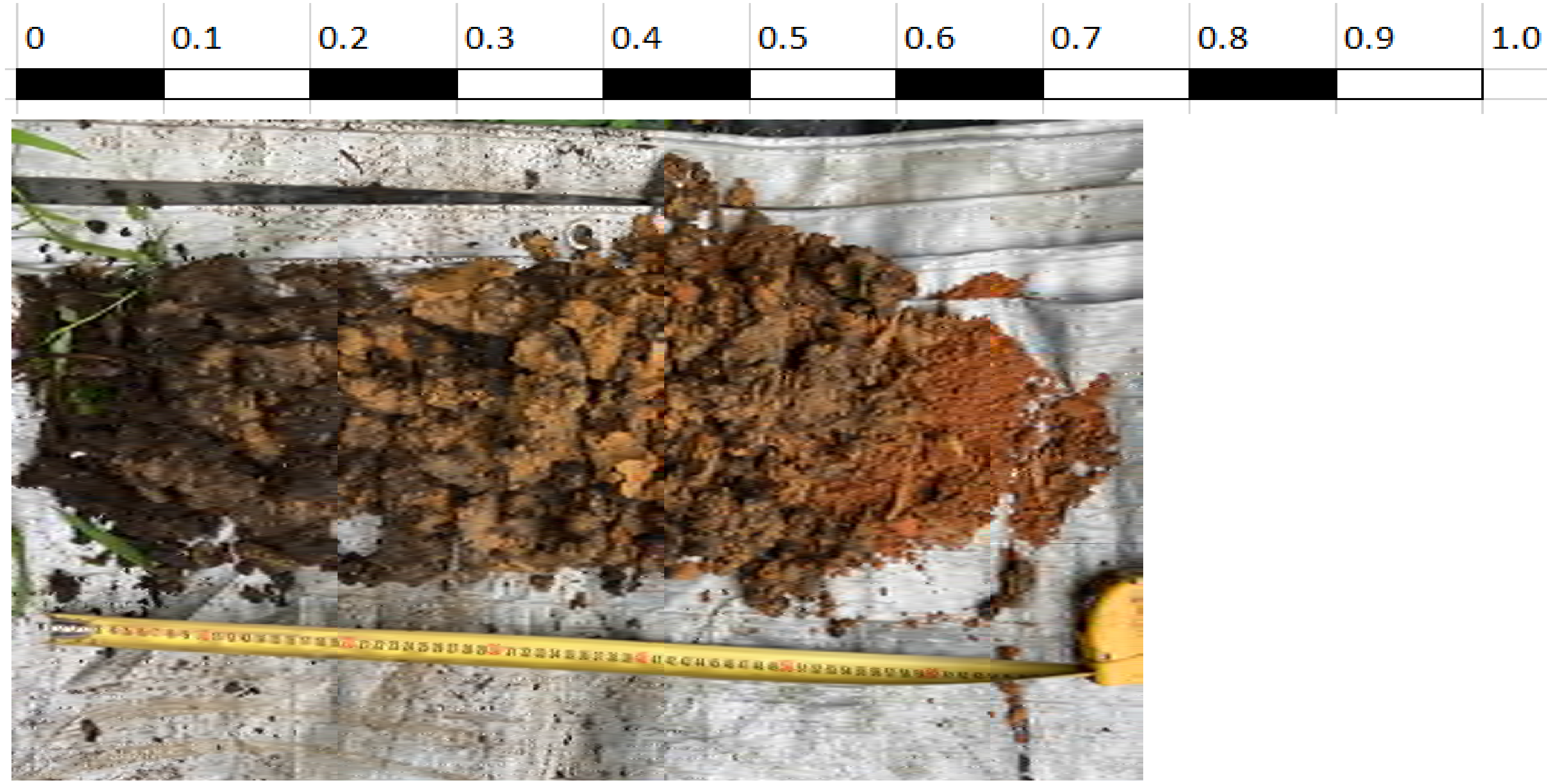
Borehoe Log: BH01

PROJECT NUMBER 210083	**DRILLING DATE** 05/10/2022	**COORDINATES** Lat:-33.70492, Long:151.29362
PROJECT NAME Landslip Remedial Works	**TOTAL DEPTH** 0.6	**COORD SYS** Decimal Deg
CLIENT Silver Wolf Projects	**DIAMETER** 125mm	**COMPLETION** Backfilled
ADDRESS 32A Nareen Parade,, Narrabeen	**CASING** Nil	**SURFACE ELEVATION** Approx. 15.5 m AHD
SHEET 1 of 1	**SCREEN** Nil	**INCLINATION** Vertical

COMMENTS See plan for location

LOGGED BY PD
CHECKED BY SD

Drilling Method	Resistance	Water	Samples	Depth (m)	Elevation (m)	Recovery	Graphic Log	Moisture	Material Description	USCS	Consistency	Additional Observations
AV	L	Dry						M	FILL: Topsoil comprising organic mulch over silty SAND, fine to medium grained with roots, bark ftragments.	N/A	N/A	Fill (Inferred poorly compacted)
				0.1	15.4							
	M /H			0.2	15.3				FILL: Silty sandy CLAY, low to med. plasticity, mottled orange/brown, slightly friable			
				0.3	15.2				Silty sandy CLAY, medium plasticity, orange/brown	CI	S/F	Residual soil
	H			0.4	15.1						St/ VSt	
				0.5	15			M/ Fb	Extremely weathered SANDSTONE recovered as silty SAND, medium to coarse grained, dark orange, friable.	N/A	EL	Extremely weathered rock
				0.6	14.9				Termination Depth at: 0.6 m Practical auger and heavy crow bar refusal. Dry on completion and after 2 hours, then backfilled.			
				0.7	14.8							
				0.8	14.7							
				0.9	14.6							
				1	14.5							
				1.1	14.4							
				1.2	14.3							
				1.3	14.2							
				1.4	14.1							
				1.5	14							
				1.6	13.9							
				1.7	13.8							
				1.8	13.7							
				1.9	13.6							



GeoReports	CLIENT Silver Wolf Projects Pty Ltd		PROJECT 32A Nareen Parade, Narrabeen		A4
	DRAWN PD	DATE 06/10/2022	TITLE Photograph of Spoil from BH01		
	CHECKED HD	DATE 07/10/2022			
	SCALE As shown		PROJECT No 2200103	Reference 2200103-001 2200107-001	FIGURE B1

GeoReports.com.au
Know your site

Borehoe Log: BH02

PROJECT NUMBER 210083	**DRILLING DATE** 05/10/2022	**COORDINATES** Lat:-33.70500, Long:151.29351
PROJECT NAME Landslip Remedial Works	**TOTAL DEPTH** 0.6	**COORD SYS** Decimal Deg
CLIENT Silver Wolf Projects	**DIAMETER** 125mm	**COMPLETION** Backfilled
ADDRESS 32A Nareen Parade,, Narrabeen	**CASING** Nil	**SURFACE ELEVATION** Approx. 5.5 m AHD
SHEET 1 of 1	**SCREEN** Nil	**INCLINATION** Vertical

COMMENTS See plan for location

LOGGED BY PD
CHECKED BY SD

Drilling Method	Resistance	Water	Samples	Depth (m)	Elevation (m)	Recovery	Graphic Log	Moisture	Material Description	USCS	Consistency	Additional Observations
AV	M	Dry		0.1 0.2	5.4 5.3			M	FILL: Silty Clay, medium plasticity, orange/brown with trace of sand and fine to medium sandstone gravel.	N/A	N/A	Fill - Inferred Landslip debris, poorly compacted
				0.3 0.4	5.2 5.1				FILL: Silty, clayey SAND, fine to medium grained, dark brown with trace of roots and organics.			Fill - inferred buried topsoil, poorly compacted
	H			0.5	5			M/ Fb	FILL: Silty sandy CLAY, medium plasticity, mottled brown/red, with trace of roots and XW sandstone gravel.			Fill - poorly compacted
				0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9	4.9 4.8 4.7 4.6 4.5 4.4 4.3 4.2 4.1 4 3.9 3.8 3.7 3.6				Termination Depth at: 0.6 m Practical auger and heavy crow bar refusal on on obstruction infered to be sandstone boulder. Dry on completion then backfilled.			

Disclaimer Refer to report limitations

produced by ESlog.ESdat.net on 25 Oct 2022

GeoReports	CLIENT Silver Wolf Projects Pty Ltd		PROJECT 32A Nareen Parade, Narrabeen		A4
	DRAWN PD	DATE 06/10/2022	TITLE Photograph of Spoil from BH02		
	CHECKED HD	DATE 07/10/2022			
	SCALE As shown		PROJECT No 2200103	Reference 2200103-001 2200107-001	FIGURE B2

APPENDIX B

DCP Logs

GeoReports
Know your site

	GeoReports						
ID:	DCP01	DCP02	DCP03	DCP04	DCP05	DCP06	DCP07
Depth							
0.1	0.1	1.0	0.1	0.1	0.1	0.1	0.5
0.2	0.1	0.1	0.1	1	0.5	1	0.5
0.3	2	0.1	0.1	2	0.5	2	2
0.4	2	6	0.1	0.5	2	-	3
0.5	3	5	0.1	0.5	2	1	5
0.6	4	1	0.1	1	3	1	3
0.7	6	1	1	1	3	2	4
0.8	20*	2	1	1	2	2	3
0.9		2	2	3	3	2	4
1		2	2	3	3	4	5
1.1		3	2	5	7	3	7
1.2		3	2	6	7	3	7
1.3		3	2	7	6	4	10
1.4		4	2	8	4	4	13
1.5		4	2	9	5	7	8
1.6		4	2	14	10	20*	12
1.7		5	1	17	15*		16
1.8		5	2	14			15/50*
1.9		5	4	18*			
2		8	8				
2.1		15	7				
2.2		13	8				
2.3		14	10				
2.4		13	10				
2.5		11	10				
2.6		8	10				
2.7		10	10				
2.8		9	14				
2.9		8	13				
3		12	7				
3.1			6				
3.2			8				
3.3			8				
3.4			10				
3.5			7				
3.6			7				
3.7			9				
3.8			10				
3.9			11				
4			16*				

Notes:
Numbers indicate blow counts per 100mm penetration
* indicates hammer bouncing
X/Y indicates X blows for Ymm penetration

Dynamic Cone Penetrometer Results

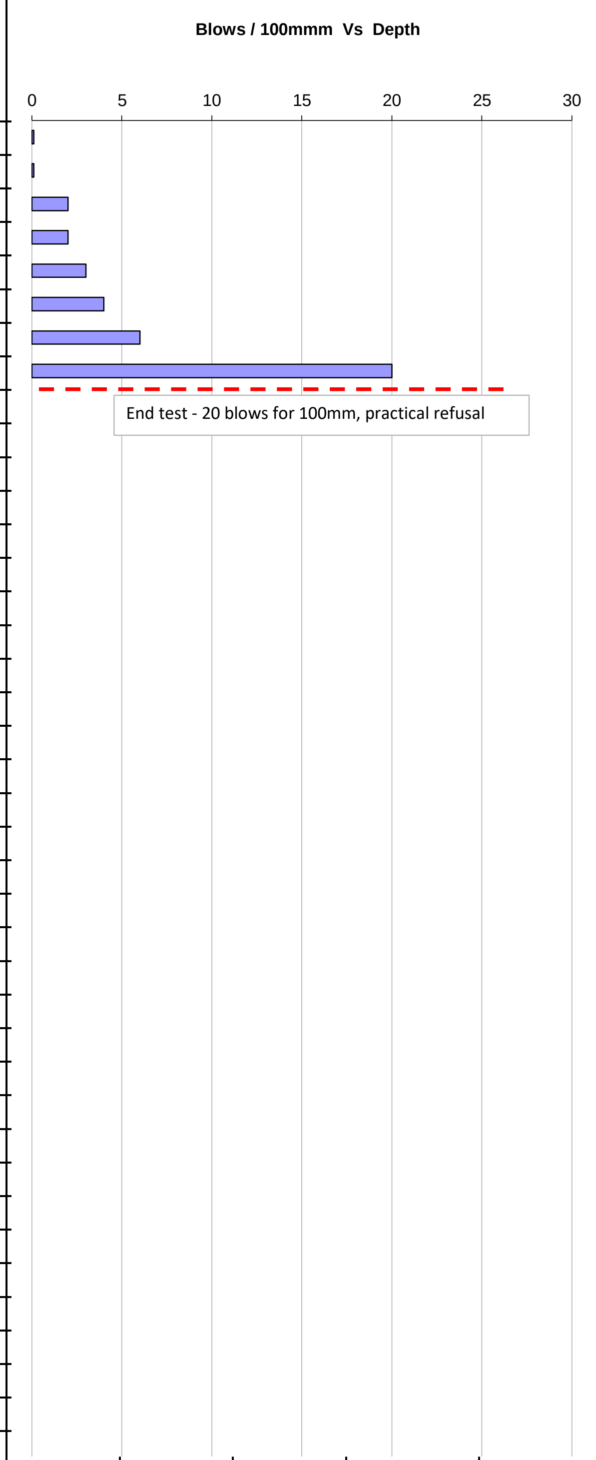
GeoReports

Test Procedure AS1289.6.3.2 – 1997

Client: Silver Wolf Projects
Project: Landslip Remediation
Location: 32A Nareen Pde. Narrabeen
Job No: 220083

Test No: **DCP01**
Test By: PD **Date:** 5/10/2022
Checked: HD **Date:** 10/10/2022

Depth (m)	Blows Per 100mm	Penetration (mm/blow)	Estimated CBR*	Inferred Consistency **
0.1	0.1	1000	0	VL
0.2	0.1	1000	0	VL
0.3	2	50	4	S
0.4	2	50	4	S
0.5	3	33	6	F
0.6	4	25	8	St
0.7	6	17	13	VSt
0.8	20	5	50	H
0.9				
1.0				
1.1				
1.2				
1.3				
1.4				
1.5				
1.6				
1.7				
1.8				
1.9				
2.0				
2.1				
2.2				
2.3				
2.4				
2.5				
2.6				
2.7				
2.8				
2.9				
3.0				
3.1				
3.2				
3.3				
3.4				
3.5				
3.6				
3.7				
3.8				
3.9				
4.0				



* Based on correlation published by Country Roads Board of Victoria Technical Bulletin No. 26, Design of flexible road pavements

** Approximate correlation, based Burt G. Look, “Handbook of GeotechnicalInvestigation and Design Tables”, Balkema, October 2006

GeoReports

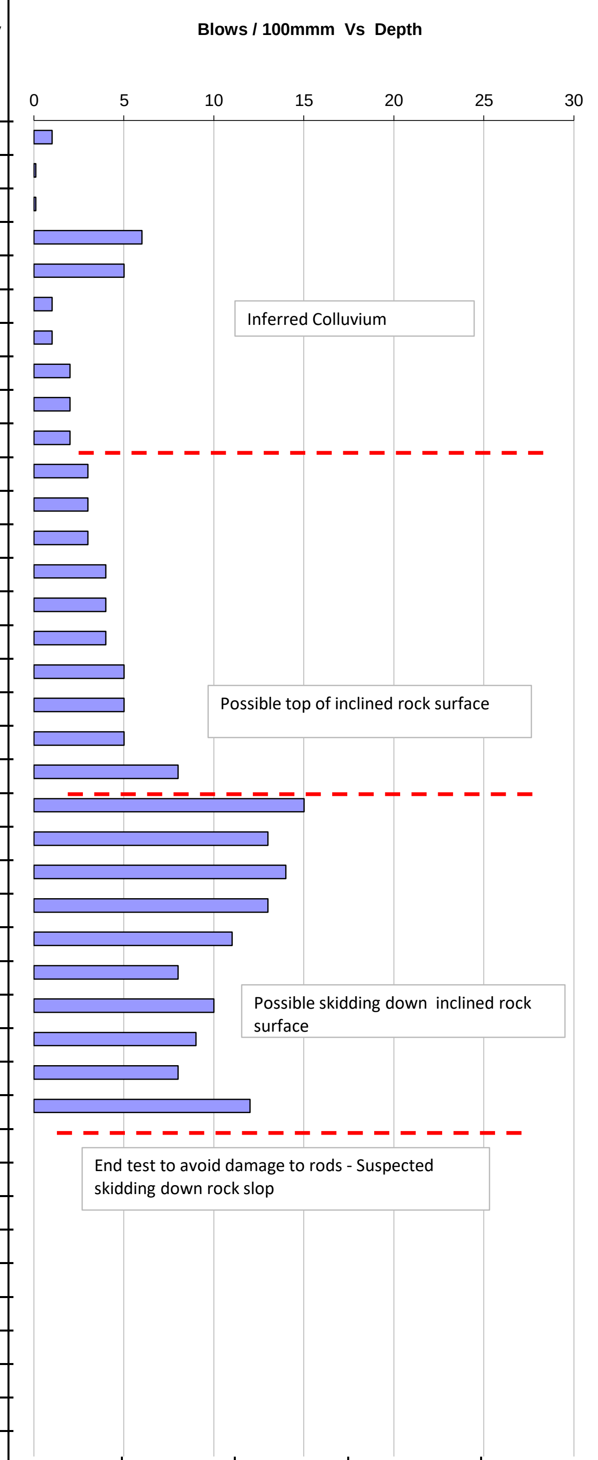
Dynamic Cone Penetrometer Results

Test Procedure AS1289.6.3.2 – 1997

Client: Silver Wolf Projects
Project: Landslip Remediation
Location: 32A Nareen Pde. Narrabeen
Job No: 220083

Test No: DCP02
Test By: PD **Date:** 5/10/2022
Checked: HD **Date:** 10/10/2022

Depth (m)	Blows Per 100mm	Penetration (mm/blow)	Estimated CBR*	Inferred Consistency **
0.1	1	100	2	MD
0.2	0.1	1000	0	VL
0.3	0.1	1000	0	VL
0.4	6	17	13	VD
0.5	5	20	10	D
0.6	1	100	2	L
0.7	1	100	2	L
0.8	2	50	4	MD
0.9	2	50	4	MD
1.0	2	50	4	MD
1.1	3	33	6	F
1.2	3	33	6	F
1.3	3	33	6	F
1.4	4	25	8	St
1.5	4	25	8	St
1.6	4	25	8	St
1.7	5	20	10	St
1.8	5	20	10	St
1.9	5	20	10	St
2.0	8	13	17	H
2.1	15	7	36	VSt
2.2	13	8	31	VSt
2.3	14	7	33	VSt
2.4	13	8	31	VSt
2.5	11	9	25	H
2.6	8	13	17	VS
2.7	10	10	23	VS
2.8	9	11	20	VS
2.9	8	13	17	VS
3.0	12	8	28	VS
3.1				
3.2				
3.3				
3.4				
3.5				
3.6				
3.7				
3.8				
3.9				
4.0				



* Based on correlation published by Country Roads Board of Victoria Technical Bulletin No. 26, Design of flexible road pavements

** Approximate correlation, based Burt G. Look, "Handbook of GeotechnicalInvestigation and Design Tables", Balkema, October 2006

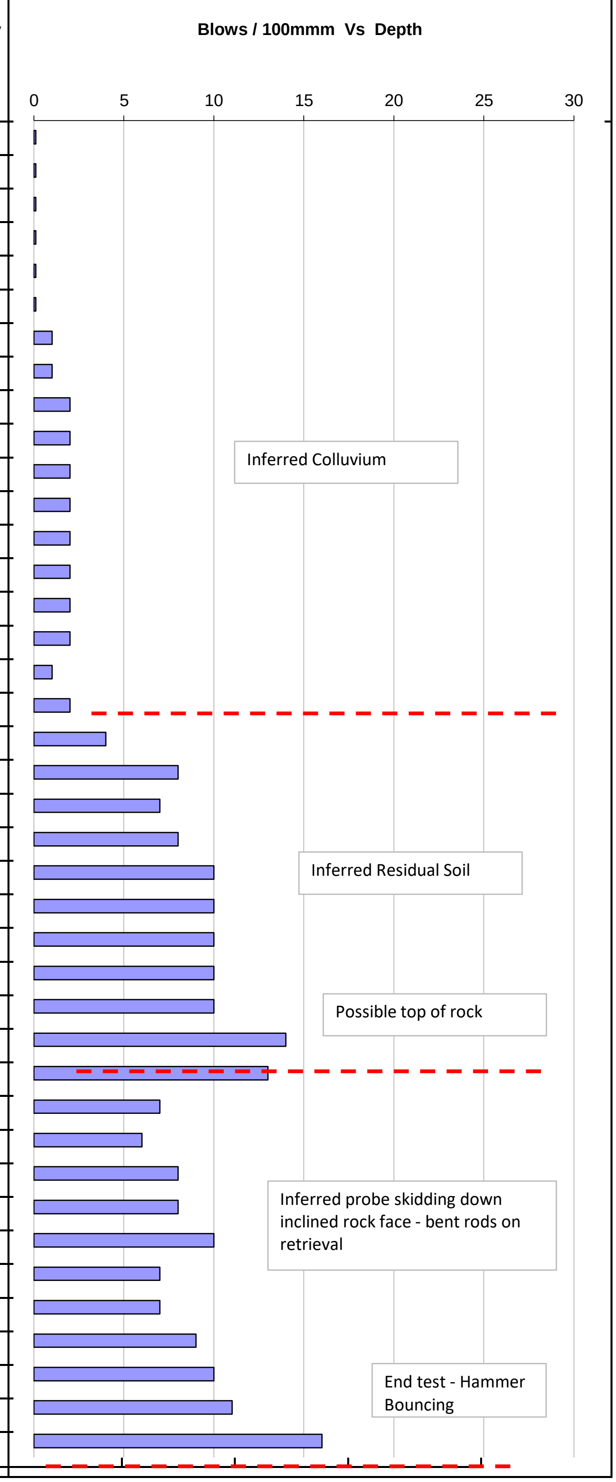
GeoReports

Dynamic Cone Penetrometer Results

Test Procedure AS1289.6.3.2 – 1997

Client:	Silver Wolf Projects	**Test No:**	**DCP03**		
Project:	Landslip Remediation	**Test By:**	PD	**Date:**	5/10/2022
Location:	32A Nareen Pde. Narrabeen	**Checked:**	HD	**Date:**	10/10/2022
Job No:	220083				

Depth (m)	Blows Per 100mm	Penetration (mm/blow)	Estimated CBR*	Inferred Consistency **
0.1	0.1	1000	0	VL
0.2	0.1	1000	0	VL
0.3	0.1	1000	0	VL
0.4	0.1	1000	0	VL
0.5	0.1	1000	0	VL
0.6	0.1	1000	0	VL
0.7	1	100	2	L
0.8	1	100	2	L
0.9	2	50	4	MD
1.0	2	50	4	MD
1.1	2	50	4	MD
1.2	2	50	4	MD
1.3	2	50	4	MD
1.4	2	50	4	MD
1.5	2	50	4	MD
1.6	2	50	4	MD
1.7	1	100	2	L
1.8	2	50	4	S
1.9	4	25	8	St
2.0	8	13	17	VSt
2.1	7	14	15	VSt
2.2	8	13	17	VSt
2.3	10	10	23	H
2.4	10	10	23	H
2.5	10	10	23	VSt
2.6	10	10	23	VSt
2.7	10	10	23	VSt
2.8	14	7	33	VSt
2.9	13	8	31	VSt
3.0	7	14	15	VSt
3.1	6	17	13	VSt
3.2	8	13	17	VSt
3.3	8	13	17	VSt
3.4	10	10	23	H
3.5	7	14	15	H
3.6	7	14	15	VS
3.7	9	11	20	VS
3.8	10	10	23	VS
3.9	11	9	25	VS
4.0	16	6	39	VS



* Based on correlation published by Country Roads Board of Victoria Technical Bulletin No. 26, Design of flexible road pavements

** Approximate correlation, based Burt G. Look, "Handbook of GeotechnicalInvestigation and Design Tables", Balkema, October 2006

GeoReports

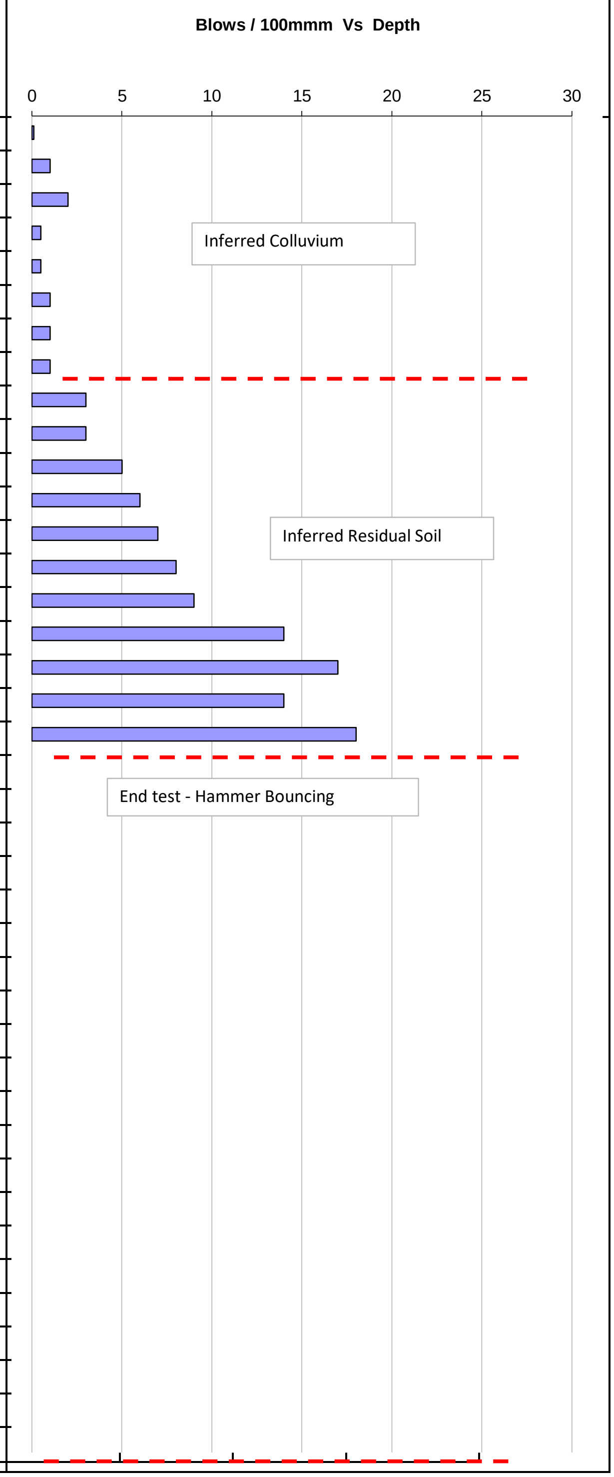
Dynamic Cone Penetrometer Results

Test Procedure AS1289.6.3.2 – 1997

Client: Silver Wolf Projects
Project: Landslip Remediation
Location: 32A Nareen Pde. Narrabeen
Job No: 220083

Test No: **DCP04**
Test By: PD **Date:** 5/10/2022
Checked: HD **Date:** 10/10/2022

Depth (m)	Blows Per 100mm	Penetration (mm/blow)	Estimated CBR*	Inferred Consistency **
0.1	0.1	1000	0	VL
0.2	1	100	2	MD
0.3	2	50	4	MD
0.4	0.5	200	1	L
0.5	0.5	200	1	VL
0.6	1	100	2	L
0.7	1	100	2	L
0.8	1	100	2	VS
0.9	3	33	6	F
1.0	3	33	6	F
1.1	5	20	10	St
1.2	6	17	13	VSt
1.3	7	14	15	VSt
1.4	8	13	17	VSt
1.5	9	11	20	VSt
1.6	14	7	33	H
1.7	17	6	42	H
1.8	14	7	33	H
1.9	18	6	44	H
2.0				
2.1				
2.2				
2.3				
2.4				
2.5				
2.6				
2.7				
2.8				
2.9				
3.0				
3.1				
3.2				
3.3				
3.4				
3.5				
3.6				
3.7				
3.8				
3.9				
4.0				



* Based on correlation published by Country Roads Board of Victoria Technical Bulletin No. 26, Design of flexible road pavements

** Approximate correlation, based Burt G. Look, "Handbook of GeotechnicalInvestigation and Design Tables", Balkema, October 2006

GeoReports

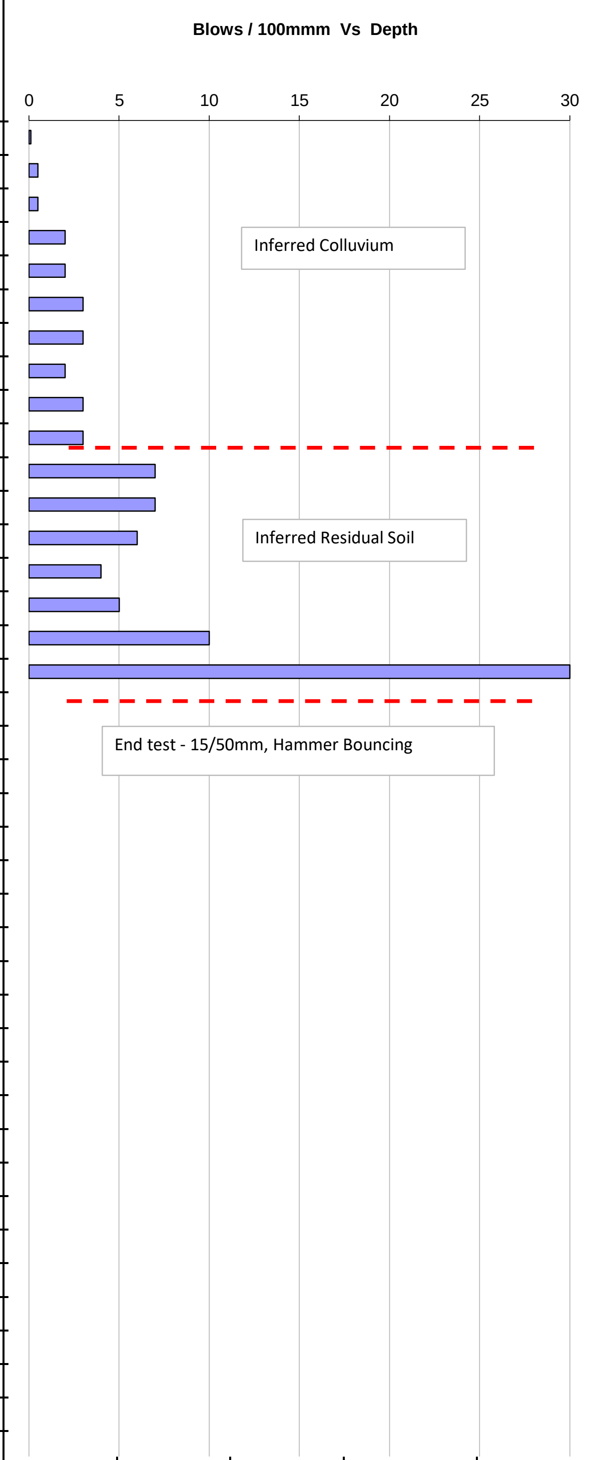
Dynamic Cone Penetrometer Results

Test Procedure AS1289.6.3.2 – 1997

Client: Silver Wolf Projects
Project: Landslip Remediation
Location: 32A Nareen Pde. Narrabeen
Job No: 220083

Test No: DCP05
Test By: PD **Date:** 5/10/2022
Checked: HD **Date:** 10/10/2022

Depth (m)	Blows Per 100mm	Penetration (mm/blow)	Estimated CBR*	Inferred Consistency **
0.1	0.1	1000	0	VL
0.2	0.5	200	1	L
0.3	0.5	200	1	L
0.4	2	50	4	MD
0.5	2	50	4	MD
0.6	3	33	6	D
0.7	3	33	6	MD
0.8	2	50	4	MD
0.9	3	33	6	MD
1.0	3	33	6	MD
1.1	7	14	15	VSt
1.2	7	14	15	VSt
1.3	6	17	13	VSt
1.4	4	25	8	St
1.5	5	20	10	St
1.6	10	10	23	VSt
1.7	30	3	80	H
1.8				
1.9				
2.0				
2.1				
2.2				
2.3				
2.4				
2.5				
2.6				
2.7				
2.8				
2.9				
3.0				
3.1				
3.2				
3.3				
3.4				
3.5				
3.6				
3.7				
3.8				
3.9				
4.0				



* Based on correlation published by Country Roads Board of Victoria Technical Bulletin No. 26, Design of flexible road pavements
** Approximate correlation, based Burt G. Look, "Handbook of GeotechnicalInvestigation and Design Tables", Balkema, October 2006

GeoReports

Dynamic Cone Penetrometer Results

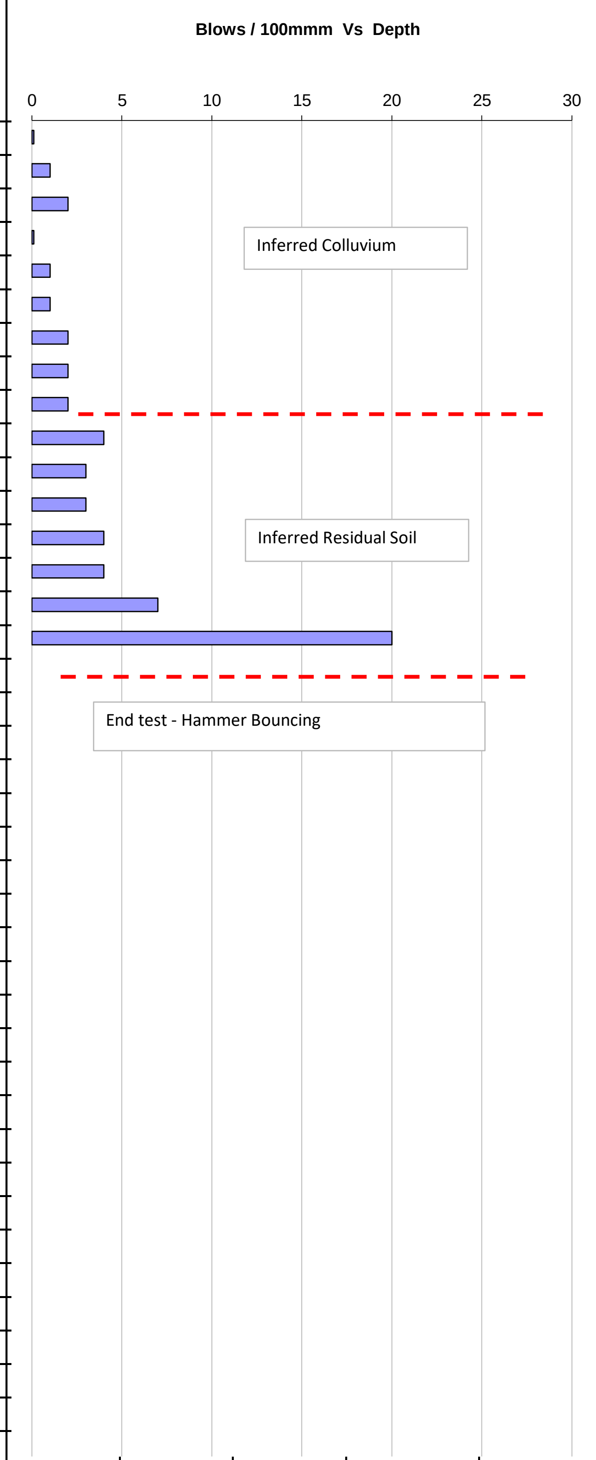
Test Procedure AS1289.6.3.2 – 1997

Client: Silver Wolf Projects
Project: Landslip Remediation
Location: 32A Nareen Pde. Narrabeen
Job No: 220083

Test No: **DCP06**
Test By: PD
Checked: HD

Date: 5/10/2022
Date: 10/10/2022

Depth (m)	Blows Per 100mm	Penetration (mm/blow)	Estimated CBR*	Inferred Consistency **
0.1	0.1	1000	0	VL
0.2	1	100	2	MD
0.3	2	50	4	MD
0.4	0.1	1000	0	VL
0.5	1	100	2	L
0.6	1	100	2	L
0.7	2	50	4	MD
0.8	2	50	4	MD
0.9	2	50	4	MD
1.0	4	25	8	St
1.1	3	33	6	F
1.2	3	33	6	F
1.3	4	25	8	St
1.4	4	25	8	St
1.5	7	14	15	VSt
1.6	20	5	50	H
1.7				
1.8				
1.9				
2.0				
2.1				
2.2				
2.3				
2.4				
2.5				
2.6				
2.7				
2.8				
2.9				
3.0				
3.1				
3.2				
3.3				
3.4				
3.5				
3.6				
3.7				
3.8				
3.9				
4.0				



* Based on correlation published by Country Roads Board of Victoria Technical Bulletin No. 26, Design of flexible road pavements
** Approximate correlation, based Burt G. Look, "Handbook of GeotechnicalInvestigation and Design Tables", Balkema, October 2006

GeoReports

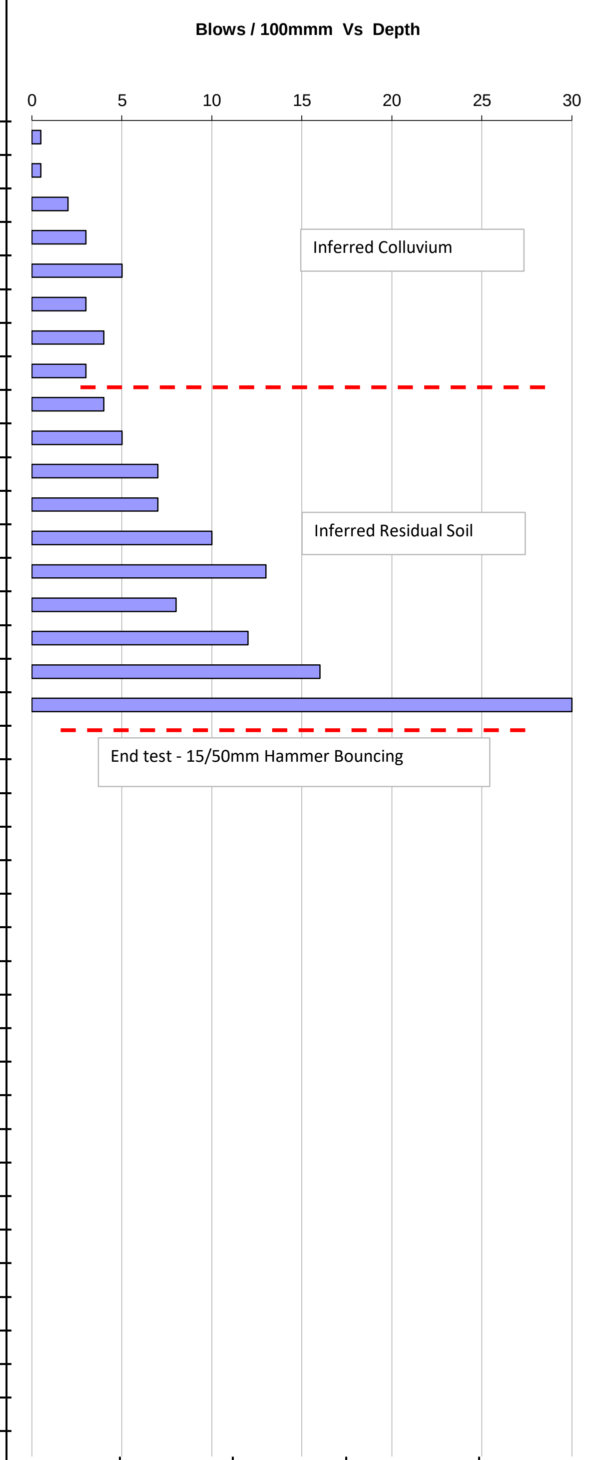
Dynamic Cone Penetrometer Results

Test Procedure AS1289.6.3.2 – 1997

Client: Silver Wolf Projects
Project: Landslip Remediation
Location: 32A Nareen Pde. Narrabeen
Job No: 220083

Test No: **DCP07**
Test By: PD — **Date:** 5/10/2022
Checked: HD — **Date:** 10/10/2022

Depth (m)	Blows Per 100mm	Penetration (mm/blow)	Estimated CBR*	Inferred Consistency **
0.1	0.5	200	1	L
0.2	0.5	200	1	L
0.3	2	50	4	MD
0.4	3	33	6	D
0.5	5	20	10	D
0.6	3	33	6	D
0.7	4	25	8	D
0.8	3	33	6	MD
0.9	4	25	8	St
1.0	5	20	10	St
1.1	7	14	15	VSt
1.2	7	14	15	VSt
1.3	10	10	23	VSt
1.4	13	8	31	H
1.5	8	13	17	VSt
1.6	12	8	28	H
1.7	16	6	39	H
1.8	30	3	80	H
1.9				
2.0				
2.1				
2.2				
2.3				
2.4				
2.5				
2.6				
2.7				
2.8				
2.9				
3.0				
3.1				
3.2				
3.3				
3.4				
3.5				
3.6				
3.7				
3.8				
3.9				
4.0				



* Based on correlation published by Country Roads Board of Victoria Technical Bulletin No. 26, Design of flexible road pavements

** Approximate correlation, based Burt G. Look, "Handbook of GeotechnicalInvestigation and Design Tables", Balkema, October 2006

APPENDIX C

Quantitative Slope Risk Assessment

Risk Assessment - Slope instability area in vicinity of 32A Nareen Parade, North Narrabeen

Table C.1 - Summary of Risk to Property

Hazard Location / ID	Identified Hazard	Property Elements at Risk	Likelihood[a]	Consequence of hazard reaching element at risk[b]	Risk[c]	Conceptual Risk Mitigation Measures	Residual Risk Rating with temporary mitigation measures
Refer to Figures 9&10 in Report for Location of Hazards			**Current**		**Current**		**After Treatment**
H1	1. Large scale global instability impacting multiple retaining structures (>50m3 volume)	Main Residence	Possible	Major	High	Remediate existing slip area by demolishing remaining walls, removing debris and installing suitably upgraded replacement walls, slope and drainage in accordance with recommendations in report and as per AS4678. Inspect, maintain (periodically flush drainage), manage erosion.	Low
		Retaining Structures	Almost Certain	Medium	Very High		Low
		Surrounding Assets / Properties	Almost Certain	Minor	High		Low
		Services and road assets	Almost Certain	Minor	High		Low
		Cars on Driveway	Possible	Minor	Moderate		Low
H2	2. Small scale wall / bench instability impacting single retaining structure (5-20m3 volume).	Main Residence	Possible	Major	High	Remediate existing slope by demolishing remaining walls, removing debris and installing suitably upgraded replacement walls. Scale unstable rock above driveway. Inspect, maintain (periodically flush drainage), divert surface and groundwater water away from walls.	Low
		Retaining Structures	Possible	Minor	Moderate		Low
		Surrounding Assets / Properties	Possible	Minor	Moderate		Low
H3	3. Local instability of soil slope (3-10m3 volume).	Main Residence	Possible	Major	High	Provide surface stabilisation using coir logs, pinned geotextiles, anchored mesh or geo-cells according to slope angle). Monitor, maintain, manage erosion. Divert surface and groundwater water away from slope/wall. Maintain small scale root-binding vegetation at crest and on slope. Optionally replace and upgrade section of post-and-panel retaining walls.	Low
		Retaining Structures	Possible	Minor	Moderate		Low
		Surrounding Assets / Properties	Possible	Minor	Moderate		Low
H4	4. Failure of RW6A/B/C impacting house (Up to approx. 20m3 volume).	Main Residence / Upper Driveway	Possible	Major	High	Remediate existing existing deforming walls by either installing suitably upgraded replacement walls, or shotcrete and soil nails through existing wall(s). Improve surface and subsurface drainage in accordance with recommendations in report and as per AS4678.*	Low
		Retaining Structures	Possible	Medium	Moderate		Low
		Surrounding Assets / Properties	Possible	Minor	Moderate		Low
H5	5. Failure of RW9 on Bdy impacting subject site (Up to approx. 20m3 volume).	Main Residence	Unlikely	Major	Moderate	Treat & Manage as per Hazard #4. Optionally engage / collaborate with owners of #30 to agree on upgrade to risk.*	Low
		Retaining Structures	Possible	Medium	Moderate		Low
		Surrounding Assets / Properties	Possible	Medium	Moderate		Low
		Services and road assets	Possible	Minor	Moderate		Low
		Cars on Driveway	Possible	Minor	Moderate		Low

*- It may be possible to identify a 'repair / strengthen' solution (rather than 'replace' option which achieves 'Low' (i.e. 'Acceptable') outcome. Improving existing risk to 'Low' outcome is a Council requirement for DA approval.

Notes:

a - The Likelihood is a combination of the likelihood of the hazard detaching, the hazard then travelling to the element at risk & the element at risk being in the location at that time.

b - The consequence is based upon a hazard reaching the element at risk and causing damage, and is described in Appendix C of Landslide Risk Management, Australian Geomechanics, 2007.

c - Risk Assessments using Appendix C of Landslide Risk Management, Australian Geomechanics, 2007.

(light green)	Very Low Risk
(light blue)	Low Risk
(yellow)	Moderate Risk
(orange)	High Risk
(red)	Very High Risk

Risk Assessment - Slope instability area in vicinity of 32A Nareen Parade, North Narrabeen

Table C.2 - Summary of Risk to Life

Location of Hazard	Identified Hazard	Persons most at Risk	Likelihood[a]	Vulnerability of persons at risk if impacted [b]	Annualised Risk to Life	Risk Evaluation[c]	Temporary Risk Mitigation Measures	Residual Risk Rating with temporary mitigation measures
Refer to Figures 9&10 in Report for Location of Hazards						**Current**		**After Treatment**
H1	1. Large scale global instability impacting multiple retaining structures (>50m3 volume)	Occupant at Main Residence	Possible	Fatality (>50% mortality Risk)	1.25×10^{-3}	Unacceptable	Remediate existing slip area by demolishing remaining walls, removing debris and installing suitably upgraded replacement walls, slope and drainage in accordance with recommendations in report and as per AS4678. Inspect, maintain (periodically flush drainage), manage erosion.	Acceptable
		Persons in garden or driveway	Unlikely	Injury (<50% mortality Risk)	2.5×10^{-5}	Tolerable		Acceptable
		Car Driver - shared driveway	Unlikely	Injury (<10% mortality Risk)	2.5×10^{-5}	Tolerable		Acceptable
H2	2. Small scale wall / bench instability impacting single retaining structure (5-20m3 volume).	Occupant at Main Residence	Possible	Injury (<25% mortality Risk)	1.25×10^{-4}	Tolerable	Remediate existing slope by demolishing remaining walls, removing debris and installing suitably upgraded replacement walls. Scale unstable rock above driveway. Inspect, maintain (periodically flush drainage), divert surface and groundwater water away from walls.	Acceptable
		Persons in garden or driveway	Unlikely	Injury (<10% mortality Risk)	1×10^{-5}	Tolerable		Acceptable
		Car Driver - shared driveway	Unlikely	Injury (<10% mortality Risk)	5×10^{-6}	Acceptable		Acceptable
H3	3. Local instability of soil slope (3-10m3 volume).	Occupant at Main Residence	Unlikely	Injury (<10% mortality Risk)	2.5×10^{-5}	Tolerable	Provide surface stabilisation using coir logs, pinned geotextiles, anchored mesh or geo-cells according to slope angle). Monitor, maintain, manage erosion. Divert surface and groundwater water away from slope/wall. Maintain small scale root-binding vegetation at crest and on slope. Optionally replace and upgrade section of post-and-panel retaining walls.	Acceptable
		Persons in garden or driveway	Unlikely	Injury (<10% mortality Risk)	2.5×10^{-5}	Tolerable		Acceptable
		Car Driver - shared driveway	Rare	Injury (<10% mortality Risk)	5.0×10^{-6}	Acceptable		Acceptable
H4	4. Failure of RW6A/B/C impacting house (Up to approx. 20m3 volume).	Occupant at Main Residence	Unlikely	Injury (<10% mortality Risk)	2.5×10^{-5}	Tolerable	Remediate existing existing deforming walls by either installing suitably upgraded replacement walls, or shotcrete and soil nails through existing wall(s). Improve surface and subsurface drainage in accordance with recommendations in report and as per AS4678.*	Acceptable
		Persons in garden or driveway	Unlikely	Injury (<10% mortality Risk)	5×10^{-6}	Tolerable		Acceptable
		Car Driver - driveway	Rare	Injury (<10% mortality Risk)	2.5×10^{-6}	Acceptable		Acceptable
H5	5. Failure of RW9 on Bdy impacting subject site (Up to approx. 20m3 volume).	Occupant at Main Residence	Rare	Injury (<5% mortality Risk)	2.5×10^{-7}	Acceptable	Treat & Manage as per Hazard #4. Optionally engage / collaborate with owners of #30 to agree on upgrade to mitigate risk.*	Acceptable
		Persons in garden or driveway	Rare	Injury (<10% mortality Risk)	1.0×10^{-6}	Acceptable		Acceptable
		Car Driver - driveway	Rare	Injury (<5% mortality Risk)	1.0×10^{-7}	Acceptable		Acceptable

*- It may be possible to identify a 'repair / strengthen' solution (rather than 'replace' option which achieves an 'Acceptable' outcome. Improving existing risk to 'Acceptable' outcome is a Council requirement for DA approval.

Notes:
a - The Likelihood shown is the annualised probability of the hazard detaching, then travelling to the person at risk & the peson at risk being at the location at that time. May be different to risk to property.
Assessed using Appendix C of Landslide Risk Management, Australian Geomechanics, 2007
b - Simplified vulnerability for risk to life once a hazard reaches the element at risk.
c - Risk Evaluation based on Appendix C of Landslide Risk Management, Australian Geomechanics, 2007.

(green)	Acceptable
(yellow)	Tolerable
(red)	Unacceptable

APPENDIX D

Australian Geoguide – Notes on Hillside Construction Practice

Australian
Geomechanics
Society

Extract from

Australian Geomechanics

Journal and News of the Australian Geomechanics Society
Volume 42 No 1 March 2007

Extract containing:

"The Australian GeoGuides for Slope Management and Maintenance"

Ref: AGS (2007e)


Landslide Risk Management

ENGINEERS
AUSTRALIA

ISSN 0818-9110

THE AUSTRALIAN GEOGUIDES
FOR SLOPE MANAGEMENT AND MAINTENANCE

AGS Landslide Taskforce, Slope Management and Maintenance Working Group

The Australian Geomechanics Society (AGS) presents on the following pages a guideline on slope management and maintenance, as part of the landslide risk management guidelines developed under the National Disaster Funding Program (NDMP). This Guideline is aimed at home owners, developers and local councils, but also has applicability to a larger audience which includes builders and contractors, consultants, insurers, lawyers, government departments and in fact any person, or organisation, with a responsibility for the management or maintenance of a slope. The objective is to inform those with little or no knowledge of geotechnical engineering about landslides.

Each GeoGuide is a stand-alone document, which is formatted so that it can be printed on two sides of a single A4 sheet. It is expected that the set of GeoGuides will increase with time to cover a range of topics. As things stand:

- **GeoGuide LR1** is an introductory sheet that should be read by all users, since it explains what the LR (landslide risk) series is about and defines terms.
- **GeoGuides LR2, 3 and 4** explain why landslides occur and provide information on different types of landslide.
- **GeoGuide LR5** discusses the critical part that water often plays in relation to landslide occurrence and discusses measures that can be adopted to limit its effect.
- **GeoGuide LR6** refers to retaining walls and their maintenance.
- **GeoGuide LR7** puts the concept of landslide risk into an everyday context, so users can relate a particular landslide risk to other risks that they know they are prepared to take, sometimes on a daily basis.
- **GeoGuide LR8** retains the ideas of good and poor hillside construction practice originally provided by an AGS sub-committee in 1985.
- **GeoGuide LR9** concentrates specifically on effluent and surface water disposal, which is an important topic in some development areas.
- **GeoGuide LR10** is specifically aimed at those who have property on the coast and could be susceptible to coastal erosion processes.
- **GeoGuide LR11** provides information about the benefits of keeping records on inspection and maintenance activities and provides a proforma record sheet for users.

It is recognised that the GeoGuides are likely to be upgraded from time to time. Feedback on use and suggested changes should be sent to the National Chair of the Australian Geomechanics Society. The latest versions of the GeoGuides will be downloadable from the AGS website www.australiangemechanics.org

Through the NDMP, Australian governments (at Commonwealth, State and Local Government levels) are also funding the development of a Landslide Zoning Guideline (AGS 2007a), and a Practice Note Guideline (AGS 2007c) to which interested readers seeking in-depth information should refer.

ACKNOWLEDGEMENTS

These guidelines have been prepared by The Australian Geomechanics Society with funding from the National Disaster Mitigation Program, the Sydney Coastal Councils Group, and The Australian Geomechanics Society.

The Australian Geomechanics Society established a Working Group within a Landslide Taskforce to develop the guidelines. The development of the guidelines was managed by a Steering Committee. Membership of the Working Group, Taskforce and Steering Committee is listed in the Appendix.

Drafts of these GeoGuides have been subject to review by members of the AGS Landslide Taskforce, members of the geotechnical profession and local government.

REFERENCES

AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management. Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1.

AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1,

AGS (2007e). The Australian GeoGuides for slope management and maintenance –. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No 1, - this paper.

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

INTRODUCTION TO LANDSLIDE RISK

Photographs courtesy of Greg Kotze and Tony Phillips

AUSTRALIAN GEOGUIDES

The **Australian GeoGuides (LR series)** are a set of information sheets on the subject of landslide risk management and maintenance, published by the Australian Geomechanics Society (AGS). They provide background information intended to help people without specialist technical knowledge understand the basic issues involved. Topics covered include:

LR1 - Introduction	LR2 - Landslides	LR3 - Landslides in Soil
LR4 - Landslides in Rock	LR5 - Water & Drainage	LR6 - Retaining Walls
LR7 - Landslide Risk	LR8 - Hillside Construction	LR9 - Effluent & Surface Water Disposal
LR10 - Coastal Landslides	LR11 - Record Keeping	

The GeoGuides explain why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local authority approval (if required) to remove, or reduce, the risk they represent.

Preparation of the GeoGuides has been funded by Australian governments through the National Disaster Mitigation Program (NDMP). This is a national program aimed at identifying and addressing natural disaster risk priorities across Australia. Technical input has been provided by experienced geotechnical engineers, engineering geologists and local government and government agency representatives from around Australia.

BACKGROUND

A number of landslides and cliff collapses occurred in Australia in the 1980's and 1990's in which lives were lost. Of these the Thredbo landslide probably received the most publicity, but there were several others. During this period the AGS issued a number of advisory notes to practitioners in relation to the assessment of landslide risk and its reduction. Building on these notes, and responding to changes in technology, a technical paper known as AGS2000 was prepared. It was followed in 2002 by an intensive nation-wide educational campaign attended by a large number of interested professionals from government departments and private industry. This resulted in an increased awareness of the risks associated with unstable slopes and a changed approach in many government departments responsible for regional planning, domestic development, roads, railways and the maintenance of natural features such as cliffs.

STATUS OF THE GEOGUIDES

The GeoGuides reflect the essence of good practice as perceived by a large number of geotechnical engineers, engineering geologists and other practitioners such as local government planners. **The GeoGuides are generic and do not, and cannot, constitute advice in relation to a specific situation. This must be sought from a geotechnical practitioner with first hand knowledge of the site.** It is expected that some local councils will refer to the GeoGuides and their companion publications in planning and building legislation. Check with your local council to see how it regards these documents. Companion publications to the GeoGuides are:

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1 and its associated commentary (AGS 2007b).
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1 2007, and its associated "Commentary" (AGS 2007d).

Copies of the above documents are available on the AGS website www.australiangeomechanics.org

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

TERMINOLOGY

Terminology tends to change with time and place and with the context in which it is used. The terms listed below have the following meanings in the GeoGuides:

Consequence	the outcome, or potential outcome, arising from the occurrence of a landslide expressed quantitatively, or qualitatively, in terms of loss, disadvantage, damage, injury, or loss of life.
Discontinuity	in relation to the ground is a crack, a bedding plane (a boundary between strata) or fault (a plane along which the ground has sheared) which forms a plane of weakness and reduces the overall strength of the ground.
Equilibrium	the condition when the forces on a mass of soil or rock in the ground, or on a retaining structure, are equal and opposite.
Factor of safety (FOS)	theoretically the forces available to prevent a part of the ground, or a retaining structure, from moving divided by those trying to move it. A FOS of one or less indicates that failure is likely to occur, but not how likely it is. To allow for unknowns and to limit movements engineers always aim to achieve a FOS significantly larger than one.
Failure	when part of the ground experiences movement as a result of the out of balance forces on it. Failure of a retaining structure means it is no longer able to fulfil its intended function.
Geotechnical practitioner	when referred to in the Australian GeoGuides (LR series), is a professional geotechnical engineer, or engineering geologist, with chartered status in a recognised national professional institution and relevant training, experience and core competencies in landslide risk assessment and management. In some government departments, technical officers are specifically trained to undertake some of the functions of a geotechnical practitioner.
Hazard	a condition with the potential for causing an undesirable consequence. In relation to landslides this includes the location, size, speed, distance of travel and the likelihood of its occurrence within a given period of time.
Landslide	the movement, or the potential movement, of a mass of rock, debris, or earth down a slope.
Likelihood	a qualitative description of probability, or frequency, of occurrence.
Partial saturation	the condition in the ground above the water table where both air and water are present as well as soil, or rock.
Perched water table	a water table above the true water table supported by a low permeability stratum.
Permeability	a measure of the ability of the ground to allow water to flow through it.
Risk	a measure of the probability and severity of an adverse effect to life, health, property or the environment.
Slip failure	landslide.
Stable	the condition when failure will not occur. Over geological time no part of the ground can be considered stable. Over short periods (eg the life of a structure) stability implies a very low likelihood of failure.
Retaining structure	anything built by humans which is intended to support the ground and inhibit failure.
Structure	in relation to rock, or soil, means the spacing, extent, orientation and type of discontinuities found in the ground at a particular location.
Tension crack	a distinct open crack that normally develops in the ground around a landslide and indicates actual, or imminent , failure.
Water table	the level in the ground below which it is saturated and the voids are filled with water.

Photograph courtesy of Phil Flentje

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.

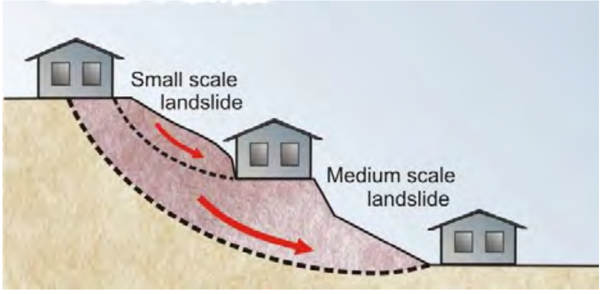


Figure 1

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.

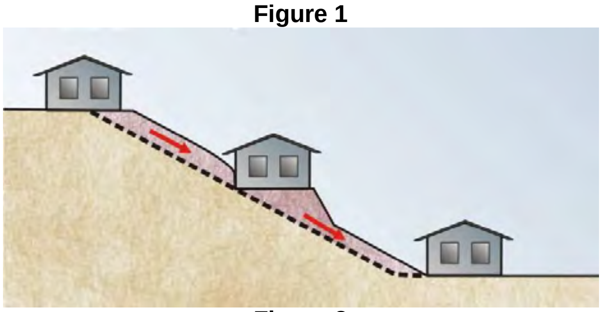


Figure 2

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.

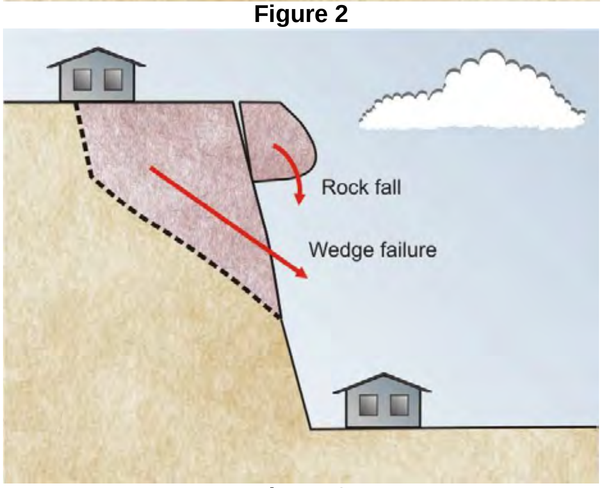


Figure 3

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.

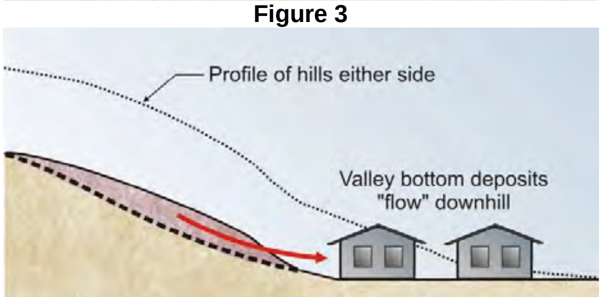


Figure 4

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.

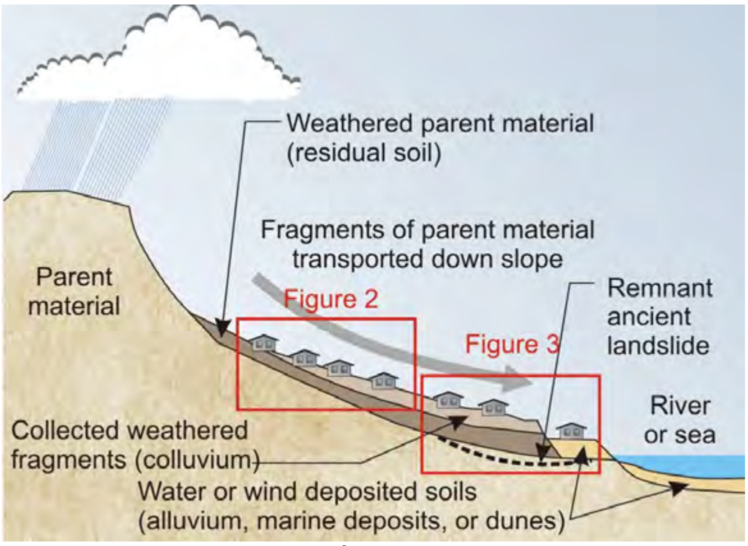


Figure 1

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.

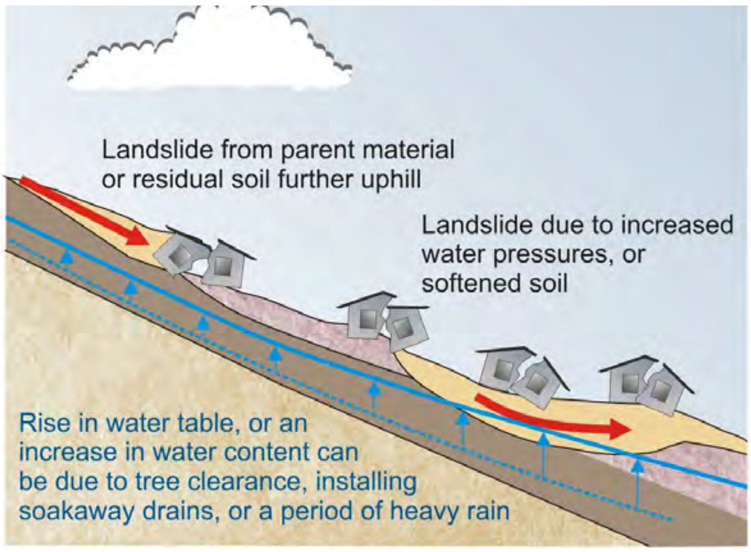


Figure 2

AUSTRALIAN GEOGUIDE LR3 (LANDSLIDES IN SOIL)

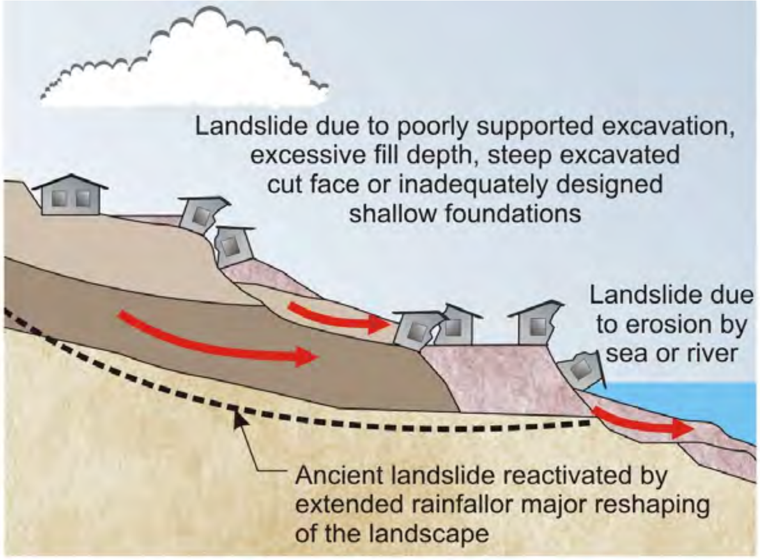


Figure 3

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

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 LR4 (LANDSLIDES IN ROCK)

LANDSLIDES IN ROCK

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

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

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

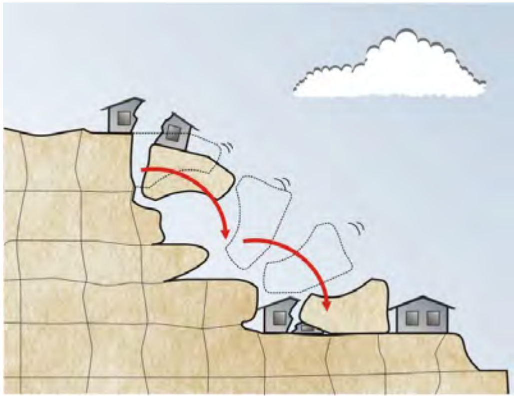


Figure 1 - Failure of an undercut block

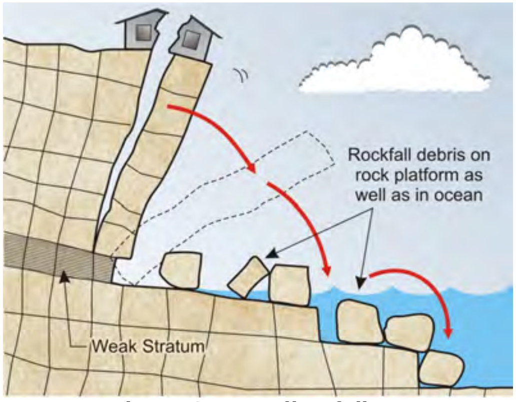


Figure 2 - Toppling failure

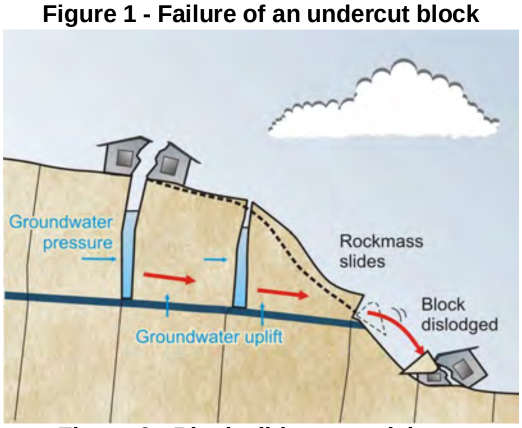


Figure 3 - Block slide on weak layer

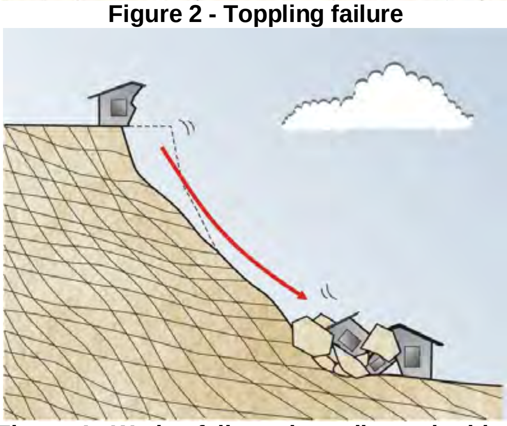


Figure 4 - Wedge failure along discontinuities

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

The most common options are:

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

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

ROCK SLOPE HAZARD REDUCTION MEASURES

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

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

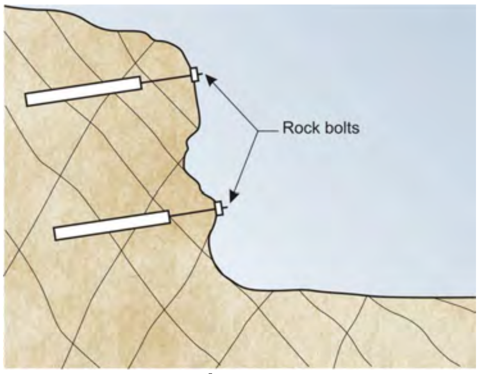


Figure 5

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

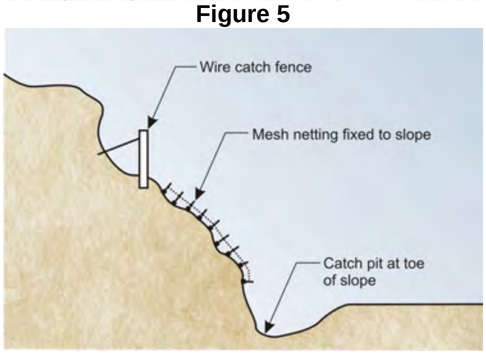


Figure 6

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

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

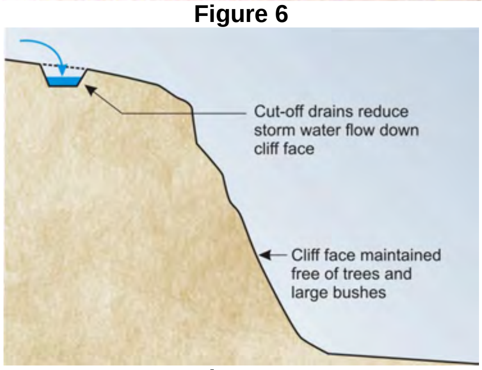


Figure 7

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

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- 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 LR5 (WATER & DRAINAGE)

WATER, DRAINAGE & SURFACE PROTECTION

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

Groundwater and Groundwater Flow

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

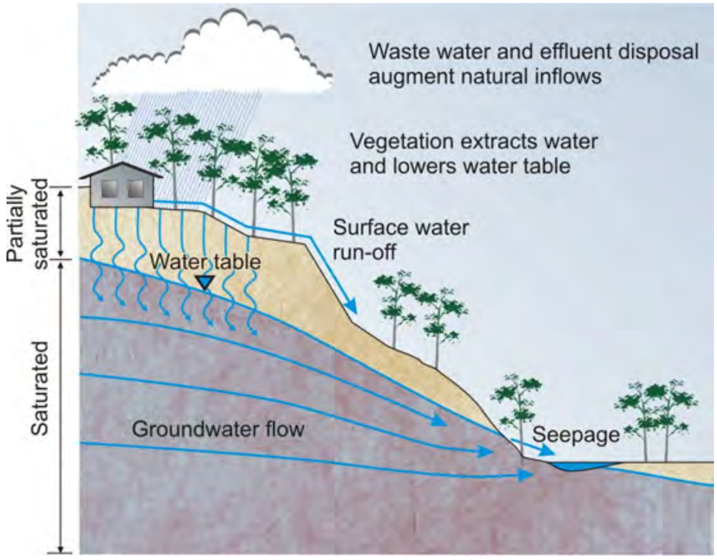


Figure 1 - Groundwater flow

Groundwater Flow and Landslides

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

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

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

Limiting the Effect of Water

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

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

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

AUSTRALIAN GEOGUIDE LR5 (WATER & DRAINAGE)

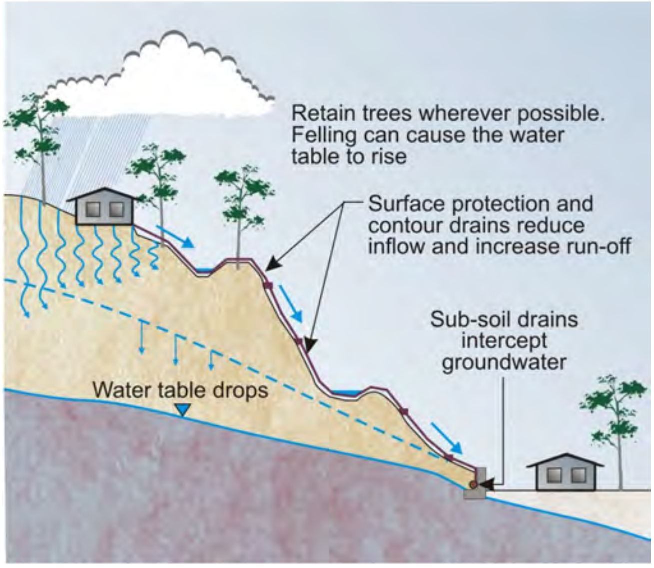


Figure 2 - Techniques used to control groundwater flow

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

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

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

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

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

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR6 - Retaining Walls
- 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.

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.

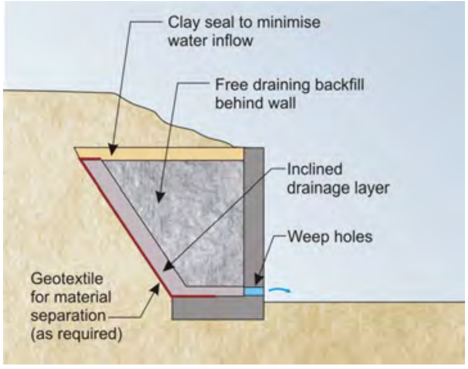


Figure 1- Typical formed concrete wall

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.

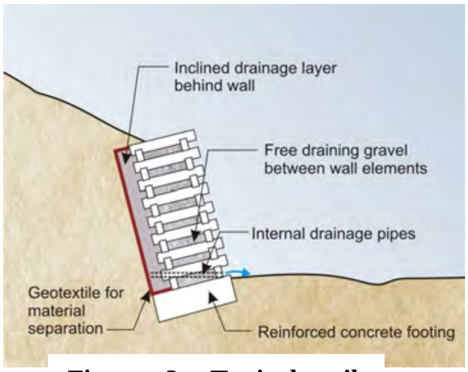


Figure 2 -Typical crib

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

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

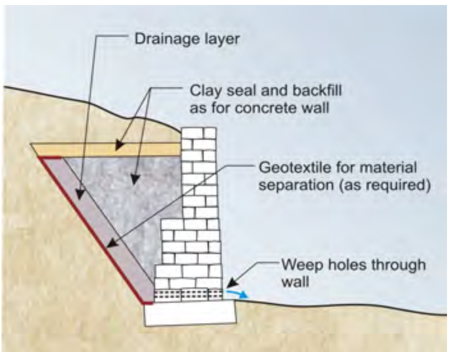


Figure 3 -Typical masonry wall

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.

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.

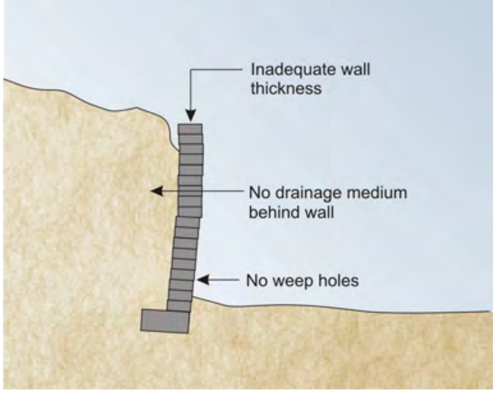


Figure 4 - Poorly built masonry wall

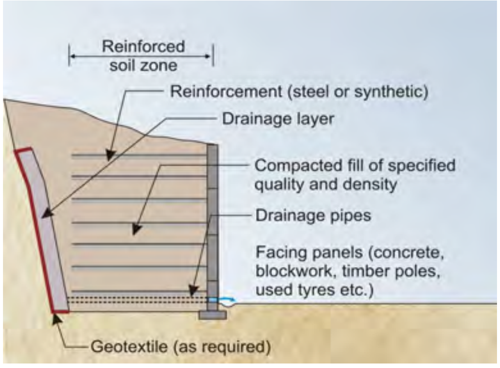


Figure 5 - Typical reinforced soil wall

OTHER WALLS

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

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

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

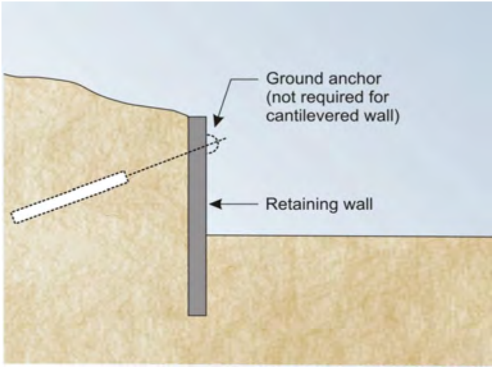


Figure 6 - Typical cantilevered or anchored wall

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".

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

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- 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.

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.

Risk to Life

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

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

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

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

TABLE 3: RISK TO LIFE

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

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

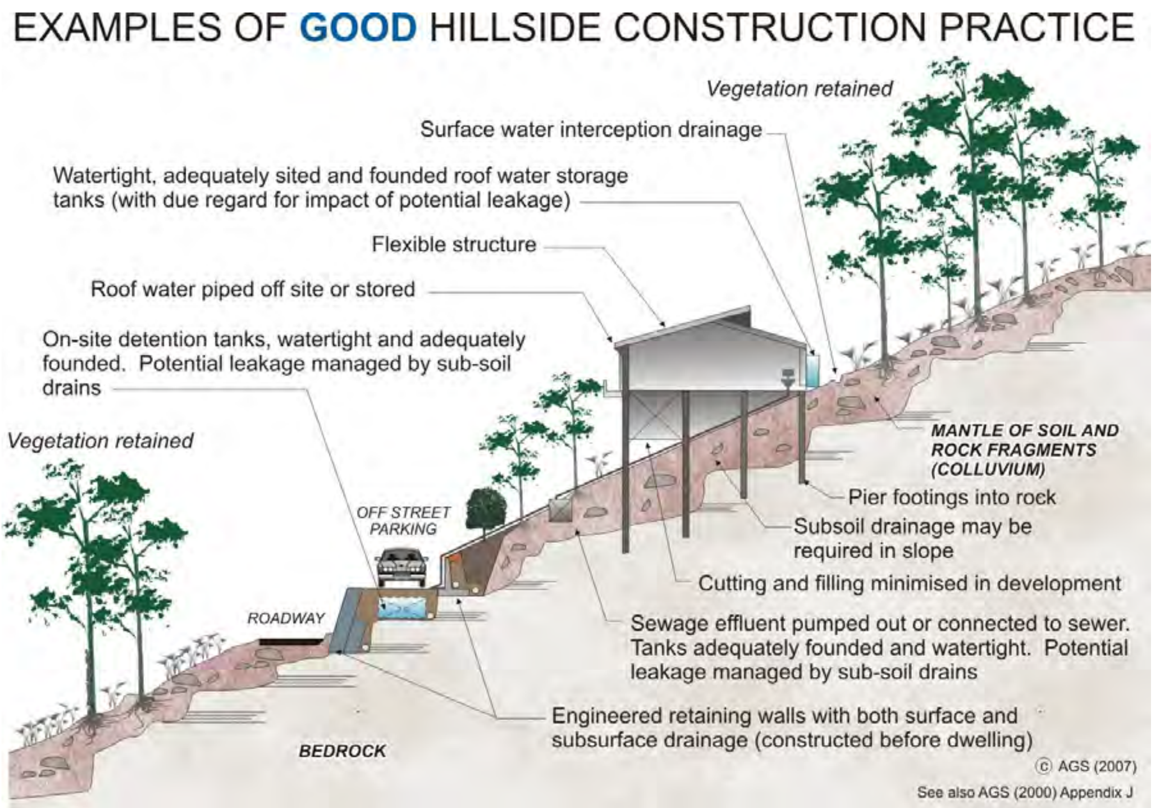
- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
  GeoGuide LR10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

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

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

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



WHY ARE THESE PRACTICES GOOD?

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

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

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

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

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

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

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

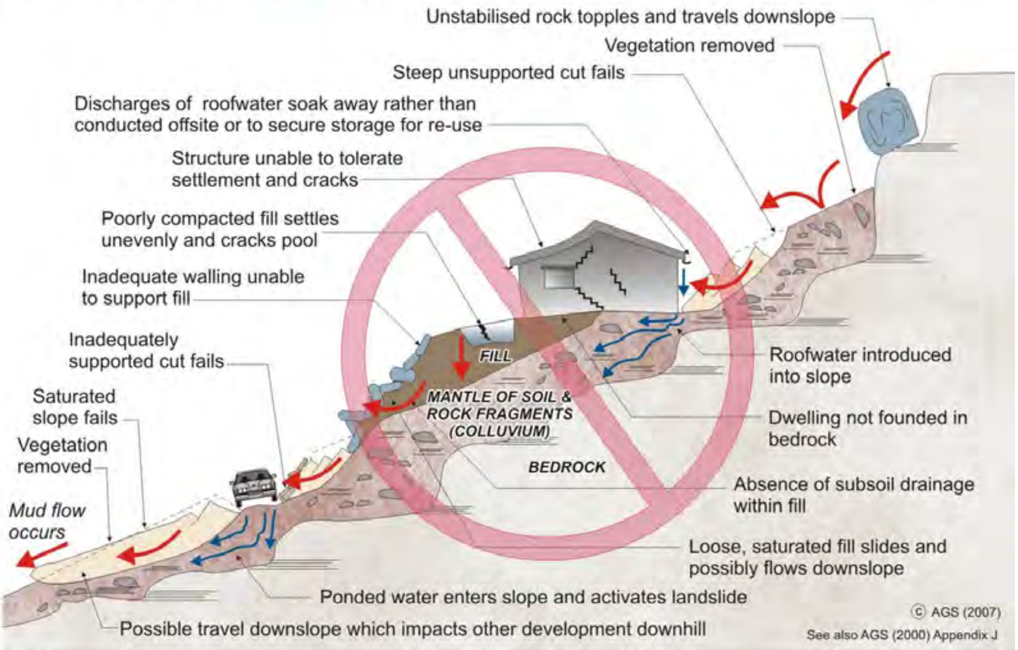
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing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

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

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF POOR HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

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

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

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

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

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

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

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

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

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- 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 LR9 (EFFLUENT DISPOSAL)

EFFLUENT AND SURFACE WATER DISPOSAL

EFFLUENT AND WASTEWATER

All households generate effluent and wastewater. The disposal of these products and their impact on the environment are key considerations in the planning of safe and sustainable communities. Cities and townships generally have reticulated water, sewer and stormwater systems, which are designed to deliver water and dispose of effluent and wastewater with minimal impact on the environment. However, many smaller communities and metropolitan fringe suburbs throughout Australia are un-sewered. Some of these are located in hillside or coastal settings where landslides present a hazard.

Processes by which wastewater can affect slope stability

As explained in GeoGuides LR3 and LR5, groundwater variations have a significant impact on slope stability. Inappropriate disposal of effluent and wastewater may result in the ground becoming saturated. The result is equivalent to a localised rise of the groundwater table and may have the potential to cause a landslide (GeoGuides LR2, LR5 and LR8).

On-site effluent disposal

In un-sewered areas disposal of effluent must be achieved through suitable methods. These methods usually involve containment within the boundaries of the site ("on-site disposal"). State environment protection agencies and local government authorities can usually provide advice on suitable disposal systems for your area. Such systems may include:

- *Septic systems,* which involve a storage/digestion tank for solids, with disposal of the liquid effluent via absorption trenches and beds, leach drains, or soak wells. Such systems are best suited to areas not prone to landslides.
- *Aerobic treatment units* which incorporate an individual household treatment plant to aid breakdown of the waste into a higher quality effluent. Such effluent is further treated and disposed of by surface or sub-surface irrigation, sub-soil dripper, or shallow leach drain system.
- *Nutrient retentive leaching systems* which utilise septic tanks to process the solid and liquid wastes in conjunction with discharge of the effluent through sand filters, media filters, mound systems and nutrient retentive leaching systems, which strip the effluent of nutrients.

Toilet (and sometimes kitchen) waste is known as *black water.* Other, less contaminated, wastewater streams from showers, baths and laundries are known as *grey water*. *Grey water re-use systems* allow a household to conserve water from bathrooms, kitchens and laundries, for re-use on gardens and lawns.

Recommendations for effluent disposal

In areas prone to landslide hazard, it is recommended that whatever effluent disposal system is employed, it should be designed by a qualified professional, familiar with how such a system can impact on the local environment. Local council, and in some instances state environment protection agency, approval is usually required as well. Many local authorities require a site assessment report, which covers all relevant issues. If approved, the report's recommendations must be incorporated in the system design. Reduction in the volume of effluent is beneficial so composting toilets and highly rated (i.e. low consumption) water appliances are recommended. It should be noted that in some state and local government jurisdictions there are restrictions on the alternative measures that can be applied. Consideration should be given to applying treated wastewater to land at low rates and over as large an area as possible. Further guidance can be found in Australian Standard AS/NZS 1547:2000 On-site domestic wastewater management.

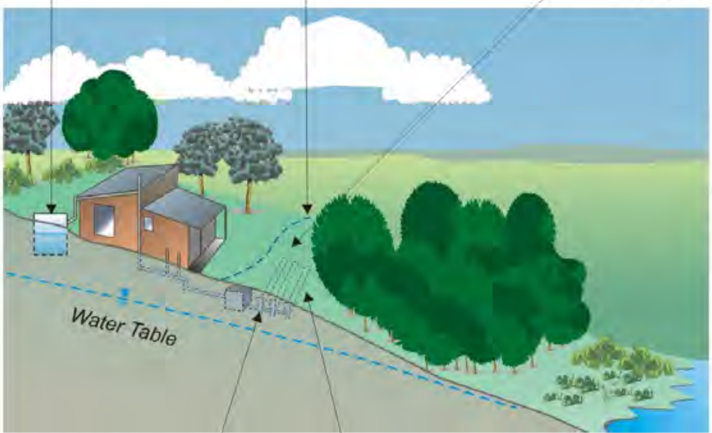
Effluent disposal fields should be sited with due consideration to the overall landscape and the individual characteristics of the property. Some guidance is provided. In particular, effluent fields should be located downslope of the building, away from stormwater, or *grey water*, discharge areas and where there is minimal potential for downstream pollution. Set backs and buffer distances vary from state to state and local requirements should be adhered to. All systems require regular maintenance and inspection. Efficient operation of the system must be a priority for property owners/occupiers to ensure safe and sustainable communities. Responsibility for maintenance rests with owners.

SURFACE WATER DRAINAGE

Attention to on-site surface water management is also important. Runoff from developments, including buildings, decks, access tracks and hardstand areas should be collected and discharged away from the development and other effluent disposal fields. Particular care must be given to the design of overflows on water tanks, as this is often overlooked. Discharge from any development should be spread out as much as possible, unless it can be directed to an existing natural water course. Ponding of water on hillsides and the concentration of water flows on slopes must be avoided.

It is recommended that a specific drainage plan and strategy should be developed in conjunction with the effluent disposal system for sites with a high potential for slope instability. Maintenance of the surface water drainage system is as important as maintenance of the effluent disposal system and again the responsibility rests with owners.

AUSTRALIAN GEOGUIDE LR9 (EFFLUENT DISPOSAL)



Note: Adapted from EPA Vic. Publication 451 (March 1996) "Code of Practice - Septic Tanks", which was sourced from Vic. Department of Planning and Loddon-Campaspe Regional Planning Authority.

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- 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 LR10 (COASTAL LANDSLIDES)

LANDSLIDES IN THE COASTAL ENVIRONMENT

Coastal Instability

The coast presents a particularly dynamic environment where change is often the norm. Hazards exist in relation to both cliffs and sand dunes. The coast is also the most heavily populated part of Australia and always regarded as "prime" real estate, because of the views and access to waterways and beaches.

Photo courtesy Greg Kotze

Waves, wind and salt spray play a significant part, causing dunes to move and cliff-faces to erode well above sea level. Our response is often to try to neutralise these effects by doing such things as dumping rock in the sea, building groynes, dredging, or carrying out dune stabilisation. Such works can be very effective, but ongoing maintenance is usually needed and total reconstruction may be necessary after a relatively short working life.

Of particular significance are extreme events that cause destruction on a scale that ignores our efforts at coastal protection. Records show that cliffs have collapsed, taking with them backyards which had been relied upon as a buffer between a house and the ocean. Sand dunes have also been washed away resulting in the dramatic loss of homes and infrastructure. As with most landslide issues, even though such events may be infrequent, they could happen tomorrow. It is easy to be lulled into a false sense of security on a calm day.

In coastal areas, typical landslide hazards (GeoGuides LR1 to LR4) are compounded by coastal erosion which, over time, undercuts cliffs and eventually results in failure. In the case of sand dunes, dune erosion and dune slumping have equally dramatic effects. Coastal locations are subject to particular processes relating to fluctuating water tables, inundation under storm tides and direct wave attack. Large sections of our more sandy coastline are receding under present sea conditions. The hazards are progressive and likely to be exacerbated through climate change.

Coastal Development

If you own, or are responsible for, a coastal property it is important that you understand that, where the shore line is receding, there is a greater landslide risk than would be the case on a similar site inland. The view may make the risk worthwhile, but does not reduce it.

Coastal Landslides

Coastal landslides are little different from other landslides in that the signs of failure (GeoGuides LR2) and the causes (LR3, LR4 & LR5) are largely the same. The main difference relates to the overriding influence of wave impact, tidal movement, salt spray and high winds.

Cliff failures

In addition to the processes that produce cliff instability on inland cliffs, coastal cliffs are also subjected to repeated cycles of wetting and drying which can be accompanied by the expansive effect of salt crystal growth in gaps in the rocks. These processes accelerate the deterioration of coastal cliffs. At the base of cliffs, direct wave attack and the impact of boulders moved by wave action causes undercutting and hence instability of the overall face. Figure 2 of GeoGuide LR4 provides an example. Whilst the processes leading to coastal cliff collapse may take years, failure tends to be catastrophic and with little warning. In many cases, waves produced by large oceanic storms are the trigger assisted by rainfall to produce collapse. These are also the conditions in which you are more likely to be inside your home and oblivious to unusual noises or movements associated with imminent failure.

Sand dune escarpment and slope failures

An understanding of coastal processes is essential when determining beach erosion potential. Waves produced by large oceanic storms can erode beaches and cut escarpments into dunes. These may be of relatively short duration, when beach re-building happens after the storm, but can be a permanent feature where long term beach recession is taking place. In many locations, houses and infrastructure are sited on or immediately behind coastal dunes. After an escarpment has eroded, those assets may be lost or damaged by subsequent slumping of the dune. It is important that, on erodible coastal soils, the potential for landward incursion of an erosion escarpment is determined. Having done this, the likelihood of slope instability can be established as part of the landslide risk management process. Injury, death and structural damage have occurred around the Australian coast from collapsing sand escarpments.

Photo courtesy DNR NSW

AUSTRALIAN GEOGUIDE LR10 (COASTAL LANDSLIDES)

The large scale and potentially high speed of coastal erosion processes means that major civil engineering work and large cost is normally involved in their control. The installation of rock bolts (LR4), drainage (LR5), or retaining walls (LR6) on a single house site may be necessary to provide local stability, but are unlikely to withstand the attack of a large storm on a beach or cliff-line.

BUILDING NEAR CLIFFS AND HEADLANDS

Coastal cliffs and headlands exist because the rock that they are made from is able to resist erosion. Even so, cliff-faces are not immune and will continue to collapse (Figure 1) by one or other of the mechanisms shown on GeoGuide LR4. If you live on a coastal cliff, you should undertake inspection and maintenance as recommended in LR4 and the other GeoGuides, as appropriate. The top of the cliff, its face, and its base should be inspected frequently for signs of recent rock falls, opening of cracks, and heavy seepage which might indicate imminent failure. Since the sea can remove fallen rocks rapidly, inspections should be made shortly after every major storm as a matter of course. **<u>If collapses are occurring seek advice from an appropriately experienced geotechnical practitioner. Advise you local council if you believe erosion is rapid or accelerating.</u>**

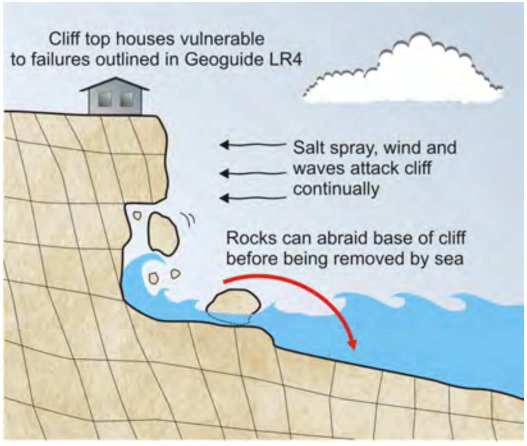


Figure 1

Building on Coastal Dunes

Any excavation in a natural dune slope is inherently unstable and must be supported and maintained (GeoGuide LR6). Dunes are particularly susceptible to ongoing erosion by wind and wave action and extreme changes can occur in a single storm. Whilst vegetation can help to stabilise dunes in the right circumstances, unfortunately a single storm has the potential to cut well into dunes and, in some cases, remove an entire low lying dune system or shift the mouth of a river. **<u>As for cliffs, it is appropriate to observe the effects of major storms on the coastline. If erosion is causing the coastline to recede at an appreciable rate, seek advice from suitably experienced geotechnical and coastal engineering practitioners and bring it to the attention of the local council.</u>**

Photo courtesy DNR NSW

CLIMATE CHANGE

The coastal zone will experience the most direct physical impacts of climate change. A number of reviews of global data indicate a general trend of sea level rise over the last century of 0.1 - 0.2 metres. Current rates of global average sea level rise, measured from satellite altimeter data over the last decade, exceed 3 mm/year and are accelerating. The most authoritative and recent (at the time of writing) report on climate change (IPCC, 2007) predicts a global average sea level rise of between 0.2 and 0.8 metres by 2100, compared with the 1980 - 1999 levels (the higher value includes the maximum allowance of 0.2 m to account for uncertainty associated with ice sheet dynamics).

In addition to sea level rise, climate change is also likely to result in changes in wave heights and direction, coastal wind strengths and rainfall intensity, all of which have the capacity to impact adversely on coastal dunes and cliff-faces. A Guideline for responding to the effects of climate change in coastal areas was published by Engineers Australia in 2004.

References

Engineers Australia 2004 'Guidelines for responding to the effects of climate change in coastal and ocean engineering." The National Committee on Coastal and Ocean Engineering , Engineers Australia , updated 2004.

IPCC (2007) *Climate Change 2007: The Physical Science Basis.* Summary for Policy Makers. Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

Nielsen, A.F., Lord D.B. and Poulos, H.G. (1992). 'Dune Stability Considerations for Building Foundations', *Aust. Civil Eng. Transactions* CE No.2, 167-174.

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- 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 <u>Australian Geomechanics Society</u>, 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 LR11 (RECORD KEEPING)

RECORD KEEPING

It is strongly recommended that records be kept of all construction, inspection and maintenance activities in relation to developments on sloping blocks. In some local authority jurisdictions, maintenance requirements form part of the building consent conditions, in which case they are mandatory.

CONSTRUCTION RECORDS

If at all possible, you should keep copies of drawings, specifications and construction (i.e. "as built") records, particularly if these differ from the design drawings. The importance of these documents cannot be over-emphasised. If a geotechnical practitioner comes to a site to carry out a landslide risk assessment and is only able to see the face of a retaining wall, the heads of some ground anchors, or the outlets of a number of sub-soil drains, it may be necessary to determine how these have been built and how they are meant to work before completing the assessment. This could involve drilling through the wall to determine how thick it is, or probing the length of the drains, or even ignoring the anchors altogether, because it is uncertain how long they are. Such "investigation" of something that may only have been built a few years before is, at best, a waste of time and money and, at worst, capable of coming up with a misleading answer which could affect the outcome of the assessment. Documentary information of this sort often proves to be invaluable later on, so treat it with as much importance as the title deeds to your property.

INSPECTION AND MAINTENANCE RECORDS

If you follow the recommendations of the Australian GeoGuides it is likely that you will either carry out periodic inspections yourself, or you will engage a geotechnical practitioner to do them for you. The collected records of these inspections will provide a detailed history of changes that might be occurring and will indicate, better than your own memory, whether things are deteriorating and, if so, at what rate. Unfortunately, without some form of written record, all information is usually lost each time a property is sold. It is recommended that a prospective purchaser should have a pre-purchase landslide risk assessment carried out on a hillside site, in much the same way that they would commission a structural assessment, or a pest inspection, of the building. If the vendor has kept good records, then the assessment is likely to be quicker and cheaper, and the outcome more reliable, than if none are available. Each site is different, but noting the following would normally constitute a reasonable record of an inspection/maintenance undertaken:

- date of inspection/maintenance and the name and professional status of the person carrying it out
- description of the specific feature (eg. cliff face, temporary rock bolt, cast *in situ* retaining wall, shallow leach drain system)
- sketch plans, sketches and photographs to indicate location and condition
- activity undertaken (eg. visual inspection; cleared vegetation from drain; removed fallen rock about 500 mm diameter)
- condition of the feature and any matters of concern (e.g. weep holes damp and flowing freely; rust on anchor heads getting worse; shotcrete uncracked and no sign of rust stains; ground saturated around leach field)
- specific outcomes (eg. no action necessary; geotechnical practitioner called in to advise on the state of the anchors; cliff face to be trimmed following the most recent rock fall; leach field to be rebuilt at new location)

A proforma record is provided overleaf for convenience. Photographs and sketches of specific observations can prove to be very useful and should be included whenever possible. Geotechnical practitioners may devise their own site specific inspection/maintenance records.

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

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide 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

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 LR11 (RECORD KEEPING)

INSPECTION/MAINTENANCE RECORD

(Tick boxes as appropriate and add information as required) Date..

Site location (street address / lot & DP numbers / map reference / latitude and longitude)

....

FEATURE

FEATURE	Inspected	Maintained	Tested	By Owner	By Professional
Slopes & surface protection:					
☐ Natural slope/cliff ☐ Cut/fill slope					
☐ Surface water drains					
☐ Shotcrete ☐ Stone pitching ☐ Other					
Retaining walls:					
☐ Cast in situ concrete ☐ Concrete block					
☐ Masonry (natural stone) ☐ Masonry (brick, block)					
☐ Cribwall (concrete) ☐ Cribwall (timber)					
☐ Anchored wall ☐ Reinforced soil wall					
☐ Sub-soil drains ☐ Weep holes					
Ground improvement:					
☐ Rock bolts					
☐ Ground anchors ☐ Soil nails					
☐ Deep subsoil drains					
Effluent and storm water disposal systems:					
☐ Effluent treatment system					
☐ Effluent disposal field					
☐ Storm water disposal field					
Other:					
☐ Netting ☐ Catch fence ☐ Catch pit					
☐ ------------------------------					
☐ ------------------------------					
☐ ------------------------------					

Observations/Notes (Add pages/details as appropriate)

....

....

....

Attachments: ☐ Sketch(es) ☐ Photograph(s) ☐ Other (eg measurements, test results)

Record prepared by .... (name): ....(signature)

Contact details: Phone:....................................... E-mail:..

Professional Status (in relation to landslide risk assessment):..

APPENDIX

AUSTRALIAN GEOMECHANICS SOCIETY

STEERING COMMITTEE

Andrew Leventhal, GHD Geotechnics, Sydney, Chair
Robin Fell, School of Civil and Environmental Engineering, UNSW, Sydney, Convenor Guidelines on Landslide Susceptibility, Hazard and Risk Working Group
Tony Phillips, Consultant, Sydney, Convenor Slope Management and Maintenance Working Group
Bruce Walker, Jeffery and Katauskas, Sydney, Convenor Practice Note Working Group
Geoff Withycombe, Sydney Coastal Councils Group, Sydney

WORKING GROUP - Guidelines on Slope Management and Maintenance
Tony Phillips, Tony Phillips Consulting, Sydney, Convenor
Henk Buys, NSW Roads and traffic Authority, Parramatta
John Braybrooke, Douglas Partners, Sydney
Tony Miner, A.G. Miner Geotechnical, Geelong

LANDSLIDE TASKFORCE
Laurie de Ambrosis, GHD Geotechnics, Sydney
Mark Eggers, Pells Sullivan Meynink, Sydney
Max Ervin, Golder Associates, Melbourne
Angus Gordon, retired, Sydney
Greg Kotze, GHD, Sydney
Arthur Love, Coffey Geotechnics, Newcastle
Alex Litwinowicz, GHD Geotechnics, Brisbane
Tony Miner, A.G. Miner Geotechnical, Geelong
Fiona MacGregor, Douglas Partners, Sydney
Garry Mostyn, Pells Sullivan Meynink, Sydney
Grant Murray, Sinclair Knight Merz, Auckland
Garth Powell, Coffey Geotechnics, Brisbane
Ralph Rallings, Pitt and Sherry, Hobart
Ian Stewart, NSW Roads and Traffic Authority, Sydney
Peter Tobin, Wollongong City Council, Wollongong
Graham Whitt, Shire of Yarra Ranges, Lillydale

APPENDIX E

Northern Beaches Council DA Form 1/1A

GEOTECHNICAL RISK MANAGEMENT POLICY FOR PITTWATER

FORM NO. 1 – To be submitted with Development Application

Development Application for DAVID PARKER C/O SILVER WOLF PROJECTS PTY LTD

Name of Applicant

Address of site 32A NAREEN PDE, NORTH NARRABEEN

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

I, PHILIP DAVIES *on behalf of* GEOREPORTS PTY LTD

(Insert Name) (Trading or Company Name)

on this the 13TH NOVEMBER 2022 certify that I am a geotechnical engineer or engineering geologist or coastal engineer as defined by the Geotechnical Risk Management Policy for Pittwater - 2009 and I am authorised by the above organisation/company to issue this document and to certify that the organisation/company has a current professional indemnity policy of at least $10million.

I: PHILIP DAVIES

Please mark appropriate box

- ✓ have prepared the detailed Geotechnical Report referenced below in accordance with the Australia Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ✓ am willing to technically verify that the detailed Geotechnical Report referenced below has been prepared in accordance with the Australian Geomechanics Society's Landslide Risk Management Guidelines (AGS 2007) and the Geotechnical Risk Management Policy for Pittwater - 2009
- ✓ have examined the site and the proposed development in detail and have carried out a risk assessment in accordance with Section 6.0 of the Geotechnical Risk Management Policy for Pittwater - 2009. I confirm that the results of the risk assessment for the proposed development are in compliance with the Geotechnical Risk Management Policy for Pittwater - 2009 and further detailed geotechnical reporting is not required for the subject site.
- ϶ have examined the site and the proposed development/alteration in detail and I am of the opinion that the Development Application only involves Minor Development/Alteration that does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- ϶ have examined the site and the proposed development/alteration is separate from and is not affected by a Geotechnical Hazard and does not require a Geotechnical Report or Risk Assessment and hence my Report is in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009 requirements.
- ϶ have provided the coastal process and coastal forces analysis for inclusion in the Geotechnical Report

Geotechnical Report Details:

Report Title: GEOTECHNICAL - INVESTIGATION REPORT – LANDSLIP REMEDIATION

Report Date: 13TH NOVEMBER 2022

Author: PHILIP DAVIES

Author's Company/Organisation: GEOREPORTS PTY LTD

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

AS LISTED IN ABOVE REPORT

I am aware that the above Geotechnical Report, prepared for the abovementioned site is to be submitted in support of a Development Application for this site and will be relied on by Pittwater Council as the basis for ensuring that the Geotechnical Risk Management aspects of the proposed development have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least ~~100~~ 60 years unless otherwise stated and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature [signature]

Name PHILIP DAVIES

Chartered Professional Status CPENG, NER

Membership No. 2381900

Company GEOREPORTS PTY LTD

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

Development Application for DAVID PARKER C/o SILVER WOLF PROJECTS PTY LTD
Name of Applicant
Address of site 32A NAREEN PARADE, NORTH NARRABEEN

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

Geotechnical Report Details:

Report Title: GEOTECHNICAL INVESTIGATION REPORT - LANDSLIP REMEDIATION
Report Date: 13 NOVEMBER 2022
Author: GEOREPORTS PTY LTD - PHILIP DAVIES
Author's Company/Organisation: "

Please mark appropriate box

✓ Comprehensive site mapping conducted 5th OCTOBER 2022
(date)
✓ Mapping details presented on contoured site plan with geomorphic mapping to a minimum scale of 1:200 (as appropriate)
✓ Subsurface investigation required
- ∍ No Justification ...
- ✓ Yes Date conducted 5th OCTOBER 2022

✓ Geotechnical model developed and reported as an inferred subsurface type-section
✓ Geotechnical hazards identified
- ∍ Above the site
- ✓ On the site
- ∍ Below the site
- ✓ Beside the site

✓ Geotechnical hazards described and reported
✓ Risk assessment conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
- ✓ Consequence analysis
- ✓ Frequency analysis

✓ Risk calculation
✓ Risk assessment for property conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
✓ Risk assessment for loss of life conducted in accordance with the Geotechnical Risk Management Policy for Pittwater - 2009
✓ Assessed risks have been compared to "Acceptable Risk Management" criteria as defined in the Geotechnical Risk Management Policy for Pittwater - 2009
✓ Opinion has been provided that the design can achieve the "Acceptable Risk Management" criteria provided that the specified conditions are achieved.
✓ Design Life Adopted:
- ∍ 100 years
- ✓ Other 60
specify

✓ Geotechnical Conditions to be applied to all four phases as described in the Geotechnical Risk Management Policy for Pittwater - 2009 have been specified
✓ Additional action to remove risk where reasonable and practical have been identified and included in the report.
∍ Risk assessment within Bushfire Asset Protection Zone.

I am aware that Pittwater Council will rely on the Geotechnical Report, to which this checklist applies, as the basis for ensuring that the geotechnical risk management aspects of the proposal have been adequately addressed to achieve an "Acceptable Risk Management" level for the life of the structure, taken as at least ~~100~~ 60 years unless otherwise stated, and justified in the Report and that reasonable and practical measures have been identified to remove foreseeable risk.

Signature [signature]
Name PHILIP DAVIES
Chartered Professional Status CPEng, NER
Membership No. 2381900
Company GEOREPORTS PTY LTD