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Our Ref: PSM5226-002L Rev1

11 June 2024

Associate
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Attention: Leesa Hovendene

Dear Leesa

RE: RISK ASSESSMENT. 10-12 VIEW POINT ROAD, MCRAE

1. Introduction

PSM were commissioned by Harwood Andrews (**HA**) on behalf of Mornington Peninsula Shire (**MPS**) to carry out a Landslide Risk Assessment (**LRA**) at 10-12 View Point Road, McRae (the "**Site"**) in accordance with the Australian Geomechanics Society (**AGS**) Guidelines on Landslide Risk Assessment (AGS, 2007). The scope of the LRA is restricted to the following:

1. PSM observations limited to a Site walkover only. PSM will outline reliance on the factual data set out in the provided documentation.
2. Risk to life at the following properties:
   a. 10-12 View Point Road (referred to herein as property "**P1**").
   b. 2 Penny Lane (referred to herein as property "**P2**").
   c. 3/613 Pt Nepean Road (referred to herein as property "**P3**").
3. The following modes of failure:
   a. Translational slide.
   b. Debris flow.

PSM has not been provided:

- A feature survey of the Site
- Recent development plans

2. Background documents

2.1 CivilTest Documents

PSM has considered a series of CivilTest Pty Ltd (**CivilTest**) documents.

The CivilTest report 1222044-3 (24 March 2023) indicates:

- Boreholes drilled at the toe of the slope in Penny Lane encountered landslide debris, Inset 1 (Section 2.1 of 1222044-3 (24 March 2023)).
- Boreholes 1 and 2 encountered landslide debris 1.2 m and 0.7 m thick respectively (Appendix C of 1222044-3 (24 March 2023)). PSM has assumed that 0.7 m of fill reported at the toe of the slope is landslide debris.
- Geotechnical laboratory testing completed on borehole 1 indicates that all four samples (depths of 3m, are a Sandy CLAY of low plasticity with between 36 to 48% fines and fine to coarse sand (typically medium grained).
- The boreholes were drilled on 1 March 2023.
- Wet soils were reported in:
  - Borehole 1 at 2.6 m below ground level (**bgl**).
  - Borehole 2 at 2.8 m bgl.
  - Borehole 3 between 1.8 m and 5.2 m bgl.

2.1 Soil Profile

Three boreholes (BH) were drilled by a mechanical auger at the approximate locations shown on the attached plan. The two boreholes drilled at the toe of the slope on Penny Lane revealed that the soil profile consists of residual material from the landslip made up of silty SAND FILL and sandy CLAY FILL, overlying Colluvial material consisting of natural sandy CLAY, SAND and gravelly SAND. This is further underlain by Aeolian silty SAND.

The borehole drilled at the top of the slope revealed that the soil prpfile consists of silty SAND FILL, overlying natural Aeolian SAND followed by sandy CLAY and silty CLAY with sand.

Groundwater was encountered in the boreholes at depths of 2.6 metres in borehole 1 and 2.8 metres in borehole 2.

Inset 1: CivilTest description of debris flow as "fill"

2.2 Stantec Documents

The Stantec Geotechnical Assessment ((V220600Report01.1, 7/12/2022) referred to herein as the "**Stantec GA**") indicates that:

- The thickness of the landslide was possibly less than 0.5m.
- Seepage was observed in the head scarp, Inset 2.
- Probabilities of landslide hazards vary from 1 in 2 years to 1 in 20 years.
- The photographs of the debris flow zone indicate to PSM that the depth/thickness of material evacuated from the debris flow zone is inferred to be less than 0.5 m.
- Existing retaining walls showed signs of tilting or overturning.

Figure 4-2 shows the main scarp of the landslide where it has undermined the existing stairs. It can be seen that the failure surface of the landslide runs parallel to the ground surface. The weathered granite is exposed in the failure surface. Looking at the side flank it can be seen that the thickness of soil that would have overlain the weathered granite is relatively shallow, possibly less than 0.5m.

Water was observed to be seeping from the head scarp at several locations more than 24 hours after the storm occurred. These seeps appear to be associated with natural springs further up slope.

Inset 2: Excerpt from Section 4.1 of the Stantec GA

2.3 Nearmap and Google Street View

PSM has considered the readily available Nearmap and Google Street view images which indicate:

- A series of trees were removed on property P1 between April 2021 and September 2021, Appendix A1 & A2. This is supported by street view images between February 2018 and October 2022, Appendix A3 & A4.
- The translational slide scarp has approximate dimensions of 8 m x 5 m (in plan), Appendix A5.
- The debris flow:
  - Initiated from an area approximately 20m southeast of the property P1 northwestern boundary and was approximately 5 m wide.
  - Run out was approximately 5 m into properties P2 and P3, Appendix A6.

2.4 Rainfall data

2.4.1 Rosebud weather station

The Rosebud weather station climate data (Station ID: 086213, Climate Data Online - Map search (bom.gov.au), accessed 31 October 2023) indicates:

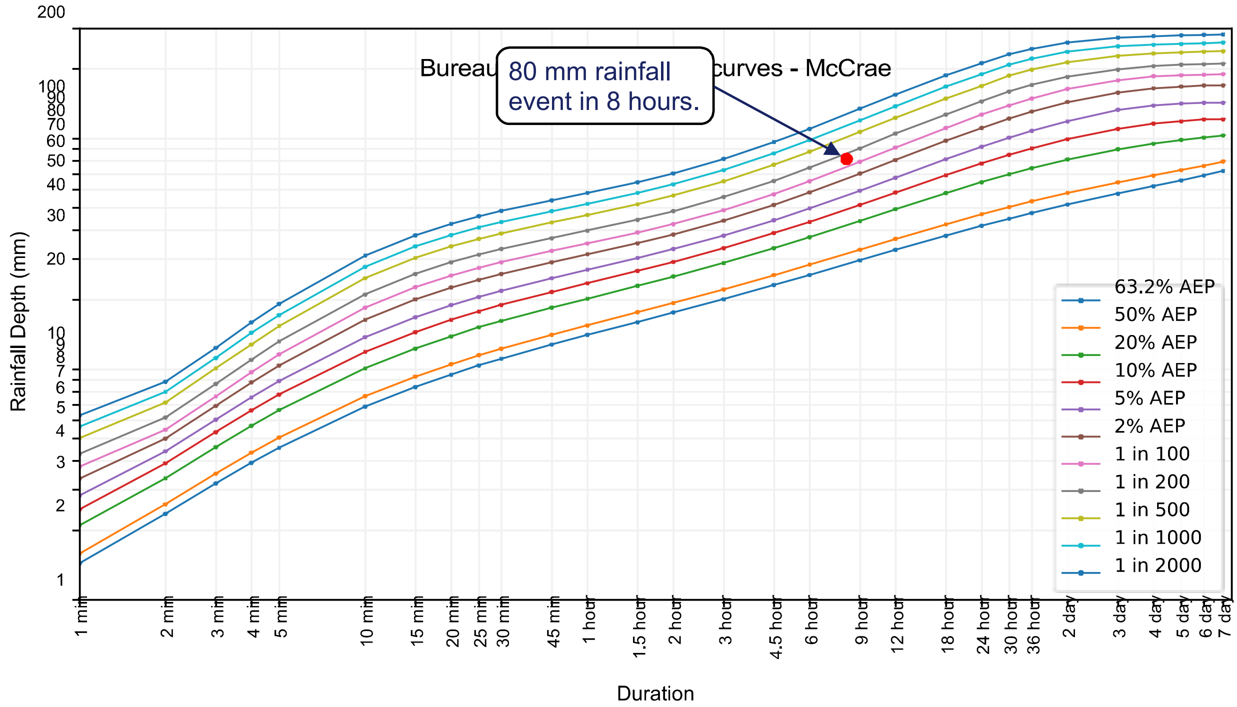
- On 14 November 2022 approximately 80mm of rainfall was recorded and reported to 9am over the preceding 24-hour period. I herein refer to this rainfall as the "**Rain Event**".
- The Rain Event was the fourth highest 24 hour recorded rainfall since records began
- The 30-day cumulative rainfall on the 14 November 2022 was 133 mm
- The 30-day cumulative rainfall on the 1 March 2023, when the CivilTest boreholes were drilled was 47 mm
- The 30-day cumulative rainfall on 23 October 2023, when the PSM site visit was undertaken was 12.5 mm
- The dataset commenced in 1927 (albeit is missing significant data) and there are at least 19 events where the 30-day cumulative rainfall has exceeded 150 mm.

2.4.2 Intensity Frequency Duration

The Australian Rainfall and Runoff Intensity Frequency Duration (IFD) curves, published by BOM (http://www.bom.gov.au/water/designRainfalls/revised-ifd/, accessed 4 December 2023) is presented in Inset 3.

These records indicate that:

- The Rain Event intensity over the 8-hour period had 1 in 100 years to 1 in 200 years probability of occurring
- 80 mm of rainfall in a 24-hour period has a 1 in 20 probability of occurring in any given year
- The Rain Event was an infrequent and intense event.



Inset 3: BOM IFD curves for McCrae, with Rain Event marked

2.4.3 Weather Chasers

Review of the Melbourne radar archive (Melbourne Radar - 128km Rain Rate (theweatherchaser.com), accessed 31/10/2023) indicates that:

- The majority of moderate to heavy rainfall was observed between 11pm on 13/11/2023 and 7am on 14/11/2023, Figures A7 to A8 of Appendix A
- Some showers were recorded for the remainder of the 14/11/2023, Figure A9 of Appendix A.

2.5 Coastal LiDAR

The Coastal LiDAR elevation data[1] captured by the Department of Sustainability and Environments between April 2007 and October 2008 has been used for understanding of the Site topography and development of cross sections and the Geotechnical Model (Refer Section 4.1).

3. Site Visit

A Site visit was completed by PSM on 23 October 2023. Selected photographs are included in Appendix B. The Site Visit was conducted during dry weather and with no rainfall reported by the BOM Rosebud Country Club weather station in the 7 days prior to the Site Visit.

The Landslide had the following characteristics:

- It initiated in the upper to middle portion of the slope, with the rear scarp approximately at the base of the Stairs, Photo 1 Appendix B
- It was inferred to have initiated as a translational slide followed by mobilisation of failed material into a debris flow which was deposited at the toe of the slope, Photo 2 Appendix B
- The Landslide had three distinct zones being:

[1] Published on www.data.vic.gov.au as VicMap Elevation Coastal 1 m DEM and 0.5m Contours

- A steep "**Upper Zone**" where the initial translational sliding occurred with approximate dimensions of 8 to 10 m wide x 8 to 10 m long x 0.3 m thick, Photo 3 Appendix B.
- A steep "**Middle Zone**" approximately 15 m long by 3 m wide through which the debris flow travelled, with some scour and erosion, Photo 3 Appendix B.
- A flatter "**Lower Zone**" of debris runout where the debris flow deposited at the toe of the slope, Photo 3 Appendix B. The approximate dimensions of deposited debris are 8 to 10 m wide, 9 to 10 m long, and 0.2 to 0.7 m thick.

- Disturbed ground that had undergone translational sliding but did not mobilise into a debris flow was observed on the right (western) flank of the Landslide, Photo 4 Appendix B
- The total area of instability was not able to be mapped in detail due to poor access and vegetation. There is still uncertainty as to the width of the unstable ground. It is possible that there is additional unstable ground to the left (east) of the observed Landslide.
- A lack of prominent backscarp, Photo 5 Appendix B, with minor steepening observed in the backscarp area and with a slope angle of approximately 45 degrees.

The following soils were observed and logged in the Landslide area:

- Residual Granite on the failure surface in the Upper Zone. This material was logged as Sandy CLAY, low to medium plasticity, pale grey, brown to mottled orange grey brown, fine to coarse grained granitic sands, dry to moist, very stiff to hard. It is possible this material is cemented Surficial Sands, Table 1, as this unit is derived from eroded Residual Granite.
- Surficial sands were found to cover the upper escarpment slope. This material was logged as Silty SAND to Sandy SILT, fine to medium grained SAND/low plasticity SILT, brown to pale grey, brown, dry, weakly cemented.
- Possible older (pre 2022 Landslide) Colluvium was observed in the lower slopes. It was logged as Silty/Clayey SAND, fine to coarse grained granitic sand, brown, trace 10-100 mm granitic gravel/cobbles, dry to moist, loose to medium dense.
- Newer Colluvium was observed in the debris flow deposits and logged as Silty SAND, fine to medium grained, pale brown, dry, loose.

The Landslide characteristics observed during the Site visit were in general agreement with those described in the Stantec GA which were made shortly after the landslide occurred (refer Section 2.2).

The Site had the following characteristics:

- Located on a prominent escarpment. The escarpment is approximately 25 m high, with an overall slope angle of 35°. The escarpment has a concave (in section) profile, with slope angles of approximately 30° in the lower slope and 40° in the upper slope. The ground above and below the escarpment has flat to gentle slopes with typical slope angles of 0 to 5°.
- No evidence of current or historic large-scale landslide features that affect the full height of the escarpment, e.g., stepped ground, hummocky ground, landslide scarps, etc.
- Groundwater was observed to be seeping from the slope to the east of the stairs, Photo 6 Appendix B.
- A variety of water infrastructure was observed across the Site, Photo 7 Appendix B, including:
  - Subsurface 'agi-drains'
  - Water pipes including taps. A 20 to 25 mm diameter blueline polyethylene pipe with a damaged connection was observed near the top of the stairs, immediately above the rear scarp of the landslide.
- A series of paths had been constructed across the slope to provide access from the top to the bottom of the escarpment, Photo 8 & 9 Appendix B. The paths are constructed from varying materials. Other infrastructure associated with the paths include minor RWs, board walks and stairs.

- The slope above the Landslide area was consistent with adjacent slopes outside of the Landslide area, with an approximate slope angle of 40°. A combination of minor RWs and vegetation have been constructed/planted in this area.
- The condition of RWs across the Site was generally poor, with overturning and bulging RWs observed. A section of RW to the east of the Landslide had significant tilts. This indicates possible instability in the ground above the RW and possible structural or geotechnical failure of the RW, Photo 10 Appendix B. RWs appear to be leaning more than as documented by Stantec (refer Section 2.2).
- Numerous fallen trees were observed across the escarpment slope, Photo 11 Appendix B. Most of the failed trees appear to have failed from causes unrelated to the Landslide, i.e., wind or poor root embedment. At least one tree appears to have fallen because of the Landslide.
- Minor erosion was observed on unvegetated areas of the escarpment.
- Leaning and curved trees were observed on the escarpment, suggesting possible creep movement of the slope, Photo 12 Appendix B.

Additional observations were made in the broader Site area to understand larger scale slope processes. These observations include:

- Anthony's Nose, approximately 600 m to the northeast of the site, is a headland where the escarpment protrudes into Port Phillip Bay. It is the only coastal exposure of Dromana Granite, as such it provides useful insights into ground conditions and slope performance. Key observations include:
  - Natural voids and internal erosion (i.e., piping) is common in the upper soil profile, Photo 13 Appendix B.
  - A sub vertical cliff profile in extremely weathered and highly weathered granite, Photo 14 Appendix B. PSM note the sub-vertical profile may be the result of road construction activities in the 1920's and 1930's.
  - Granite rock is exposed in shore platform below the road.
  - Steep to sub-vertical upper slopes is inferred to fail by undercutting and erosion of the lower slope leading to toppling/wedge style failures, Photo 15 Appendix B.
- A new stormwater drainage system has been constructed in View Point Rd. A constant flow of water was observed to be running in this drainage system.
- The Site is located on the lower slopes of Arthurs Seat where those slopes meet Port Phillip Bay and have formed an escarpment, Photo 14 & 15 Appendix B. In proximity to the Site the general topography of the areas slopes to the northwest. There is extensive residential development above the Site on the lower slopes of Arthurs Seat.

4. Geotechnical Model

4.1 Topography and drainage

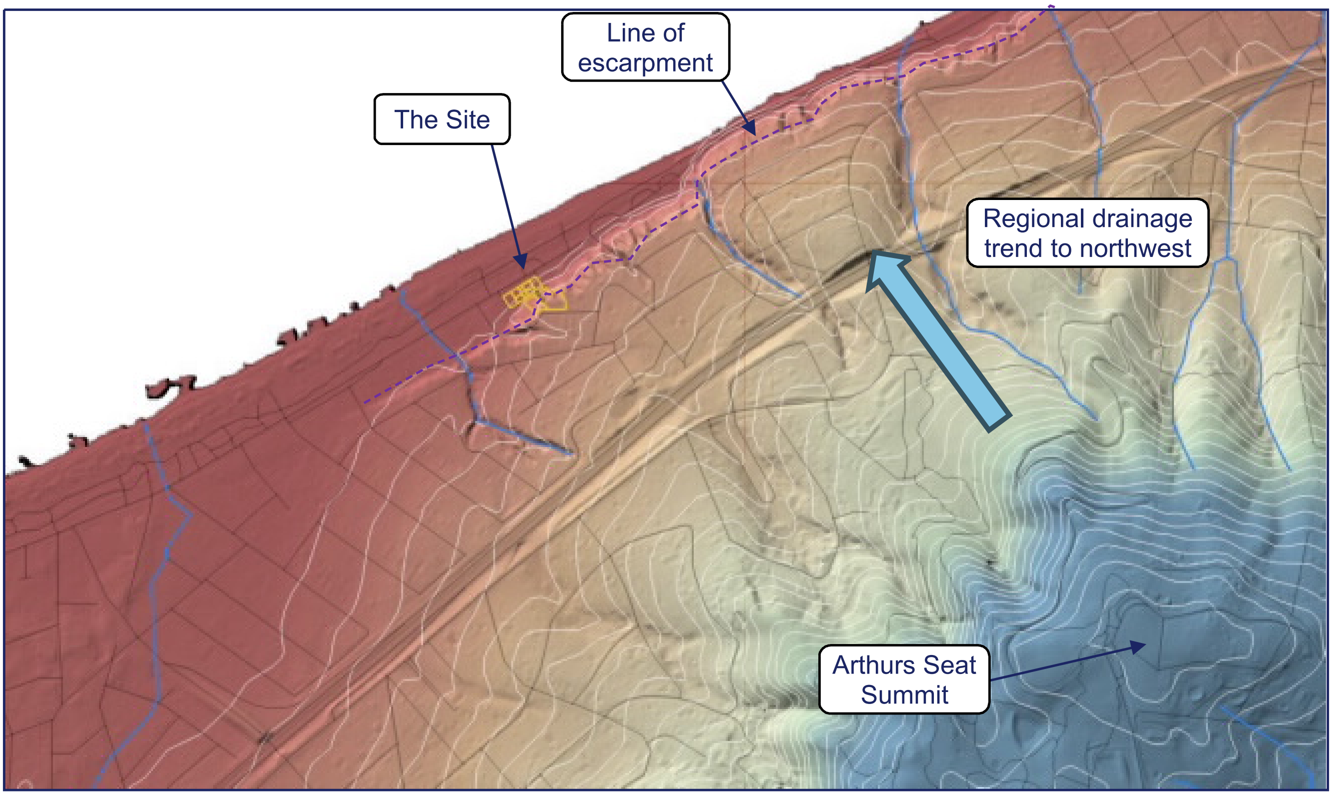
The Site is located at the lower escarpment of Arthurs Seat, Inset 4 (GeoVic Anonymous (gsv.vic.gov.au), accessed 1 November 2023) with approximately 270 of metres of relief measured in a northwest direction from the summit of Arthurs Seat to the escarpment at the Site. Several drainage paths strike in a north to northwest direction and that the Mornington Peninsula Freeway provides significant disruption to surface and sub-surface water flows in the region.

In the immediate area of the Landslide on P1 the Coastal LiDAR data indicates:

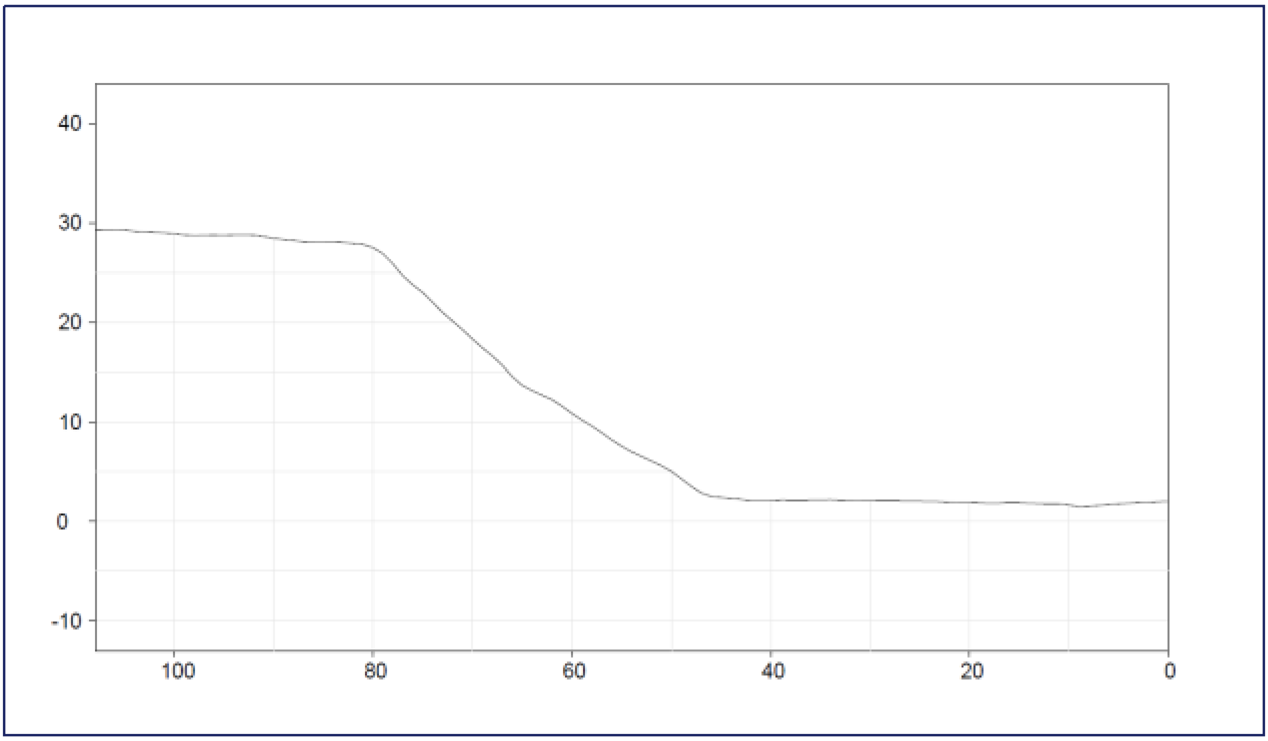
(a) The strike of the escarpment line changes from 030° to 100°. This creates a local convex geometry or "bullnose" slope (in plan) at the location of the Landslide.
(b) 25 to 30 metres of relief between the toe and crest of the escarpment.
(c) A typical overall slope angle of 30 to 35°.
(d) A concave (in section) slope profile with the upper half of the escarpment being steeper (typically 35 to 40°) than the lower half of the escarpment (typically 25 to 30°).

(e) Pre-failure slope geometry of the Landslide is shown in Inset 5.

(f) A lack of large-scale features other than gullies, that may indicate the presence of a large, full height slope failure mechanism.



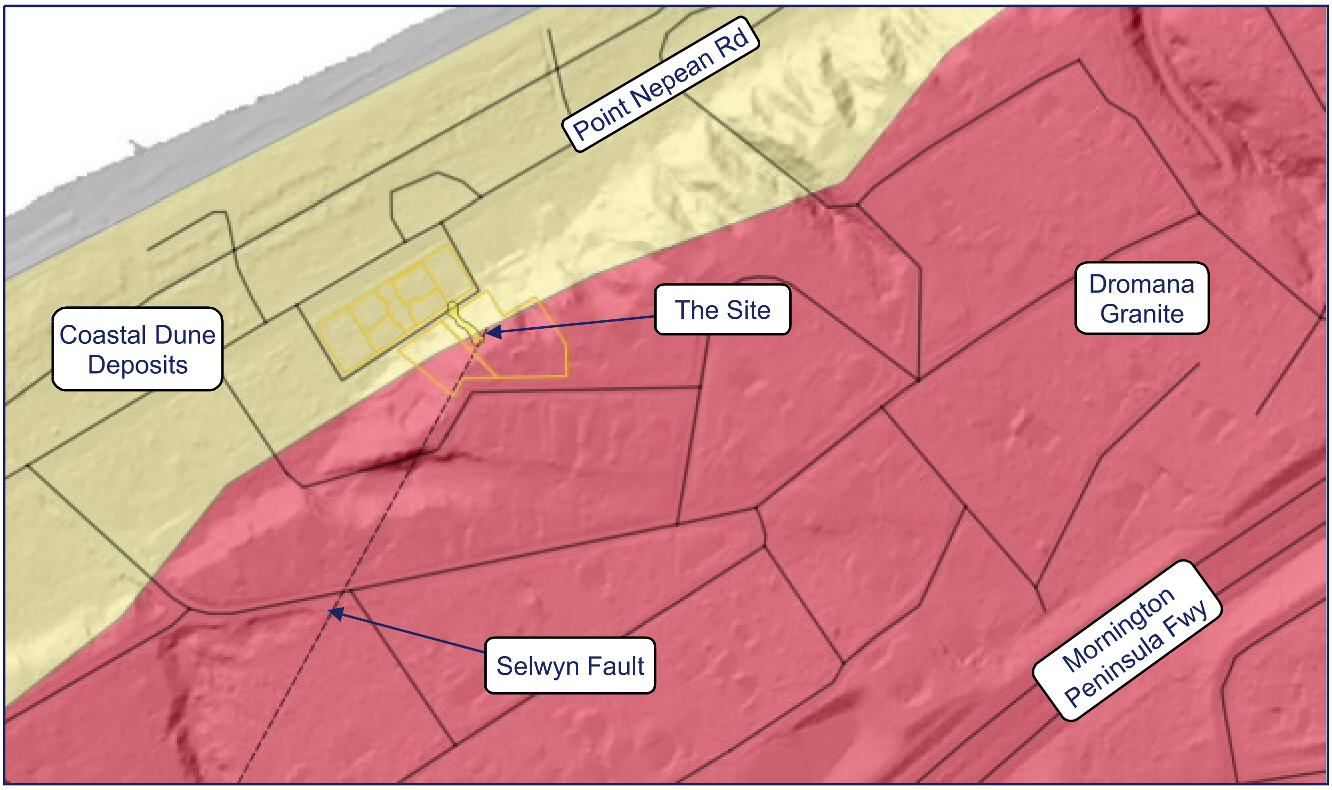
Inset 4: Topography and drainage paths of Arthurs Seat



Inset 5: Prefailure slope geometry through the centre of the Landslide from Coastal LiDAR 1 DEM.

4.2 Geology

The Victoria Seamless Geology (Earth Resources publications (efirst.com.au) , (2014)) model indicates that the Site is close to the boundary of Quaternary aged dune deposits (with siliceous and calcareous sands) and Devonian aged Dromana granite. The Earth Resources mapping portal (GeoVic Anonymous (gsv.vic.gov.au), accessed 1 November 2023) indicates that the inferred location of the Selwyn Fault traverses the Site, Inset 6.



Inset 6: Earth Resources seamless geology map of the area, with Selwyn Fault highlighted.

4.3 Sub-surface conditions

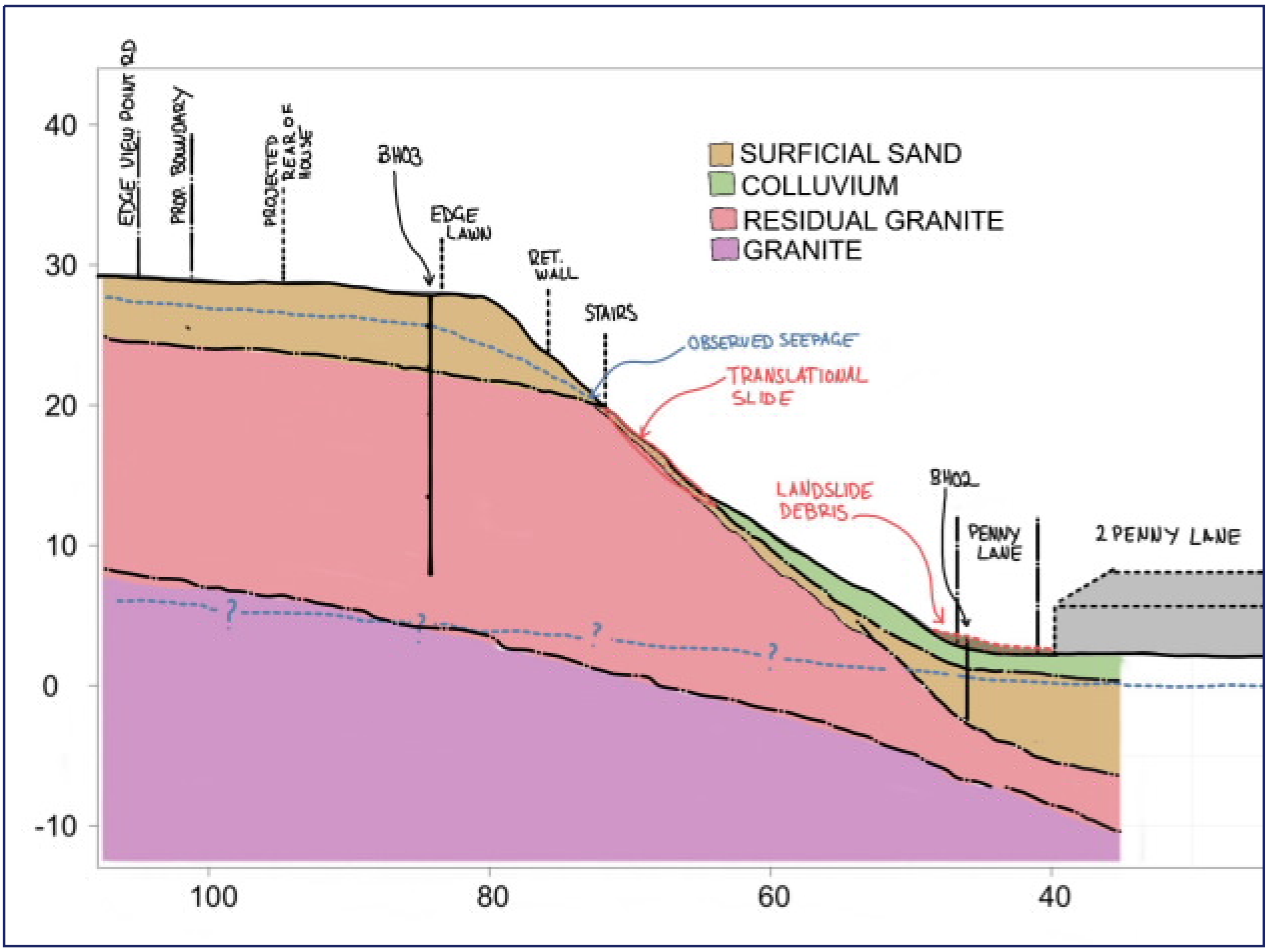
The conditions documented by others in the boreholes and observations from the PSM site visit indicated subsurface conditions generally consistent with those described on the geological map. Table 1 presents the PSM interpretation of the geotechnical units.

Table 1 – Geotechnical units

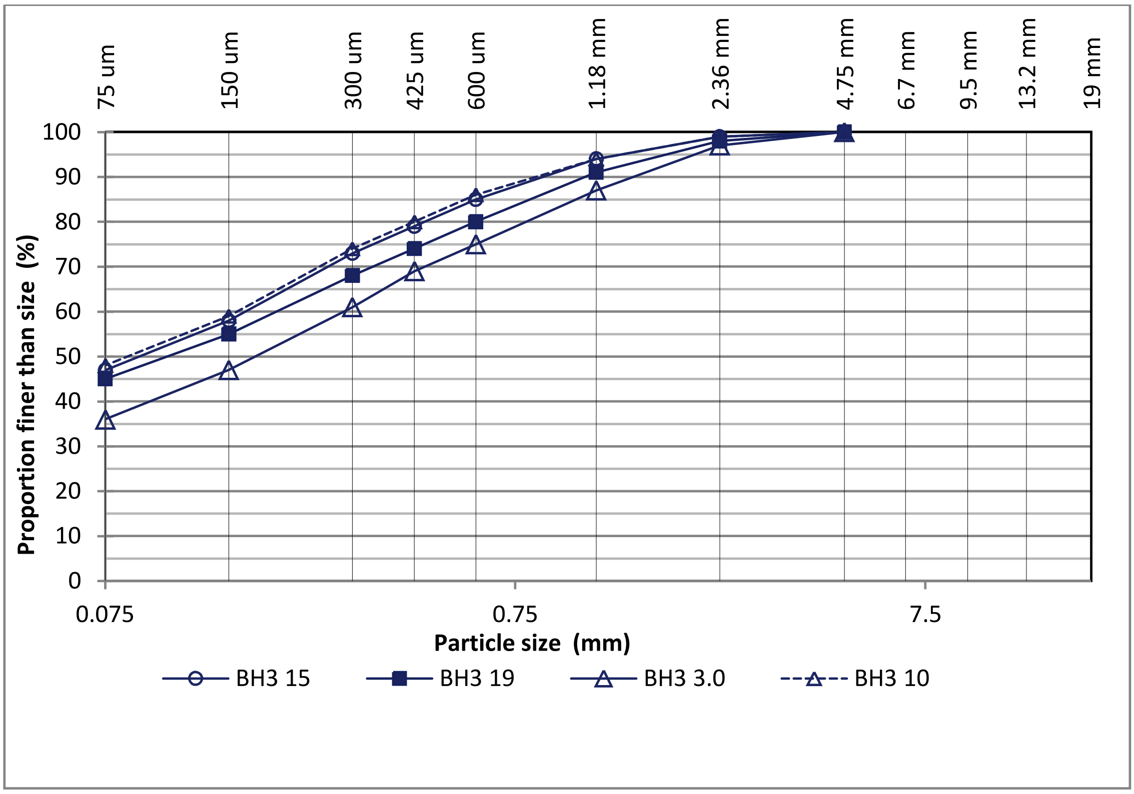
Unit	Description
SURFICIAL SAND (1)	SAND and Silty/Gravelly SAND, fine to coarse grained, brown to pale grey, brown, moist to wet, inferred medium dense. SPT N value of 10 at 1.5 m bgl. Contact with underlying Residual Granite (3) is difficult to define.
COLLUVIUM (2)	Inferred to be a mixture of Units 1 and 3. Recent Colluvium (the debris flow from 2022 landslide) is Silty SAND/Sandy CLAY. Old Colluvium buried by 2022 landslide is Sandy CLAY and SAND. This unit has no strength testing.
RESIDUAL GRANITE (3)	Sandy to Silty CLAY/Clayey SAND, low plasticity, pale grey, brown to mottled orange grey brown, fine to coarse grained, wet at contact with overlying Surficial Sands otherwise moist, typically medium dense to dense/stiff to very stiff. SPT N values vary from 12 to 34 with a mean of 25 from 3 m to 20 m bgl.

Our interpretation of the geological conditions is presented in Inset 7. With regards to the geological model PSM notes the following key observations:

- There is uncertainty regarding the contact between the SURFICAL SAND and the RESIDUAL GRANITE owing to the likelihood of some of the parent material of the SURFICAL SAND being derived from erosion of the Dromana Granite. PSM has assumed that the wet soils are an indicator of the contact between the two geotechnical units.
- The laboratory testing indicates that all samples between 3 m and 19 m bgl have very similar Particle Size Distributions, Inset 8, and Atterberg limits indicate low plasticity CLAY fines.



Inset 7: PSM geological model



Inset 8: CivilTest Particle Size Distributions

4.4 Groundwater

PSM notes that no groundwater monitoring has been conducted on the Site.

Based on published literature and the observations on the CivilTest borehole logs, a perched water table is likely to exist at the contact of the SURFICIAL SAND and the underlying RESIDUAL GRANITE. This is supported by:

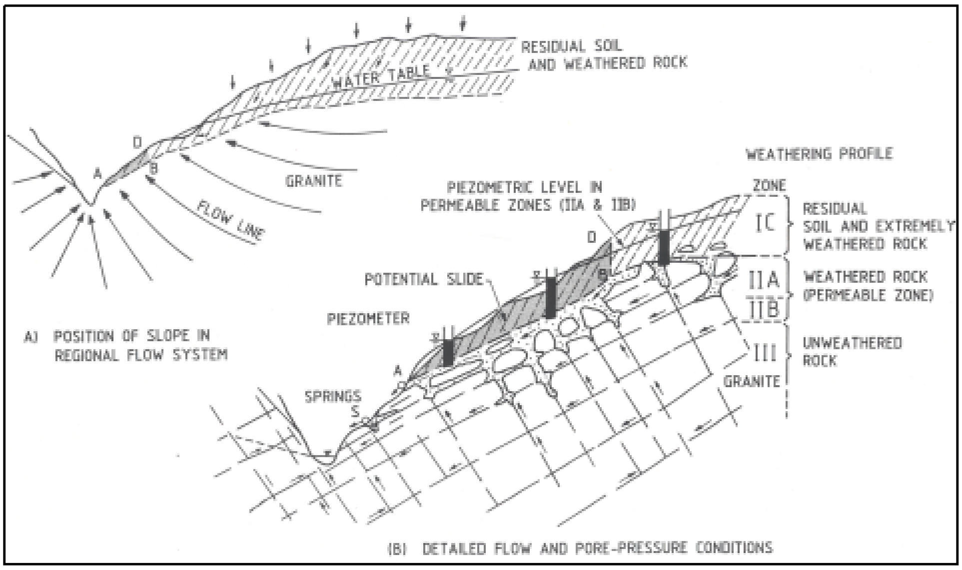
- Wet soils observed in CivilTest borehole 3 (refer to Section 2.1).
- Erosion pipes in the SURFICIAL SAND (refer to Section 3), which indicate a pathway of past and preferential sub-surface water flow.
- Observations in the Stantec report (refer to Section 2.2)
- Observations of seepage during the Site Visit (refer to Section 3).

The presence of the perched water table will not necessarily be limited to periods of wet weather due to:

- The size of the catchment of Arthurs Seat and slopes and drainage paths that fall towards the northwest, the Site and the escarpment (refer to Section 4.1).
- Local sources of water common to residential development and subdivisions (garden watering, street catchment run off, leaky pipes (private and public sources).

The presence of the perched water table not being limited to periods of wet weather is supported by:

- The observation by CivilTest of wet soils encountered in borehole 3 between 1.8 m and 5.2 m bgl in March 2023. I note that this was not during or following a period of high rainfall, Section 2.4.1.
- Furthermore, the CivilTest observation is consistent with published groundwater models in weathered granitic profiles, Inset 9.
- Observations of seepage during the Site visit (refer to Section 3).



Inset 9: Possible piezometric conditions in weathered granitic soils (Fell et al, 2004)[2].

Groundwater was observed on Penny Lane between 2.4 m to 2.6 m bgl. This is consistent with water levels of the adjacent Port Phillip Bay. These levels are anticipated to fluctuate with tidal levels.

5. Landslide Risk Assessment

5.1 Introduction

Fundamentally the risk to life cannot improve where:

- a debris flow has entered a property
- no control measures have been adopted to remediate the source of the debris flow
- dilated/disturbed ground is noted in a similar area as the previous landslide.

Due to the presence of a preferred flow path and an increase in the slope angle at the toe of the slope (due to deposition of debris) the risk is most likely higher.

PSM notes that the selection of detachment probabilities is subjective and variations between authors of an order of magnitude are not uncommon. Nonetheless, a LRA has been completed in accordance with the requirements of the AGS (2007) to assess the risk to life for the properties P1 to P3.

The level of “Tolerable Risk” should be defined by the Regulator (in this case, MPS) (Section 8.2 of AGS (2007c). “Tolerable Risk” as defined in Table 1 of Section 8.2 of AGS (2007c) is presented in Table 2.

Table 2 – Tolerable Risk as per Section 8.2 of AGS (2007c)

Risk Type for Low Rise Residential Development	Tolerable Risk Level
Risk to Life for existing slopes and development (Quantitative Assessment)	1×10^{-4}
Risk to Life for new slopes and development (Quantitative Assessment)	1×10^{-5}

[2] Fell,R. MacGregor, P.Stapledon, D. Bell, G. 2005. Geotechnical Engineering of Dams. CRC Press.

5.2 Hazards and modes of failure

Table 3 provides a summary of the modes of failure and hazards. The hazards are presented on Inset 10. The November 2022 landslide had the following characteristics:

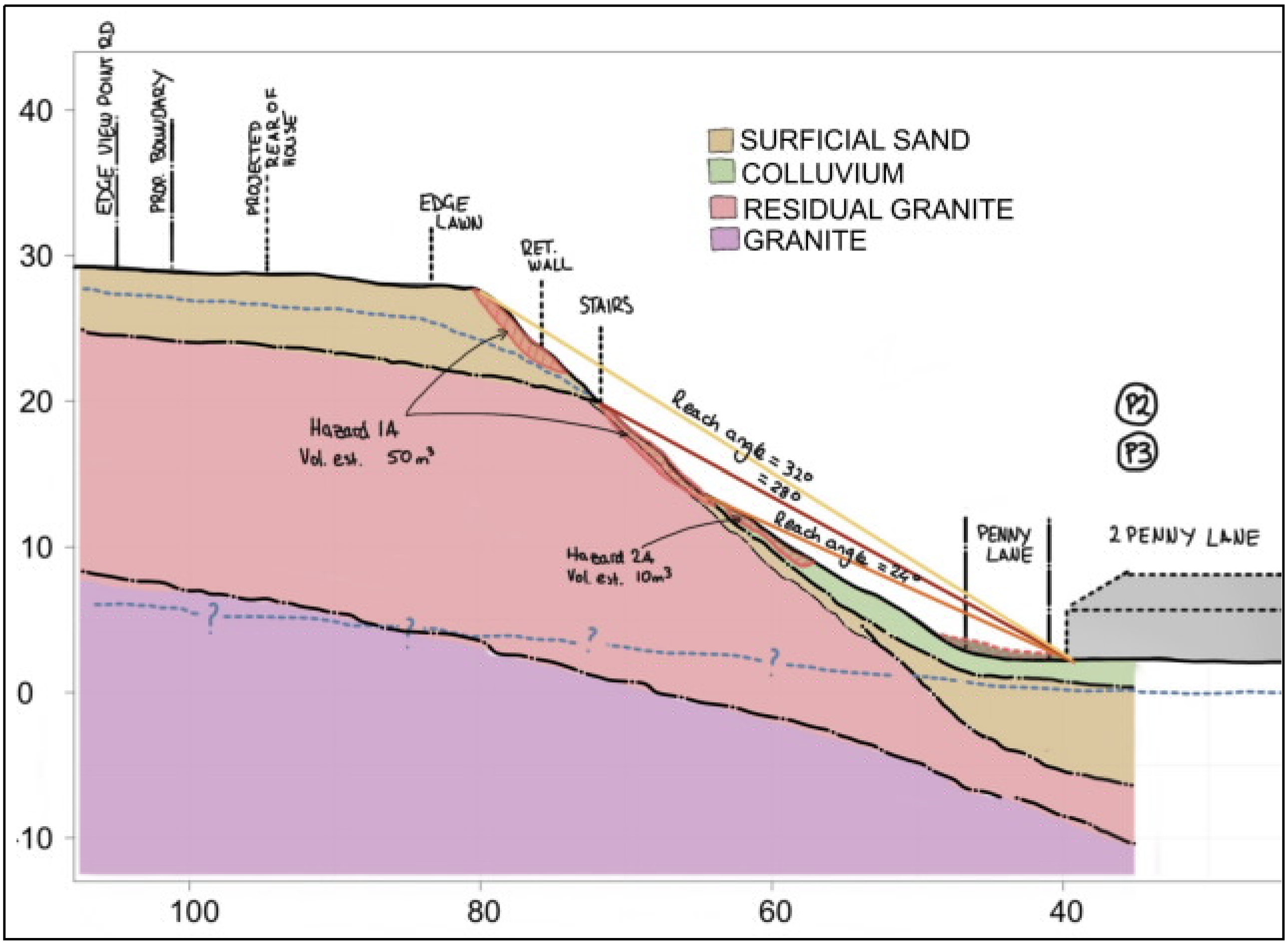
- Two events with an initial translational slide followed by the debris flow.
- For the translational slide:
  - Approximate dimensions of 8 m to 10 m wide x 8 m to 10 m long x 0.3 m deep (parallel to slope).
  - Approximate mobile volume of 20 m^3 to 30 m^3.
- The reach angle in the order of 28° measured from the base of the stairs.
- For the debris flow:
  - Approximate dimensions of 5 m wide x 25 m long (travel distance)
  - Approximate volume of 20 m^3
  - Reach angle in the order of 24° to 28°. There is some uncertainty as to the head scarp location of the debris flow.
- The reach angles are in agreement with those published by Finlay et al (1999)[(3)] and Mostyn and Sullivan (2002)[4] for washout and liquefaction failures in fills, Inset 11.

PSM notes that tree removal is a significant conditional event that has occurred at the Site and suction will change in the escarpment slopes over a period of 12 months to 5 years from tree removal (Richards, 1983)[5]. Trees have been removed in 2021 and further vegetation has been removed by the landslide. In PSM's experience it is common in Victoria for surficial soil landslides to follow tree/vegetation removal (either by fire, storm or physical removal).

[(3)] Finlay, P.J. Mostyn, G.R. Fell, R. 1999. Landslides: Prediction of travel distance and guidelines for vulnerability of persons. Australian Geomechanics June 1999. Pp.45-54.

[4] Mostyn.G. Sullivan. T.2002.Quantitative Risk Assessment of the Thredbo Landslide. Australian Geomechanics May 2002. Pp 169-181.

[5] Richards, B.G., Peter, P., Emerson, W.W. 1983. The effects of vegetation on the swelling and shrinkage of soils in Australia. Geotechnique, 33(2), 127-139.



Inset 10: **Landslide hazards**

Table 3 – Summary of hazards

Hazard ID	Mode of Failure	Discussion	Estimated $P_{(H)}$
1A	Translational slide – New landslide outside of area affected by 2022 landslide	Volume estimate = 20 to 50 m^3 Table 7 of RMS (2014): • Detachment mechanism is apparent, but failure does not appear imminent. • Triggering could be expected to required severe event. AGS (2007c): *The event will probably occur under adverse conditions over the design life* Assumed to initiate from upper slope areas not affected by November 2022 landslide.	$1x10^{-2}$ to $5x10^{-3}$
1B	Debris flow following 1A	Volume estimate = 20 m^3 Similar rainfall event to November 2022 rain event and occurring between 8 to 24 hours considered a likely trigger or possible infrastructure damage following 1A. Adopt 50% conditional probability of infrastructure damage or ponding water in debris from other source	$1x10^{-2}$ to $5x10^{-3}$
2A	Translational slide of flanks of landslide scarp	Volume estimate = 10 m^3 Table 7 of RMS (2014): • Detachment mechanism is active AGS (2007c): *The event is expected to occur over the design life.*	$5x10^{-1}$
2B	Debris flow following 2A	Volume estimate = 10 m^3 Similar rainfall event to November 2022 rain event and occurring between 8 to 24 hours considered a likely trigger.	$5x10^{-2}$ to $1x10^{-2}$

5.3 Risk to life

The risk of loss of life ($R_{(LoL)}$) can be estimated using the AGS quantitative risk assessment, expressed with the following equation:

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

5.3.1 Annual Probability of Occurrence, $P_{(H)}$:

The Probability of Occurrence, $P_{(H)}$: is the annualised probability that a landslide occurs (i.e. detaches from the slope). It is analogous to terminology applied to rainfall or flood events such as "1 in a 100 year event". This probability is statistical measure of how likely a landslide is to occur in any given year, and is not a direct measure of the imminency of failure (i.e how soon a landslide may be expected to occur). Assessment of the imminency of a landslide, is typically done with slope monitoring whereby the movement trends of the slope inform when a landslide may occur.

Values for the annual probability of occurrence are calculated based on frequency analysis and checked against the following guides for consistency:

- Appendix C of AGS (2007c) which recommends values for the probability of occurrence and the qualitative descriptor equivalent.
- Table 7 of the RMS (2014)[6].

Supporting evidence and discussion for $P_{(H)}$ is provided in Section 5.2 and Table 3.

5.3.2 Probability of Spatial Impact, $P_{(S:H)}$:

The Probability of Spatial Impact, $P_{(S:H)}$, is the probability that the landslide physically reaches the element at once the landslide has occurred. This probability is largely affected by distance from the landslide source area, and typically the further an element at risk is away from the source of the landslide the lower the probability of spatial impact. The LRA has considered landslide impacts on:

- Dwellings in which occupants may be situated.
- Slopes on which pedestrians may be situated.

For property P1:

- Spatial risks are high (1) when on or below the landslide hazards.

For properties P2 and P3:

- The November 2022 translational slide did not reach P2 and P3. However, the debris slide reached P2 and P3 and created a preferential flow path with significantly less obstructions for future landslides.
- Measured reach angles of the November 2022 landslide and those of the downslope dwellings to the respective hazards upslope are presented in Inset 10 and Inset 11.
- The measured reach angle between the hazards and the dwellings generally are between one and two standards deviations of the mean of the published Mostyn and Sullivan (2002) data set, Inset 11 (excluding the debris flow data point).
- For debris flow Hazard 1B, based on the comparison to published data sets and the measured debris flow the adopted $P_{(S:H)}$ is 0.43.
- For debris flow Hazard 2B the previous landslide has created a preferential flow path making impact more likely. The $P_{(S:H)}$ for this scenario is taken as 1.

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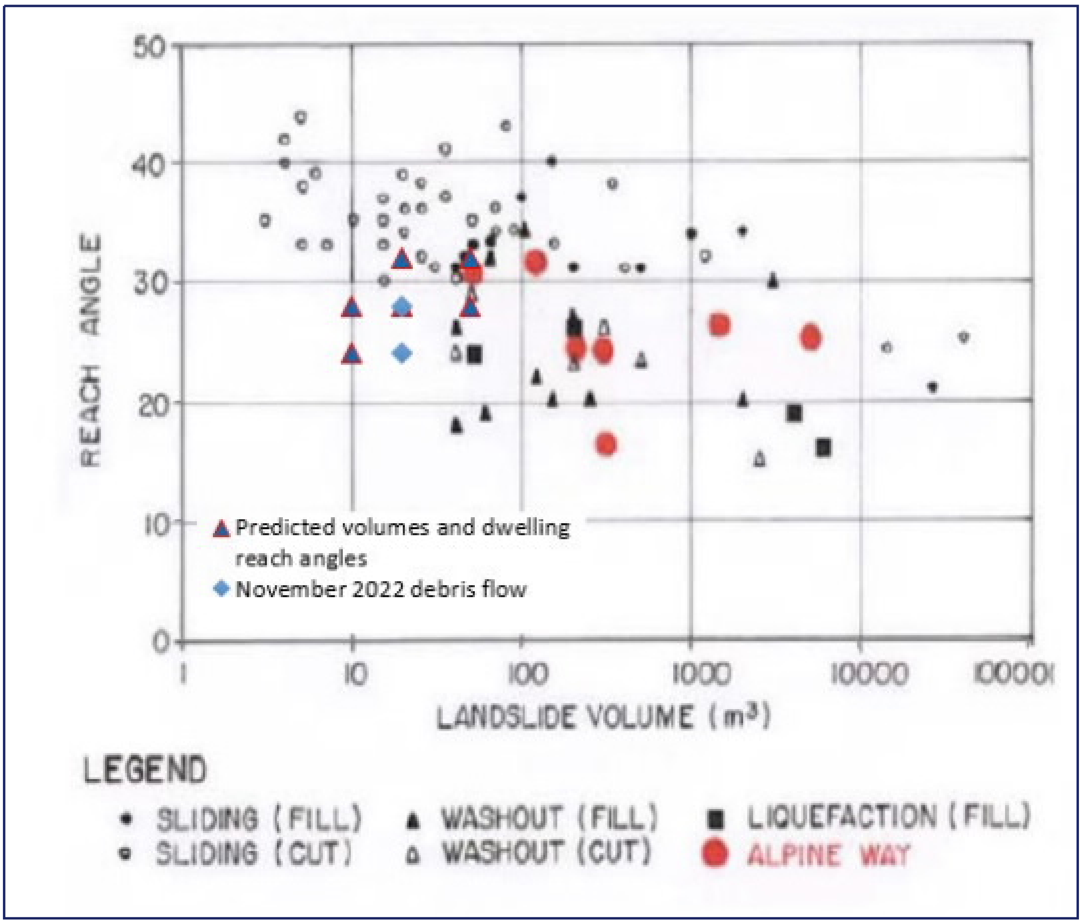
[6] RMS. 2014. RMS Guide to Slope Risk Analysis Version 4.



Inset 11: Predicted volumes and measured reach angles to P2 and P3, plotted on Mostyn and Sullivan (2002) landslide data

5.3.3 Temporal Spatial Probability $P_{(T:S)}$:

The Temporal Spatial Probability $P_{(T:S)}$ is the probability of a person being at the Site (or in the house) at the time the landslide occurs. It is measured as the percentage of the year that a person is present where they may be impacted by the landslide.

PSM have assumed the following:

- Pedestrians on lower slopes (maintenance/gardening/use of access track) are present 0.5 hour per day (1/48)
- The P2 and P3 homes are occupied 80% of the time:
  - If the homes are destroyed in an event $P_{(T:S)} = 0.8$
  - If the homes are partially damaged in an event, $P_{(T:S)} = 0.5 \times 0.8 = 0.4$ (representing use of the rear of the dwellings for half of the day).

5.3.4 Vulnerability, $V_{(D:T)}$

Vulnerability $V_{(D:T)}$ is the probability of death if a person is impacted by a landslide. Example vulnerability values are provided in Appendix F of AGS 2007c. The basic approach adopted by PSM is presented in Finlay, Mostyn & Fell (1999) and discussed as follows:

- PSM site observations indicate the debris flow is approximately 0.7 m thick on Penny Lane. It is assumed that this volume of material would:
  - Bury a pedestrian.
  - Cause severe damage or partial collapse of a building.

- Pedestrians and occupants of dwellings have a high vulnerability where buried by large slides (1.0), but reduced vulnerability where they are not buried (0.1 to 0.2).
- For the Site, rapid failure has occurred and therefore significant damage to properties P2 and P3 and burial of pedestrians and occupants is possible and for this reason vulnerability of 1.0 has been adopted.
- Pedestrians on top of a translational slide and within the zone of potential hazards have a low vulnerability (0.1) as they may fall rather than be struck or buried by debris.

5.4 Results of assessment

The results of the assessment are provided in Appendix A and indicate:

- For pedestrians below the escarpment and within run out distances of the hazards, the risk to life varies from 2.1 $x10^{-5}$ to 1.1 $x10^{-3}$. In accordance with Table 1 of Section 8.2 of AGS (2007c), this is not a tolerable risk to life.
- For occupants of P2 and P3 the risk to life varies from 2.0 x 10^{-5} to 8.0 x 10^{-3}. In accordance with Table 1 of Section 8.2 of AGS (2007c), this is not a tolerable risk to life
- As a check against uncertainty in key input parameters, the risk to life was also checked using less adverse (i.e. less conservative) input parameters. It was found the risk to life for dwellings P2 and P3 is still considered not tolerable. The results of the sensitivity checks show:
  - For Hazard 1A the risk to life is $2.2x10^{-4}$ for the occupants of dwellings P2 and P3 and is considered not tolerable, where it is assumed that:
    - The return period of the translational slide is 1:200 years (which is not well supported by actual rainfall data)
    - The occupants of dwellings P2 and P3 are not buried with the adopted vulnerability taken as 0.2.
  - For hazard 1B the risk to life is 1.4 x 10^{-4}, for the occupants of dwellings P2 and P3 and is considered not tolerable where it is assumed that:
    - The return period of the debris flow is 1:200 years (which is not well supported by actual rainfall data)
    - The occupants of dwellings P2 and P3 are not buried with the adopted vulnerability taken as 0.2

6. Conclusion

In accordance with Table 1 of Section 8.2 of AGS (2007c), the results of the risk assessment indicate the risk to life is not tolerable for occupants of dwellings P2 and P3 and pedestrians on and below the escarpment slopes at the Site on properties P1 to P3.

The scope of this risk assessment excludes the assessment of all other neighbouring downslope properties.

Yours Sincerely

Irrelevant and Sensitive

DANE POPE
PRINCIPAL

Enclosed:

Appendix A – Figures

Appendix B – Selected Site Photographs

Appendix C – Risk Assessment

Appendix A
Figures

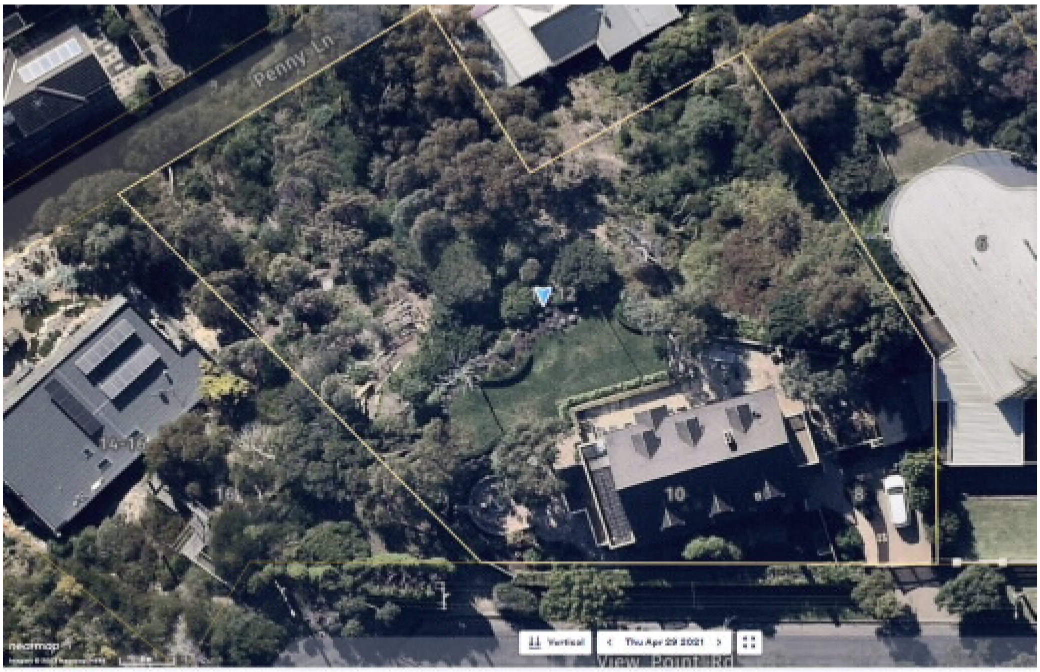


Figure A1: Nearmap 29/04/2021

Figure A2: Nearmap16/09/2021

Harwood Andrews Risk Assessment 10-12 View Point Road, McRae Tree removal	
PSM5226-002L REV 1	Appendix A

Figure A3: Google Street View February 2018

Figure A4: Google Street View October 2022

Harwood Andrews Risk Assessment 10-12 View Point Road, McRae Tree Removal	
PSM5226-002L REV 1	Appendix A

Figure A5: Nearmap 3/12/2022 approximate head scarp dimensions

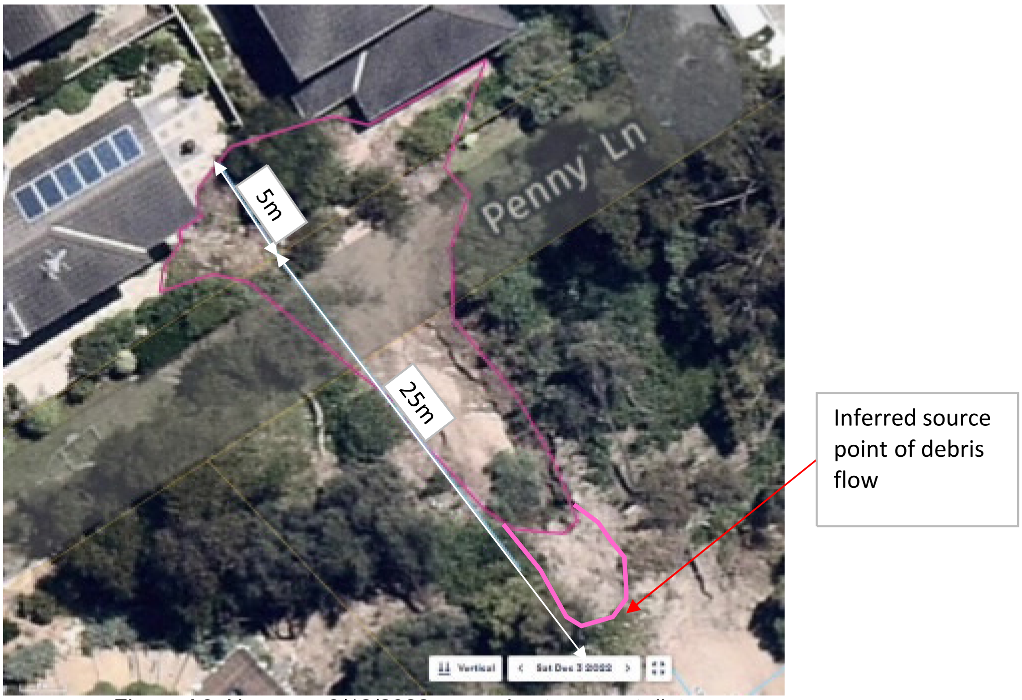


Figure A6: Nearmap 3/12/2022 approximate run out distances

Harwood Andrews Risk Assessment 10-12 View Point Road, McRae Landslide characterisation	
PSM5226-002L REV 1	Appendix A

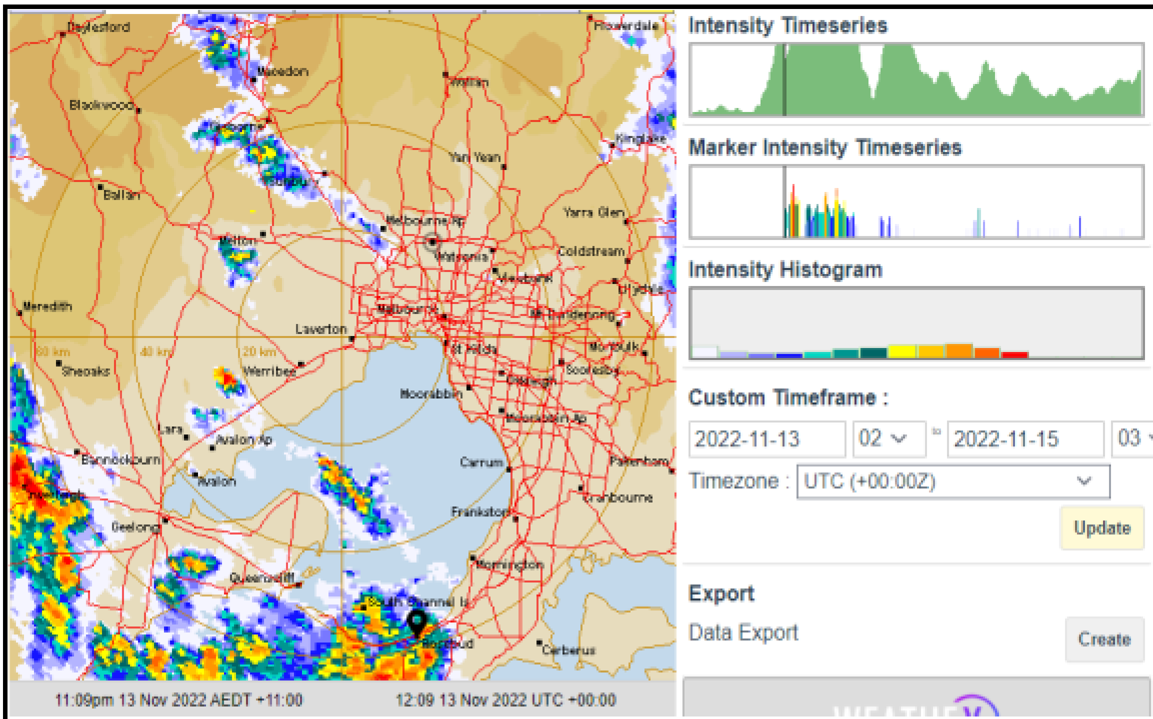


Figure A7: Radar plot 11:09 pm on 13/11/2022

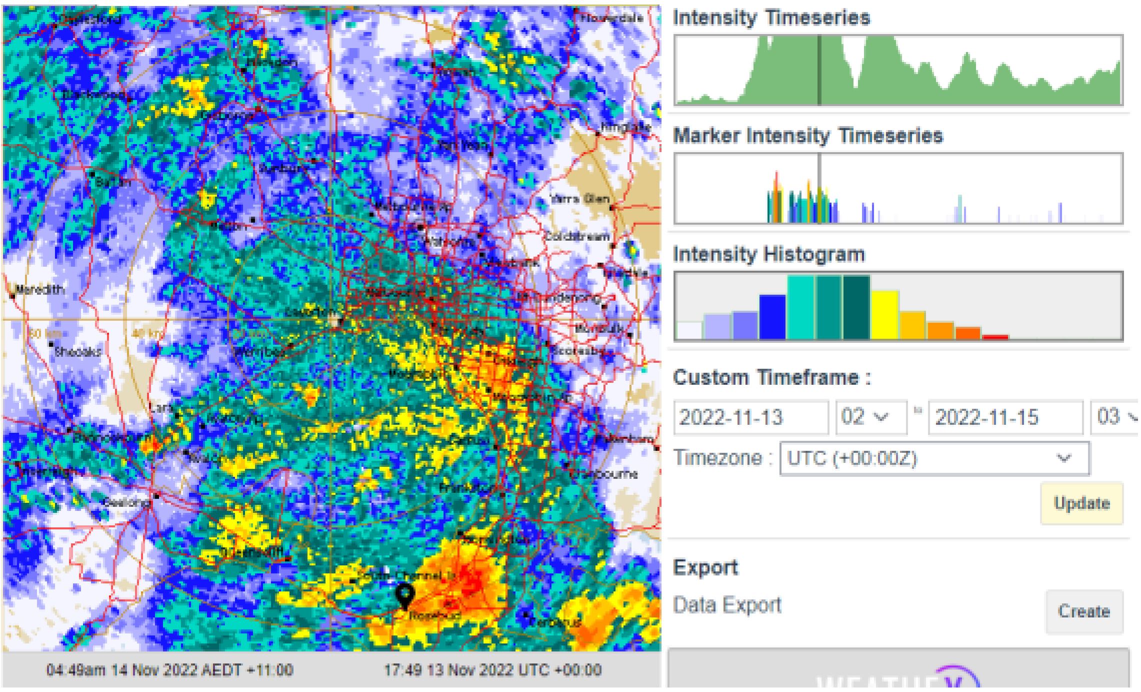


Figure A8: Radar plot 04:49 am on 14/11/2022

Harwood Andrews Risk Assessment 10-12 View Point Road, McRae Archived radar imagery	
PSM5226-002L	Appendix A

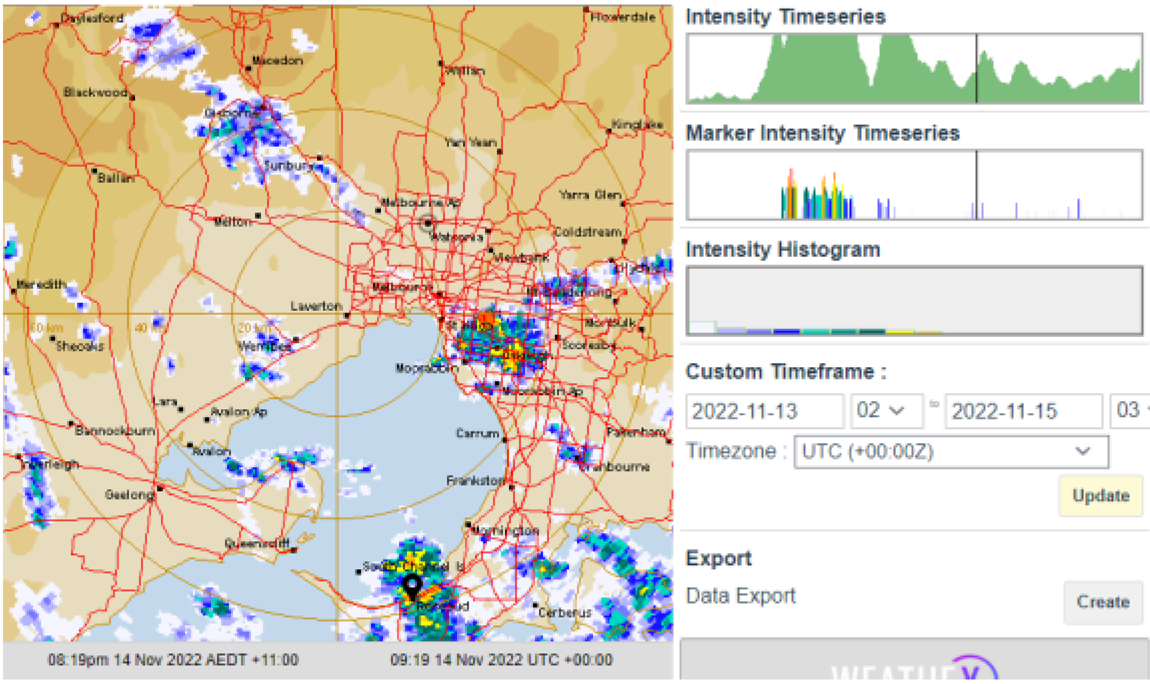


Figure A9: Radar plot 8:19 pm on 14/11/2022

Harwood Andrews

Risk Assessment

10-12 View Point Road, McRae

Archived radar imagery

PSM5226-002L	Appendix A

Appendix B
Selected Site Photographs


Photo 1 - Upper translational sliding area


Photo 2 - Debris flow runout area, Property P2 visible in background

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Expert Witness - Rectification

10-12 View Point Rd, McCrae

Selected Site Photographs (1 of 8)

PSM

PSM5226-002L	**Appendix B**

Photo 3 - Landslide Overview, with zones indicated

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Expert Witness - Rectification

10-12 View Point Rd, McCrae

Selected Site Photographs (2 of 8)

PSM5226-002L	**Appendix B**

Photo 4 - Failed material still on slope

Photo 5 - Rear scarp of landslide, note lack of oversteepened backscarp

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Expert Witness - Rectification
10-12 View Point Rd, McCrae
Selected Site Photographs (3 of 8)

PSM

PSM5226-002L | **Appendix B**

Groundwater seeping from slope

Photo 6 - Groundwater seepage

Photo 7 - Water infrastructure including water pipes (on left), and subsurface 'agi drains' (on right)

Hardwood Andrews **Expert Witness - Rectification** **10-12 View Point Rd, McCrae** **Selected Site Photographs (4 of 8)**	
PSM5226-002L	**Appendix B**

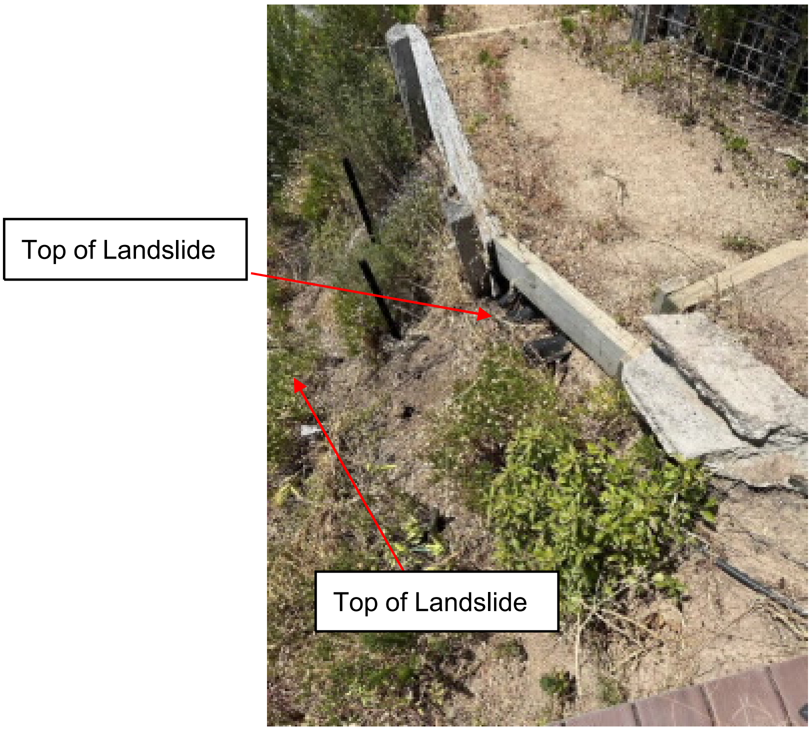

Photo 8 - Path above Landslide, note minor retaining walls and 'agi drains' from Photo 7

Photo 9 - Granite stairs leading from garden area to path at top of landslide

Hardwood Andrews

Expert Witness - Rectification

10-12 View Point Rd, McCrae

Selected Site Photographs (5 of 8)

PSM5226-002L	**Appendix B**

Photo 10 - Tilitng retaining walls on left side of Landslide

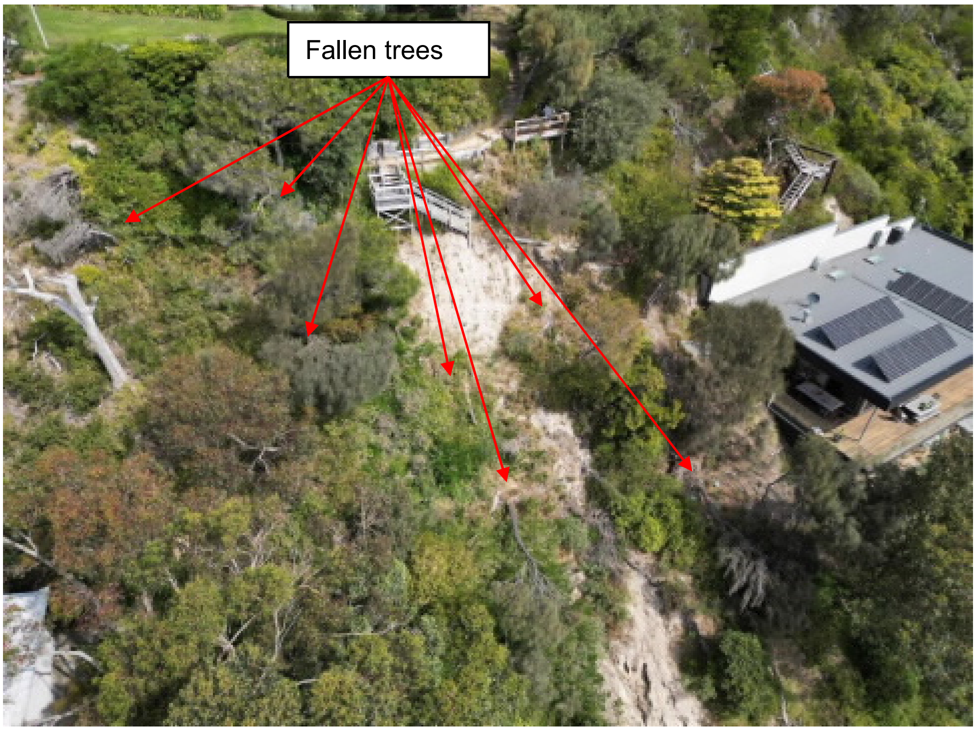

Photo 11 - Fallen trees

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Expert Witness - Rectification

10-12 View Point Rd, McCrae

Selected Site Photographs (6 of 8)

PSM

PSM5226-002L	**Appendix B**

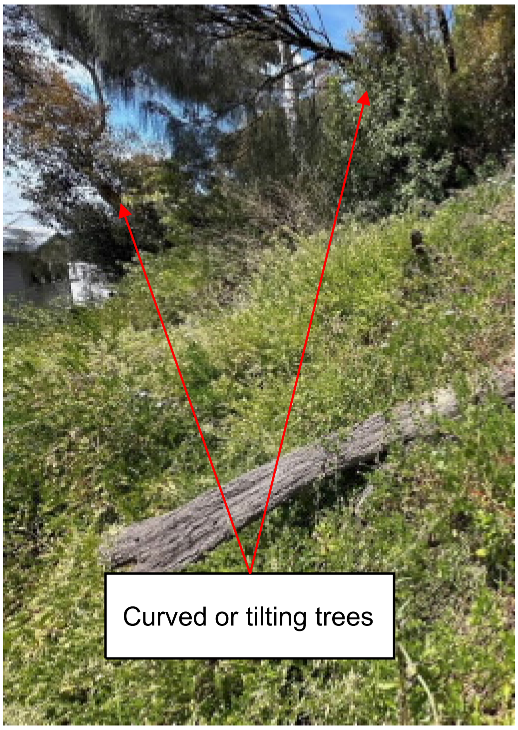

Photo 12 - Curved or tilting trees

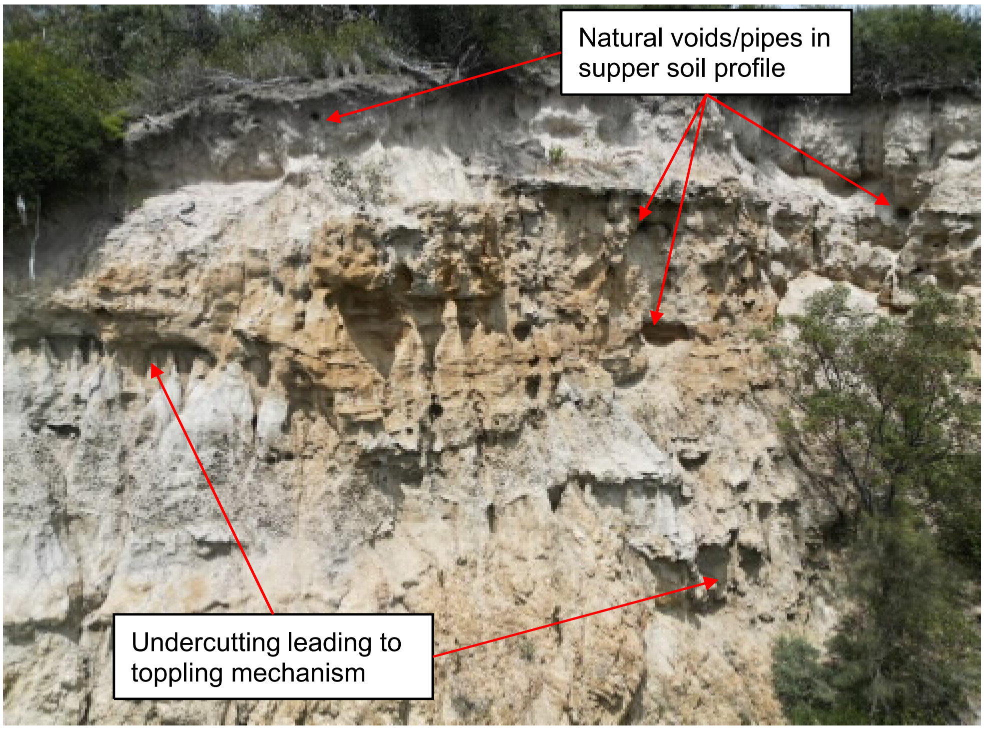

Photo 13 - Natural cliff profile near Anthony's Nose

Hardwood Andrews

Expert Witness - Rectification

10-12 View Point Rd, McCrae

Selected Site Photographs (7 of 8)

PSM

PSM5226-002L	**Appendix B**

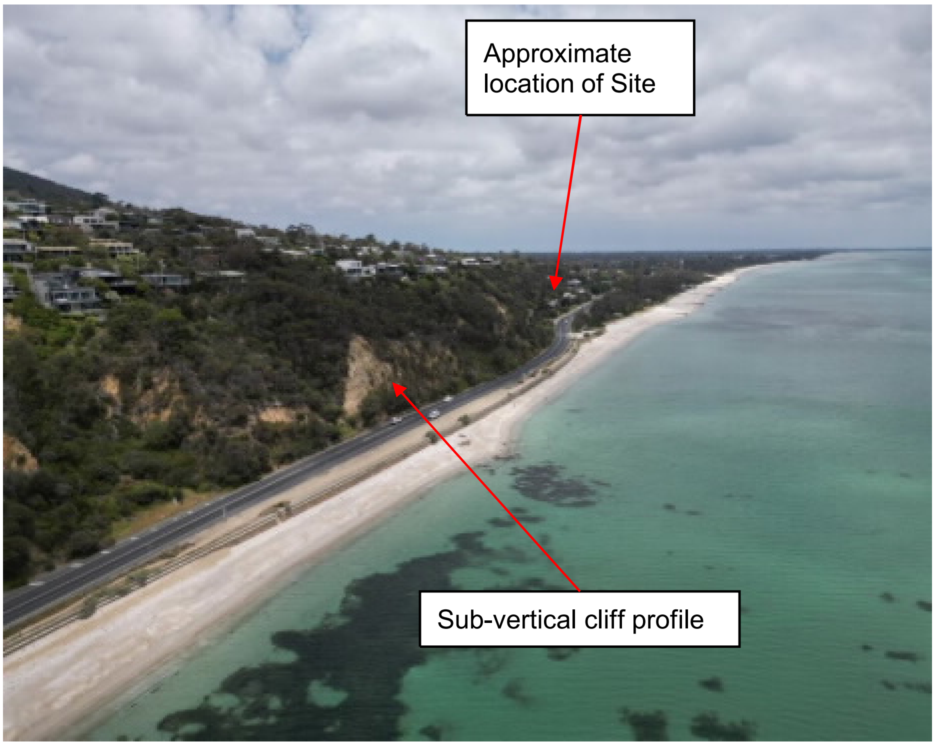

Photo 14 - Anthony's Nose

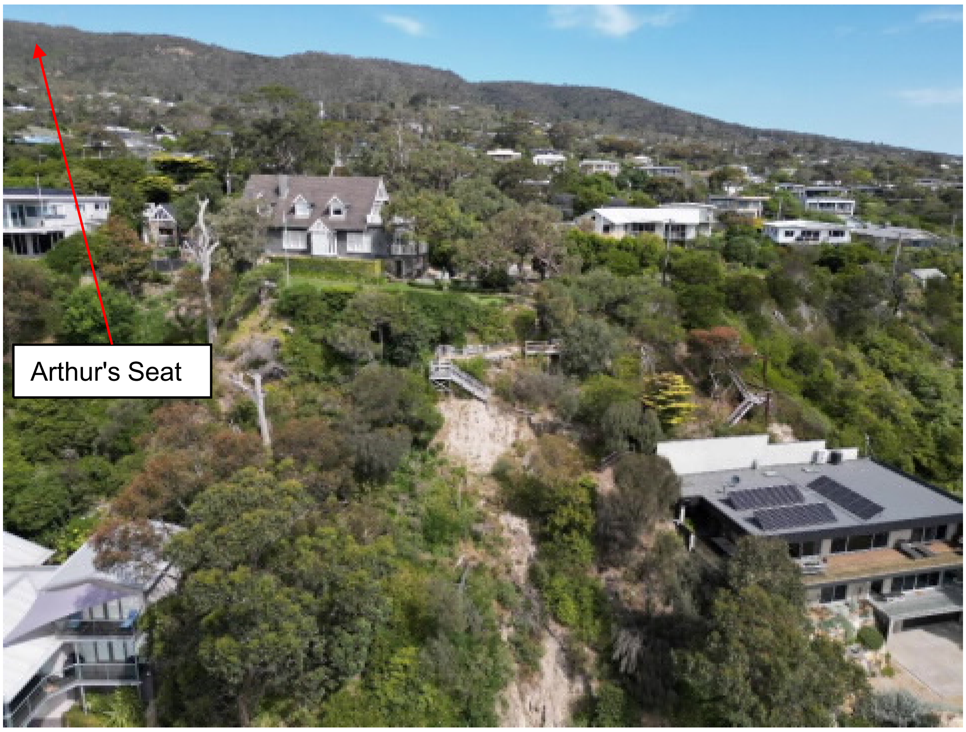

Photo 15 - Arthur's Seat in background

Hardwood Andrews **Expert Witness - Rectification** **10-12 View Point Rd, McCrae** **Selected Site Photographs (8 of 8)**	
PSM5226-002L	**Appendix B**

Appendix C
Risk Assessment

QUANTITATIVE RISK ASSESSMENT - LIFE

Job Number: PSM5226
Site Address: 10-12 View Point Road

Hazard ID	DESCRIPTION	SLOPE TYPE	VOLUME ESTIMATE (m^3)	REACH ANGLE (°)	Element at Risk	CURRENT RISK TO LIFE						ADDITIONAL CONTROL MEASURES	RESIDUAL RISK TO LIFE					
						$P_{(H)}$	$P_{(SH)}$	$P_{(TS)}$	$V_{(DT)}$	$R_{(LoL)}$	TOLERABLE RISK		$P_{(H)}$	$P_{(SH)}$	$P_{(Ts)}$	$V_{(DT)}$	$P_{(DI)}$	TOLERABLE RISK
1A	Translational slide – New landslide outside of area affected by 2022 landslide	Existing	50	32	Occupant in damaged house	1E-02	0.27	0.40	1	1.07E-03	NO							
				On slope below failure	Pedestrian on property	1E-02	1.0	0.02	0.1	2.08E-05	YES							
1B	Debris flow following 1A	Existing	20	32	Occupant in damaged house below	1E-02	0.43	0.40	1	1.74E-03	NO							
				On slope below failure	Pedestrian on property	1E-02	1.0	0.02	1	2.08E-04	NO							
2A	Translational slide of flanks of landslide scarp	Existing	10	24	Occupant in damaged house	5E-01	1.00E-04	0.40	1	2.00E-05	YES							
				On slope below failure	Pedestrian on property	5E-01	1.0	0.02	0.1	1.04E-03	NO							
2B	Debris flow following 2A	Existing	10	24	Occupant in damaged house	2E-02	1.0	0.40	1	8.00E-03	NO							
				On slope below failure	Pedestrian on property	2E-02	1.0	0.02	1	4.17E-04	NO							

LEGEND

$P_{(H)}$ **Annual probability of the landslide**

$P_{(Ts)}$ Temporal Probability

$R_{(LoL)}$ Risk (annual probability of loss of life (death) of an individual)

$P_{(SH)}$ **Spatial impact by hazard**

$V_{(DT)}$ Vulnerability