TECHNICAL MEMORANDUM

To	Derek Rotter & Chris Lyne Mornington Peninsula Shire	**From**	Davin Slade Cardno now Stantec
Project	Penny Lane, McCrae	**Date**	7/12/2022
Subject	Geotechnical Assessment	**Ref No.**	V220600Report01.1

1 INTRODUCTION

Cardno now Stantec was engaged by Derek Rotter of Mornington Peninsula Shire on 15 of November 2022 with regard to a landslide that had recently occurred in the vicinity of Penny Lane, McCrae. It was requested that an engineer from Cardno now Stantec attend the site to inspect the landslide and to make recommendations with regard to the suitability of emergency orders that had been issued with regard to residences in the nearby area.

Figure 1-1 shows the location of the site relative to the locations of Point Nepean Road, Penny Lane and View Point Road

Figure 1-1: Location of Site

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2 LIMITATIONS

This report is limited to a discussion of the immediate risk to the properties in the vicinity of the landslides that occurred up slope of Penny Lane on 14 and 15 November 2022 with regard to a reactivation of those landslides. This assessment does not include a longer term risk assessment for the site as events such as future rainfall, climate change and development of the site can impact on such risk. Assessment of longer term risk should form part any rehabilitation works to be undertaken for the site.

Furthermore, the properties along the McCrae escarpment on the southern side of Point Nepean Road fall within an area of known landslide susceptibility. Any assessment of landslide risk from other potential landslides is beyond the scope of this report. It is important for residents in this area to be aware of the risks of living in the vicinity of steep slopes and having appropriate hillside practices.

The Australian GeoGuides for Slope Management and Maintenance that form part of the Australian Geomechanics Society Guidelines for Landslide Risk Management (AGS 2007e) provide detailed guidance on appropriate practices for areas with steep slopes. The Mornington Peninsula Shire is directed to this resource with regard to providing information to the local residents.

3 BACKGROUND

A site inspection was conducted by a Senior Principal from Cardno now Stantec on the afternoon of 15 November 2022. During that inspection independent observations were made as well as having discussions with local residents to source anecdotal information.

From the anecdotal discussions it is understood that an initial landslide is likely to have occurred in the late afternoon on Monday 14 November 2022. This day was a day of very heavy rain with approximately 80mm of rain recorded at the Bureau of Meteorology rain gauge located at Rosebud Country Club approximately 3-4km away. According to the data this was the highest single day of rainfall at that rain gauge since February 2005. This was coupled on top of what had already been a wet year. This landslide appears to have occurred as a translational landslide of the upper slope to the rear (north) of the house at 10-12 View Point Road.

Subsequently in the early morning of Tuesday 15 November 2022 a second landslide occurred. This landslide appears to have occurred as a debris flow from the middle part of the slope down to the toe resulting in impact on the dwelling at 3 Penny Lane as well as debris flowing into the yard of 3/613 Pt Nepean Road. From evidence on site, it appears that the debris flow may have been triggered by an irrigation pipe that could have been ruptured by the initial landslide.

While the initial landslide may have been relatively moderate to rapid in nature (i.e. in the order of metres per hour to metres per minute), it is likely that the subsequent debris flow would have been very rapid to extremely rapid (i.e. in the order of metres per second).

An oblique view of the site showing the locations of the two parts of the landslide is shown in Figure 3-1.

Figure 3-1: Oblique view of landslides

4 SITE INSPECTION

The site inspection involved walking the site around the perimeter of the landslide. The purpose of the inspection was to identify the extents of the landslide and the zone of influence around the landslide that might be impacted by further ground movement.

The following sections discuss the site observations for the upper and lower slopes.

4.1 UPPER SLOPE

The upper slope is dominated by a translational landslide that appears to have occurred in the upper soils overlying the underlying completely weathered granite. Across the area of the landslide a majority of the upper soils have translated downslope while the completely weathered granite has generally remained in place and is exposed in areas.

Figure 4-1 shows an aerial view of the site taken by Victoria Police drones. It shows the extent of the upper landslide and pertinent features associated with the landslide.

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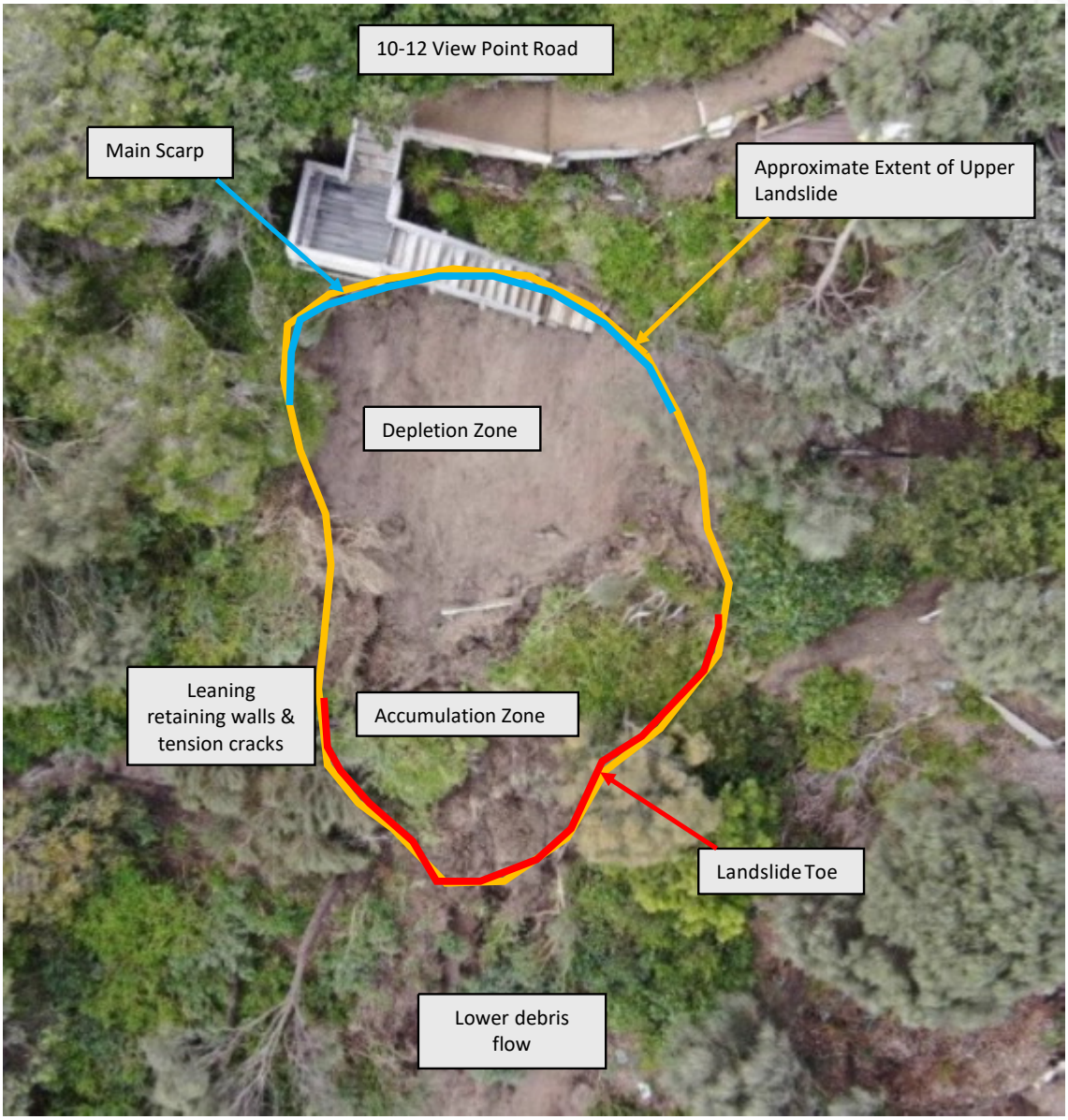

Figure 4-1: Aerial view of upper slope

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.

Figure 4-3 shows the accumulation zone of the upper landslide. It can be seen in the photograph that there is a significant volume of accumulated material and debris sitting at the toe of the landslide.

It is considered possible that with another significant rainfall event the material in the accumulation zone could remobilize and flow down slope. In addition, it is possible that some regression of the head scarp

could occur but that it would most likely be confined to the steep section of the slope or the immediate vicinity of the flatter area upslope.

The irrigation pipe that is likely to have failed during the initial landslide can be seen to be stretched tight in both figures.

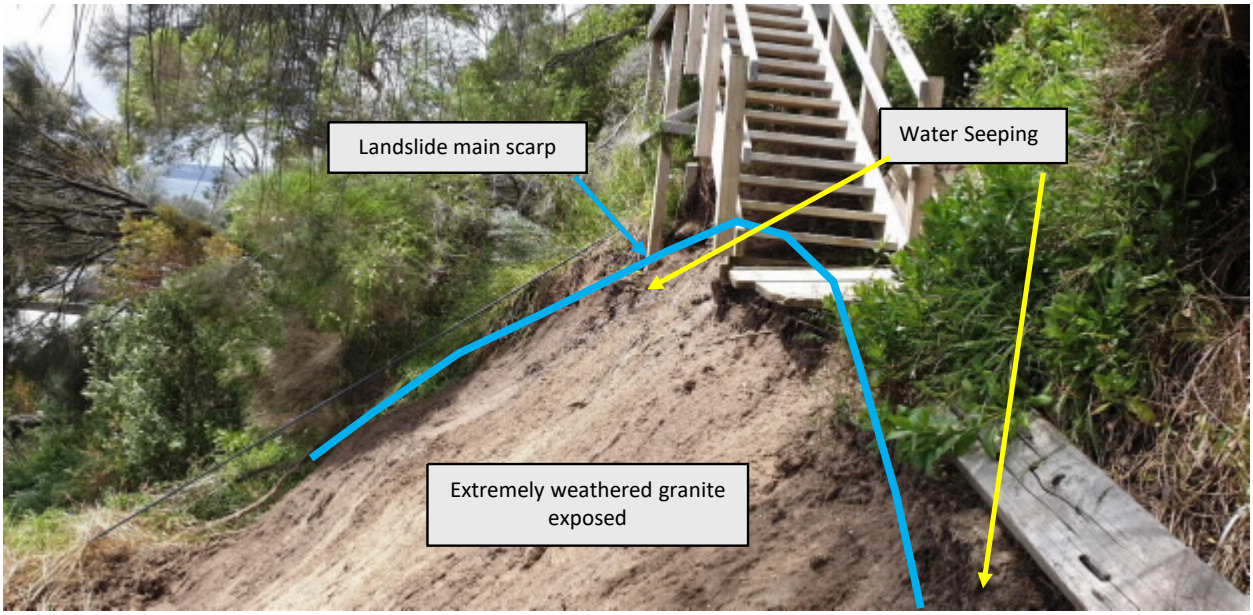

Figure 4-2: Main scarp of landslide

Figure 4-3: Accumulation zone of landslide

As shown in Figure 4-4 there is a tension crack on the right flank of the upper landslide. It appears to be confined to the immediate vicinity within 2-3m of the landslide. It is considered possible that the landslide could widen in this area by several metres.

Figure 4-4: Tension crack on right flank

On the left flank there was an old timber retaining wall present. It was significant leaning and there was evidence of water seeping through the wall. To the front of these walls there were several tension cracks. These tension cracks appeared to be in two forms. One set of cracks appeared to indicate the rupture surface at the toe of movement further up slope while the second set of cracks appeared to indicate a developing head scarp of a landslide of the lower slope.

The tension cracks on the left flank appeared to extend approximately 5m from the existing landslide. This indicates that there is potential for widening of the existing landslide by several metres should heavy rainfall continue.

The retaining wall and tension cracks are shown in Figure 4-5.

Figure 4-5: Leaning retaining wall and tension cracks on left flank

4.2 LOWER SLOPE

The lower slope is dominated by a debris flow that has been initiated by a significant increase in ground moisture, most likely as a combination of significant rainfall and potentially the failure of an irrigation pipe after the upper landslide occurred. Figure 4-5 shows an aerial view of the site taken by Victoria Police drones. It shows the debris flow initiated within the accumulation zone of the upper landslide and then flowed downslope across Penny Lane and into the rear of the properties of 3 Penny Lane and 3/613 Pt Nepean Road.

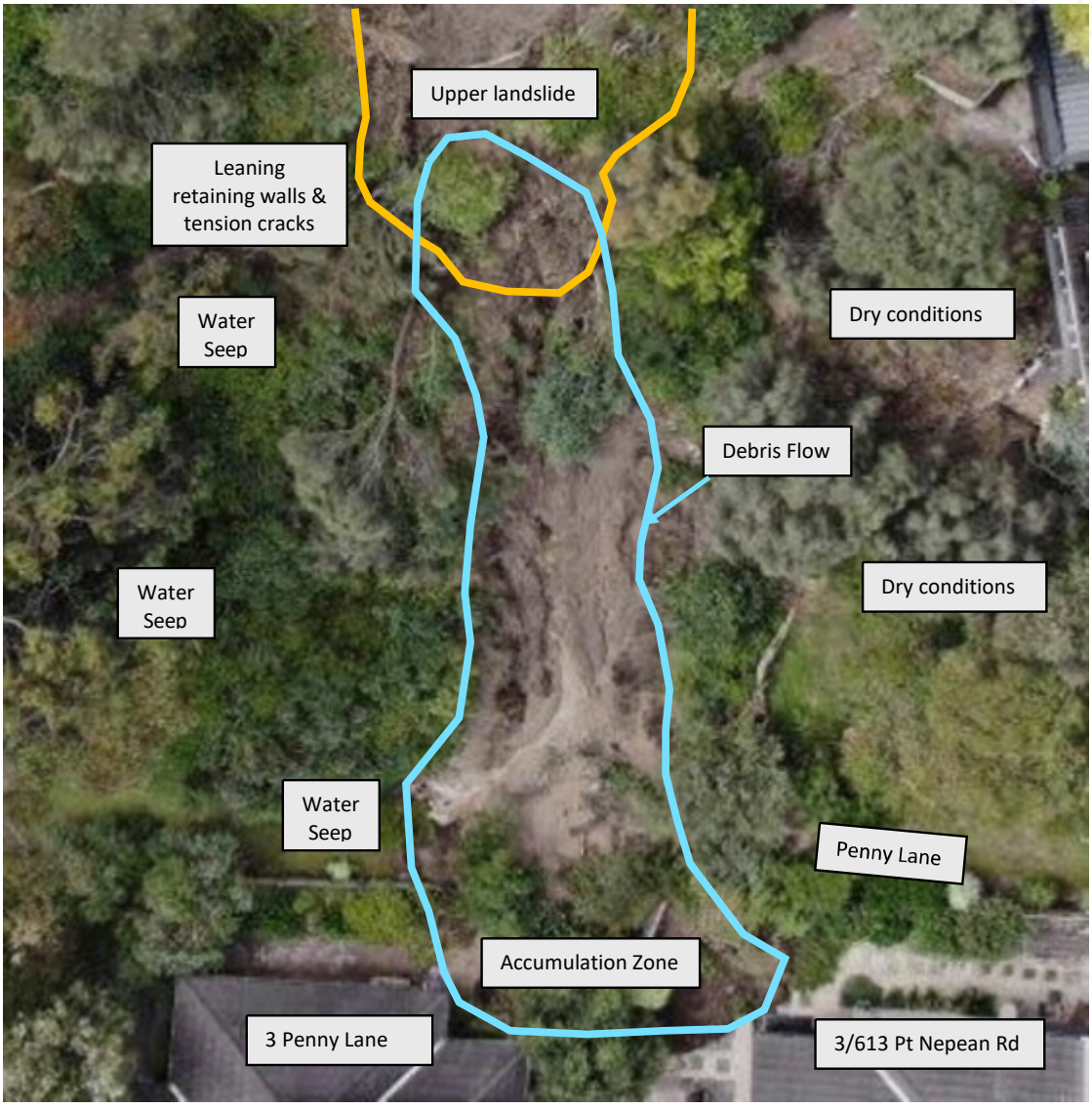

Figure 4-6: Aerial view of lower debris flow

Figure 4-6 shows the path of the debris flow. It can be seen that the upper vegetation has been stripped and that there has been some scour of the underlying soils. The deepest sections of scour have eroded down to the top of the extremely weathered granite.

Figure 4-7 shows the accumulation zone of the debris flow. It can be seen that the debris flow crossed over Penny Lane, which lies between 10-12 View Point Road and the houses along Pt Nepean Road, and into the rear of two properties.

While a large amount of the upper soils have already flowed down slope, it is considered that there is potential for addition debris flows to initiate in the accumulation zone of the landslide and impact on the area down slope.

Figure 4-7: Debris flow path

Figure 4-8: Accumulation zone of debris flow and view to top of landslide

The conditions on either side of where the debris flow occurred were observed to be significantly different. On the right (western) side the conditions were quite dry and there was no evidence of water seepage. However, on the left (eastern) side there were a number of water seeps observed. These water seeps were observed to be flowing freely more than 24 hours after the heavy rainfall event.

Based on the evidence of tension cracks up slope of this eastern area and that there are significant springs in the area, it is considered that there is potential for a landslide or debris flow to develop within the eastern area especially if there is another heavy rainfall event. However, such a landslide would be unlikely to extend as far east as the property at 2 Penny Lane.

An example of one of the water seeps is shown in Figure 4-8.

Figure 4-9: Water seepage on left side of site

5 RISK ASSESSMENT

The site inspection has identified a number of landslide hazards. These hazards have the potential to reactivate, especially while the current wet weather conditions persist. In order to determine whether it is appropriate for people to return to their properties a Landslide Risk Assessment (LRA) has been conducted to assess the Risk to Life for people on the properties. The LRA has been conducted under the general guidance of the Australian Geomechanics Society *Practice Note Guidelines for Landslide Risk Management 2007* (AGS 2007).

5.1 LANDSLIDE HAZARDS

A number of different potential landslide hazards have been identified for the site. These are identified on Figure 5-1 as numbers 1 to 6 with a description provided below. The properties at risk are shown as letters A to F.

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Figure 5-1: Potential Landslide Hazards and Properties at Risk

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The potential landslide hazards are:

1. Recession of the head scarp of the upper landslide resulting in a translation landslide down slope. It is considered such a landslide would be similar to that which recently occurred on the upper slope such that material would most likely translate to a lower part of the slope but most likely not cross Penny Lane such that it remains within Property C. The landslide would most likely be moderate to rapid. While most likely people in the area would identify the landslide moving and move out of the way, there is potential some people would be impacted.
2. Widening of the landslide on the upper slope to the right of the existing landslide, where the tension cracks are currently located. It is considered such a landslide would be similar to that which recently occurred on the upper slope such that material would most likely translate to a lower part of the slope but most likely not cross Penny Lane. This landslide would predominantly be within Property C but could flow over the eastern edge of Property D. The landslide would most likely be moderate to rapid. While most likely people in the area would identify the landslide moving and move out of the way, there is potential some people would be impacted.
3. Reactivation of the upper landslide debris as a translational landslide. This landslide could occur due to moisture build up within the landslide debris resulting in this material translating down slope. It is considered that there is sufficient material that the landslide could flow into the rear of Property F and potentially Property E. The landslide would most likely be rapid to very rapid and as such people would have difficulty avoiding the landslide if they were engaged in other activities in the area at the time.
4. New debris flow similar that that which previously occurred. Due to the build up of material at the base of the upper landslide there is potential for this material to become saturated, especially if a heavy rainfall event occurred. Should a debris flow occur rather than a translational landslide then the event would be very rapid to extremely rapid and would flow into the rear of Property E and F with similar or greater impact than the recent debris flow.
5. Widening of the landslide on the upper slope to the left of the existing landslide. It is considered such a landslide would be similar to that which recently occurred on the upper slope such that material would most likely translate to a lower part of the slope but most likely not cross Penny Lane. This landslide would predominantly be with within Property D and would be unlikely to extend to Property B. The landslide would most likely be moderate to rapid. While most likely people in the area would identify the landslide moving and move out of the way, there is potential some people would be impacted.
6. Activation of a translational landslide on the lower slope to the left of the existing landslide. This area is very wet and showing some signs of movement. If such a landslide were to occur it could flow across Penny Lane and impact on the dwelling at Property F. It could also potentially flow as wide as the drive way of Property B. The landslide would most likely be rapid to very rapid and as such people would have difficulty avoiding the landslide if they were engaged in other activities in the area at the time.

The properties that were considered to potentially be at risk are:

A. The Penny Lane Road Reserve
B. 3 Penny Lane
C. 10-12 View Point Road (Only considers area to north (rear) of house, house not at risk)
D. 14-16 View Point Road
E. 3/613 Pt Nepean Road
F. 2 Penny Lane

Properties not mentioned are considered to not be at risk from the current landslides.

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5.2 ANNUAL PROBABILITY

In order to determine the risk from the different landslides it is necessary to estimate the annual probability of them occurring. As there a number of different landslides with different mechanisms each landslide will have a different probability. The estimates made are based on different factors such as whether the landslide is new or a reactivation and then how much rainfall may be required to trigger such a landslide. For example, for the recession of the upper landslide it may take a similar event to that which occurred recently (i.e. 1 in 20 years) while to reactivate an existing landslide it may only take a 1 in 1 year event.

It is important to understand that these estimates are generally order of magnitude only.

The following is a summary of the estimated annual probability for each landslide hazard:

1. 1 in 20 years (0.05)
2. 1 in 5 years (0.2)
3. 1 in 2 years (0.5)
4. 1 in 5 years (0.2)
5. 1 in 5 years (0.2)
6. 1 in 5 years (0.2)

5.3 SPATIAL PROBABILITY

The spatial probability of a landslide involves the proportion of a property that may be impacted by a potential landslide. That is, if a landslide flowed onto a property to occupy 10% of that property, then the spatial probability would be 0.1. If a landslide occupies the whole property, then the spatial probability is 1.0. While if the landslide does not impact on the property then the spatial probability is 0.0. For Property B and D it is considered very unlikely that the landslides would extend to those properties and as such a spatial probability of 0.0 has been adopted, with the exception of Hazard 6 for Property B and Hazard 2 for Property D where a nominal value has been adopted to allow for the a low potential of the hazard spreading beyond the boundary.

The spatial probability needs to be estimated for each hazard for each property.

The estimated spatial probability for each combination of hazard and property is provided in Table 5-1.

Table 5-1: Spatial probability for different hazards and properties

	Property A	Property B	Property C	Property D	Property E	Property F
Hazard 1	0.1	0.0	0.3	0.0	0.1	0.1
Hazard 2	0.1	0.0	0.3	0.01	0.1	0.1
Hazard 3	0.5	0.0	0.2	0.0	0.2	0.3
Hazard 4	0.5	0.0	0.2	0.0	0.2	0.4
Hazard 5	0.1	0.0	0.3	0.0	0.0	0.1
Hazard 6	0.5	0.01	0.2	0.0	0.0	0.3

5.4 TEMPORAL PROBABILITY & VULNERABILITY

The temporal probability is the likelihood of a person being on site at the location of the landslide at the time that it occurs.

For Properties C, E & F a conservative assumption that a person may be in their house for 12 hours a day (12/24 = 0.5) and in the open area outside their house for 3 hours per day (3/24 = 0.125) has been adopted.

For Properties B & C the areas that are at risk are relatively less accessible steep parts of the site. A nominal amount of access in the order of 1 hour per day has been allowed for. (1/24 = 0.04)

For Penny Lane it is assumed that a single person may walk through this area for at most 15 minutes per day. (0.25/24 = 0.01)

The vulnerability is the likelihood that a person would be killed or very seriously injured if impacted by the landslide. The vulnerability is dependent on a number of factors such as the speed of the landslide, whether the person is up slope or down slope of the landslide or whether they are protected by a building or not. Based on the observations of the landslides that have occurred, it is considered that a person outside is significantly more vulnerable than a person inside, possibly at a factor of 1 in 4.

Therefore, the combination of temporal probability and vulnerability for a person outside will be adopted for each of the properties and hazards. The estimated temporal probability (first number) and vulnerability (second number) is shown for each hazard and property in Table 5-2.

Table 5-2: Combined temporal probability and vulnerability for different hazards and properties

	Property A	Property B	Property C	Property D	Property E	Property F
Hazard 1	0.01 x 0.25	0.04 x 0.1	0.25 x 0.25	0.04 x 0.1	0.25 x 0.25	0.25 x 0.25
Hazard 2	0.01 x 0.25	0.04 x 0.1	0.25 x 0.25	0.04 x 0.25	0.25 x 0.25	0.25 x 0.25
Hazard 3	0.01 x 0.8	0.04 x 0.1	0.25 x 0.4	0.04 x 0.1	0.25 x 0.8	0.25 x 0.8
Hazard 4	0.01 x 0.9	0.04 x 0.1	0.25 x 0.5	0.04 x 0.1	0.25 x 0.9	0.25 x 0.9
Hazard 5	0.01 x 0.25	0.04 x 0.25	0.25 x 0.25	0.04 x 0.1	0.25 x 0.25	0.25 x 0.25
Hazard 6	0.01 x 0.8	0.04 x 0.5	0.25 x 0.4	0.04 x 0.1	0.25 x 0.8	0.25 x 0.8

5.5 ACCEPTANCE CRITERIA

AGS 2007 indicates that different levels of risk are appropriate when considering existing slopes or developments and new developments.

For existing slopes AGS (2007) suggests that 'tolerable' risk should be less than or equal to $1x10^{-4}$. For newly engineered slopes or new developments AGS (2007) suggests that 'tolerable' risk should be less than or equal to $1x10^{-5}$.

Therefore, for this site a tolerable risk of not greater than $1x10^{-4}$ needs to be achieved for the existing slope. However, any remediation works would need to achieve a risk of $1x10^{-5}$.

It is important to understand that a risk assessment does not state that a death or serious injury will or will not occur. It is a statistical likelihood based on a number of factors that is then compared against a pre-defined level of tolerability.

5.6 RISK TO LIFE ASSESSMENT

The risk to life from the different hazards to people occupying the different properties has been conducted. The results of the quantitative risk are provided in Table 5-3.

Table 5-3: Risk to Life for different properties and hazards

	Property A	Property B	Property C	Property D	Property E	Property F
Hazard 1	1.3×10^{-5}	0.0	9.4×10^{-4}	0.0	3.1×10^{-4}	3.1×10^{-4}
Hazard 2	5.0×10^{-5}	0.0	3.8×10^{-3}	2.1×10^{-5}	1.3×10^{-3}	1.3×10^{-3}
Hazard 3	2.0×10^{-3}	0.0	1.0×10^{-2}	0.0	2.0×10^{-2}	3.0×10^{-2}
Hazard 4	9.0×10^{-4}	0.0	5.0×10^{-3}	0.0	9.0×10^{-3}	1.8×10^{-2}
Hazard 5	5.0×10^{-5}	0.0	3.8×10^{-3}	0.0	0.0	1.3×10^{-3}
Hazard 6	8.0×10^{-4}	4.2×10^{-5}	4.0×10^{-3}	0.0	0.0	1.2×10^{-2}
Combined	3.8×10^{-3}	4.2×10^{-5}	2.7×10^{-2}	2.1×10^{-5}	3.1×10^{-2}	6.3×10^{-2}
Risk to Life is Acceptable						
Risk to Life is Tolerable						
Risk to Life is Not Tolerable						

It can be seen from the table above that the combined risk for Property B and Property D are both 'Tolerable' while the combined risk for Properties A, C, E & F is 'Not Tolerable'. A discussion with regard to the risk to each property and mitigation measures required to reduce the risk to a 'Tolerable' level is provided in the following section.

6 CONCLUSION

The risk analysis has shown that the Risk to Life for Property B (3 Penny Lane) & Property D (14-16 View Point Lane) in the slope's current condition is Tolerable. As such it is considered that the occupiers of these two properties should be allowed open access to their properties provided they are made aware of good hillside practices as provided in AGS(2007e). A brief discussion was provided on site to the occupiers. However, it is recommended that the Shire provide the AGS(2007e) document for further reference.

The risk analysis has shown that the Risk to Life for Property A (the Penny Lane road reserve) is 'Not Tolerable' in the slope's current condition. The risk for Property A will continue to remain at this level of risk until appropriate remediation works have been conducted to reduce the risk. As such it is recommended that Penny Lane be barricaded off from the driveway of Property D through to the driveway of Property B. Barricading off the site will significantly reduce the temporary probability of people being impacted by the landslide such that the risk can be reduced to a 'Tolerable' level.

The risk analysis has shown that the Risk to Life for Property C (10-12 View Point Road) is 'Not Tolerable' in the slope's current condition. However, the 'Not Tolerable' is considered to only apply to the steep section of the site and the area within 5m of the crest of the slope. The area beyond 5m from the slope at the crest is considered to have a 'Tolerable' risk. As such it is recommended that the area within 5m of the crest of the slope be barricaded off to prevent access to the site. The barricade should extend from one side of the

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property to the other and then down the boundaries with the neighbouring properties to Penny Lane. This will reduce the risk to a 'Tolerable' level for the occupiers of Property C provided that the do not enter the barricaded area. In addition, the occupiers should be provided with the AGS(2007e) so that they are aware of appropriate hillside practices. It is important to note that in order to conduct remediation works it will be necessary for workers to enter the affected area. An remediation works should include an appropriate safety plan that outlines methodologies and practices that will be adopted to reduce the risk to workers to an acceptable level as well as minimize the risk to the buildings of Properties E & F during these works.

The risk analysis has shown that the Risk to Life for Properties E (3/613 Pt Nepean Road) and F (3 Penny Lane) is 'Not Tolerable'. Unfortunately barricading off the properties is not considered sufficient to allow people to return. This is because the barricades would not prevent the landslides from occurring and the risk to people even within the houses would not be tolerable. As such it is recommended that the occupants of these two properties are not allowed to return to living to their homes until appropriate rectification works are undertaken. Limited access to the properties may be allowed to the properties to gather belonging etc. provided that it is conducted under the control of a Shire engineer who will need to inspect the site prior to the occupants entering the area and be on site will the occupants are on site.

We trust this meets with your requirements.

Yours sincerely,

Personal Information

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