Geotechnical Investigation Report

Project

Proposed Residential Development
4 Forest Road, Warriewood NSW

Prepared for

BMN Properties

Date

5 December 2024

Report No

18120-GR-1-1-Rev1

alliance
geotechnical & environmental solutions

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0	03/07/2024	Original issue	TE	LT
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Author Signature		**Reviewer Signature**	
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APPENDICES

1 Introduction

This report presents the results of a geotechnical investigation for a proposed residential development at 4 Forest Road, Warriewood NSW (the Site). The investigation was commissioned on 14 June 2024 by Brad Pym of BMN Properties (the Client). The work was carried out in accordance with the email quotation by Alliance Geotechnical Pty Ltd (Alliance) dated 14 June 2024.

Drawings supplied by the client for this investigation comprised:

- Previous Geotechnical Report by Willows Engineering ref: 2122-1—R1 Rev 0 dated 9/12/22 (including some ground testing conducted by Alliance)
- A survey plan including proposed cut and fill locations on the subject site

The scope of works included a desktop study of the location, a site walkover assessment by an experienced engineering geologist, drilling of seven boreholes, and in-situ soil testing.

2 Proposed Development

An updated development layout plan was supplied by the client subsequent to the investigation (prepared by Acor Consultants Pty Ltd, Proj. No. NSW210416, Issue C, dated 27/11/2024).

The proposed development includes demolition of the existing dwelling and the construction of 13 new split level residential dwellings including access roads. The proposed subdivision is provided in Figure 1.

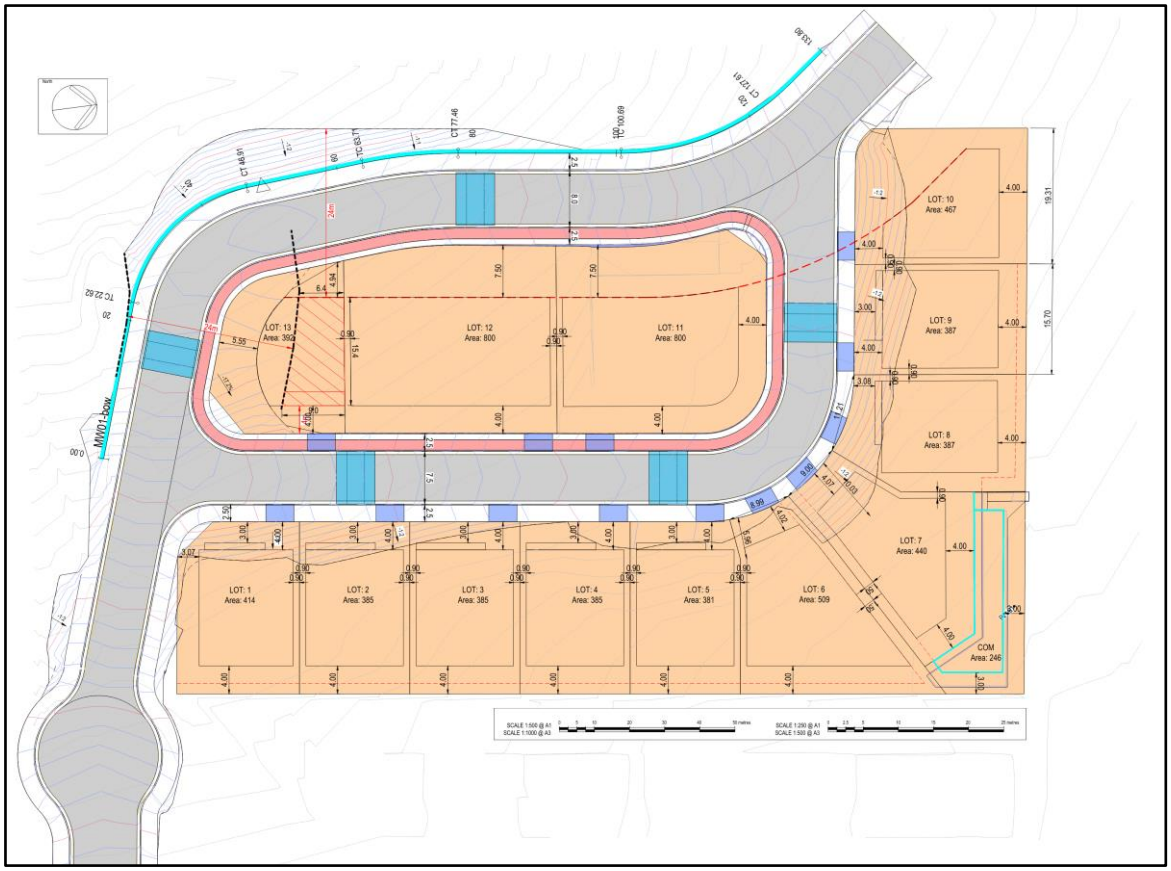

Figure 1 - Proposed Subdivision at 4 Forest Road, Warriewood NSW

3 Site Description and Regional Geology

3.1 Site Description

The site (Figure 1) is located on the mid portion of an east-northeast flanking slope. The general gradient of the slope across the entire block is ~20 degrees, leveling to ~5 degrees in the north-east corner of the block. The slope is interrupted by the driveway which is unsealed and levelled and runs from the south-east corner of the block to a residential dwelling. The driveway appears to be constructed on a man-made level plateau.

The site comprises majority grassed areas with uncut lawns found in the southern, eastern and north-eastern portions of the site. There is a single residential dwelling located in the middle of the block which comprises a two-storey brick residence with a tile roof. The structure appears in reasonable condition for its age with no obvious signs of movement or structural dilapidation. There are concrete block retaining walls to the rear (west) and southern side of the dwelling. These show some moderate dilapidation with some cracking apparent and minor (<1 degree) rotation from vertical. There are two dilapidated cottages located to the north of the residence. Access to the dwelling is provided by a level unsealed driveway.

The site is bound by residential dwellings to the north and east, Mater Maria Secondary College to the south and natural bushland comprising large native shrubs and trees to the west. Vegetation on the site is a variety of grassed areas and low-lying shrubs with some larger trees found along the southern and western boundaries. A line of palms and medium sized trees are located along the eastern edge of the driveway.

The site drains toward the north-east corner. At the time of the site works, the ground was moderately wet, likely due to recent (within 48 hours) heavy rain falls. No significant overland water flows were observed.

Bedrock was observed outcropping on the upper portions of the slope with further outcrops noted in the forested bush land to the west. In addition to bedrock, sandstone floaters were also present in the profile on the upper slope. These ranged in size from ~0.5-3.0m. All the noted floaters appeared to be well embedded in the soil profile. The photos in Appendix A detail the site conditions and observations noted during the fieldworks.

Figure 2 - Site Location – 4 Forest Road, Warriewood NSW (Image from Sixmaps)

3.2 Regional Geology

The Sydney 1:100,000 Geological Map indicated the site lies on the boundary between the mid-Triassic Hawkesbury Sandstone (Rh) and The interbedded Shale, Laminite and Sandstone of the Newport Formation of the Narrabeen Group (Rnn). The Hawkesbury Sandstone unit typically comprises medium to coarse grained quartz sandstone with very minor shale and laminate lenses. The Newport Formation consists of interbedded laminate, shale and quartz to lithic-quartz sandstone.

The results of testing and the observations on site suggest that the geological boundary bisects the site approximately along the line of the existing driveway. Bedrock was noted at relatively shallow depths (where not outcropping) on the upper slope, while rock was not encountered during testing at lower elevations.

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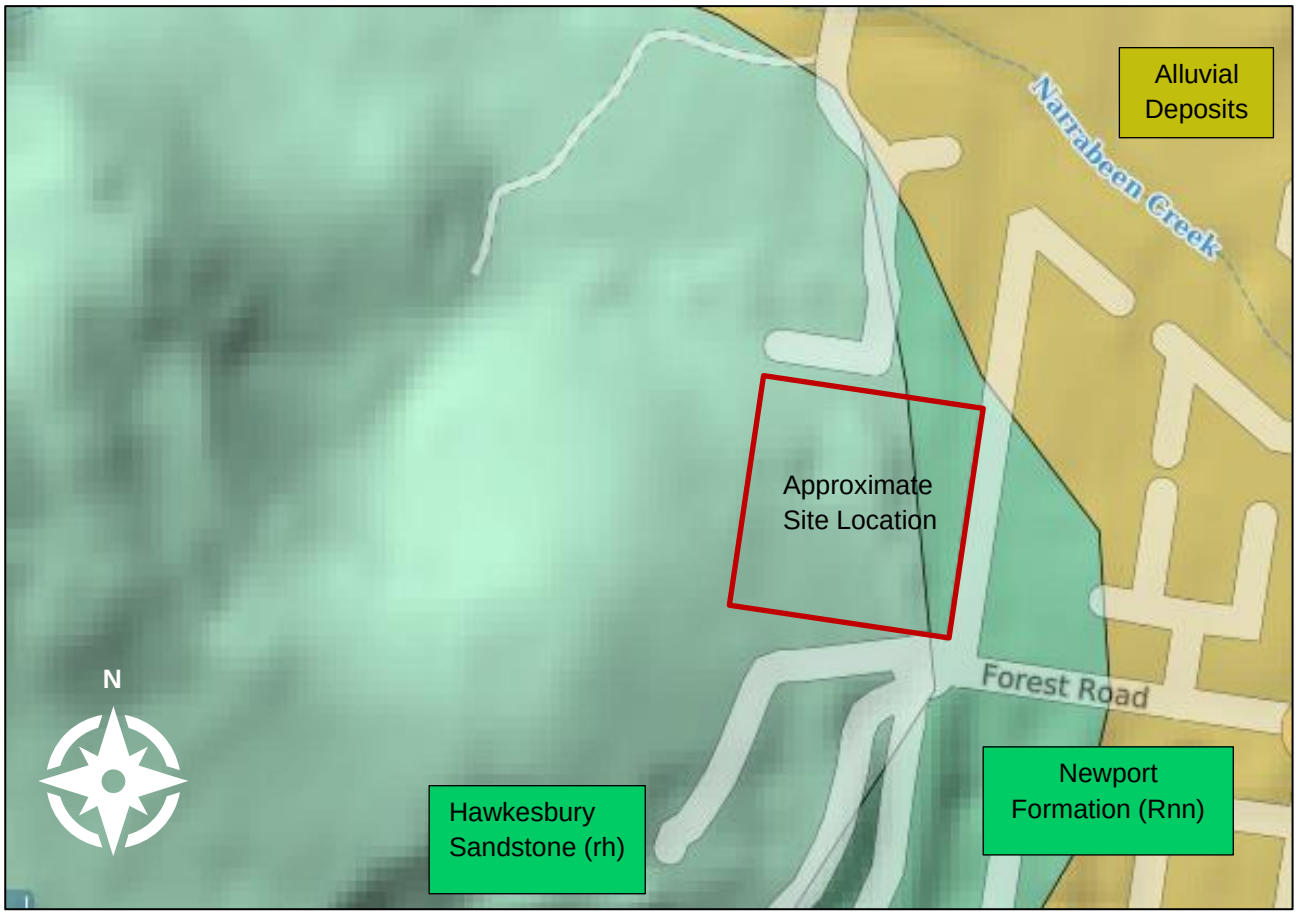

Figure 3 - Geological Setting (Extracted from Minview)

4 Fieldwork

4.1 Methods

The geotechnical site investigation was carried out on 20 and 24 June 2024. Selected site photographs taken during the fieldwork are presented in Appendix A. The investigation comprised the initial scanning of underground utilities and setting out test locations, followed by the drilling of seven boreholes (BH101 to BH107) to a maximum depth of 5.0m.

The boreholes were drilled using a track-mounted drilling rig operated by a drilling subcontractor. Boreholes were advanced through the soil profile using solid flight augers fitted with a tungsten carbide bit (TC-bit).

A further 5 boreholes (HA1-5) were drilled in the upper portion of the slope via hand auger.

Dynamic Cone Penetrometer (DCP) tests were undertaken to assess the upper soil layers consistency across the lot.

The encountered subsurface profiles were documented by an experienced engineering geologist from Alliance generally in accordance with AS 1726 – 2017 Geotechnical Site Investigation.

On completion, the boreholes were backfilled with drilling spoil, then generally made flush with the surrounding surface.

The approximate borehole locations are shown on the Borehole Location Plan (Drawing 18120-GR-1-1-B) presented in Appendix B.

The borehole log sheets are attached in Appendix C. These log sheets should be read in conjunction with the attached Explanatory Notes, which explain the terms, abbreviations and symbols used, together with the interpretation and limitation of the logging procedure.

4.2 Results

Reference to the individual borehole log sheets, attached in Appendix C, should be made for a full description of the subsurface conditions encountered at each borehole. Summarised descriptions of the encountered subsurface geotechnical units are provided in **Table 1**.

Table 1 - Summary of Subsurface Profile

Soil Profile	Upper Slope	Mid Slope	Lower Slope
TOPSOIL/FILL – Silty SAND	0.00 - 0.30	0.00-1.70	0.00-0.30
Residual soil – Clay/Sand including ironstone beds	0.30 – 1.70	0.50->5.00	0.30->5.00
Bedrock (Sandstone/Shale)	1.10-1.70	>5.00	>5.00
Termination Depth (m)	At Refusal (1.10-1.70)	5.00	5.00

Notes:

1. The depths and unit thicknesses are based on the information from the test locations only and do not necessarily represent the maximum and minimum values across the site.
2. Rock classification to Pells, P.J.N., Mostyn, G. & Walker, B.F., Foundations on Sandstone and Shale in the Sydney Region, Australian Geomechanics Journal, December 1998.

Note for Interpretation of DCP Results

Caution must be used when inferring subsurface conditions from DCP results. Refusal can be encountered on obstructions such as gravel, cemented materials, rock floaters, or other inclusions within a soil mass. DCP testing on soils with a gravel component or cementation can indicate a higher density than actual. Also, the DCP results in clay soils are significantly affected by the in-situ moisture content. It is therefore strongly recommended that an experienced Geotechnical Engineer is engaged to confirm the inferred subsurface conditions during construction and to provide advice where subsurface conditions are significantly different.

The site subsurface profile varied from the upper, mid to lower portions of the site. The upper portions were comprised of a thin cover of fill/topsoil to a depth of 0.30m overlaying residual sands followed by sandstone bedrock. The mid portion of the site had increased levels of fill where the existing driveway and residence are located. Fill levels in this section went to a maximum depth of 1.70m and were overlaying gravelly sand and clays. The lower section having a thinner layer of fill/topsoil (up to 0.30) overlaying the same residual gravelly sand/clays encountered in the mid portion of the block. Occasional indurated layers of ironstone were encountered at depths in excess of 3.0m in the lower elevations. Bedrock was not encountered in the mid and lower elevations and will be found in excess of 5.0m depth.

4.3 Groundwater

Groundwater seepage was not encountered during augering. Groundwater seepage may still occur at the interface of residual soils and bedrock and also through the bedrock joints/defects. It should be noted that groundwater conditions are subject to seasonal variations and major weather events (i.e. prolonged rainfall).

4.4 Slope Risk Assessment Observations

A site walkover assessment was undertaken by an experienced engineering geologist from Alliance, during which the following observations were noted:

- The proposed developments are located upslope of existing residential properties along the eastern boundary (2 Forest Road). The neighbouring properties appeared to be ~1-2m below the level of the boundary with 4 Forest Road. It is unclear as to the condition and construction of any retaining structures along this boundary which may be impacted by the proposed development.

- The site is located on an east – north-east directional slope, with an approximate slope gradient of 15-20°, which shallows toward the north-eastern boundary, where it becomes ~5°.

- The site was heavily vegetated, with the majority of the soil covered by grass or shrubs and trees. No evidence of surface erosion or tension cracking could be seen at the time of the walkover.

- The existing dwelling has concrete block retaining walls along the rear (western) and southern boundaries of the dwelling. The walls are up to ~3.0m in height and run for an approximate length of 40m. These walls show some evidence of structural dilapidation including cracking and minor rotation form vertical.

- The upper elevations of the block and the wooded bushland reserve to the western boundary contained a variety of detached sandstone floaters/joint blocks. These ranged in size from ~0.30-3.00m in size. These are interpreted to have originated from the Hawkesbury Sandstone which acts as a capping unit overlaying the Narrabeen Group bedrock which is found at lower elevations. These rocks will have moved down slope over geological timeframes and appeared to be well embed in the soil profile.

- No significant bedrock escarpments were noted in the upper elevations.

5 AGS Slope Risk Assessment

The Australian Geomechanics Society (AGS) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Planning (2007) has been used to assess the levels of land stability risks associated with a development during and after completion of its construction. The risk assessment process involves the identification of hazards that could potentially affect the stability of the site and surrounding land, as well as identification of “elements at risk” should a landslide occur.

The risk criteria in the AGS guidelines (see copy attached) can then be applied to assess the ‘risk to property’ for each hazard type and to determine suitable risk management requirements for the proposed site development.

5.1 Identified Geotechnical Hazards

Based on observations made during the site walkover and the previous engineering experience with projects of a similar nature with similar subsurface conditions, the following geotechnical hazards were identified:

- Hazard A: Long-term soil creep over the slope.

- Hazard B: Deep-seated rotational failure of the slope
- Hazard C: Scouring of the Slope
- Hazard D: Movement of embedded sandstone floaters located in the soil profile at the upper elevations of the block

These hazards can be brought about by the following failure mechanisms:

- Uncontrolled and concentrated surface water runoff, leading to erosion of soil at surface.
- Soil creep along the slope.
- Excessive vibrations, inducing slope failure.
- Removal of vegetation covering face of slope.
- Animal burrowing

5.2 Risk to Property

The risk to property assessment in its existing conditions have been presented below and refer to the geotechnical hazards identified in Section 5.1.1.

Table 2 provides Alliance's assessment of the level of "Risk to Existing Property" after appropriate risk management measures have been implemented.

The AGS 2007 risk assessment tables are provided in Appendix E.

Table 2 – AGS Risk Assessment – Risk to Property

Affected Structure	Geotechnical Hazards existing on site			
	Hazard Type	Likelihood	Consequence	Risk
Proposed Building	A: Long-term Soil Creep	Possible	Insignificant	Low
	B: Deep-seated rotational failure of the slope	Rare	Major	Low
	C: Scouring of slope surface	Possible	Insignificant	Low
Proposed Building and neighbouring properties	D: Movement of embedded sandstone floaters located in the soil profile at the upper elevations of the block	Rare	Major	Low

5.3 Risk to Life

The AGS 2007 guidelines provide the following equation to be used for 'risk to life' calculations:

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

Where:

- $R_{(LoL)}$ is the risk (annual probability of loss of life (death) of an individual).
- $P_{(H)}$ is the annual probability of the landslide.

- $P_{(S:H)}$ is the probability of spatial impact of the landslide impacting a building (location) considering the travel distance and travel direction given the event.
- $P_{(T:S)}$ 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.
- $V_{(D:T)}$ is the vulnerability of the individual (probability of loss of life of the individual given the impact).

The geotechnical hazards with the potential to pose a risk to person/s have been considered in the 'risk to life' calculations. The selected probability values for 'risk to life' calculations are based on the worst-case terms in the risk to property assessment in Section 7.1, in terms of their impact to persons inhabiting the property. The results of the assessment are set out in Table 3 below.

Table 3 - Summary of Risk to Life Calculations considering Risk Management Measures

Hazard	Annual Probability	Probability of spatial impact	Temporal spatial probability given there is warning of occurrence	Vulnerability of the Individual most at risk	Annual Probability of the Loss of Life	Risk of Injury or Loss of Life
Personal injury for people (below the slope) due to Long-term soil creep	1×10^{-3} (Possible)	0.1	0.01	0.05	5×10^{-8}	Acceptable
Personal injury for people (below the slope) due to deep-seated rotational failure	1×10^{-5} (Rare)	0.25	0.01	0.25	6.25×10^{-9}	Acceptable
Personal injury for people (in the dwelling) due to deep-seated rotational failure	1×10^{-5} (Rare)	0.25	0.4	0.5	5×10^{-7}	Acceptable
Personal injury for people (below the slope) due to scouring of slope surface	1×10^{-3} (Possible)	0.1	0.01	0.05	5×10^{-8}	Acceptable
Personal injury for people (below the slope) due to movement of embedded sandstone floaters	1×10^{-5} (Rare)	0.25	0.4	0.5	5×10^{-7}	Acceptable
Personal injury for people (in the dwelling) due to movement of embedded sandstone floaters	1×10^{-5} (Rare)	0.25	0.4	0.5	5×10^{-7}	Acceptable

NOTE:

- The values of the probability terms in Table 3 have been estimated for the site by engineering judgement based on previous experience with risk assessment calculations, hillside building developments and landslide stabilisation works.

The geotechnical hazards identified on site can be effectively managed to maintain a Low level of "Risk to Property" provided Alliance's recommendations are followed in the construction of the building and for site preparation works.

5.4 Risk Management Measures & Residual Risks

It is noted that most of the identified geotechnical issues which are pertinent to the construction of the proposed building are typical to those expected on sloping land and can be managed by established hillside construction practice (see attached AGS GeoGuide LR8), in conjunction with regular construction review by a geotechnical engineer. The risks associated with the hazards described in Section 5.1 can be maintained at Acceptable levels of "Low" provided the following recommendations are implemented and maintained:

- Measure A: Measures to divert surface and subsurface water by installation of permanent drainage
- Measure B: Slope surface protection against rain, erosion, and weathering.
- Measure C: Removal of any poorly embedded sandstone floaters encountered during excavation.

Table 4 below shows the risk to property after implementation of these risk management measures specific to each hazard.

Table 4 - AGS Assessment: Residual Risk to Property

Affected Structure	Hazard Type	Likelihood	Consequence	Risk
Proposed Building	A: Long-term Soil Creep	Unlikely	Insignificant	Very Low
	B: Deep-seated rotational failure of the slope	Rare	Major	Low
	C: Scouring of the Slope Surface	Rare	Minor	Very Low
Proposed Building and neighbouring properties	D: Movement of embedded sandstone floaters	Unlikely	Major	Very Low

By reference to the risk assessment set out in Table 2 and Table 3, it is noted that:

- The geotechnical risks to property and life associated with the proposed development have been assessed as 'Acceptable' in accordance with the "Practice Note Guidelines for Landslide Risk Management" by the Australian Geomechanics Society (AGS 2007).
- The quantitative risk to life calculations indicates that the probability of loss of life for the individual most at risk is Acceptable with a risk probability of less than 1×10^{-6} per annum.

5.5 Site Classification

Due to the presence of trees, fill, and existing site structures (causing abnormal moisture conditions), the site is classified as a Class P (Problem) Site in accordance with AS 2870–2011 "Residential Slabs and Footings". This requires that footings be designed from first principles, rather than adopting prescriptive designs as per AS2870-2011. Where footings are founded on the underlying natural shale and sandstone bedrock, then

footings may be designed and constructed in accordance with the requirements in AS2870-2011 for a Class A site.

6 Limitations

In addition to the limitations inherent in site investigations, it must be pointed out that the recommendations in this report are based on assessed subsurface conditions from limited investigations. To confirm the assessed soil and rock properties in this report, further investigation would be required such as coring and strength testing of rock and should be carried out if the scale of the development warrants, or if any of the properties are critical to the design, construction or performance of the development.

It is recommended that a qualified and experienced Geotechnical Engineer be engaged to provide further input and review during the design development; including site visits during construction to verify the site conditions and provide advice where conditions vary from those assumed in this report. Development of an appropriate inspection and testing plan should be carried out in consultation with the Geotechnical Engineer.

This report and details for the proposed development should be submitted to relevant regulatory authorities that have an interest in the property (e.g. Council) or are responsible for services that may be within or adjacent to the site, for their review.

Alliance accepts no liability where our recommendations are not followed or are only partially followed.

7 References

AS1726 – 2017 - Geotechnical Site Investigations

AS 2870–2011 Residential Slabs and Footings

Practice Note Guidelines on Landslide Risk Assessment - Australian Geomechanics Society (AGS 2007)

APPENDIX A – Site Photographs

Photo 1: Looking north from the southern boundary toward the upper elevations of the subject site.

Photo 2: Looking North-east from the driveway toward the lower elevations of the subject site.

Photo 3: Fill materials on the auger from BH101

Photo 4: Example of a detached sandstone floater present in the wooded reserve area to the west of the block.

APPENDIX B – Investigation Location Plan

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Site Plan Scale 1:500 on A3

Client Name:	BMN Properties Pty Ltd	N 0 15 Metres	Figure Number:	18120-GR-1-1-B
Project Name:	Proposed Residential Development		Figure/Drawing Date:	3/07/2024
Project Location	4 Forest Rd, Warriewood NSW		Report Number:	18120-GR-1-1

APPENDIX C – Borehole Logs and Explanatory Notes

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Explanatory Notes
Drill & Excavation Logs

General

Information obtained from site investigations is recorded on log sheets. Soils and very low strength rock are commonly drilled using a combination of solid-flight augers with a Tungsten-Carbide (TC) bit. Descriptions of these materials presented on the “Borehole Log” are based on a combination of regular sampling and in-situ testing. Rock coring techniques commences once material is encountered that cannot be penetrated using a combination of solid-flight augers and Tungsten-carbide bit. The "Cored Borehole Log" presents data from drilling where a core barrel has been used to recover material - commonly rock.

The "Excavation – Geological Log" presents data and drawings from exposures of soil and rock resulting from excavation of pits or trenches.

The heading of the log sheets contains information on Project Identification, Hole or Test Pit Identification, Location and Elevation. The main section of the logs contains information on methods and conditions, material description and structure presented as a series of columns in relation to depth below the ground surface which is plotted on the left side of the log sheet. The scale is presented in the depth column as metres below ground level.

As far as is practicable the data contained on the log sheets is factual. Some interpretation is included in the identification of material boundaries in areas of partial sampling, the location of areas of core loss, description and classification of material, estimation of strength and identification of drilling induced fractures, and geological unit. Material description and classifications are based on Australian Standard Geotechnical Site Investigations: AS 1726 - 2017 with some modifications as defined below.

These notes contain an explanation of the terms and abbreviations commonly used on the log sheets.

Drilling

Drilling, Casing and Excavating

Drilling methods deployed are abbreviated as follows

Abbreviation	Method
AS	Auger Screwing
ADV	Auger Drilling with V-Bit
ADT	Auger Drilling with TC Bit
BH	Backhoe
E	Excavator
HA	Hand Auger
HQ	HQ core barrel (~63.5 mm diameter core) *
HMLC	HMLC core barrel (~63.5 mm diameter core) *
NMLC	NMLC core barrel (~51.9 mm diameter core) *
NQ	NQ core barrel (~47.6 mm diameter core) *
RR	Rock Roller
WB	Wash-bore drilling

* Core diameters are approximate and vary due to the strength of material being drilled.

Drilling Fluid/Water

The drilling fluid used is identified and loss of return to the surface estimated as a percentage. It is introduced to assist with the drill process, in particular, when core drilling. The introduction of drill fluid/water does not allow for accurate identification of water seepages.

Drilling Penetration/Drill Depth

Core lifts are identified by a line and depth with core loss per run as a percentage. Ease of penetration in non-core drilling is abbreviated as follows:

Abbreviation	Description
VE	Very Easy
E	Easy
F	Firm
H	Hard
VH	Very Hard

Groundwater Levels

Date of measurement is shown.


Standing water level measured in completed borehole


Level taken during or immediately after drilling


Groundwater inflow water level

Samples/Tests

Samples collected and testing undertaken are abbreviated as follows

Abbreviation	Test
ES	Environmental Sample
DS	Disturbed Sample
BS	Bulk Sample
U50	Undisturbed (50 mm diameter)
C	Core Sample
SPT	Standard Penetration Test
N	Result of SPT (*sample taken)
VS	Vane Shear Test
IMP	Borehole Impression Device
PBT	Plate Bearing Test
PZ	Piezometer Installation
HP	Hand Penetrometer Test
HB	Hammer Bouncing

Excavation Logs

Explanatory notes are provided at the bottom of drill log sheets. Information about the origin, geology and pedology may be entered in the "Structure and other Observations" column. The depth of the base of excavation (for the logged section) at the appropriate depth in the "Material Description" column. Refusal of excavation plant is noted should it occur. A sketch of the exposure may be added. Photos are recommended.

Material Description – Soil

Material Description - In accordance with AS 1726-2017

Classification Symbol - In accordance with the Unified Classification System (AS 1726-2017).

Abbreviation	Typical Name
GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
GP	Poorly graded gravels and gravel-sand mixtures, little or no fines, uniform gravels.
GM	Silty gravels, gravel-sand-silt mixtures.
GC	Clayey gravels, gravel-sand-clay mixtures.
SW	Well graded sands, gravelly sands, little or no fines.
SP	Poorly graded sands and gravelly sands; little or no fines, uniform sands.
SM	Silty sand, sand-silt mixtures.
SC	Clayey sands, sand-clay mixtures.
ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.
CL, CI	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
OL	Organic silts and organic silty clays of low plasticity. *
MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, clastic silts.
CH	Inorganic clays of high plasticity, fat clays.
OH	Organic clays of medium to high plasticity, organic silts. *
Pt	Peat and other highly organic soils. *

* Additional details may be provided in accordance with the Von Post classification system (1922).

Organic Soils – Identification using laboratory testing:

Material	Organic Content - % of dry mass
Inorganic	<2
Organic Soil	<2 ≤ 25
Peat	> 25

Organic Soils – Descriptive terms for the degree of decomposition of peat:

Term	Decomposition	Remains	Squeeze
Fibrous	Little or none	Clearly recognizable	Only water No solid
Pseudo-fibrous	Moderate	Mixture of fibrous and amorphous	Turbid water < 50% solids
Amorphous	Full	Not recognizable	Paste > 50% solids

Particle Characteristics – Definitions are as follows:

Fraction	Component (& subdivision)		Size (mm)
Oversize	**Boulders**		> 200
	Cobbles		> 63 ≤ 200
Coarse grained soils	**Gravel**	Coarse	> 19 ≤ 63
		Medium	> 6.7 ≤ 19
		Fine	> 2.36 ≤ 6.7
	Sand	Coarse	> 0.6 ≤ 2.36
		Medium	> 0.2 ≤ 0.6
		Fine	> 0.075 ≤ 0.21
Fine grained soils	**Silt**		0.002 ≤ 0.075
	Clay		< 0.002

Secondary and minor soil components

In coarse grained soils – The proportions of secondary and minor components are generally estimated from a visual and tactile assessment of the soils. Descriptions for secondary and minor soil components in coarse grained soils are as follows.

Designation of components	Percentage fines	Terminology (as applicable)	Percentage accessory coarse fraction	Terminology (as applicable)
Minor	≤ 5	Trace clay / silt	≤ 5	Trace sand / gravel
	> 5 ≤12	With clay / silt	> 5 ≤12	With sand / gravel
Secondary	> 12	Silty or clayey	> 30	Sandy or gravelly

Descriptions for secondary and minor soil components in fine grained soils are as follows.

Designation of components	Percentage coarse grained soils	Terminology (as applicable)
Minor	≤ 5	Trace sand / gravel / silt / clay
	> 5 ≤12	With sand / gravel / silt / clay
Secondary	> 30	Sandy / gravelly / silty / clayey

Plasticity Terms - Definitions for fine grained soils are as follows:

Descriptive Term	Range of Liquid Limit for silt	Range of Liquid Limit for clay
Low Plasticity	≤ 50	≤ 35
Medium Plasticity	N/A	> 35 ≤50
High Plasticity	> 50	> 50

Particle Characteristics

Particle shape and angularity are estimated from a visual assessment of coarse-grained soil particle characteristics. Terminology used includes the following:

Particle shape – spherical, platy, elongated,

Particle angularity – angular, sub-angular, sub-rounded, rounded.

Moisture Condition – Abbreviations are as follows:

D	Dry, looks and feels dry.
M	Moist, No free water on remoulding.
W	Wet, free water on remoulding.

Moisture content of fine-grained soils is based on judgement of the soils moisture content relative to the plastic and liquid limit as follows:

MC < PL	Moist, dry of plastic limit.
MC ≈ PL	Moist, near plastic limit.
MC > PL	Moist, wet of plastic limit.
MC ≈ LL	Wet, near liquid limit.
MC > LL	Wet of liquid limit.

Consistency - of cohesive soils in accordance with AS 1726-2017, Table 11 are abbreviated as follows:

Consistency Term	Abbreviation	Indicative Undrained Shear Strength Range (kPa)
Very Soft	**VS**	< 12
Soft	**S**	12 ≤ 25
Firm	**F**	25 ≤ 50
Stiff	**St**	50 ≤ 100
Very Stiff	**VSt**	100 ≤ 200
Hard	**H**	≥ 200
Friable	**Fr**	-

Density Index (%) of granular soils is estimated or is based on SPT results. Abbreviations are as follows:

Description	Abbreviation	Relative Density	SPT N
Very Loose	**VL**	< 15%	0 - 4
Loose	**L**	15 - 35%	4 - 10
Medium Dense	**MD**	35 - 65%	10 - 30
Dense	**D**	65 - 85%	30 - 50
Very Dense	**VD**	> 85%	> 50

Structures – Fissuring and other defects are described in accordance with AS 1726-2017 using the terminology for rock defects

Origin – Where practicable an assessment is provided of the probable origin of the soil, e.g. fill, topsoil, alluvium, colluvium, residual soil.

MATERIAL DESCRIPTION - ROCK

Material Description – In accordance with AS 1726-2017

Rock Naming – Where possible conventional geological names are used within the logs. Engineering properties cannot be inferred directly from the rock names in the table, but the use of a particular name provides an indicative range of characteristics to the reader. Lithological identification of rock is provided to appreciate the geology of an area, to correlate geological profiles seen in boreholes or to distinguish boulders from bedrock.

Grain Size – Grain size is done in accordance with AS1726-2017 as follows:

For sedimentary rock:

Coarse grained	Mainly 0.6mm to 2mm
Medium grained	Mainly 0.2mmto 0.6mm
Fine grained	Mainly 0.06mm to 0.2mm

For igneous and metamorphic rock:

Coarse grained	Mainly greater than 2 mm
Medium grained	Mainly 0.6mm to 2mm
Fine grained	Mainly less than 2mm

Colour - Rock colour is described in the moist condition.

Texture and Fabric

Frequently used terms:

Sedimentary Rock	Metamorphic Rock	Igneous
Bedded	Banded	Amorphous
Cross-bedded	Cleaved	Crystalline
Folded	Folded	Flow banded
Graded	Foliated	Folded
Interbedded	Gneissose	Lineated
Laminated	Lineated	Massive
Massive	Schistose	Porphyritic

Bedding and fabric:

Description	Spacing
Very Thickly Bedded	> 2m
Thickly Bedded	0.6m to 2m
Medium Bedded	0.2m to 0.6m
Thinly Bedded	60mm to 200mm
Very Thinly Bedded	20mm to 60mm
Thickly Laminated	6mm to 20mm
Thinly Laminated	< 6mm

Degree of development:

Massive	No layering or fabric. Rock is homogeneous.
Indistinct	Layering or fabric just visible, There is little effect on strength properties.
Distinct	Layering or fabric obvious. The rock may break more easily parallel to the fabric.

Features, inclusions, and minor components - Features, inclusions and minor components within the rock material shall be described where those features could be significant such as gas bubbles, mineral veins, carbonaceous material, salts, swelling minerals, mineral inclusions, ironstone or carbonate bands, cross-stratification, or minerals the readily oxidise upon atmospheric exposure.

Moisture content - Where possible descriptions are made by the feel and appearance of the rock using one according to following terms:

Dry	Looks and feels dry.
Moist	Feels cool, darkened in colour, but no water is visible on the surface.
Wet	Feels cool, darkened in colour, water film or droplets visible on the surface.

The moisture content of rock cored with water may not be representative of its in-situ condition.

Durability – Descriptions of the materials durability such as tendency to develop cracks, break into smaller pieces or disintegrate upon exposure to air or in contact with water are provided where observed.

Rock Material Strength – The strength of the rock material is based on uniaxial compressive strength (UCS). The following terms are used:

Term / Abbreviation		Description	UCS (MPa)	Point Load Strength Index (MPa)
Very Low	**VL**	Crumbles under firm blow with sharp end of pick, can be peeled with a knife; too hard to cut a triaxial by hand; 30mm pieces can be broken by hand.	0.6 – 2	0.03 – 0.1
Low	**L**	Easily scored with a knifed; indentations 1-3mm show with firm blows of the pick point; has dull sound under hammer. A piece of core 150mm long 50mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.	2 – 6	0.1 – 0.3
Medium	**M**	Readily scored with a knife; a piece of core 150mm long by 50mm diameter can be broken by hand with difficulty.	6 – 20	0.3 – 1
High	**H**	A piece of core 150mm long by 50mm diameter cannot be broken by hand but can be broken by a pick with a single firm blow; rock rings under hammer.	20 – 60	1 – 3
Very High	**VH**	Hand specimen breaks with pick after more than one blow; rock rings under hammer.	60 – 200	3 – 10
Extremely High	**EH**	Specimen requires many blows with geological pick to break into intact materials; rock rings under hammer.	> 200	> 10

Strengths are estimated and where possible supported by Point Load Index Testing of representative samples. Test results are plotted on the graphical logs as follows:

D	Diametral Point Load Test
A	Axial Point Load Test

Where the estimated strength log covers more than one range it indicates the rock strength varies between the limits shown. Point Load Strength Index test results are presented as $I_{s\,(50)}$ values in MPa.

Weathering – Weathering classification assists in identification but does not imply engineering properties. Descriptions are as follows:

Term / Abbreviation		Description
Residual Soil	**RS**	Material has soil properties. Mass structure and material texture and fabric of original rock not visible, but the soil has not been significantly transported.
Extremely Weathered	**EW**	Material has soil properties. Mass structure, material texture and fabric of original rock are still visible.
Highly Weathered	**HW**	Material is completely discoloured, significant decrease in strength from fresh rock.
Moderately Weathered	**MW**	Material is `completely discoloured, little or no change of strength from fresh rock.
Slightly Weathered	**SW**	Partly stained or discoloured, little or no change to strength from fresh rock.
Fresh	**FR**	No signs of mineral decomposition or colour change.

Alteration – Physical and chemical changes of the rock material due to geological processes by fluids at depth at pressures and temperatures above atmospheric conditions. Unlike weathering, alteration shows no relationship to topography and may occur at any depth. When altered materials are recognized, the following terms are used:

Term / Abbreviation				Description
Extremely Altered		**XA**		Material has soil properties. Structure, texture, and fabric of original rock are still visible. The rock name is replaced with the name of the parent material, e.g., Extremely Altered basalt. Soil descriptive terms are used.
Highly Altered	**Distinctly altered**	**HA**	**DA**	The whole of the rock material is discoloured. Rock strength is changed by alteration. Some primary minerals are altered to clay minerals. Porosity may be higher or lower due to loss of minerals or precipitation of secondary minerals in pores.
Moderately Altered	**Distinctly altered**	**MA**	**DA**	The whole of the rock material is discoloured. Little or no change of strength from fresh rock. The term 'Distinctly Altered' is used where it is not practicable to distinguish between 'Highly Altered' and 'Moderately Altered'. Distinctly Altered is defined as follows: - The rock may be highly discoloured; - Porosity may be higher due to mineral loss; or may be lower due to precipitation of secondary minerals in pores; and - Some change of rock strength.
Slightly Altered		**S**		Rock is slightly discoloured. Little or no change of strength from fresh rock.

Alteration is only described in the context of the project where it has relevance to the civil and structural design.

Defect Descriptions

General and Detailed Descriptions – Defect descriptions are provided to suit project requirements. Generalized descriptions are used for some projects where it is unnecessary to describe each individual defect in a rock mass, or where multiple similar defects are present which are too numerous to log individually. The part of the rock mass to which this applies is delineated.

Detailed descriptions are given of defects judged to be particularly significant in the context of the project. For example, crushed seams in an apparently unstable slope. As a minimum, general descriptions outlining the number of defect sets within the rock mass and their broad characteristics are provided where it is possible to do so.

Defect Type – Defect abbreviations are as follows:

BP	Bedding parting	**SSM**	Sheared seam	**DB**	Drilling break
JT	Joint	**CS**	Crushed seam	**HB**	Handling break
SS	Shear surface	**SM**	Infilled seam		
SZ	Sheared zone	**EWS**	Extremely weathered seam		

Sheared surfaces, sheared zones, sheared seams, and crushed seams are generally faults in geological terms.

Defect Orientation

For oriented core: The dip and dip direction are recorded as a two-digit and three-digit number separated by a slash, are collected e.g., 50°/240° and there is not core loss that could obscure core orientation. If alternative measurements are made, such as dip and strike or dip direction relative to magnetic north this shall be documented.

For non-oriented core: The dip is recorded as a two-digit number, e.g., 10°. In vertical boreholes the dip is generally measured relative to the horizontal plan. If the borehole is inclined the dip is generally measured from the core axis.

Surface Roughness – Defect surface roughness is described as follows:

VR	**Very rough**	Many large surface irregularities with amplitude generally more than 1 mm.
RO	**Rough**	Many small surface irregularities with amplitude generally less than 1 mm.
SO	**Smooth**	Smooth to touch. Few or no surface irregularities.
PO	**Polished**	Shiny smooth surface
SK	**Slickensided**	Grooved or striated surface, usually polished.

Surface Shape – Defect surface roughness is described as follows:

PL	**Planar**	The defect does not vary in orientation.
CU	**Curved**	The defect has a gradual change in orientation
UN	**Undulating**	The defect has a wavy surface.
ST	**Stepped**	The defect has one or more well defined steps
IR	**Irregular**	The defect has many sharp changes of orientation

Defect Infilling – Common abbreviation as follows:

Ca	Calcite	**Fe**	Iron Oxide	**Qz**	Quartz
Cy	Clay	**MS**	Secondary mineral	**X**	Carbonaceous

Defect Coatings and Seam Composition - Coatings are described using the following terms:

CN	**Clean**	No visible coating.
SN	**Stained**	No visible coating but surfaces are discoloured.
VN	**Veneered**	A visible coating of soil or mineral, too thin to measure; may ne patchy.
CO	**Coating**	A visible coating up to 1 mm thick. Soil in-fill greater than 1 mm shall be described using defect terms (e.g., infilled seam). Defects greater than 1 mm aperture containing rock material great described as a vein.

Defect Spacing, Length, Openness and Thickness – Described directly in millimetres and metres. In general descriptions, half order of magnitude categories is used, e.g. joint spacing typically 100 mm to 300 mm, sheared zones 1m to 3m thick.

Depending on project requirements and the scale of observation, spacing may be described as the mean spacing within a set of defects, or as the spacing between all defects within the rock mass. Where spacing is measured within a specific set of defects, measurements shall be made perpendicular to the defect set.

Where significant, the nature of the defect end condition is recorded in the context of the scale of the exposure.

Block Shape – Where it is considered significant, block shape should be described using terms given in Table 23, AS 1725:2017.

Stratigraphic Unit – Geological maps related to the project are used for the designation of lithological formation name and, where possible geological unit name, e.g., Bringelly Shale, Potts Hill Sandstone Member.

Core Loss – Core loss occurs when material is lost during the drilling process It is shown at the bottom of the run unless otherwise indicated where core loss is known.

Total Core Recovery – The percentage of rock recovered excluding core loss per core run.

Defect Spacing – The spacing of successive defects or the mean spacing for relatively broken core.

Fracture Index – Which is the number defects per metre of core.

Rock Quality Designation (RQD) – The percentage of sound core pieces of 100mm or greater per core run and is calculated using Deere et al. (1989) method.

Rock Classification System – For design purpose, Sydney Rock Mass Classification System (Pells et al. 1998, 2019) is adopted.

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Geotechnical Log - Borehole

BH101

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,082.98	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,723.60	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 30.75 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				SW	FILL: Gravelly SAND, fine to medium grained, dark brown, fine to medium gravel, with building refuse materials.	M		Fill	3				
									2				
									4				
		0.5		CL-CI	FILL: Sandy CLAY, low to medium plasticity, fine to medium grained sand, with fine to medium sized gravel, red brown, moderately compacted, rounded clasts .	w < PL	MC	Fill	4				
									4				
		0.75		SC	Clayey Gravelly SAND, fine to medium grained, red brown, fine to medium sized ironstone gravel, low plasticity clay.	M	D	Residual	2				
									4				
		1							3				
									4	2, 6, 7, (N = 13)	100		
									5				
		2											
										4, 6, 10, (N = 16)	100		
		3		CL	Sandy Gravelly CLAY, low plasticity, red brown, fine to medium sized gravel, fine grained sand.	w < PL	St	Residual					

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Geotechnical Log - Borehole

BH101

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,082.98	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,723.60	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 30.75 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				CL	Sandy Gravelly CLAY, low plasticity, red brown, fine to medium sized gravel, fine grained sand.	w < PL	St	Residual		12, 15, 6/0mm, (N = R)			
		5			**BH101 Terminated at 5m (Target depth reached.)**								
		6											
		7											

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Geotechnical Log - Borehole

BH102

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,091.51	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,748.52	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 27.09 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
		0		SC	FILL: Clayey SAND, fine to medium grained, dark brown, with fine to medium sized gravel, poorly compacted.	M	PC	Fill	1 5 8 5				
		0.7		SC	Clayey SAND, fine to medium grained, pale brown, low plasticity clay, with fine to medium sized gravel.		MD	Residual	4 5 6 6 6 6	3, 6, 9, (N = 15)			
		1											
		2								7, 12, 15, (N = 27)			
		3											

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Geotechnical Log - Borehole

BH102

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,091.51	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,748.52	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 27.09 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing			Samples	Remarks
									DCP	SPT	PP		
				SC	Clayey SAND, fine to medium grained, pale brown, low plasticity clay, with fine to medium sized gravel.		MD	Residual		10, 15, 25/50mm (N = R)			
		5			**BH102 Terminated at 5m (Target depth reached)**								
		6											
		7											

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Geotechnical Log - Borehole

BH103

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,094.75	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,760.75	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 25.61 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				SC	FILL: Gravelly Clayey SAND. medium grained, dark brown and dark grey, medium plasticity clay, fine to medium subrounded gravel, appears poorly to moderately compacted.	M	PC	Fill	1 5 9 6				
		0.6		SC	Clayey SAND, fine to medium grained, pale brown, low plasticity clay, trace fine sized gravel.		MD	Residual	3 4 8 5 5 6				
		1											
		2								3, 10, 13 (N = 23)			
		2.2		CL-Cl	Sandy CLAY, low to medium plasticity, red brown, fine to medium grained sand, with fine to medium sized gravel.	w ≈ PL	St-VSt	Residual					
		3								12, 15, 25/50mm (N = R)			

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Geotechnical Log - Borehole

BH103

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,094.75	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,760.75	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 25.61 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				CL-Cl	Sandy CLAY, low to medium plasticity, red brown, fine to medium grained sand, with fine to medium sized gravel.	w ≈ PL	St-VSt	Residual					
		4.2		Cl	CLAY, medium plasticity, grey, trace fine sized gravel.	w < PL	VSt	Residual		11, 15, 25/50mm (N = R)			
		5			**BH103 Terminated at 5m (Target depth reached.)**								
		6											
		7											

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Geotechnical Log - Borehole

BH104

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,097.80	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,776.38	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 24.29 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 3.5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				SC	FILL: Gravelly Clayey SAND, fine to medium grained, dark brown, medium plasticity clay, fine to medium sized gravel, appears poorly compacted.	M	PC	Fill	2 4 8 15 10				
		0.75		SC	Clayey SAND, fine to medium grained, pale brown, low plasticity clay, trace fine sized gravel.		MD	Residual	6 3 5 7 9	5, 4, 2, (N = 6)			
		1											
		2								7, 9, 12, (N = 21)			
		3											
		3.2		GW	GRAVEL, fine to medium, angular to subangular, ironstone, red brown	D		Extremely Weathered Material					
					BH104 refusal at 3.5m (practical refusal on ironstone bed)								

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Geotechnical Log - Borehole

BH105

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,096.74	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,796.46	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 22.99 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 4.25 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
		0		SW	FILL: Gravelly SAND, fine to medium grained , grey, fine to medium sized gravel, trace low plasticity clay, appears poorly compacted.	M	PC	Fill	2				
									4				
									5				
		0.5		CL-CI	Sandy CLAY, low to medium plasticity, pale brown, medium grained sand, trace fine sized gravel.	w ≈ PL	F-St	Residual	2				
									4				
									5				
		1							5				
									4				
									6	2, 4, 9, (N = 13)			
									7				
		2											
		2.5		SC	Clayey SAND, fine to medium grained, red brown, trace fine to medium sized gravel (ironstone gravel content increasing with depth).	M	MD-D	Residual		8, 11, 12, (N = 23)			
		3											

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Geotechnical Log - Borehole

BH105

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,096.74	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,796.46	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 22.99 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 4.25 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing			Samples	Remarks
									DCP	SPT	PP		
				SC	Clayey SAND, fine to medium grained, red brown, trace fine to medium sized gravel (ironstone gravel content increasing with depth).	M	MD-D	Residual		17, 13/100mm (N = R)			
		5			**BH105 Terminated at 4.25m (SPT Refusal on Inferred Low Strength Sandstone)**								
		6											
		7											

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Geotechnical Log - Borehole

BH106

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,076.49	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,775.19	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 29.81 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				SM	FILL: Gravelly Silty SAND, fine grained, grey, fine sized gravel, with building refuse materials, appears poorly compacted	D	PC	Fill	13 4 8 7 6	5, 6, 7, (N = 13)			
		1											
		1.6		SW	FILL: Gravelly SAND, fine to medium grained, red mottled yellow, fine to medium sized gravel, sandstone and ironstone gravels, colour grading to grey with depth		MD	Fill		5, 5, 3, (N = 8)			
		2											
		3											
		3		CL-CI	Gravelly Sandy CLAY, low to medium plasticity, red brown, fine grained sand, fine to medium sized gravel.	w < PL	St	Residual		10, 9/60mm, (N = R)			

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Geotechnical Log - Borehole

BH106

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,076.49	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,775.19	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 29.81 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				CL-Cl	Gravelly Sandy CLAY, low to medium plasticity, red brown, fine grained sand, fine to medium sized gravel.	w < PL	St	Residual					
		4.5		CL	Sandy CLAY, low plasticity, red mottled pale grey, medium grained sand, trace fine sized gravel.		St-VSt	Residual					
		5			**BH106 Terminated at 5m (Target depth reached.)**								
		6											
		7											

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Geotechnical Log - Borehole

BH107

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,076.50	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,753.91	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 30.26 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				SC	FILL: Clayey SAND, fine to medium grained, pale brown, medium plasticity clay, with fine to medium sized gravel, with building refuse materials, appears poorly to moderately compacted.	M	PC-MC	Fill	4				
									4				
									3				
									3				
									5	1, 2, 4, (N = 6)			
									8				
		1							5				
									3				
									5				
									5				
		1.7		CI	Clayey to sandy CLAY, medium plasticity, red brown, fine grained sand, with fine to medium sized gravel.	w < PL	St-VSt	Residual		7, 10, 10, (N = 20)			
		2											
		3											

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Geotechnical Log - Borehole

BH107

UTM	: 56H	**Drill Rig**	: GT-10	**Job Number**	: 18120
Easting (m)	: 341,076.50	**Driller Supplier**	: Geonalysis	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,753.91	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 30.26 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 5 m BGL	**Date**	: 20/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				CI	Clayey to sandy CLAY, medium plasticity, red brown, fine grained sand, with fine to medium sized gravel.	w < PL	St-VSt	Residual		12, 15, 5/0mm, (N = R)			
		5			**BH107 Terminated at 5m**								
		6											
		7											

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Geotechnical Log - Borehole

HA1

UTM	: 56H	**Drill Rig**	: Hand Auger	**Job Number**	: 18120
Easting (m)	: 341,075.83	**Driller Supplier**	: Alliance	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,715.53	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 32.43 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 1.5 m BGL	**Date**	: 24/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
		0.3		SM	FILL: Silty SAND, fine to medium grained, dark grey, with fine sized gravel, appears poorly compacted.	M	PC	Fill					
				SW	Gravelly SAND, fine to medium grained , red brown, fine sized gravel.		MD	Residual					
		1											
					HA1 refusal at 1.5m								
		2											
		3											

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Geotechnical Log - Borehole

HA2

UTM	: 56H	**Drill Rig**	: Hand Auger	**Job Number**	: 18120
Easting (m)	: 341,059.48	**Driller Supplier**	: Alliance	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,720.03	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 35.40 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 1.2 m BGL	**Date**	: 24/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
				SM	FILL: Silty SAND, fine to medium grained, dark grey, with fine sized gravel, appears poorly compacted.	M	PC	Fill					
		0.2		SW	Gravelly SAND, fine to medium grained , red brown, fine to medium sized gravel.		MD	Residual					
		1											
		2			**HA2 refusal at 1.2m**								
		3											

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Geotechnical Log - Borehole

HA3

UTM	: 56H	**Drill Rig**	: Hand Auger	**Job Number**	: 18120
Easting (m)	: 341,049.34	**Driller Supplier**	: Alliance	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,722.24	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 37.47 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 1.6 m BGL	**Date**	: 24/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
		0		SM	FILL: Silty SAND, fine to medium grained , dark grey, with fine sized gravel, appears poorly compacted.	M	PC	Fill					
		0.15		SP	Gravelly SAND, fine to medium grained , red brown, fine sized gravel.		MD	Residual					
		1											
		2			**HA3 refusal at 1.6m**								
		3											

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Geotechnical Log - Borehole

HA4

UTM	: 56H	**Drill Rig**	: Hand Auger	**Job Number**	: 18120
Easting (m)	: 341,054.58	**Driller Supplier**	: Alliance	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,734.10	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 35.30 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 1.6 m BGL	**Date**	: 24/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
		0		SM	FILL: Silty SAND, fine to medium grained , dark grey, with fine sized gravel, appears poorly compacted.	M	PC	Fill					
		0.3		SP	Gravelly SAND, fine to medium grained , red brown, fine sized gravel.		MD	Residual					
		1											
		2			**HA4 refusal at 1.6m**								
		3											

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Geotechnical Log - Borehole

HA5

UTM	: 56H	**Drill Rig**	: Hand Auger	**Job Number**	: 18120
Easting (m)	: 341,026.81	**Driller Supplier**	: Alliance	**Client**	: BMN Properties Pty Ltd
Northing (m)	: 6,271,732.83	**Logged By**	: TE	**Project**	: Proposed Residential Development
Ground Elevation	: 41.57 (m)	**Reviewed By**	: LT	**Location**	: 4 Forest Road, Warriewood NSW, Australia
Total Depth	: 1.1 m BGL	**Date**	: 24/06/2024	**Loc Comment**	:

Drilling Method	Water	Depth (m)	Graphic Log	Classification Code	Material Description	Moisture	Consistency/Density	Soil Origin	Testing: DCP	Testing: SPT	Testing: PP	Samples	Remarks
		0.3		SM	FILL: Silty SAND, fine to medium grained, with fine sized gravel, dark grey, poorly compacted.	M	PC	Fill					
				SW	Gravelly SAND, fine to medium grained, fine sized gravel, red brown.		MD	Residual					
		1											
					HA5 refusal at 1.1m								
		2											
		3											

APPENDIX D – Dynamic Cone Penetrometer Testing Results

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Dynamic Cone Penetrometer (DCP) Test Report

Client	BMN Properties Pty Ltd	**Report Number**	18120-DCP-01
Project Name	Residential Development	**Project Number**	18120
Project Location	4 Forest Road, Warriewood	**Date Tested**	20/6/24
Test Method	AS 1289.6.3.2		

Test Number	**BH101**	**BH102**	**BH103**	**BH104**	**BH105**
Test Locations	Refer to Drawing 18120-GR-1-1-B				
Surface Material					
Surface Conditions					
Approximated RL (m AHD)					
0.00 – 0.15	3	1	1	2	2
0.15 – 0.30	2	5	5	4	4
0.30 – 0.45	4	8	9	8	5
0.45 – 0.60	4	5	6	15	2
0.60 – 0.75	4	4	3	10	4
0.75 – 0.90	2	5	4	6	5
0.90 – 1.05	4	6	8	3	5
1.05 – 1.20	3	6	5	5	4
1.20 – 1.35	4	6	5	7	6
1.35 – 1.50	5	6	6	9	7
1.50 – 1.65					
1.65 – 1.80					
1.80 – 1.95					
1.95 – 2.10					
2.10 – 2.25					
2.25 – 2.40					
2.40 – 2.55					
2.55 – 2.70					

Notes: This test report is intended to be read in conjunction with the geotechnical report by Alliance Geotechnical (ref: 18120-GR-1-1).

Dynamic Cone Penetrometer (DCP) Test Report

Client	BMN Properties Pty Ltd	**Report Number**	18120-DCP-01
Project Name	Residential Development	**Project Number**	18120
Project Location	4 Forest Road, Warriewood	**Date Tested**	20/6/24
Test Method	AS 1289.6.3.2		

Test Number	**BH106**	**BH107**	**HA1**	**HA2**	**HA3**
Test Locations	Refer to Drawing 18120-GR-1-1-B				
Surface Material					
Surface Conditions					
Approximated RL (m AHD)					
0.00 – 0.15	13	4	5	1	3
0.15 – 0.30	4	4	3	3	3
0.30 – 0.45	8	3	5	4	3
0.45 – 0.60	7	3	6	4	3
0.60 – 0.75	6	5	2	2	4
0.75 – 0.90	5	8	7	4	5
0.90 – 1.05	9	5	6	3	3
1.05 – 1.20	11	3	5	3	7
1.20 – 1.35	5	5	9		5
1.35 – 1.50	6	5	7		4
1.50 – 1.65					2
1.65 – 1.80					
1.80 – 1.95					
1.95 – 2.10					
2.10 – 2.25					
2.25 – 2.40					
2.40 – 2.55					
2.55 – 2.70					

Notes: This test report is intended to be read in conjunction with the geotechnical report by Alliance Geotechnical (ref: 18120-GR-1-1).

Dynamic Cone Penetrometer (DCP) Test Report

Client	BMN Properties Pty Ltd	**Report Number**	18120-DCP-01
Project Name	Residential Development	**Project Number**	18120
Project Location	4 Forest Road, Warriewood	**Date Tested**	20/6/24
Test Method	AS 1289.6.3.2		

Test Number	HA4	HA5	DCP1	DCP2	DCP3	DCP4
Test Locations	Refer to Drawing 18120-GR-1-1-B					
Surface Material						
Surface Conditions						
Approximated RL (m AHD)						
0.00 – 0.15	2	4	4	4	4	3
0.15 – 0.30	2	2	3	6	3	4
0.30 – 0.45	3	2	3	7	3	4
0.45 – 0.60	5	5	5	4	6	4
0.60 – 0.75	4	6	7		5	3
0.75 – 0.90	5	4	8		3	
0.90 – 1.05	4	7	5		6	
1.05 – 1.20	4	4	6		6	
1.20 – 1.35	3		7		5	
1.35 – 1.50	8		3		3	
1.50 – 1.65	3				4	
1.65 – 1.80					3	
1.80 – 1.95						
1.95 – 2.10						
2.10 – 2.25						
2.25 – 2.40						
2.40 – 2.55						
2.55 – 2.70						

Notes: This test report is intended to be read in conjunction with the geotechnical report by Alliance Geotechnical (ref: 18120-GR-1-1).

APPENDIX E – AGS 2007 Risk Assessment Tables

APPENDIX A

DEFINITION OF TERMS

INTERNATIONAL UNION OF GEOLOGICAL SCIENCES WORKING GROUP ON LANDSLIDES, COMMITTEE ON RISK ASSESSMENT

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Hazard – A condition with the potential for causing an undesirable consequence (*the landslide*). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the likelihood of their occurrence within a given period of time.

Elements at Risk – Meaning the population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Probability – The likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes. Probability is expressed as a number between 0 and 1, with 0 indicating an impossible outcome, and 1 indicating that an outcome is certain.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.

Likelihood – used as a qualitative description of probability or frequency.

Temporal Probability – The probability that the element at risk is in the area affected by the landsliding, at the time of the landslide.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Risk Analysis – The use of available information to estimate the risk to individuals or populations, property, or the environment, from hazards. Risk analyses generally contain the following steps: scope definition, hazard identification, and risk estimation.

Risk Estimation – The process used to produce a measure of the level of health, property, or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis, and their integration.

Risk Evaluation – The stage at which values and judgements enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental, and economic consequences, in order to identify a range of alternatives for managing the risks.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk, and the implementation, or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Management – The complete process of risk assessment and risk control (*or risk treatment*).

Individual Risk – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental, and other losses.

Acceptable Risk – A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.

Tolerable Risk – A risk that society is willing to live with so as to secure certain net benefits in the confidence that it is being properly controlled, kept under review and further reduced as and when possible.

In some situations risk may be tolerated because the individuals at risk cannot afford to reduce risk even though they recognise it is not properly controlled.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Note: Reference should also be made to Figure 1 which shows the inter-relationship of many of these terms and the relevant portion of Landslide Risk Management.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

RISK LEVEL IMPLICATIONS

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

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