PRECISION Engineering Group

Site Inspection Report

Date: 26 November 2020

Reference No: PE20052 SIR_A

Attention: Nick Frier
Company: Complete Trade
Email: Nick@completetrade.com.au

Proposed Alterations and Additions
23 Waterview Street, Mona Vale, NSW

As requested, our Senior Geotechnical Engineer, Andrew Frost, visited the above site on the 23rd November 2020 to complete a subsurface investigation and walkover inspection of the site for the proposed alterations and additions. The south-western margin of the site is mapped within Geotechnical Area 'G2' on the Northern Beaches Council Potential Geotechnical Landslip Hazard Map.

We have been provided with the following information:

- Survey Drawing prepared by Iping Survey Group (Ref. 200123-001, Issue A, dated 4 September 2020)
- Architectural Drawings prepared by Complete Trade (Drawings Nos. A.01.1, A.02.1, A.03.1, A.03.2, A.04.1, A.04.2, A.04.3, A.04.4, A.05.1, A.06.1, A.06.2, dated 29 September 2020)

Based on the provided information we understand the proposed alterations and additions comprise:

- Modification of the existing deck including relocation of the staircase to the southern end of the deck and a north western extension.
- Internal reconfiguration of the existing ground and first floor.

No filling, bulk excavation or retention is proposed as part of the works. We expect localised excavation for shallow or piled footings may be required to support the proposed deck extension and staircase.

Whilst on site we completed the following:

- A walkover inspection of the topographic, surface drainage and geological conditions of the site and its immediate environs to identify any potential geotechnical hazards with regards to the proposed works.
- Drilling of one borehole (BH1) using a hand auger to a refusal depth of 2.1m and completion of two Dynamic Cone Penetrometer tests (DCP1 and DCP2) to refusal depths of 3.2m and 2.4m, respectively.

A plan identifying the key geotechnical features, and, borehole and DCP test locations is attached. The geotechnical mapping symbols and landslide terminology used in this report are presented in Appendix A and B. A summary of our findings is provided below.

Walkover Inspection

- The site is situated in moderately undulating terrain at the toe of a hillside which slopes down to the north-east at an average of 6°.
- A batter slope measuring a maximum of 1.3m vertical height grades down to the north-east at between 12° and 31° adjacent to Waterview Street along the sites western boundary. The majority of the site is relatively level, grading down to the north-east at between 2° and 5°.
- The site was occupied by a two-storey weatherboard house which appeared to be in good condition.

- A series of walls of maximum 1.2m height comprising either brick, sandstone masonry or timber retained the sites rear yard along the eastern boundary. The walls appeared to range from good to good/fair condition. Active stormwater discharge pipes were observed at the toe of the brick retaining wall.
- A brick wall at the northern end of the rear yard retained a maximum height of 1m on its northern side and appeared to be in good condition.
- Scattered medium to large trees lined the northern, eastern and western ends of the site. The trees appeared to be stable, displaying no signs of leaning, bowing or undercutting.
- An open, unlined watercourse which drained to the north was observed within a minor gully feature beyond the sites eastern boundary.
- No apparent signs of slope instability (ie. tension cracking, slumping, hummocky ground, unstable trees, poorly performing retaining walls and other structures) were observed whilst on site.

Subsurface Investigation

- BH1 encountered moderately to well compacted gravelly clayey sand fill over residual clayey and sandy soils. The clays were assessed to be of hard strength and the sands ranged from medium dense to very dense relative density.
- Weathered sandstone bedrock has been inferred from the refusal depths of the DCP testing at depths of 3.2m (DCP1) and 2.4m (DCP2).
- No colluvial soils were observed or encountered during the investigation.
- BH1 was 'dry' during and on completion of hand auger drilling.

Geotechnical Assessment

We have considered completing a geotechnical slope stability risk assessment in accordance with Australian Geomechanics Society (2007c) *'Practice Note Guidelines for Landslide Risk Management'*, however do not consider it appropriate in this instance, with respect to the proposed alterations and additions for the following reasons.

- No observed signs of instability or geotechnical hazards were identified on, above or below the site during our walkover inspection.
- Our subsurface investigation did not encounter soils considered to be associated with slope instability (ie. 'over-wet', colluvial etc) and the site appears to be well drained.
- The site structures including the existing house and retaining walls appear to be performing adequately.
- The footprint of the proposed deck falls outside both the zone of influence of any adjacent slopes and the 'G2' zoning on the Northern Beaches Council Potential Geotechnical Landslip Hazard Map.
- The scope of works does not involve any major cut/fill or modification to natural watercourses which may increase the risk of instability during or following construction.

Based on the above, we expect the risk to property and risk to life would be considered 'Acceptable' in accordance with the criteria given in Appendix C. We have assumed that no foreseeable activities on surrounding land which may affect the risk on the subject site would be carried out. We have further assumed that all Council's buried services are, and will be regularly maintained to remain, in good condition. Notwithstanding, in order to maintain an acceptable level of risk during and following construction, our recommendations outlined below should be adopted.

Geotechnical Recommendations

We consider that the proposed development may proceed provided the following specific design, construction and maintenance recommendations are adopted to maintain and reduce the present risk of instability of the site and to control future risks. These recommendations address geotechnical issues only and other conditions may be required to address other aspects. Design and construction should also follow the recommendations provided in Appendix D.

- Footings for the proposed deck should be founded below the fill profile within either the natural residual soils or weathered sandstone bedrock. All footings should be excavated, inspected by the geotechnical engineer and poured with minimal delay. The footings should be free from all loose or softened materials prior to pouring. If water ponds in the base of footings it should be removed and the footing over-excavated to remove all loose or water softened materials.
- Footings must be founded below a zone of influence line projected up at 1 Vertical in 2 Horizontal (1V:2H) from the toe of any of any adjacent slopes. All surcharge loads, including constructions loads and tracked plant, must be kept outside a similar zone of influence line from the crest of any slopes or batters. Based on the geometry of the site and proposed work areas. this appears readily achievable.
- Good and effective site drainage should be maintained both during construction and for long-term site maintenance. The principle aim of the drainage is to promote run-off and reduce ponding.

Should you require any clarification or further information, please do not hesitate to contact the undersigned.

Andrew Frost | Senior Engineering Geologist / Project Manager

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Attachments

Figure 1 – Geotechnical Mapping and Borehole Location Plan
Borehole Log (BH1)
Dynamic Cone Penetrometer Test Results (DCP1 and DCP2)

Appendix A: Geotechnical Mapping Symbols
Appendix B: Landslide Risk Management Terminology
Appendix C: Hazard Identification, Risk Assessment and Risk Management Guidelines
Appendix D: Some Guidelines for Hillside Construction

Report Explanation Notes

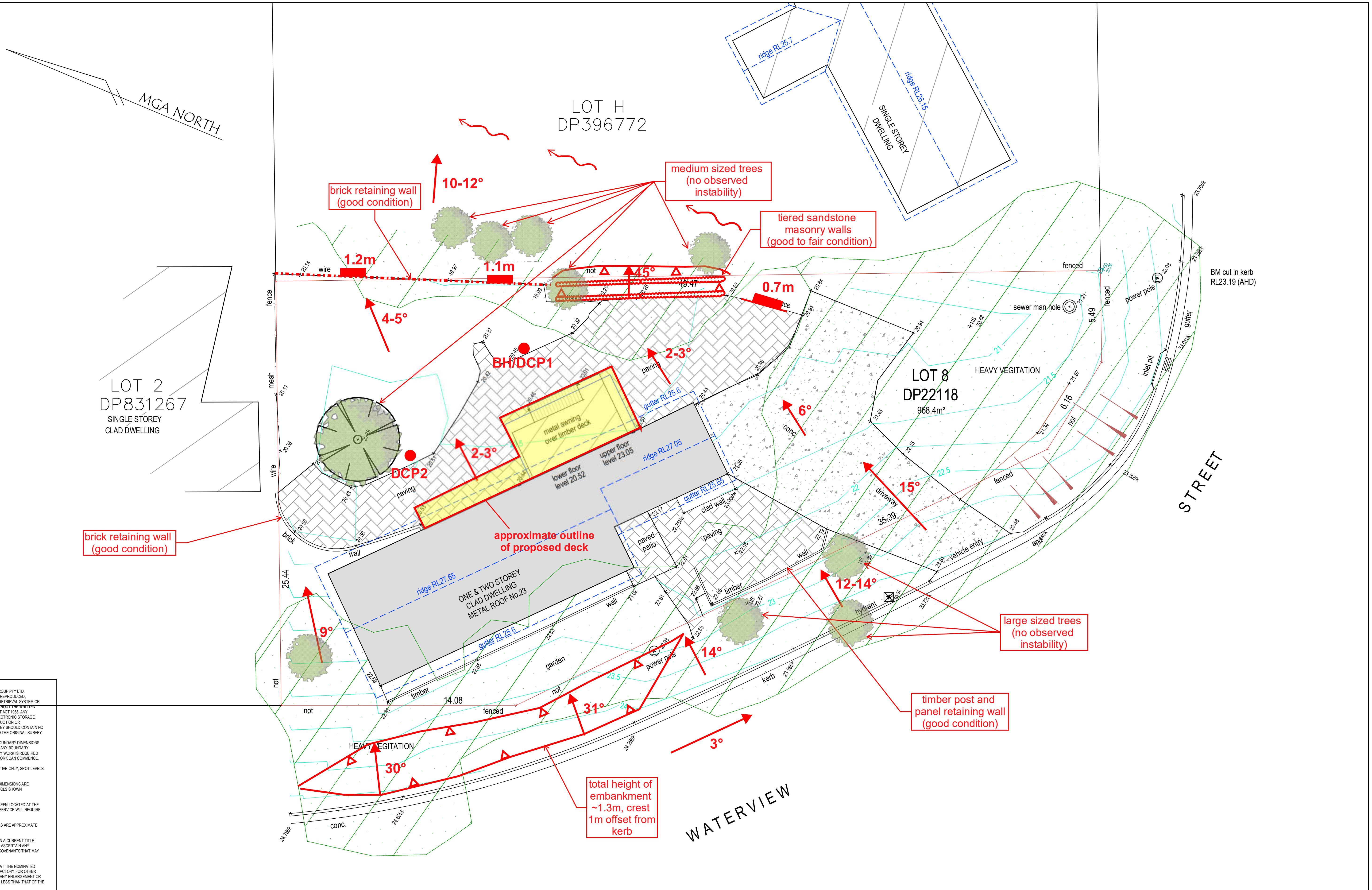

FIGURE 1 - GEOTECHNICAL MAPPING AND TEST LOCATION PLAN

THIS PLAN SHOWS TITLE AND BOUNDARY DIMENSIONS ONLY, THIS DOES NOT INCLUDE ANY BOUNDARY DEFINITION. ADDITIONAL SURVEY WORK IS REQUIRED BEFORE ANY CONSTRUCTION WORK CAN COMMENCE.

CONTOURS SHOWN ARE INDICATIVE ONLY, SPOT LEVELS TAKE PRECEDENCE

ANY TREE DESCRIPTIONS AND DIMENSIONS ARE APPROXIMATE ONLY, AND SYMBOLS SHOWN DIAGRAMMATIC ONLY.

ONLY VISIBLE SERVICES HAVE BEEN LOCATED AT THE SURFACE ANY UNDERGROUND SERVICE WILL REQUIRE FURTHER INVESTIGATION.

BUILDING FEATURES AND LEVELS ARE APPROXIMATE ONLY.

PRIOR TO ANY USE OF THIS PLAN A CURRENT TITLE SEARCH MUST BE OBTAINED TO ASCERTAIN ANY EASEMENT, RESTRICTIONS OR COVENANTS THAT MAY AFFECT THE LAND.

THIS PLAN HAS BEEN CREATED AT THE NOMINATED SCALE AND MAY NOT BE SATISFACTORY FOR OTHER PURPOSES. THE ACCURACY OF ANY ENLARGEMENT OR OTHER REPRODUCTION MAY BE LESS THAN THAT OF THE ORIGINAL.

THESE NOTES MUST BE INCLUDED WHEN PRINTING OR SHARING THIS PLAN.

IPING SURVEY GROUP

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~ AMENDMENTS ~

No.	AMENDMENT	DATE

~ CHECKED ~ D.IPING

~ DRAWN ~ HITCHCOCK

DATED: 04-09-20
DATUM: AHD
LEVEL ORIGIN: SSM24504 RL:23.884
CONTOUR INTERVAL: 0.5m

LOT(S) & DP(S): 8 / D.P.22118
STREET ADDRESS: 23 WATERVIEW STREET
LOCALITY: MONA VALE
LOCAL GOV: NARRABEEN

~ DRAWING TITLE ~ DETAIL & CONTOUR SURVEY

~ CLIENT ~ Complete Trade

JOB REFERENCE: 200123-001
ISSUE: A
SHEET No. 1 of 1
SCALE: 1:150 @ A2

BOREHOLE LOG

JOB NO.	PR20052	**Surface Level:**		**BH No.** 1
PROJECT	Proposed Alterations and Additions	**UTM** **Zone:** N/A		
CLIENT	Complete Trade	N/A	**mE**	1 / 1
LOCATION	23 Waterview Street, Mona Vale, NSW	N/A	**mS**	

RL	Depth (m)	Graphic Log	Strata Description	Sampling	Testing	Soil/Rock Strength	Moisture / Weathering	G.W.	Additional Comments
	0.5		FILL: Gravelly Clayey Sand, fine to medium grained, brown, fine to coarse sandstone gravel, trace root fibres and silt.		DCP from surface to 3.2m depth	-	D / M		Appears moderately to well compacted
	1.0, 1.5		Silty Sandy CLAY: Medium plasticity, brown	A		FR	w < PL		Residual
	2.0		Clayey SAND: Fine to medium grained orange brown, trace silt			MD	M	DOC	
			End of Borehole at 2.1m						Hand auger refusal on dense to very dense sand

Logged By: A.F. Date: 23/11/2020

Drilling Method: Hand Auger

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DYNAMIC CONE PENETRATION TESTING

PROJECT	Proposed Alterations and Addtions	**JOB NO.**	PR20052	1 / 1
CLIENT	Complete Trade	**Tested By:**	AF	
LOCATION	23 Waterview Street, Mona Vale, NSW	**Date:**	23/11/20	

Test No.	**1**	**2**						
Surface Level:								
Depth (mm)	Blow Count/100mm Penetration							
0 - 100	3	6						
100 - 200	6	10						
200 - 300	7	11						
300 - 400	6	8						
400 - 500	8	6						
500 - 600	4	8						
600 - 700	3	9						
700 - 800	3	7						
800 - 900	3	4						
900 - 1000	4	5						
1000 - 1100	4	6						
1100 - 1200	5	8						
1200 - 1300	6	7						
1300 - 1400	6	9						
1400 - 1500	7	11						
1500 - 1600	7	11						
1600 - 1700	8	13						
1700 - 1800	9	13						
1800 - 1900	10	13						
1900 - 2000	9	15						
2000 - 2100	10	18						
2100 - 2200	12	21						
2200 - 2300	13	21						
2300 - 2400	12	25						
2400 - 2500	12	REFUSAL						
2500 - 2600	13							
2600 - 2700	14							
2700 - 2800	15							
2800 - 2900	16							
2900 - 3000	18							
3000 - 3100	20							
3100 - 3200	23							
3200 - 3300	REFUSAL							
3300 - 3400								
3400 - 3500								
3500 - 3600								
3600 - 3700								
3700 - 3800								
3800 - 3900								
3900 - 4000								

Testing has been conducted in accordance with AS1289.6.3.2-1997 (R2013)
Hammer Weight & Drop: 9kg/510mm, Rod & Point Diameter: 16mm/20mm
Refusal is assumed where blow counts > 20 per 100mm

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Report Explanation Notes

INTRODUCTION

These notes have been provided to supplement the geotechnical report with regards to our Geotechnical Scope, Investigation Findings and Recommendations. Not all information detailed below is applicable to each report.

The geotechnical model developed for the purpose of reporting relies upon limited data points and information collected from the site and assumptions based on geotechnical and geological experience. Inherently, due to natural and man-made processes, variability of subsurface conditions and deviations from the geotechnical model are possible. Our findings and advice apply specifically to the subject site at the time of the investigation.

INVESTIGATION METHODS

Test Pits: Excavated using a backhoe, tracked excavator or handheld equipment and limited to depths of approximately 1.5m, 3m and 6m respectively or prior refusal. Allows in-situ testing and inspection of subsurface conditions with regards to soils, 'weaker' bedrock, groundwater and details of existing foundations or retention. Due to the restrictive nature of test pit excavations, reinstatement involves replacement of site won soils and constrained compaction. Where a certain standard of reinstatement is necessary for post investigation activities, specific compaction equipment and testing may be required.

Hand Auger Drilling: Borehole carried out using manually operated equipment. Diameters typically between 50mm and 110mm. The top of the bedrock profile may be inferred from the refusal depth, however this depth may also represent obstructions with any fill encountered or 'corestones', 'floaters' and other hard layers present within natural soils.

Spiral Auger Drilling: Carried out using a pendulum auger fitted to an excavator, piling rig or drilling rig. Drilling rig augers are typically 80-110mm or large diameter, utilising a 'V' or 'TC' drilling bit. Samples which are either continuously returned to the surface during rotation or periodically extracted in 'lifts' are disturbed and often mixed providing limited reliability with regards to precise soil structure, horizons and depths.

Rotary Non-core Drilling: Carried out utilising a drilling rig utilising either a 'PCD' or 'rock roller' drilling bit. Highly disturbed soil and rock cuttings are returned to the surface using circulated drilling fluid (water and usually various additives) providing limited subsurface information and sampling ability, particularly in soils.

Core Drilling: A rotary technique utilising a diamond tipped drilling bit and water flush which, with favourable rock conditions, typically returns a continuous core sample within the core barrel either by conventional means or using a 'triple tube' and wireline retrieval. Can be undertaken using a drilling rig or hand portable 'Melvelle' equipment with typical core diameters of 52mm (NMLC), 61mm (HQ) and 85mm (PQ) depending on application. Near surface, short length core drilling may also include concrete coring techniques using a 'diatube' drilling bit, typical diameters ranging from 50mm to 300mm.

IN-SITU TESTING

Hand Penetrometer

Handheld device utilised for instant estimates of unconfined compressive strength and derivation of unconfined shear strength and stiffness of cohesive soils. The 6.4mm diameter penetration piston is pushed into the soil surface to a groove machined on the piston at 6.4mm depth. Penetration resistance from the calibrated spring is registered on a gauge in kPa.

Dynamic Cone Penetrometer (DCP)

Undertaken by advancing a 16mm diameter steel rod with an attached 20mm diameter cone tip at its leading end via repeated raising (510mm) and dropping of a weighted (9kg) hammer on the tail end of the rod string. The test is conducted in accordance with AS1289.6.3.2-1997 (R2013) - *Methods of Testing Soils for Engineering Purposes, Soil Strength and Consolidation Tests – Determination of the Penetration Resistance of a Soil – 9kg Dynamic Cone Penetrometer Test*. Refusal of the equipment is assumed where blow counts exceed 20 per 100mm. The top of the bedrock profile may be inferred from the DCP refusal depth, however this depth may also represent obstructions within any fill encountered or 'corestones', 'floaters' and other hard layers present within natural soils.

DCP testing can allow an assessment to be made of apparent compaction of fill, relative density of natural granular soils, strength of natural cohesive soils and estimated in-situ CBR value via an empirical relationship between blow counts, typically averaged over a 300mm depth interval.

Standard Penetration Test (SPT)

Typically undertaken utilising a drilling rig within the soil profile at regular intervals by advancing a 50mm diameter split 'spoon' sampling tube via repeated impact from a 63kg hammer weight with a free fall of 760mm on the tail end of the rod string. The test is conducted in accordance with AS1289.6.3.2-1997 (R2013) - *Methods of Testing Soils for*

Engineering Purposes, Soil Strength and Consolidation Tests, Test 6.3.1. Testing is typically taken over three successive 150mm increments and an 'N' value determined as the sum of the number of blows over the final 300mm. Refusal of the equipment is assumed where blow counts exceed 20 per 150mm. Refusal usually occur within dense sands, hard clays or weak rock but may also represent obstructions within any fill encountered or 'corestones', 'floaters' and other hard layers present within natural soils.

SPT results are reported in the following manner:

8, 11, 16 **N = 27**	where full penetration of each 150mm interval is achieved.
8, 5/50mm **N > 13**	where premature refusal and only 50mm penetration occurred during the second test interval.

SPT testing can allow an assessment to be made of apparent compaction of fill, relative density of natural granular soils and a secondary tool for strength of natural cohesive soils in combination with hand penetrometer testing via an empirical relationship using the N value.

SAMPLING

A number of different sample types may be collected during geotechnical investigation of a site, depending on the equipment used, proposed laboratory testing and the depth and amount of the sample required. A summary of the common sample types is outlined below:

A (Auger): a highly disturbed lump sample obtained from recovered material during spiral or hand auger drilling.

S (SPT): a disturbed sample obtained from the split spoon sampler during an SPT test.

T (Test Pit): a highly disturbed lump sample obtained from a spoil pile of the base/sidewalls of a hand or machine excavated test pit.

E (Environmental): sample collected for environmental purposes in accordance with an assigned procedure designated by the environmental consultant. Samples may include acid sulfate soils, waste classification, contamination, asbestos etc.

B (Bulk): disturbed sample of larger volume, required for certain test procedures including CBR testing.

P-Push Tube: an undisturbed sample obtained via pushing a thin-walled sample tube of 50mm, 75mm of 100mm (U50, U75, or U100) into the soil profile (typically cohesive soils) to preserve additional information on the natural soils conditions and allow for specific strength and shrink-swell related laboratory testing.

SOIL DESCRIPTION AND CLASSIFICATION

The methods of description and classification of soils used in this report are based on Australian Standard AS1726-2017 Geotechnical Site Investigations which should be read in conjunction with the notes provided below. In general descriptions cover soil type, plasticity or particle size/shape, colour, strength or density, moisture, inclusions and origin as follows:

Soil Type

Components	Subdivision	Size (mm)
BOULDERS		> 200
COBBLES		63 – 200
GRAVEL	Coarse	19 – 63
	Medium	6.7 – 19
	Fine	2.36 – 6.7
SAND	Coarse	0.6 – 2.36
	Medium	0.21 – 0.6
	Fine	0.075 – 0.21
SILT		0.002 – 0.075
CLAY		< 0.002

The components of a soil are assessed to be primary, secondary or minor. Primary assessment is made according to whether the total dry mass of the coarse grained (>0.075mm) fraction exceeds 65% (a coarse soil) or the fine fractions (<0.075mm) exceed 35% (a fine soil).

Secondary and minor components are determined as follows:

Terminology	Coarse grained soils		Fine soils
	% fines	% coarse	% coarse
Trace	≤5	≤15	≤15
With	>5 to ≤12	>15 to ≤30	>15 to ≤30
Secondary*	>12	>30	>30

* Prefix soil name with 'silty', 'clayey', 'sandy' or 'gravelly' as applicable

Fine Grained Soil Plasticity

Where lab testing is available, clays and silts are described according to their plasticity as defined below. In the absence of lab testing, soils are assessed based on tactile examination with respect to dry strength, dilatancy and toughness.

Descriptive Term	Range of liquid limit	
	Silt	Clay
Non-plastic	N/A	N/A
Low Plasticity	≤ 50	≤35
Medium Plasticity	N/A	>35 and ≤50
High Plasticity	>50	>50

Fine Grained Soil Strength

Strength	Symbol	Undrained Shear Strength
Very Soft	**VS**	≤ 12kPa
Soft	**S**	12kPa to ≤ 25kPa
Firm	**F**	25kPa to ≤ 50kPa
Stiff	**St**	50kPa to ≤ 100kPa
Very Stiff	**VSt**	100kPa to ≤ 200kPa
Hard	**Hd**	>200kPa
Friable	**Fr**	N/A

Coarse Grained Soil Strength

Relative Density	Symbol	Density Index %
Very Loose	**VL**	≤ 15
Loose	**L**	15 to ≤ 35
Medium Dense	**MD**	35 to ≤ 65
Dense	**D**	65 to ≤ 85
Very Dense	**VD**	>85

Moisture

Soil Type	Term	Soil Character
Coarse Grained	Dry **(D)**	Non-cohesive and free running
	Moist **(M)**	Feels cool, darkened in colour, tends to stick together.
	Wet **(W)**	Feels cool, darkened in colour, tends to stick together, free water forms when handling
Fine Grained	Moist, dry of plastic limit. **(w < PL)**	Hard and friable or powdery
	Moist, near plastic limit. **(w ≈ PL)**	Can be moulded
	Moist, wet of plastic limit. **(w > PL)**	Usually weakened and free water forms when handling
	Wet, near liquid limit **(w ≈ LL)**	
	Wet, wet of liquid limit **(w ≈ LL)**	

Soil Origin

Origin	Description
Fill	Anthropogenic deposits or disturbed material
Topsoil	Zone of soil affected by roots and root fibres
Colluvial	Material transported down slopes by gravity
Aeolian	Transported and deposited by wind
Alluvial	Deposited by rivers
Estuarine	Deposited in coastal estuaries
Lacustrine	Deposited in freshwater lakes
Marine	Deposits in marine environments
Residual Soil	Formed by in situ weathering of rock, with no structure/fabric of parent rock evident
Extremely weathered	Formed by in situ weathering of geological formations, with the structure/fabric of parent rock intact but with soil strength properties

ROCK DESCRIPTION

The methods of description and classification of rocks used in this report are based on Australian Standard AS1726-2017 Geotechnical Site Investigations which should be read in conjunction with the notes provided below. In general descriptions cover rock type, grain size, structure, colour, degree of weathering, strength, minor components or inclusions, and where applicable, the defect types, shape, roughness and coating/infill.

Rock Type

Generalised rock names are provided to allow a reasonable engineering description rather that a precise geological classification to be made. The rock name is typically derived from a subclassification of the four primary rock types: Sedimentary (ie. conglomerate, sandstone, siltstone, claystone), Igneous (ie. granite, dolerite, basalt), Metamorphic (gneiss, schist, marble, serpentinite) and Duricrust (ie. silcrete, calcrete).

Grain Size and Type

The following grain sizes are applicable to the different rock types:

Rock Type	Grain Size	Size (mm)
SEDIMENTARY	Coarse	0.6 – 2
	Medium	0.2 – 0.6
	Fine	0.06 – 0.2
IGNEOUS* METAMORPHIC*	Coarse	> 2
	Medium	0.06 – 2
	Fine	< 0.06

* If mineral grains are readily identifiable, they may also be described

Weathering

Degree	Code	Definition
Residual Soil	**RS**	Weathered to an extent that rock has soil properties absent of original rock, structure texture and fabric
Extremely Weathered	**XW**	Weathered to an extent that rock has soil properties with structure, texture and fabric generally preserved
Highly Weathered	**HW**	Rock is completely discoloured (ie. from iron staining or bleaching. Rock strength and porosity significantly changed, and some minerals weathered to clay.
Moderately Weathered	**MW**	Rock is completely discoloured (ie. from iron staining or bleaching. Rock strength has little to no change relative to fresh rock.
Slightly Weathered	**SW**	Rock is partially discoloured with staining or bleaching along joints but shows little or no change of strength from fresh rock
Fresh	**FR**	Rock shows no sign of decomposition of individual minerals or colour changes

Strength

Classification of rock strength is based Assessment of rock strength can be undertaken using a number of methods, notably tactile examination and moisture content correlation, point load strength testing and Unconfined Compressive Strength (UCS) testing. Where it is not practical to conduct UCS tests or such information is not available, classification of strength may be made on the basis of an estimation of, or laboratory testing of the Point Load Index ($I_{s}50$) as follows:

Term	Code	Point Load Index, $I_{s}50$ (MPa)*
Very Low	**VL**	0.03 to 0.1
Low	**L**	0.1 to 0.3
Medium	**M**	0.3 to 1.0
High	**H**	1.0 to 3
Very High	**VH**	3 to 10
Extremely High	**EH**	>10

* Refers to intact rock strength at or close to the in-situ moisture content.

Defects

The depth, dip (angle from horizontal) and dip direction (where possible to determine) of any defects present within the rock are expressed in addition to information including defect type, planarity, roughness, and infill as follows:

Type

Term	Symbol	Term	Symbol
Bedding	**B**	Joint	**J**
Foliation	**F**	Vein	**V**
Extremely Weathered Seam	**XWS**	Fractured Zone	**FZ**
Seam	**S**	Sheared Zone	**SZ**

Planarity

Term	Symbol	Definition
Planar	**Pl**	No variation in orientation
Curved	**Cu**	Gradual change in orientation
Undulating	**Un**	Wavy surface
Irregular	**Ir**	Sharp changes in orientation
Stepped	**St**	One or more defined steps

Roughness

Term	Symbol	Definition
Rough	**Ro**	Many surface irregularities
Smooth	**Sm**	Smooth to touch
Polished	**Po**	Shiny smooth surface
Slickensided	**Sl**	Grooved or striated surface

Infill*

Term	Symbol	Definition
Clean	**Cn**	No visible coating/staining
Stained	**Sd**	Surfaces discoloured
Veneer	**Vr**	Up to 1mm thickness
Coating	**Cg**	Greater than 1mm thickness

* Infill thickness to be included when greater than 1mm and infill material described as follows

Infill Material

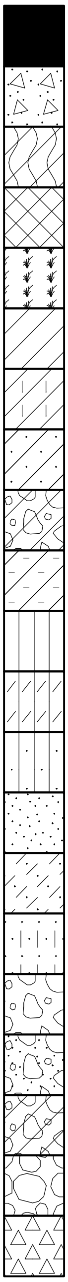
Term	Symbol
Clay	**Cl**
Carbonaceous	**Cb**
Coaly	**Co**
Ferruginous	**Fe**
Siliceous	**Si**
Calcareous	**Ca**

GROUNDWATER

Symbol	Definition
DOC	Dry On Completion (of excavation or drilling)
—▶—	Seepage water level (during excavation or drilling)
▼	Groundwater level

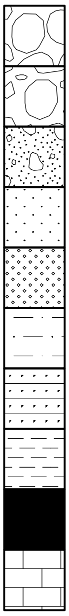
GRAPHIC SYMBOLS FOR SOIL & ROCK

SOIL



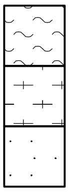
BITUMINOUS CONCRETE
CONCRETE
TOPSOIL
FILLING
PEAT
CLAY
SILTY CLAY
SANDY CLAY
GRAVELLY CLAY
SHALY CLAY
SILT
CLAYEY SILT
SANDY SILT
SAND
CLAYEY SAND
SILTY SAND
GRAVEL
SANDY GRAVEL
CLAYEY GRAVEL
COBBLES/BOULDERS
TALUS

SEDIMENTARY ROCK



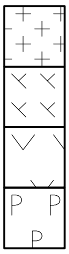
BOULDER CONGLOMERATE
CONGLOMERATE
CONGLOMERATIC SANDSTONE
SANDSTONE FINE GRAINED
SANDSTONE COARSE GRAINED
SILTSTONE
LAMINITE
MUDSTONE, CLAYSTONE, SHALE
COAL
LIMESTONE

METAMORPHIC ROCK



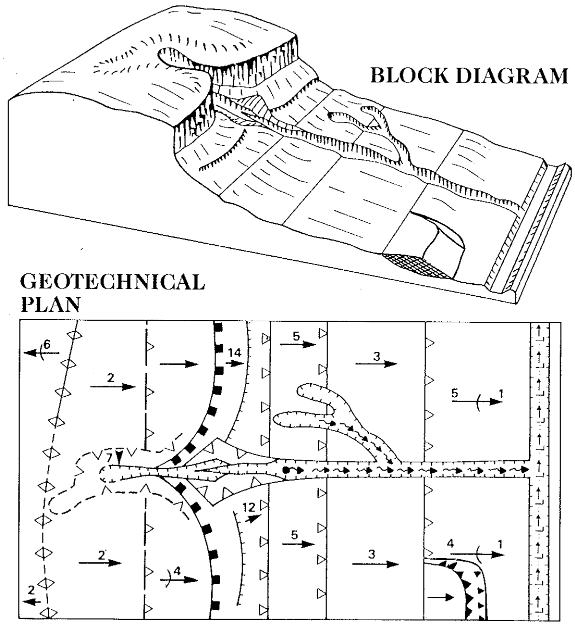
SLATE, PHYLITTE, SCHIST
GNEISS
QUARTZITE

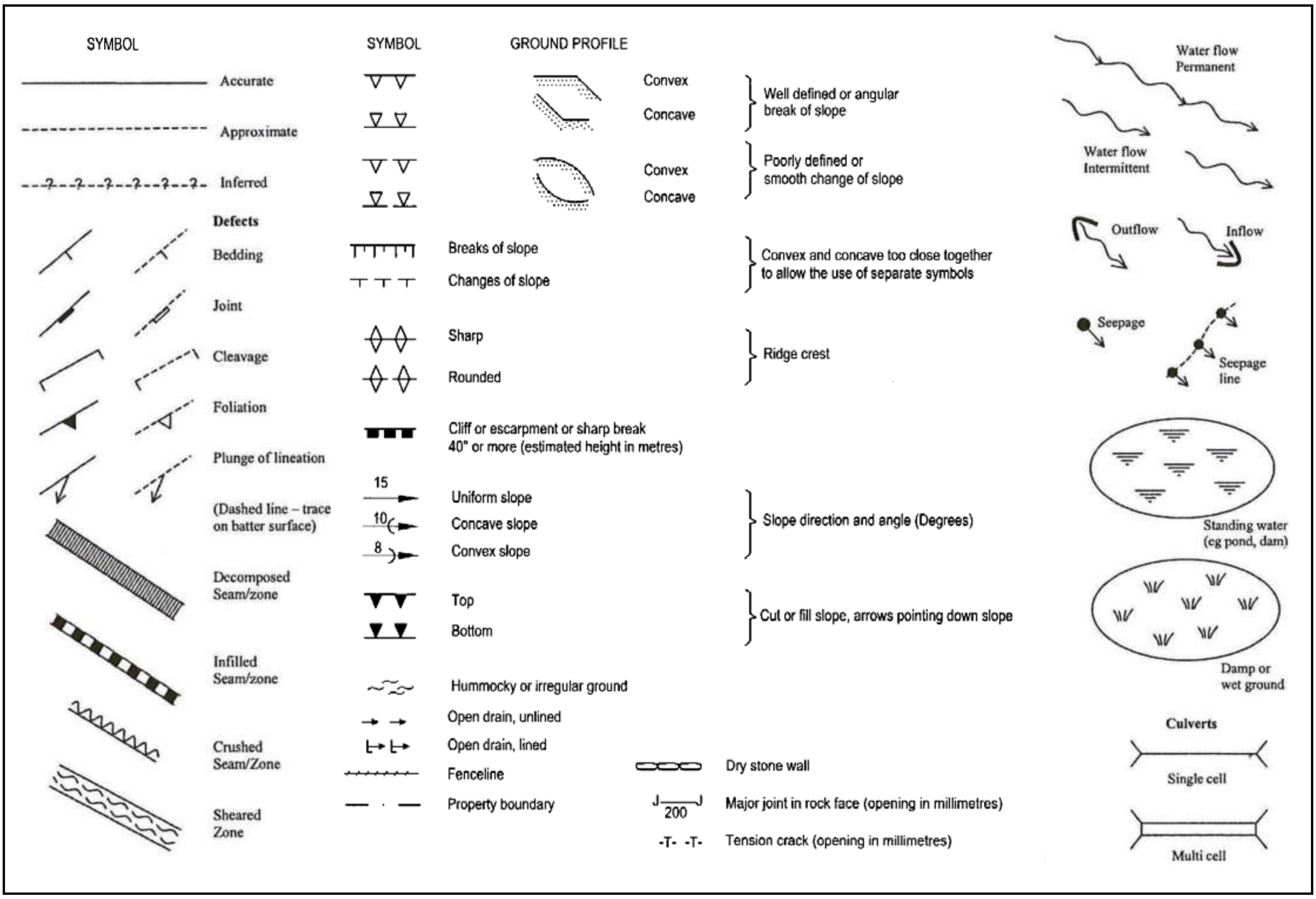
IGNEOUS ROCK



GRANITE
DOLERITE, BASALT
TUFF
PORPHYRY

APPENDIX A - GEOTECHNICAL MAPPING SYMBOLS





Source: modified version of Australian Geomechanics Society (2007c) 'Practice Note Guidelines for Landslide Risk Management', Australian Geomechanics, Vol 42, No 1, March 2007, Appendix E, pp110-111.

APPENDIX B - LANDSLIDE TERMINOLOGY

The following provides a summary of landslide terminology which should (for uniformity of practice) be adopted when classifying and describing a landslide. It has been based on Cruden & Varnes (1996) and the reader is recommended to refer to the original documents for a more detailed discussion, other terminology and further examples of landslide types and processes.

Landslide

The term ***landslide*** denotes "the movement of a mass of rock, debris or earth down a slope". The phenomena described as landslides are not limited to either the "land" or to "sliding", and usage of the word has implied a much more extensive meaning than its component parts suggest. Ground subsidence and collapse are excluded.

Classification of Landslides

Landslide classification is based on Varnes (1978) system which has two terms: the first term describes the material type and the second term describes the type of movement.

The material types are ***Rock***, ***Earth*** and ***Debris***, being classified as follows:-

The material is either rock or soil.

Rock: is "a hard or firm mass that was intact and in its natural place before the initiation of movement."

Soil: is "an aggregate of solid particles, generally of minerals and rocks, that either was transported or was formed by the weathering of rock in place. Gases or liquids filling the pores of the soil form part of the soil."

Earth: "describes material in which 80% or more of the particles are smaller than 2 mm, the upper limit of sand sized particles."

Debris: "contains a significant proportion of coarse material; 20% to 80% of the particles are larger than 2 mm and the remainder are less than 2 mm."

The terms used should describe the displaced material in the landslide <u>before</u> it was displaced.

The types of movement describe how the landslide movement is distributed through the displaced mass. The five kinematically distinct types of movement are described in the sequence ***fall***, ***topple***, ***slide***, ***spread*** and ***flow***.

The following table shows how the two terms are combined to give the landslide type:

Table B1: Major types of landslides. Abbreviated version of Varnes' classification of slope movements (Varnes, 1978).

<table>
<tr><th colspan="2" rowspan="3">TYPE OF MOVEMENT</th><th colspan="3">TYPE OF MATERIAL</th></tr>
<tr><th rowspan="2">BEDROCK</th><th colspan="2">ENGINEERING SOILS</th></tr>
<tr><th>Predominantly Coarse</th><th>Predominantly Fine</th></tr>
<tr><td colspan="2">FALLS</td><td>Rock fall</td><td>Debris fall</td><td>Earth fall</td></tr>
<tr><td colspan="2">TOPPLES</td><td>Rock topple</td><td>Debris topple</td><td>Earth topple</td></tr>
<tr><td rowspan="2">SLIDES</td><td>ROTATIONAL</td><td rowspan="2">Rock slide</td><td rowspan="2">Debris slide</td><td rowspan="2">Earth slide</td></tr>
<tr><td>TRANSLATIONAL</td></tr>
<tr><td colspan="2">LATERAL SPREADS</td><td>Rock spread</td><td>Debris spread</td><td>Earth spread</td></tr>
<tr><td colspan="2" rowspan="2">FLOWS</td><td>Rock flow</td><td>Debris flow</td><td>Earth flow</td></tr>
<tr><td>(Deep creep)</td><td colspan="2">(Soil creep)</td></tr>
<tr><td colspan="2">COMPLEX</td><td colspan="3">Combination of two or more principle types of movement</td></tr>
</table>

Figure B1 gives schematics to illustrate the major types of landslide movement. Further information and photographs of landslides are available on the USGS website at http://landslides.usgs.gov.

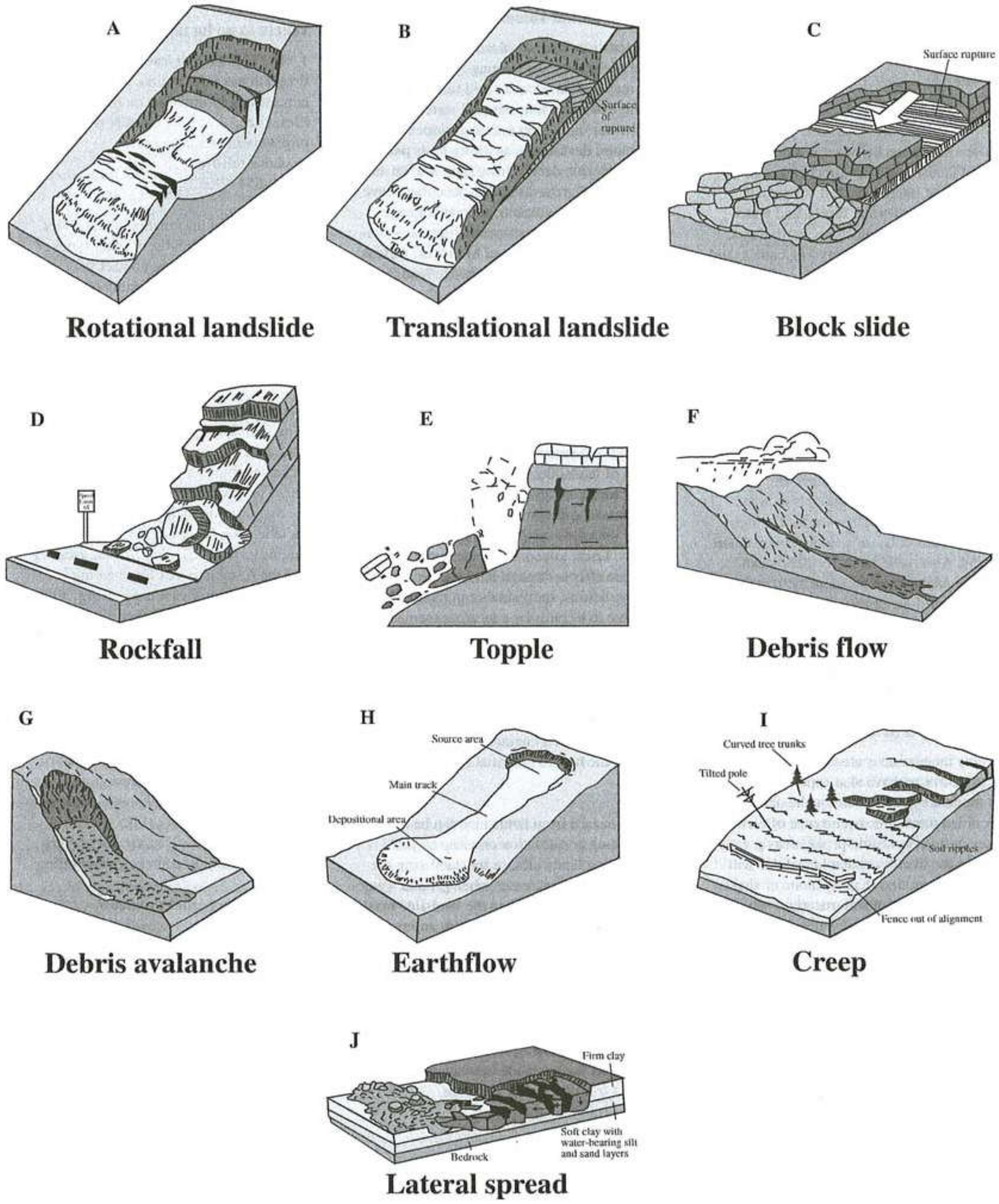


Figure B1: These schematics illustrate the major types of landslide movement.
(From US Geological Survey Fact Sheet 2004-3072, July 2004, with kind permission for reproduction.)

The nomenclature of a landslide can become more elaborate as more information about the movement becomes available. To build up the complete identification of the movement, descriptors are added in front of the two-term classification using a preferred sequence of terms. The suggested sequence provides a progressive narrowing of the focus of the descriptors, first by time and then by spatial location, beginning with a view of the whole landslide, continuing with parts of the movement and finally defining the materials involved. The recommended sequence, as shown in Table B2, describes activity (including state, distribution and style) followed by descriptions of all movements (including rate, water content, material and type). Definitions of the terms in Table B2 are given in Cruden & Varnes (1996).

Second or subsequent movements in complex or composite landslides can be described by repeating, as many times as necessary, the descriptors used in Table B2. Descriptors that are the same as those for the first movement may then be dropped from the name.

For example, the very large and rapid slope movement that occurred near the town of Frank, Alberta, Canada, in 1903 was a *complex, extremely rapid, dry rock fall – debris flow*. From the full name of this landslide at Frank, one would know that both the debris flow and the rock fall were extremely rapid and dry because no other descriptors are used for the debris flow.

The full name of the landslide need only be given once; subsequent references should then be to the initial material and type of movement; for the above example, "the rock fall" or "the Frank rock fall" for the landslide at Frank, Alberta.

Table B2: Glossary for forming names of landslides.

Activity

State	Distribution	Style
Active	Advancing	Complex
Reactivated	Retrogressive	Composite
Suspended	Widening	Multiple
Inactive	Enlarging	Successive
Dormant	Confined	Single
Abandoned	Diminishing	
Stabilised	Moving	
Relict		

Description of First Movement

Rate	Water Content	Material	Type
Extremely rapid	Dry	Rock	Fall
Very rapid	Moist	Earth	Topple
Rapid	Wet	Debris	Slide
Moderate	Very Wet		Spread
Slow			Flow
Very slow			
Extremely slow			

Note: Subsequent movements may be described by repeating the above descriptors as many times as necessary. These terms are described in more detail in Cruden & Varnes (1996) and examples are given.

Landslide Features

Varnes (1978, Figure 2.1t) provided an idealised diagram showing the features for a *complex earth slide – earth flow*, which has been reproduced here as Figure B2. Definitions of landslide dimensions are given in Cruden & Varnes (1996).

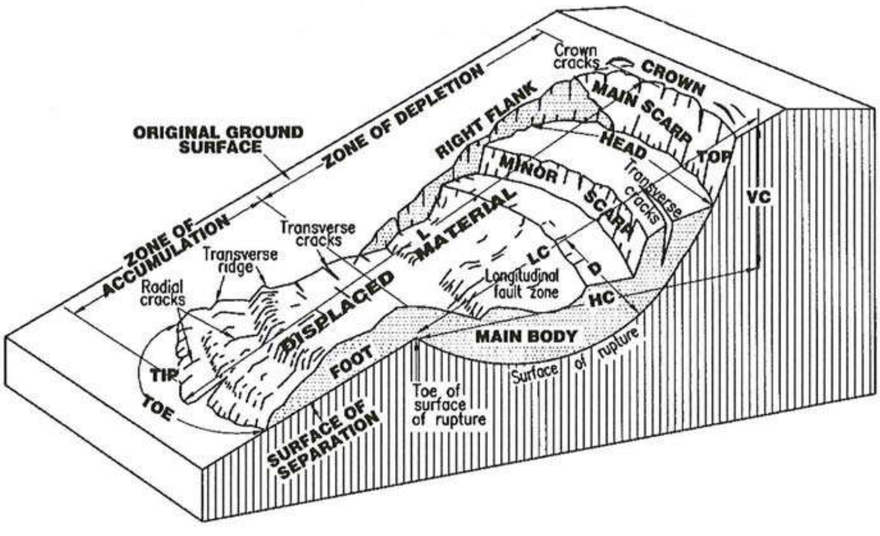


Figure B2: Block of Idealised Complex Earth Slide – Earth Flow

(*Varnes, D J (1978,)Slope Movement Types and Processes. In Special Report 176: Landslides: Analysis and Control(R L Schuster & R J Krizek, eds.), TRB, National Research Council, Washington, DC, pp.11-33).*

Rate of Movement
Figure B3 shows the velocity scale proposed by Cruden & Varnes (1996) which rationalises previous scales. The term "creep" has been omitted due to the many definitions and interpretations in the literature.

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		5×10^{3}	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		5×10^{1}	3 m/min	
5	Rapid			Escape evaluation possible; structures; possessions, and equipment destroyed
		5×10^{-1}	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		5×10^{-3}	13 m/month	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		5×10^{-5}	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		5×10^{-7}	15 mm/year	
	Extremely **SLOW**			Imperceptible without instruments; construction **POSSIBLE WITH PRECAUTIONS**

Figure B3: Proposed Landslide Velocity Scale and Probable Destructive Significance.

Source: Australian Geomechanics Society (2007c) 'Practice Note Guidelines for Landslide Risk Management', Australian Geomechanics, Vol 42, No 1, March 2007, Appendix B, pp87-90.

APPENDIX C
HAZARD IDENTIFICATION, RISK ASSESSMENT AND RISK MANAGEMENT GUIDELINES

PART C GUIDELINES FOR PRACTITIONERS

4 SCOPE DEFINITION

Establish the purpose and scope of the risk assessment study.

The practitioner needs to take into account the initial brief from the client and the requirements of the regulator. Usually these will be sufficient for the practitioner to decide on the appropriate scope and level of the study which should then be advised to the client as a "reverse brief". In the LRM process, the practitioner will have a role to advise the client as to how the landslide risk can be reduced, avoided or otherwise controlled including options or alternatives.

5 HAZARD ANALYSIS

5.1 DATA GATHERING / DESK STUDY

Assemble relevant data and record their sources.

Often there is a body of local experience which becomes invaluable for the assessment process. Such experience includes published papers, geological maps, aerial photographs and general studies such as Hazard Zoning studies completed for the regulator. Local experience can include previous assessments and knowledge of problematic areas which should be available from the regulator's landslide inventory. Practitioners new to an area should discuss with locals their knowledge and experience.

Preferred data for the assessment will include site specific data, such as survey plan showing existing features, spot heights, contours and location and nature of services. Initial design proposals are required so that the risk assessment may be completed and appropriate risk control measures specified. (It is a necessary requirement in the performance of a risk assessment for there to be an element at risk, hence the need for a preliminary design or for an assumed development which should be defined in the LRM report).

5.2 FIELD INVESTIGATION REQUIREMENTS

5.2.1 Complete investigations sufficient to establish a geotechnical model, identify geomorphic processes and associated process rates.

The investigation may involve a number of methods and may be completed in stages, with each stage sufficiently detailed to provide a model appropriate to the level of study being undertaken. Further discussion is given in the Commentary.

5.2.2 Inspect the site and surrounds including field mapping of the geomorphic features.

This must be completed by the practitioner for every assessment. The field mapping is to document the observations and to enable formulation of the geotechnical model.

Mapping should be completed to scale on an available survey plan and must include the surrounds (above, below and adjacent) to the site as appropriate to define the landslides and the geotechnical model.

Where a survey plan is not available, then simple survey using hand held tape and clinometer methods should be used to draw up a plan, to scale, using standard mapping symbols and terminology to represent the geological and geomorphic features. (Examples of geological and geomorphic mapping symbols are presented in Appendix E.)

5.2.3 Determine the subsurface profile from exposures or subsurface investigation such as by boreholes and/or test pits.

This is necessary as part of the geotechnical model. Often exposures or knowledge from a nearby site may be sufficient.

Where such data is not available or not appropriate, subsurface investigation is required to enable formulation of the model and must include determination of the depth to rock or to below the depth of potential failure surfaces if this is greater.

Source: Australian Geomechanics Society (2007c) 'Practice Note Guidelines for Landslide Risk Management', Australian Geomechanics, Vol 42, No 1, March 2007, pp69-82.

Where pre-existing landslides are expected or suspected, then where practical, use should be made of either test pits (to enable sufficient sample/material to be seen for identification of shear planes or other relevant structure) or boreholes (with appropriate sampling and installation of inclinometers for monitoring for evidence of movements).

5.2.4 Assess likely groundwater levels and responses to trigger rainfall events.

Consideration of the likely ground water response will enable assessment of response to rainfall trigger events. Use may be made of experience in the area, as observation of site specific data will frequently require prolonged periods of monitoring to enable formulation of a groundwater response model taking into account the statistical significance of rainfall events during the monitoring period. For relatively straightforward projects with low to moderate risks, a basic qualitative estimate of groundwater levels and responses may be appropriate when there is a lack of data. However, other more complicated projects, or where risk levels are higher, will require a greater level of understanding of groundwater levels and responses.

For more detailed analysis, particularly of possible stabilisation measures by subsurface drainage, observation of groundwater levels and their response to significant rainfall events is advisable to enable subsequent assessment of the effectiveness of subsurface drainage measures. Careful consideration must be given to the location of piezometers and their construction details.

5.2.5 Prepare a cross section drawing (to scale) through selected parts of the site to demonstrate the geotechnical model of site conditions and on which landslides may be identified.

The resulting geotechnical model should integrate all the data obtained from the mapping and investigations.

The section should demonstrate the likely variation in subsurface conditions on the section including groundwater levels. On large or complex sites, more than one section may be required. All sections are to be drawn to natural scale. If exaggerated vertical scale is required for clarity, then a summary section at natural scale should also be included.

Adequate investigation has been completed when the geotechnical model is sufficiently defined to understand the slope forming processes relevant to the site and surrounds, the form and extent of landslides, likely triggers for the landslides and process rates associated with the landslides. The report should include explanation of uncertainties associated with the model.

5.2.6 Take into account slope forming process rates associated with the geotechnical model and landslides.

An understanding of the slope forming process relevant to the landslides and associated process rate is fundamental for evaluation of likelihood.

5.2.7 Identify landslides types/locations appropriate to the geotechnical model based on local experience and general experience in similar circumstances.

The types of landslides will be dependent on the geotechnical model and to some extent on the nature of existing and/or proposed development. The expected characteristics of the landslides (such as the size, type of material involved, rate of failure and travel distance) need to be assessed. The range of landslide sizes can vary from the very large landslides, which may encompass a whole hillside or region, to a small site specific landslide. The model should include assessment of the fundamental cause as well as likely trigger events. The report must document the hazard assessment which will include the estimated likelihood for each landslide type.

The hazard assessment must address areas upslope from the site, downslope from the site and across the slope adjacent to the site where these may affect the site.

5.2.8 If required, further detailed investigations should be completed to better define the model, the landslides, the triggers, the frequency (likelihood) or design of stabilisation measures to control the risk.

Such additional investigation is most likely to be required on sites where the risk is judged to be intolerable and/or where further input is required to resolve uncertainties.

5.3 LANDSLIDE CHARACTERISATION

Characterise the landslides based on the desk study and field investigations. Use Appendix B for terminology to describe the landslides.

The characterization should include the classification, volume, location and potential travel distance of all landslides which may occur on the site or travel on to or regress into the site.

5.4 FREQUENCY ANALYSIS

5.4.1 Techniques for Frequency Analysis

a) Adopt a frequency analysis technique appropriate to the level of study and complexity of the geotechnical model and slope forming process.

The appropriate technique may change with different levels of study, or for different stages of a project, or with the project brief and available budget. For example, techniques and level of detail may be different for:

- Subdivision stage LRM
- Residential dwellings LRM
- Infrastructure and utilities LRM
- Natural resource and environmental LRM

It is essential that the assessment be based on the best estimates available and that expert judgment be applied to answers so derived.

It is essential to understand the slope forming process before moving on to the frequency assessment.

The assessment must document the reasoning in a transparent manner.

b) Gather local and historical knowledge of slope performance and landslide characteristics and occurrence. The resulting inventory enables assessment of frequency.

This technique is a basic starting point and essential for all studies. However, a common shortcoming is that "local knowledge" is often poorly documented and difficult to collate and assess. Local Council records and experience should be accessed via a landslide inventory made available to practitioners. Analysis of aerial photographs and possibly maps may provide additional data.

Documentation of events by local newspapers may also be a useful source, depending on the quality of reporting and what events are judged at the time to be of local interest.

c) Empirical methods based on slope instability ranking systems.

These methods are often devised by expert groups to assist with prioritisation of treatment measures.

The methods are usually based on subjective judgment of the relative importance of contributory factors. The results obtained may be difficult to calibrate or it may be difficult to obtain consistent results and hence may be inaccurate. The methods do not usually allow assessment of frequencies.

d) Relationship to geomorphology and geology.

This method is based on the principle put forward by Varnes (1984) that the past and present are guides to the future. Hence, this leads to the assumptions that:

1. it is likely that landsliding will occur where it has occurred in the past and
2. landslides are likely to occur in similar geological, geomorphologic and hydrological conditions as they have in the past.

The use of historic records and landslide inventories of past performance are likely to be required to enable frequency values to be assessed. However, it should be noted that landslide frequency, size and intensity may differ from past performance where altered trigger events are introduced, e.g. due to man made changes or climate change. In addition, other factors (such as periodic or seasonal wetting and drying cycles resulting in soil creep, cyclic degradation and strength loss) can also result in failures after relatively "normal" rainfall events.

The use of other slope attribute factors (such as slope angle, slope drainage, slope age, presence of groundwater, slope orientation) may assist with assessment of particular slopes relative to the broad geomorphic model.

e) Prepare a statistical evaluation of rainfall and relate to history of landsliding and population of slopes within area of similar slope type.

Rainfall, and the consequent effect on groundwater levels, is widely recognized as a main trigger event for landsliding. Therefore, indicative frequency values may be related to the frequency of rainfall provided there is sufficient historical data to enable the relationship between rainfall frequency, antecedent rainfall and landslide events to be correlated.

A similar approach may be adopted for other forms of triggering events such as earthquakes.

f) Consider use of simulation models and Monte Carlo sampling analyses to derive a frequency of failure.

These methods (including simulation modelling of groundwater response to rainfall, evapotranspiration, and ground water flows) can be difficult to carry out reliably. Picarelli *et al.* (2005) outline some of the difficulties with these methods. Simulation modelling is most likely to be applicable only to medium to large, deep seated landslides where extensive monitoring data is available to enable calibration over a range of rainfall and piezometric responses.

Experience shows that full probabilistic analysis is difficult and time consuming (Robin Fell personal comm.). Therefore this method should only be carried out for special cases where sufficient data is available to enable the results to be meaningful.

g) Use knowledge based expert judgment or 'degree of belief' method which combines experience, expertise and general principles.

For most assessments this may be the only suitable option to estimate frequency due to the lack of objective data. The assessment relies to a large degree on subjective assessment of available data where other more rigorous methods are not available or viable. The method still requires some degree of research to obtain relevant data and an understanding of the geological model to qualify the judgment of likelihood. Nonetheless, the approach requires the proposition of various possible scenarios followed by the systematic testing and elimination of options as a result of investigation, discussion and judgment to develop an estimate of frequency (Lee and Jones 2004).

The result is conditioned by the 'degree of belief' of the practitioner. Typically, the resulting accuracy for a frequency assessment and, perhaps, a consequence assessment could vary from half an order of magnitude at best, to one order of magnitude or perhaps two orders of magnitude. As a result, the risk assessment should clearly display its sensitivity to the input parameters and, unless justified by further investigations, a conservative outcome should be adopted.

h) Where appropriate, use event trees to provide a structur

i) ed and auditable approach for the use of expert judgment and subjective probability assessment.

An event tree analysis uses a graphical construct to show the logical sequence of events or considerations that can be used to analyse the system leading to a particular outcome. It can be used for evaluation of probability of failure of a landslide, or consequence of failure, or risk. The logical sequence within the system is mapped as a branching network with conditional probabilities assigned to each branch of a node. The frequency of achieving a certain outcome is the product of the conditional probabilities leading to that outcome times the frequency of the initiating "trigger" such as rainfall.

i) Other methods.

The above may not be an exhaustive list but covers the principal methods/approaches. Specific circumstances of a particular area or project may enable other approaches or combinations of approaches to be used. Field techniques may develop to offer alternatives, for example remote sensing by satellite.

Further comment is given in the Commentary together with some guidance on different site investigation methods.

5.4.2 Estimation of Annual Probability (Frequency) ($P_{(H)}$) of Each Landslide

a) Use 'best estimates' for frequency but consider range / uncertainty / sensitivity.

Suitable methods are outlined in Section 5.2.

It is important not to infer greater accuracy than is reasonably possible. Evaluation of the sensitivity arising from uncertainty is part of the consideration.

A best estimate is to be derived for each landslide which is then applied to both risk to property and risk to life assessments. The estimate may be related to the size of the landslide and/or the expected amount of movement as part of the hazard assessment. The appropriate qualitative term is chosen from the estimated probability based on the frequency assessment. Note that the reverse, the adoption of a probability value from a qualitative term, should not be undertaken as it has been demonstrated that this results in a range of estimates of frequency several orders of magnitude apart depending on the practitioner.

b) Estimates of frequency may be derived by partitioning the problem to (Annual probability of trigger event) x (Probability of sliding given the trigger event) over the range of trigger events.

Landslides of the one 'type', but having varying possible scales (magnitude/travel distance/velocity etc.) need to be assessed separately. Each could well have a different frequency of occurrence. The landslide inventory of performance for an area will provide some basis for the assessment.

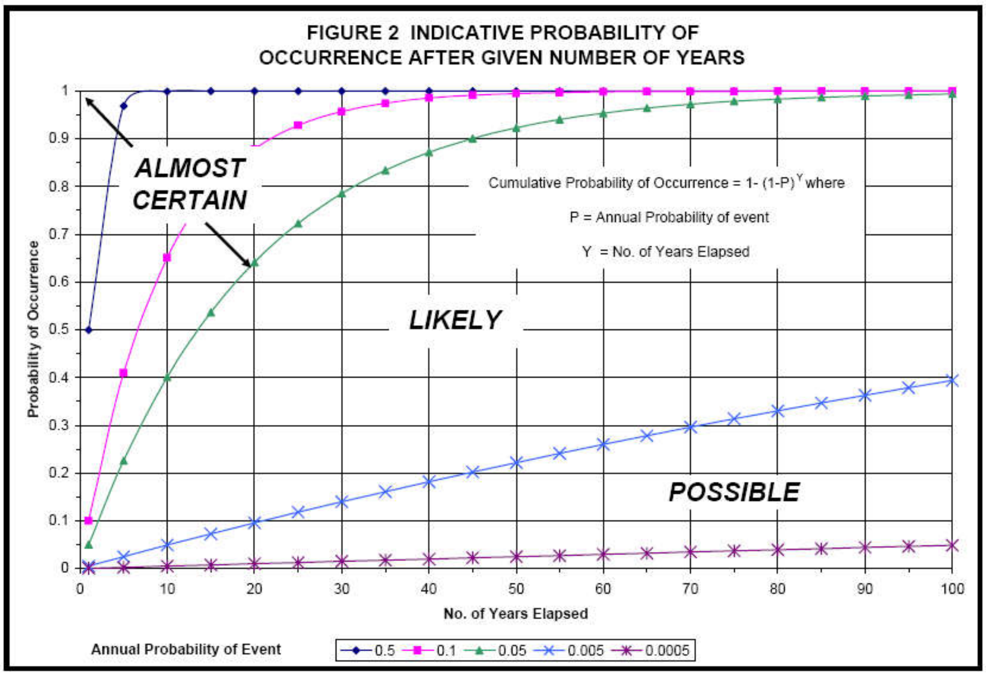
A trigger event for a particular locality (e.g. a certain intensity/duration or recurrence interval of rainfall) will not necessarily cause each potential landslide event in that locality to occur. There will be a finite probability (value) that the landslide under consideration may not be set off by the trigger event.

The frequency of landsliding should be assessed over the full range of the triggering events, and the total frequency carried forward in the risk analysis. In practice this process may be simplified to consider only the highest frequency triggering events. An example is presented in the Commentary.

c) Complete a review of the assessed frequency in relation to the implied cumulative frequency of the event occurring within the design life and known performance within the area.

This is a 'sanity check' on the result of the assessment. It is import to apply judgment or bias on the final outcome only, not on the input estimates.

Values of the cumulative probability are shown on Figure 2 for different annual probability values as a function of time over usual design life intervals. The resulting cumulative probabilities should be checked to confirm they are reasonable in relation to experience. The implications of the cumulative probability values shown in Figure 2 are discussed further in the Commentary.



5.4.3 Assess the Travel Distance and the Probability of Spatial Impact ($P_{(S:H)}$) of the Elements at Risk

When assessing risk arising from landsliding, it is important to be able to estimate the distance the slide mass will travel and its velocity. These factors determine the extent to which the landslide will affect property and persons downslope and the ability of persons to take evasive action.

The travel distance depends on:

- Slope characteristics
  - Height
  - Slope
  - Nature of material
- Mechanism of failure and type of movement such as
  - Slide, fall, topple etc.
  - Sliding, rolling, bouncing, flow
  - Strain weakening or not
  - Collapse in undrained loading (static liquefaction)
  - Influence of surface water and groundwater
  - Comminution of particles
- Characteristics of the downhill path
  - Gradient and gradient direction
  - Channelisation
  - The potential for depletion/accumulation
  - Vegetation

Information on travel distance from previous events on or near the site may be collected during the site inspection. Predictions of travel distance and travel direction should be based on the assessed mechanism of future events and site characteristics.

For rotational landslides which remain essentially intact, the method proposed by Khalili *et al* (1996) or experience with landslides in similar geological, topographic and climatic conditions can be used to estimate the displacement. Further discussion is given in the Commentary.

For slides which break up, and in some cases become flows, and slides from steep cuts, the travel distance is usually estimated from empirical methods, such as Hunter and Fell (2002) and Corominas (1996). These methods are only approximate, and the wide scatter of data on travel distance angles reflects the range of topographical, geological and climatic environments, different slide mechanisms and limited quality of data from which the methods are derived.

If the empirical methods are to be used for predictions of travel distance and the probability of spatial impact of the elements at risk, much judgement will be required and it is important to try to calibrate the methods with landslide behaviour in the study area. It is often useful to allow for a range of travel distances in the calculation and express that range in probabilistic terms as discussed in the Commentary.

The annual probability of the landslide and probability of spatial impact may be considered together in qualitative terms as likelihood of impact on the element at risk being considered.

6 CONSEQUENCE ANALYSIS

6.1 ELEMENTS AT RISK

The elements at risk will include:

- Property, which may be subdivided into portions relative to the hazard being considered.
- People, who either live, work, or may spend some time in the area affected by landsliding.
- Services, such as water supply or drainage or electricity supply.
- Roads and communication facilities.
- Vehicles on roads, subdivided into categories (cars, trucks, buses).

These should be assessed and listed for each landslide hazard.

For some cases, other risks may also have to be considered. For example:

- Environmental, where the elements at risk are environmental (rather than man made), such as forests or water bodies.
- Social, where the consequences of the landslide may have an impact on social conditions, such as the cost of disruption to traffic where roads are affected.
- Political, where the consequences may not be acceptable in political terms.

6.2 TEMPORAL SPATIAL PROBABILITY ($P_{(T:S)}$)

When the elements at risk are mobile (e.g. persons on foot, in cars, buses and trains) or where there is varying occupancy of buildings (e.g. between night and day, week days and weekends, summer and winter), it is necessary to make allowance for the probability that persons (or a particular number of persons) will be in the area affected by the landslide. This is called the Temporal Spatial Probability**.**

For where the elements at risk are mobile it is proportion of a year (between 0 and 1.0) in which a person, car or bus will be below or on the landslide when it occurs. For occupancy of buildings it is a calculation of the proportion of a year (between 0 and 1.0) which the number of persons being considered occupy the building, or the area of the building likely to be impacted.

These calculations should allow for the possibility that the persons may have warning of trhe impending landslide and may evacuate the area. Each case should be considered by taking account of the details of the situation. Generally persons <u>on</u> a landslide are more likely to observe the initiation of movement and move off the slide, than those who are <u>below</u> a slide which falls or flows onto them unless the rates of movement are slow.

6.3 EVALUATION OF CONSEQUENCE TO PROPERTY

6.3.1 Estimate the extent of damage likely to property arising from each of the landslides.

This requires an understanding of the landslide characteristics and experience in assessing the likely impact on property. The consequences are often calculated using the vulnerability ($\mathbf{V}_{(Prop:S)}$) of the elements at risk to the landslide.

The factors which most affect vulnerability of property are:

- The volume of the slide in relation to the element at risk.
- The position of the element at risk, e.g. on the slide, or immediately downslope.
- The magnitude of slide displacement, and relative displacements within the slide (for elements sited on the slide).
- The rate of slide movement.

It should be noted that the vulnerability refers to the degree of damage (or damage value in absolute or relative terms) which is judged to be likely if the landslide does occur.

As discussed below, the assessment should be based on a quantitative estimate to enable clarification of the judgment which for a qualitative assessment may be subject to considerable interpretation.

6.3.2 Estimate the indicative cost of the damage.

This requires use of indicative costs of building and remedial works. Frequently, broad brush ‘guesstimates’ will suffice, but the ‘guesstimate values’ and basis should be documented. Some guidance is given in the Commentary. It should not be necessary to use a quantity surveyor to establish a more accurate estimate as usually the broad brush guesstimate will suffice for allocation of a consequence term in a qualitative scheme such as in Appendix C.

The indicative cost of damage is to be the Total Cost as this is the most relevant to the owner. Components to be considered comprise:-

- Direct costs related to reinstatement works for damaged portions of the property (structures and the land).
- Stabilization works required to render the site to an tolerable risk level for the landslide.
- Professional and approvals fees.
- Consequential costs (such as legal fees and alternative temporary accommodation).

It does not include additional stabilisation works to address other landslides which may affect the property.

6.3.3 Estimate the market value.

This may be achieved by reference to property sale values within the local area which will reflect the value of the land plus structures. The client is likely to have some knowledge of the local market values. Again, a broad-brush guesstimate should often suffice.

6.3.4 Consider the resulting Consequence classification, such as using Appendix C, and implied accuracy of the above estimates.

It is not expected that the assessor will be a quantity surveyor or have similar experience, but that sensible estimates, possibly as a range, can be made and documented. Statement of limits of accuracy or uncertainty are appropriate for sensitivity and appraisal analysis.

6.4 EVALUATION OF CONSEQUENCES TO PERSONS

The following factors influence the likelihood of deaths and injuries or vulnerability ($\mathbf{V}_{(D:T)}$) of persons who are impacted by a landslide:

- Volume of slide.
- Type of slide, mechanism of slide initiation and velocity of sliding.
- Depth of slide.
- Whether the landslide debris buries the person(s).
- Whether the person(s) are in the open or enclosed in a vehicle or building.
- Whether the vehicle or building collapses when impacted by debris.
- The type of collapse if the vehicle or building collapses.

Persons are very vulnerable in the event of complete or substantial burial by debris, or the collapse of a building. It should be noted that even small slides, and single boulders, can kill people.

Appendix F provides some indicative examples of vulnerability values. The Commentary provides some more detailed discussion.

7 RISK ESTIMATION

7.1 QUANTITATIVE RISK ESTIMATION

Quantitative risk estimation involves integration of the frequency analysis and the consequences.

For property, the risk can be calculated from:

$$\mathbf{R}_{(Prop)} = \mathbf{P}_{(H)} \times \mathbf{P}_{(S:H)} \times \mathbf{P}_{(T:S)} \times \mathbf{V}_{(Prop:S)} \times \mathbf{E} \qquad \textbf{(1)}$$

Where

$\mathbf{R}_{(Prop)}$ is the risk (annual loss of property value).

$\mathbf{P}_{(H)}$ is the annual probability of the landslide.

$\mathbf{P}_{(S:H)}$ is the probability of spatial impact by the landslide on the property, taking into account the travel distance and travel direction.

$\mathbf{P}_{(T:S)}$ is the temporal spatial probability. For houses and other buildings $\mathbf{P}_{(T:S)}= 1.0$. For Vehicles and other moving elements at risk$1.0< \mathbf{P}_{(T:S)} >0$.

$\mathbf{V}_{(Prop:S)}$ is the vulnerability of the property to the spatial impact (proportion of property value lost).

$\mathbf{E}$ is the element at risk (e.g. the value or net present value of the property).

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

$$\mathbf{R}_{(LoL)} = \mathbf{P}_{(H)} \times \mathbf{P}_{(S:H)} \times \mathbf{P}_{(T:S)} \times \mathbf{V}_{(D:T)} \qquad \textbf{(2)}$$

Where

$\mathbf{R}_{(LoL)}$ is the risk (annual probability of loss of life (death) of an individual).

$\mathbf{P}_{(H)}$ is the annual probability of the landslide.

$\mathbf{P}_{(S:H)}$ is the probability of spatial impact of the landslide impacting a building (location) taking into account the travel distance and travel direction given the event.

$\mathbf{P}_{(T:S)}$ is the temporal spatial probability (e.g. of the building or location being occupied by the individual) given the spatial impact and allowing for the possibility of evacuation given there is warning of the landslide occurrence.

$\mathbf{V}_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).

A full risk analysis involves consideration of all landslide hazards for the site (e.g. large, deep seated landsliding, smaller slides, boulder falls, debris flows) and all the elements at risk.

For comparison with tolerable risk criteria, the individual risk from all the landslide hazards affecting the person most at risk, or the property, should be summed.

The assessment must clearly state whether it pertains to 'as existing' conditions or following implementation of recommended risk mitigation measures, thereby giving the 'residual risk'.

7.2 SEMI-QUANTITATIVE AND QUALITATIVE RISK ESTIMATION FOR RISK TO PROPERTY

When considering the risk to property, it may be useful to use qualitative terms to report the results of the analysis, rather than quantitative values. The risk calculation may be completed quantitatively or by the use of qualitative terms.

A semi quantitative analysis (where the likelihood is linked to an indicative probability) or a qualitative analysis may be used:

- As an initial screening process to identify hazards and risks which require more detailed consideration and analysis.
- When the level of risk does not justify the time and effort required for more detailed analysis.
- Where the possibility of obtaining numerical data is limited such that a quantitative analysis is unlikely to be meaningful or may be misleading.

Section 7.3 describes a suitable and preferred terminology.

7.3 RISK MATRIX FOR PROPERTY LOSS

a) Adopt a defined qualitative terminology for likelihood, consequence and risk.

Qualitative terminology is presented in Appendix C for property loss. The terminology has been developed from Appendix G in AGS (2000) taking into account the experience and comments as discussed in the Commentary.

For ease of use, the frequency estimate, expressed as an annualized probability and taking into account the probability of spatial impact, is expressed qualitatively as likelihood.

The terminology is aimed primarily at residential development but may also be used for other situations. It is noted that provision of specific numerical values at the Notional Boundaries for the terms adopted does not reduce the uncertainty that may be associated with assessment of appropriate numerical values.

Where sufficient data is available, the risk should be determined from a quantitative analysis. The results can then be objectively compared, especially with quantified allowable risk criteria.

Where there is insufficient data or the study is at a walk over or preliminary design level, then use of qualitative methods or terms may be more appropriate. Use of risk ranking schemes, where component inputs are assigned relative ranks, may be suitable for initial screening. In other cases, it is likely that expression of the likelihood, consequence and risk using qualitative terms is preferable for communication purposes; (for example using terminology as in Appendix C). Selection of the appropriate term should be based on an appropriate evaluation of likelihood or consequence ranges.

Semi-quantitative methods may be a combination of both, for example considering risk to property qualitatively, and risk to life quantitatively based on the appropriate best estimates of likelihood.

b) The practitioner should adopt the preferred risk matrix presented in Appendix C.

The terminology presented in Appendix C of this Practice Note has addressed the shortcomings identified with the scheme in Appendix G AGS (2000). Appendix G of AGS (2000) is now superseded and should no longer be used. Adoption of Appendix C as a preferred risk matrix will assist with uniformity of assessment and interpretation. This is discussed further in the Commentary.

The regulator should only accept non standard schemes where the terms have been clearly defined, the terms have been explained in relation to the preferred terminology, and it can be reasonably demonstrated by the practitioner that the alternative is better suited to the particular circumstances of the assessment.

7.4 ESTIMATION OF RISK OF LOSS OF LIFE

a) Estimate the risk of loss of life quantitatively for the person most at risk.

The annual probability of loss of life for the person most at risk from the landslide(s) should be estimated using the equations in Section 7.1. The person most at risk will often but not always be the person with the greatest spatial temporal probability.

The individual risk, as determined by summing the risk, for the person most at risk, from all the landslide hazards, is used for comparison with the tolerable risk criteria.

b) For situations where there is a potential for large numbers of lives to be lost in a single landslide event, estimate the frequency (f) –number (N) of lives lost pairs and total annual risk.

If the possible loss of large numbers of lives from a landslide incident is high, society will generally expect that the probability that the incident might actually occur should be low. This accounts for society's particular intolerance to incidents that cause many simultaneous casualties and is embodied in the criteria for tolerable societal risk. Societal Risk is discussed further in the Commentary.

In many cases there will be more than one landslide hazard (e.g. rockfall, which may lead to one or two lives lost; medium volume rapid landslide which may lead to several lives lost; and large rapid landslide which may lead to many lives lost). The frequency (annual probability, "f") of the "event" and the number of lives lost (N) should be estimated for each landslide hazard.

The total annual risk = $\sum$ (f x N) should also be estimated.

8 RISK ASSESSMENT

8.1 RISK EVALUATION

Evaluate the risks against Tolerable Risk Criteria for loss of life and property loss.

Accept the risks if tolerable, or seek to reduce risks to tolerable levels by risk mitigation.

The main objectives of risk evaluation are usually to decide whether to accept or treat the risks and to set priorities. The Tolerable Risk Criteria are usually imposed by the regulator, unless agreed otherwise with the owner/client

Non- technical clients may seek guidance from the practitioner on whether to accept the risk. In these situations, risk comparisons, discussion of treatment options and explanation of the risk management process can help the client make his decision.

It is desirable, if not essential, that the practitioner who prepared the risk assessment be involved in the decision making process because the process is often iterative, requiring assessment of the sensitivity of calculations to assumptions, modification of the development proposed and revision of risk mitigation measures.

Risk evaluation involves making judgements about the significance and tolerability of the estimated risk. Evaluation may involve comparison of the assessed risks with other risks or with risk acceptance criteria related to finance, loss of life or other values. Risk evaluation may include consideration of issues such as environmental effects, public reaction, politics, business or public confidence and fear of litigation.

In a simple situation where the client/owner is the only affected party, risk evaluation may be a simple value judgement. In more complex situations, value judgements on acceptable risk appropriate to the particular situation are still made as part of an acceptable process of risk management.

8.2 TOLERABLE RISK CRITERIA

The regulator is to establish the Tolerable Risk Criteria for loss of life and property loss.

As discussed in Section 3.5, the regulator is the appropriate authority to set standards for tolerable risk which may relate not only to perceived safety in relation to other risks, but also to government policy. Implementation of a tolerable risk level has implications to the community at large, both in terms of relative risks or safety and in terms of economic impact on the community.

The Commentary provides discussion and gives the AGS recommendations in relation to tolerable risk for loss of life. These are summarized in Table 1

Table 1: AGS Suggested Tolerable loss of life individual risk.

Situation	**Suggested Tolerable Loss of Life Risk for the person most at risk**
Existing Slope (1) / Existing Development (2)	10^{-4} / annum
New Constructed Slope (3) / New Development (4) / Existing Landslide (5)	10^{-5} / annum

Notes:

1. "Existing Slopes" in this context are slopes that are not part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
2. "Existing Development" includes existing structures, and slopes that have been modified by cut and fill, that are not located on or part of a recognizable landslide and have demonstrated non-failure performance over at least several seasons or events of extended adverse weather, usually being a period of at least 10 to 20 years.
3. "New Constructed Slope" includes any change to existing slopes by cut or fill or changes to existing slopes by new stabilisation works (including replacement of existing retaining walls or replacement of existing stabilisation measures, such as rock bolts or catch fences).
4. "New Development" includes any new structure or change to an existing slope or structure. Where changes to an existing structure or slope result in any cut or fill of less than 1.0m vertical height from the toe to the crest and this change does not increase the risk, then the Existing Slope / Existing Structure criterion may be adopted. Where changes to an existing structure do not increase the building footprint or do not result in an overall change in footing loads, then the Existing Development criterion may be adopted.
5. "Existing Landslides" have been considered likely to require remedial works and hence would become a New Constructed Slope and require the lower risk. Even where remedial works are not required per se, it would be reasonable expectation of the public for a known landslide to be assessed to the lower risk category as a matter of "public safety".

Acceptable risks are usually considered to be one order of magnitude lower than the Tolerable Risks.

It is important to distinguish between "acceptable risks" and "tolerable risks".

Tolerable Risks are risks within a range that society can live with so as to secure certain benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if practicable.

Acceptable Risks are risks which everyone affected is prepared to accept. Action to further reduce such risk is usually not required unless reasonably practicable measures are available at low cost in terms of money, time and effort.

AGS suggests that for most development in existing urban area criteria based on Tolerable Risks levels are applicable because of the trade-off between the risks, the benefits of development and the cost of risk mitigation.

The Commentary discusses Individual and Societal risk to loss of life. Usually Societal risk need not be considered for a risk evaluation in relation to a single dwelling. Societal risk should be evaluated for buildings having high numbers of occupants, such as schools, hospitals, hotels or motels where many lives are at risk. This then addresses society's aversion to loss of many lives from single landslide events.

The Tolerable Risk Criteria for property loss may be determined by the Importance Level of the development (Appendix A) as discussed in the Commentary.

9 RISK MANAGEMENT

9.1 RISK MITIGATION PRINCIPLES

9.1.1 Feasible options for risk mitigation for each risk assessment are to be identified and discussed including the reduced risk by adoption of those options.

Alternative methods to be explored include:

a. ***Accept the risk***, which is only an option subject to the criteria set by the regulator. Where the risk is not tolerable then risk mitigation measures are required.

b. ***Avoid the risk***, such as relocation of the site of proposed development, or revise the form of the development, or abandon the development (though this may still require some risks to be controlled due to possible effect on third parties adjacent or nearby).

c. ***Reduce the frequency of landsliding***, by stabilisation measures to control the initiating circumstances, such as by re-profiling the surface geometry where existing slopes are 'over steep', by provision of improved surface water drainage measures, by provision of subsurface drainage scheme, by provision of retaining structures such as retaining walls, anchored walls or ground anchors.

d. ***Reduce the consequences***, by provision of defensive stabilisation measures or protective measures such as a boulder catch fence, or amelioration of the behaviour of the landslide, or by relocation of the development to a more favourable location.

e. ***Manage the risk by establishing monitoring and warning systems,*** such as by regular site visits, or by survey, which enable the risks to be managed as an interim measure in the short term or as a permanent measure for the long term by alerting persons potentially affected to a change in the landslide condition. Such systems may be regarded as a method of reducing the consequences provided it is feasible for sufficient time to be available between the alert being raised and appropriate action being implemented.

f. ***Transfer the risk,*** such as by requiring another authority to accept the risk (possibly via a court appraisal) or by provision of insurance to cover potential property damage.

g. ***Postpone the decision,*** where there is sufficient uncertainty resulting from the available data, provided that additional investigations or monitoring are likely to enable a better risk assessment to be completed. Postponement is only a temporary measure and implies the risks are being temporarily accepted, even though they may not be acceptable or tolerable.

Adoption of particular risk mitigation measures needs to be documented so that the decisions are transparent to future land owners and to the regulator. The documentation will need to make it clear whether there is ongoing maintenance required or not. Responsibility for implementation of the risk mitigation measures (including auditing and reporting) resides with the land owner, particularly where ongoing maintenance is required.

It should be recognized that there may be situations where the risk is such that either no development should occur, or that very strict conditions and/or extensive investigations and implementation of risk control measures will be required. Such risk control measures may render the proposed development unworkable.

9.1.2 Wherever possible the recommended options should be engineered to reduce the uncertainties.

It is not possible to remove risk, but it can be reduced.

Risk mitigation options should include robust engineering design to reduce uncertainties and hence the risk.

Guidance on good engineering practice for hillside design and construction is given in Appendix G which has been reproduced from AGS (2000).

It is necessary that the options considered lower the risk to at least tolerable levels. In many cases, the ALARP principle ("As Low As Reasonably Practicable" as discussed in the Commentary) may apply so that reduction to a tolerable level is a pragmatic result since reduction to acceptable levels is not viable in the context of the cost to the individual or community. In other cases, good practice may suggest that risk reduction be applied since it is relatively cheap or cost effective to implement even though risk levels are assessed to already be at acceptable levels. In other words, risk minimization should be a governing feature or tenet of LRM.

Evaluation of mitigation options may take into account relative costs and effectiveness of the measures and inherent uncertainties. Combinations of mitigation measures may be appropriate.

The options should be reassessed if there is a need to reduce uncertainties or if suitable engineering options cannot be adopted.

An issue will be who decides on what level of risk reduction is appropriate. This is dependent on the risk tolerance criteria set by the regulator. The owner is likely to input into selection of the options, subject to approvals by the regulator. For some cases, there may be discussion between the stakeholders to select a suitable scheme of risk mitigation measures.

9.1.3 The adopted risk mitigation measures are to be detailed in a mitigation plan to explain and document the implementation of the measures.

The mitigation plan should identify responsibilities for each stakeholder during and after implementation. It may also include cost estimates, programme, required inspection regime, performance measures and expected outcomes. The level of detail will depend on the priority for the option and stage of the evaluation and implementation process.

The mitigation plan may include an emergency plan which should establish from the outset the sequence of events or monitoring results that will activate this plan. The plan may include a number of warning levels and consequent actions. The plan must be carefully reviewed to confirm it is workable and will achieve the desired risk mitigation.

The existence of the mitigation plan needs to be readily known to subsequent land owners. The most readily available method for this is to register the mitigation plan details on the land title.

9.1.4 The risk should be subject to monitoring and review during the assessment of options, during implementation of the risk mitigation measures and during the on going monitoring.

Further data may come to light during the management process which enables the risks to be reassessed. Such data may be adverse, requiring more stringent risk mitigation measures, or alternatively may be positive by demonstrating satisfactory slope performance under adverse conditions. It is anticipated that the practitioner would have a primary role in the monitoring and review process and particularly to confirm the requirements of the approval conditions had been fulfilled.

9.2 SITE SPECIFIC DEVELOPMENT CONDITIONS

Identify appropriate site specific development conditions to provide good practice and control the risks to acceptable levels.

In the context of advice from a technical expert (the practitioner) acting in a consultant capacity, development controls would usually constitute ‘recommendations’, but as they will be integral with the risk assessment of the final development they may not be optional to the client. The practitioner should provide a statement as to the appropriateness of the development proposals in relation to the risk management requirements.

If ‘certification’ of the completed development is required (by the planning scheme or regulator’s approval conditions), then the development conditions and associated inspections and documentation must be sufficient to enable this to be provided at the later date.

The development conditions should be subdivided into those required at each of the stages of detailed design, construction (including appropriate sequencing and temporary works), and for maintenance. The development conditions must address all the factors relevant to controlling the landslide risk.

9.3 DESIGN LIFE

9.3.1 Design of the risk mitigation measures is to be suitable for the time frame of the life of the structure - the design life. The design life is to be clearly stated on the design drawings.

Often the design life will be that specified by relevant design codes such as 40 to 60 years for AS3600 Concrete Code, 50 years for AS2870 Residential Slabs and Footings, or for 5 years to 120 years for temporary site works to major public works respectively for AS4678 Earth Retaining Structures.

A design life of at least 50 years would be considered to be reasonable for permanent structures used by people. Some local government policies may require a longer design life as discussed in the Commentary. However, for some structures, such as timber retaining walls, inherent performance of the materials will limit the effective performance life to less than the required design life.

9.3.2 Where the effective performance life is less than the required design life, then the effective life should be extended by a maintenance regime designed to overcome the limitations and to enable the performance to be assessed throughout the required design life. This is likely to require more extensive repair and replacement as determined by regular maintenance inspections.

For example, experience shows the longevity of timber crib walls is less than for a concrete structure, due to faster degradation of timber with time. Therefore, a more frequent inspection and maintenance / repair / replacement regime will be required for timber crib walls to enable suitable repair and replacement so that a reasonable design life can be achieved. Similar considerations will apply to subsoil drains and stressed anchors.

9.4 MAINTENANCE REQUIREMENTS

9.4.1 The design is to include details of required inspections and maintenance to enable the risk mitigation measures to remain effective for at least the design life of the structure.

Risk mitigation is not just an exercise in LRM documentation, design of the works and construction of the risk mitigation measures. The owner, including all owners subsequent to those responsible for commissioning the risk mitigation measures, has a responsibility to inspect and maintain the risk mitigation measures.

9.4.2 Refer to the AGS Australian GeoGuide LR111 which provides advice on record keeping.

The other GeoGuides (AGS, 2007e) also provide advice on the frequency of maintenance tasks.

9.4.3 Implementation of the maintenance plan may require 'enforcement' by annotation on the land title so that subsequent purchasers become aware of the requirements and that relevant documents are available for the maintenance plan. Such 'enforcement' will be a benefit to subsequent owners as they will be better informed as to their required input responsibilities.

10 REPORTING STANDARDS

10.1 The report on the risk assessment is to document the data gathered, the logic applied and conclusion reached in a defensible manner.

The practitioner will gather relevant data, will assess the relevance of the data and will reach conclusions as to the appropriate geotechnical model and basic assessment of the slope forming processes and rates. Full documentation of these results provides evidence of completion, provides transparency in the light of uncertainty, enables the assessment to be re-examined or extended at a later date and enables the assessment to be defended against critical review. The process often identifies uncertainties or limitations of the assessment which also need to be documented and understood.

10.2 The data to be presented includes:

a. List of data sources.
b. Discussion of investigation methods used, and any limitations thereof.
c. Site plan (to scale) with geomorphic mapping results.
d. All factual data from investigations, such as borehole and test pit logs, laboratory test results, groundwater level observations, record photographs.
e. Location of all subsurface investigations and/or outcrops/cuttings.
f. Location of cross section(s).
g. Cross section(s) (to scale) with interpreted subsurface model showing investigation locations.
h. Evidence of past performance.
i. Local history of instability with assessed trigger events.
j. Identification of landslides, on plan or section or both, and discussed in terms of the geomorphic model, relevant slope forming process and process rates. Landslides need to be considered above the site, below the site and adjacent to the site.
k. Assessed likelihood of each landslide with basis thereof.
l. Assessed consequence to property and life for each landslide with basis thereof.
m. Resulting risk for each landslide.
n. Risk assessment in relation to tolerable risk criteria (e.g. regulator's published criteria where appropriate).
o. Risk mitigation measures and options, including reassessed risk once these measures are implemented.

Where any of the above is not or cannot be completed, the report should document the missing elements, including an explanation as to why.

The report needs to clearly state whether the risk assessment is based on existing conditions or with risk treatment measures implemented. In some cases, the assessment for both existing and after treatment should be documented to demonstrate the effect of risk control measures on reducing risk.

A report which does not properly document the assessment is of limited value and would appear to have no reasonable basis.

11 SPECIAL CHALLENGES

11.1 MINOR WORKS

Adoption of all the provisions of the Practice Note for minor works may not be appropriate or reasonable. However, the basic principles still need to be considered. Although some policies may make provision for less onerous consideration for minor works, the practitioner will still have a duty of care to advise on all aspects and may have other landslides not connected with the proposed works that will still need to be considered.

Minor works should be evaluated on a site by site basis but are likely to comprise proposed works of relatively low monetary value (such as may be completed by an owner builder with appropriate approvals and insurances) or those which do not change the existing risk, provided the existing risk has been assessed to be within the tolerable range. In some cases, the risk to life may be much higher than the risk to property and may dictate the need for risk mitigation to achieve tolerable risk levels.

11.2 PART OF THE SITE NOT ACCEPTABLE

Existing or proposed development may not involve the full site area. Nonetheless, the practitioner's report must address all risks and advise the client and/or regulator of necessary works to control risks on other parts of the site or adjacent/nearby sites upslope or down slope as appropriate (as a primary duty of care issue).

Where additional development is proposed, it may be found that risks associated with the proposed development are tolerable but that landslide risks on other parts of the site are not. These other risks still must be addressed.

11.3 ADJOINING AREAS NOT UNDER RESPONSIBILITY OF THE SITE OWNER

In some cases, the risk posed by landslides in areas beyond the control of the land owner may be intolerable.

The LRM assessment report must identify these landslides and provide a preliminary assessment of appropriate risk mitigation measures, which may require further investigation to better assess the risk.

The regulator may then implement appropriate orders (as appropriate to the legal/regulatory framework) to enforce appropriate risk mitigation measures and/or investigations. Alternatively, it may not be appropriate for development to proceed in such cases.

11.4 COASTAL CLIFFS

LRM reports on coastal cliffs should include consideration of the existing slope profile, evidence of past instability, geology, defects, ground water, degradation cycles, and degradation rates and possible effects of wave attack, wave run-up and sea spray. The cliff areas should be examined from the face side as well as from the land side.

Assessment of coastal cliffs is likely to require special expertise to consider the combined effects associated with recession rates, rock mechanics and wave environment. The LRM assessment may require some input from coastal engineers to address possible effects from storm events in terms of wave heights, run-up and frequency. The most frequent hazard is often boulder falls which will have risk determined by the temporal spatial probability.

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

Source: Australian Geomechanics Society (2007c) 'Practice Note Guidelines for Landslide Risk Management', Australian Geomechanics, Vol 42, No 1, March 2007, Appendix C pp91-92.

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.
(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

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

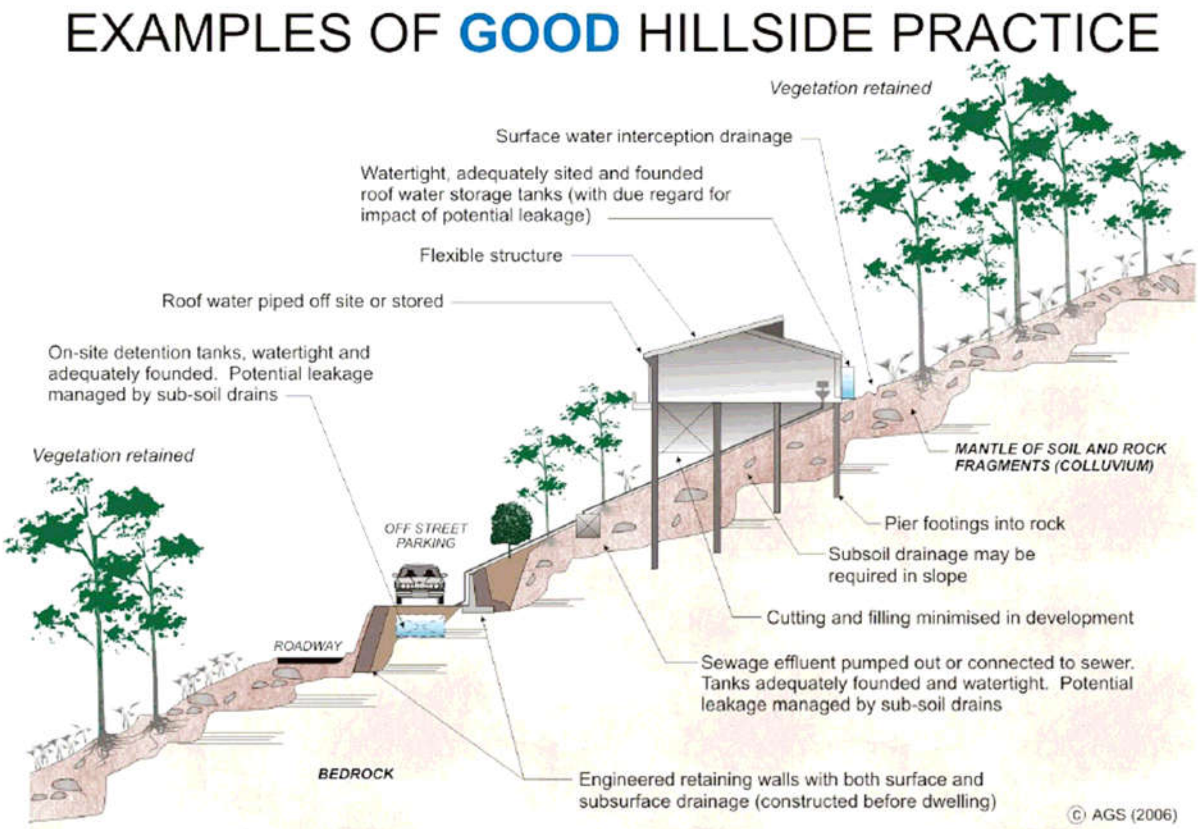
Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.

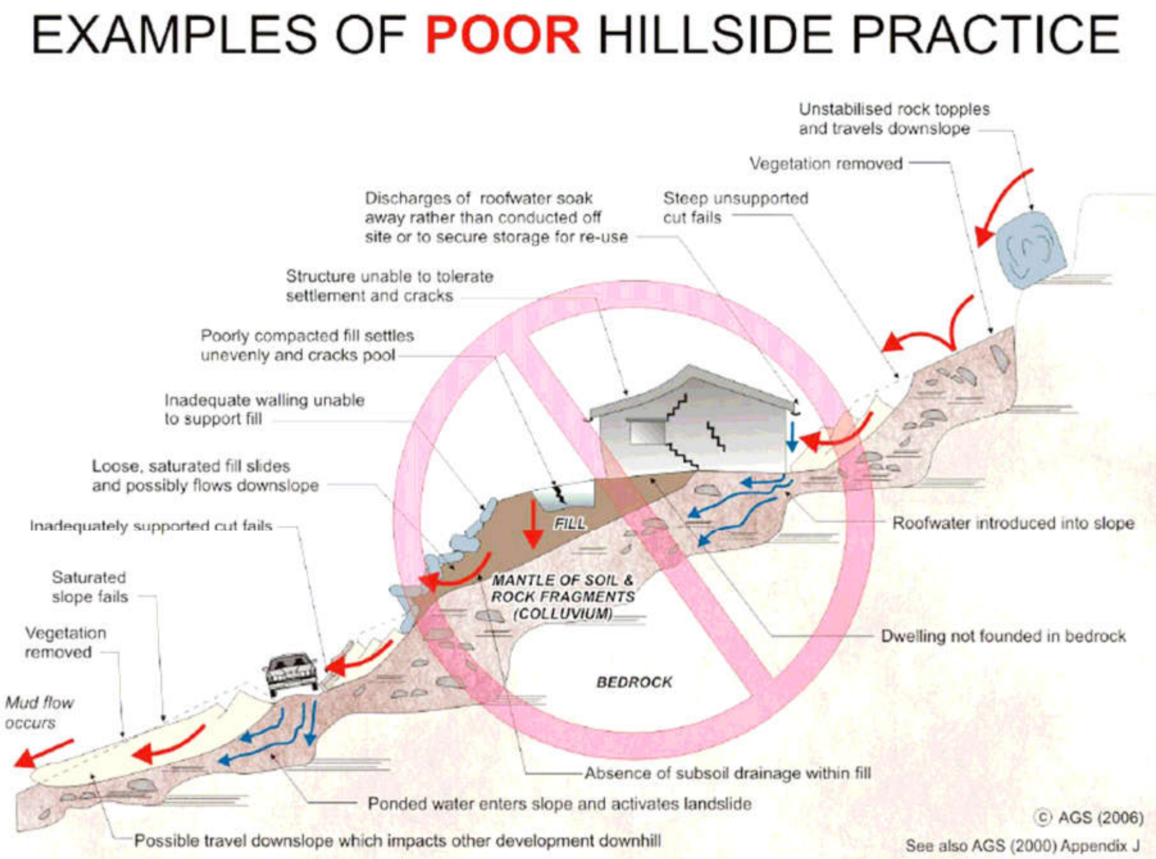
Source: Australian Geomechanics Society (2007c) 'Practice Note Guidelines for Landslide Risk Management', Australian Geomechanics, Vol 42, No 1, March 2007, Appendix C pp91-92.

APPENDIX D - SOME GUIDLINES FOR HILLSIDE CONSTRUCTION

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

Source: Australian Geomechanics Society (2007c) 'Practice Note Guidelines for Landslide Risk Management', Australian Geomechanics, Vol 42, No 1, March 2007, Appendix G, pp113-114.





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