REPORT

Wolgan Gap, Wolgan Road

Slope Risk Assessment Update 2022 - Domain 1 and 2

Submitted to:

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Executive Summary

Wolgan Road traverses an area of historic and ongoing slope hazard which has been managed by Lithgow City Council (Council) in accordance with the Wolgan Road – Wolgan Gap Road Slope Instability Management Plan (Golder 2009a and Golder 2019b) since 2006. Between 2006 and 2016, the dominant slope hazard affecting road users was rockfall with an upslope source zone over a length of approximately 240 m north of Wolgan Gap lookout. Following a rockfall in that area on 8th September 2008, Council scheduled a re-assessment of the risks posed by upslope hazards to road users and undertook targeted remediation works. The remediation works (completed in 2009) included installation of permanent monitoring points for selected rock topple hazards, scaling and targeted rock bolting. On-going periodic monitoring and re-assessment of the area continued and from 2009 to the end of 2021 the dominant slope hazard affecting road users continued to be rockfall with an upslope source zone.

During 2022, protracted above average rainfall triggered mobilisation of numerous upslope and downslope landslides resulting in extensive material loss and damage to the road. As part of the Review of Wolgan Gap Slope Hazards 2022 (WSP-Golder 2023) in addition to the existing rockfall hazards, a further 128 specific slope hazard locations were identified over an approximately 2.7 km length of the road. Of the additional 128 slope hazards, 37 were identified as active based on observed displacements with the potential for further movement. Those 37 active slope hazards predominantly comprise upslope and downslope debris flows and debris slides, up to 100 m in width (i.e. across the slope) and up to more than 50 m in length (i.e. up the slope). At one location approximately 100 m of the south-bound lane has undergone more than 2 m vertical displacement as a result of active slope movements between October 2022 and January 2023.

The slope hazards currently pose an annual individual loss of life risk of more than 200 times greater than industry tolerable limits ($R_{(LOL)} = 2 \times 10^{-3}$ per annum). The calculated annual societal risk of one or more fatalities is 1000 times greater than industry tolerable limits ($F = 1 \times 10^{-1}$ per annum). Wolgan Road at Wolgan Gap is currently closed due to the annual loss of life risk to road users.

If financially feasible, re-opening Wolgan Road requires extensive remediation works to reduce the risk to road users. A minimum of 13 hazards, referred to as Category 1 hazards, require careful staged remediation due to their active status and the risk they pose to investigation and remediation workers. A preliminary indicative estimate of the potential remediation cost for those 13 hazards is over $20 million. If those 13 Category 1 hazards are remediated and removed from life risk calculations, the modified annual individual loss of life risk and societal risk remains unacceptable - being 9 times and 100 times greater than industry tolerable limits, respectively. The residual annual property risk also remains unacceptable with an estimated annual loss of value of $2 million per annum for unrepaired hazards. Remediation of all Category 1 and 2 hazards and selected Category 3 hazards, with a preliminary indicative cost of more than $60 million, has been calculated to achieve marginally acceptable residual risk. Remediation may be impractical and such high remediation costs may be disproportionate to risk improvements obtained.

Because of the high $R_{(LOL)}$ values, Wolgan Road would need to remain closed until investigation, design, procurement and remediation construction was complete, which would likely extend over a lengthy period. If more affordable remedial measures with a short design life were to be adopted, a robust on-going annual budget for relatively frequent repairs or replacement would be needed. Given that the road has been the primary access to the Wolgan Valley for over 100 years, remediation measures with a further 100-year design life would need to be considered, accommodating potential growth in usage and ongoing extreme climatic events. Even with extensive and costly remediation, residual annual loss of life and annual property risk would remain and an on-going annual budget allocation would be required for monitoring, inspection and

maintenance. Given the very high costs and the need for on-going closure of the road (and significant worker safety challenges) Council may wish to consider alternative access in an area of lower slope hazard susceptibility. An alternative access might provide a more resilient, cost effective and future proofed access solution to the Wolgan Valley.

Table of Contents

TABLES

FIGURES

APPENDICES

1.0 INTRODUCTION

Wolgan Road at Wolgan Gap traverses an area of rockfall and landslide hazard which has been managed by Lithgow City Council (Council) in accordance with the Wolgan Road – Wolgan Gap Road Slope Instability Management Plan (Golder 2009a and Golder 2019b). The Instability Management Plan recommends on-going periodic inspection, Quantitative Risk Analysis (QRA) and Slope Risk Assessment (SRA) as part of the management of the slope hazard at the Wolgan Gap site.

Following a landslide which occurred at Wolgan Road on Saturday 5th November 2022, Wolgan Road at Wolgan Gap, was closed to all traffic due to unacceptably high loss of life risk posed by that landslide and other geotechnical slope hazards. For details of those hazards, reference can be made to the Review of Wolgan Gap Slope Hazards 2022 (WSP-Golder 2023).

This report provides an update of previous SRA undertaken for the site (Golder 2021a) for the increased length of Wolgan Road at Wolgan Gap assessed and the updated geotechnical slope hazards presented in our Review of Wolgan Gap Slope Hazards 2022 (WSP-Golder 2023).

This report has been prepared by WSP Australia Pty Ltd (WSP) in response to Council's request (Purchase Order 126931-OPER).

1.1 Glossary of Terms

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

ALARP – (As Low As Reasonably Practicable); that principle which states that risks, lower than the limit of tolerability, are tolerable only if risk reduction is impracticable or if its cost is grossly disproportionate (depending on level of risk) to the improvement gains.

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.

Hazard – A condition with the potential for causing an undesirable consequence.

Individual Risk to Life – The risk of fatality or injury to an individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject them to the consequences of the landslide.

Elements At Risk (EAR) – The population, buildings and engineering works, economic activities, public service utilities, infrastructure and environmental features in the area potentially affected by the landslides. For the SRA reported herein, the EAR considered are restricted to those described in Section 2.3.1.

Landslide – The movement of a mass of rock, debris, or earth (soil) down a slope. The phenomena described as landslides are not limited to either the "land" or to "sliding" and the word implies a more extensive meaning than its component parts suggest. In accordance, with Figure B1 of the Practice Note Guidelines for Landslide Risk Management 2007 (AGS 2007b), rockfall is included within the broad definition of landslide. For the purposes of the QRA reported herein failure of retention elements (e.g. soil nail remediation or retaining walls) and drainage elements (e.g. culverts) have been included.

Landslide Activity – The stage of development of a landslide; *pre-failure* when the slope is strained throughout but is essentially intact; failure characterized by the formation of a continuous surface of rupture; *post-failure* which includes movement from just after failure to when it essentially stops and *reactivation* when

the slope slides along one or several pre-existing surface of rupture. Reactivation may be occasional (e.g. seasonal) or continuous (in which case the slide is “active”).

Landslide Susceptibility – A quantitative or qualitative assessment of the classification, volume (or area) and spatial distribution of landslides which exist or potentially may occur in an area.

Person Most At Risk (PMAR) – An individual who follows the pattern of life described in Section 2.3.1 and is assumed to be the public road user with the highest exposure to the possible consequences of the slope hazards described herein as a result of traversing (by motor vehicle) the section of road assessed. For scenarios other than those addressed in this report and described in Section 2.3.1 (e.g. scenarios associated with remediation construction), the PMAR would be different and have a different (e.g. higher or lower) risk profile than the PMAR defined herein depending on their specific exposure and the particular hazards to which they are exposed.

Quantitative Risk Analysis (QRA) – An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. For life loss; the annual probability that the person most at risk will lose his or her life taking account of the landslide hazard and the temporal spatial probability and vulnerability of the person. For property loss; the annual probability of the consequence or the annualized loss taking account of the elements at risk, their temporal spatial probability and vulnerability.

Risk Analysis – The use of available information to estimate the risk to individual, population, property, or the environment, from hazards.

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

Slope Hazard – An identifiable slope condition (i.e. landslide) with the potential for causing an undesirable consequence.

Societal Risk – The risk of multiple fatalities or injuries in society as a whole. In this report the societal risk refers to the annual probability of one or more fatalities (i.e. N ≥ 1 case in relation to a Frequency (F) versus Number of fatalities (N) plot).

Slope Risk Assessment (SRA) – The process of risk evaluation on the basis of the results of Risk Analysis undertaken for Slope Hazards.

Tolerable Risk – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

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.

1.2 Background for Tolerable Risk Assessment

For Council’s consideration and guidance, Table 1 of AGS 2007b is reproduced below.

Table 1: AGS Suggested Guidelines on tolerable risk for loss of individual life risk

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

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

Based on Note 5 of Table 1 above, it is envisaged that a limiting tolerable loss of life criteria for the person most at risk of no more than 1×10^{-5} /annum may be considered tolerable by Council. As further noted by AGS 2007a, acceptable risk may often be considered to be one order of magnitude lower than the tolerable risk, i.e $1x10^{-6}$.

Australian Geoguide LR7 (Landslide Risk) contains published risk levels for various activities including motor cycling, motor vehicle use, airline travel and train travel and is provided in Appendix C for reference.

Typically adopted industry tolerability criteria for societal risk of one or more fatality (i.e. $N \geq 1$) is 1×10^{-3} p.a. for existing slopes as described in Note 1 of Table 1 and 1×10^{-4} p.a. for existing landslides as described in Note 5 of Table 1.

For Council's consideration in assessing the property risk reported herein, the upper bound annualised costs (as a proportion of property value) of Table CC1 of Appendix CC of the Commentary on the Practice Note Guidelines for Landslide Risk Management 2007 (AGS 2007c) are provided in Table 2 below. Also shown are the recommended risk evaluation thresholds of Table CC1.

Table 2: AGS Recommended Risk Evaluation Thresholds for property risk (AGS 2007c)

Property Risk Level	Proportion of Property Value (Upper Bound)	AGS Recommended Risk Evaluation
Very High	100 %	UNACCEPTABLE
High	10%	UNACCEPTABLE
Moderate	1%	TOLERABLE: For existing structures, but treatment to reduce risk to Low should be identified and implemented as soon as practicable.
Low	0.1%	ACCEPTABLE: For new and existing slopes/works.
Very Low	0.005%	ACCEPTABLE: For new and existing slopes/works.

2.0 2022 SRA UPDATE

Prior to 2022, the dominant slope hazard affecting the Wolgan Road at Wolgan Gap was rockfall with an upslope source zone in the area described as Domain 1 herein (i.e. up to approximately 700 m north of the Wolgan Gap lookout) and shown on Figure A2 of Appendix A.

Following protracted above average rainfall during 2022, the mobilisation of hazards in addition to rockfall resulted in obstruction of Wolgan Road, damage and loss of the road embankment in some areas. These hazards were upslope and downslope debris flows and slides. This QRA update includes the approximately 2.7 km length of Wolgan Road shown on Figures A1 to A4 of Appendix A (i.e. Domain 1 and Domain 2). The QRA was undertaken in accordance with AGS 2007b, using the following methodology:

Loss of Life Calculation

The annual risk of loss of life for an individual Element At Risk (EAR) was calculated from:

$$R_{LoL} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)} \qquad \text{Eq.1}$$

Where:

$R_{(LoL)}$: annual risk of loss of life for an individual,

$P_{(H)}$: annual probability of landslide/rockfall,

$P_{(S:H)}$: annual probability of spatial impact, considering travel distance and direction,

$P_{(T:S)}$: annual temporal spatial probability (exposure of the individual at risk to the hazard),

$V_{(D:T)}$: vulnerability of the individual (probability of loss of life given the impact).

Assumptions, including values adopted for input to Equation 1 are discussed in Section 2.3 below.

Annual Property Risk Calculation

The annual property risk (i.e. an annual loss of value, expected for the 2.7 km length of road assessed) has been calculated from:

$$R_{Prop} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(PROP:S)} \times E \qquad \text{Eq. 2}$$

Where:

$R_{(Prop)}$: annual property risk (annual loss of property value),

$P_{(H)}$: annual probability of landslide/rockfall,

$P_{(S:H)}$: annual probability of spatial impact with the property (i.e. the road and its components, including barriers), considering travel distance and direction,

$P_{(T:S)}$: annual temporal spatial probability (for the road and its components $P_{T:S}$ = 1.0),

$V_{(Prop:S)}$: vulnerability of the property to the spatial impact (proportion of property value lost),

E: the element at risk (the value of the property).

Assumptions, including values adopted for input to Equation 2 are provided in Section 2.4 below.

2.1 Geotechnical Slope Hazards Considered

The following geotechnical slope hazards have been considered in the 2022 QRA update for Wolgan Road at Wolgan Gap. For details including descriptions, examples of general hazards which apply to the full 2.7 km length (e.g. rockfall) and conditions at specific hazard locations reference can be made to the Review of Wolgan Gap Slope Hazards 2022 (WSP-Golder 2023).

- H1.1.1 Small rockfall (nominally 0 m to 1 m diameter).
- H1.1.2 Large rockfall (nominally 1 m to 5 m diameter).
- H1.2 – Rock Topple.
- H1.3 – Rock Slide.
- H2.1 – Upslope Debris Flow, specific location.
- H2.2 – Upslope Debris Slide, specific location.
- H3.1 - Downslope Debris Flow, specific location.
- H3.2 – Downslope Debris Slide specific location.
- H4.1 – Retention Element Failure (e.g. sandstone block retaining wall).
- H4.2 – Drainage Element Failure (e.g. culvert).

In addition to the risk posed by type H2.1, H2.2, H3.1 and H3.2 at specific locations nominated within the Review of Wolgan Gap Slope Hazards 2022, there remains the potential for slope movement consistent with those hazard types to occur elsewhere along the length of Wolgan Road assessed. To account for that, the following additional general hazard types have been considered in the SRA reported herein and applied to portions of the slope not already addressed by specific hazard locations.

- H2.3 – Upslope Debris Slide/Flow, general.
- H3.3 – Downslope Debris Slide/Flow, general.

2.2 Trigger Mechanism(s)

The dominant trigger for rockfall and landslide at the site is rainfall and reference can be made to Golder 2021a for details regarding the influence of rainfall on rockfall frequency at the site. The dominant contribution of rainfall to triggering landslides is inferred to be build-up of water pressure, although scour from surface flows also contributes to de-stabilisation of the slopes (particularly where scour removes material supporting the toes of previous landslides).

On-going protracted above average rainfall was experienced at the site throughout 2022. This resulted in the most cumulative rainfall in any 12-month period (since 1974) on record at the Maddox Lane Bureau of Meteorology (BOM) Rainfall Station (BOM Station 63132). The record was surpassed on 10th October 2022. A new record was set a further 4 times in October 2022 and a further 3 times in November 2022, up to the current maximum record on 4th November 2022.

2.3 2022 SRA Update for Loss of Life Risk

Wolgan Road at Wolgan Gap is currently closed to all traffic, due to the loss of life risk posed by slope hazards. The following 3 categories have been applied to the slope hazards identified in Golder-WSP 2023 to aid Council in considering the effort that may be required and relative merits of investigation and remediation of particular slope hazards. This effort includes the time and cost which may be required versus residual property and life risk and likely on-going costs in maintaining that section of road following remediation.

- Category 1 Hazards – Hazards which present such a high loss of life risk in their current condition that access via conventional means for investigation (e.g. boreholes) and/or implementation of remedial measures (e.g. earthworks, drain installation, culvert replacement etc) presents significant worker safety challenges. These are typically active, enlarging hazards comprising several thousand cubic metres of material or more. These hazards would require removal or remediation as a priority to enable access, investigation and remediation of any other hazard.
- Category 2 Hazards – Additional hazards which are calculated to require remediation in order to meet industry annual individual loss of life risk tolerability criteria as described in Table 1 of Section 1.2 above.
- Category 3 Hazards – Remainder of assessed slope hazards not falling within Category 1 or 2.

Annual individual loss of life risk for the PMAR and the annual societal risk as described in Section 2.3.1 has been calculated and is reported in Section 2.3.2 for the following cases.

- Case 1 – Category 1, 2 and 3 hazards un-remediated (i.e. the current condition)
- Case 2 – Category 2 and 3 hazards remain un-remediated (i.e. Category 1 hazards removed to estimate the potential most favourable effect of their remediation on residual risk).
- Case 3 – Only selected Category 3 hazards remain un-remediated, targeted towards meeting industry annual societal risk tolerability criteria (i.e. Category 1, Category 2 and Selected Category 3 hazards are removed to estimate the potential most favourable effect of their remediation on residual risk).

Cases 2 and 3 are theoretical cases, whereby the remediation has been 'wished into place' to result in no residual loss of life risk for Category 1 or 2 or selected Category 3 hazards. In reality, some residual risk will remain after implementation of remedial measures even within their design life (except for where a hazard can be completely removed without de-stabilising the surrounding area, e.g. in some cases possible for a boulder removed from a cutting crest). The magnitude of residual risk will depend on the nature and extent of the remediation adopted. Calculation of the residual risk for Case 2 and Case 3 would require consideration of the particular remediation measures adopted along with any impacts their installation may have on surrounding hazards.

The annual loss of life risk reported herein for the hazards described above is for a ***mobile road user only*** and the temporal spatial probability, probability of spatial impact and vulnerability (i.e. $P_{(T:S)}$, $P_{(S:H)}$ and $V_{(D:T)}$ of Equation 1 above) adopted in Section 2.3.1 does not consider the risk to others who may be exposed to the hazards (e.g. workers undertaking investigation and/or remediation works).

The planning and execution of investigation and remediation works, where able to be undertaken, would require careful consideration and mitigation of the loss of life risk which the hazards pose based on the specific exposure conditions (e.g. static or mobile, duration of exposure, protection measures). Furthermore, there are additional hazards which would need to be considered in assessing investigation and remediation loss of life risk which do not form part of this assessment such as the risk of tree fall which is increased in areas of active landslides due to the de-stabilising effect of ground movement on vegetation.

2.3.1 Loss of Life Risk Calculation Assumptions

Item 1 and 2 below describe the EAR considered in this QRA, for individual and societal loss of life risk calculations respectively.

1) The Person Most At Risk (PMAR) – assumed to be an individual road user traversing the 2.7 km length of Wolgan Road in a motor vehicle.

2) Road users as a collective group (based on Council supplied traffic counts), who traverse the 2.7 km length of Wolgan Road in a motor vehicle individually.

The PMAR has been assumed to be a road user who traverses the road on average 2 times per day (i.e. one return trip), every day of the year.

The annual societal risk of one or more fatalities has been calculated based upon a Council supplied traffic count of 114 vehicle per day (i.e. 41610 vehicles p.a.).

2.3.1.1 Probability of Landslide Movement (P_H) and Spatial Impact ($P_{S:H}$)

Adopted probability of rockfall values have been based upon Council's inventory of rockfall events (Golder 2021a). For large rockfalls the following $P_{(H)}$ and diameter value has been adopted, (i.e. in the High hazard descriptor category in Table 5 of AGS 2007a).

- Large rockfall H1.1.2 (3 m diameter adopted for calculations), $P_{(H)}$ = 0.4 per km p.a.

For small rockfall an order of magnitude higher value has been adopted (i.e. a Very High hazard descriptor category in Table 5 of AS 2007), as follows.

- Small rockfall H1.1.1 (0.5 m diameter adopted for calculations), $P_{(H)}$ = 4 per km p.a.

The $P_{(H)}$ values adopted for rockfall are based on calculated annual averages using long term annual average rainfall conditions. We consider this approach appropriate for the purpose of calculation of annual loss of life risk for the EAR described above. However, the frequency of rockfall has been observed to increase at the Wolgan Road site under protracted above average rainfall conditions (Golder 2021a). An annual average approach to determination of rockfall probability is considered reasonable for calculation of the annual loss of life risk for a mobile road user over the course of a year, but that same approach may not be reasonable for other EAR, durations of exposure and exposure conditions. For example, we would not consider it appropriate to use an annual average probability in calculation of the risk faced by a work crew undertaking works only during or immediately following a period of protracted above average rainfall. In that case, the anticipated rockfall probability is expected to be higher than the annual average.

The potential for above average rainfall conditions to influence geotechnical slope hazard probability should be considered for EAR and durations of assessment other than the annual case reported herein, including where work crews may be exposed to hazards during investigation or remediation. On-going review of what constitutes an annual average rainfall condition and its relationship with landslide and rockfall frequencies would be necessary as part of longer term slope risk management of Wolgan Road, were it to be re-opened.

As the rockfall inventory has only recorded events which have impacted the road a $P_{(S:H)}$ value of 1 has been applied in conjunction with $P_{(H)}$ values for rockfall above.

Probability of landslide (i.e. $P_{(H)}$) and spatial impact (i.e. $P_{(S:H)}$) values for all other slope hazards as defined in Section 2.1 than rockfall have been adopted based on engineering geological judgement, our current understanding of the instability mechanisms and our observations of the performance of the slopes above and below Wolgan Road. The probabilities of landslide ($P_{(H)}$) have been assigned in general accordance with the hazard descriptor categories of Table 5 of the Guideline for Landslide Susceptibility, Hazard and Risk Zoning in AGS 2007 (i.e. ranging between Very Low to Very High) and in the range from $P_{(H)}$ = 0.0001 p.a. to $P_{(H)}$ = 1 p.a. The type, number and hazard category ratings for each slope hazard analysed are summarised in Table B1 of Appendix B.

We have set the upper limit for probability of specific landslides assessed herein to $P_{(H)}$ = 1 p.a.

The approach of setting an upper limit of $P_{(H)}$ = 1 p.a. for specific landslides has been taken cautiously in consideration of the calculated lack of sensitivity of the outcomes of this SRA to adoption of expected times of failure of less than one year. The calculated annual loss of life risk and annual property risk values herein are many times greater than industry risk tolerability criteria without breakdown of specific landslide probabilities (i.e. $P_{(H)}$ values) to shorter than annual time intervals. The probabilities of landslide for those hazards assigned a P_H = 1 p.a. herein should be considered lower bound estimates appropriate for the assessment of annual loss of life risk for a mobile vehicle occupant and no other purpose.

In the case of 'active' landslides, the landslide has already 'occurred' and the probability assigned herein is an estimate of the expected time before further movement of the landslide mass (both volume and velocity) which would result in the consequence to the EAR. The consequence is quantified by the multiple of expected temporal spatial probability and vulnerability (i.e. $P_{(T:S)} \times V_{(D:T)}$).

The assessment undertaken herein considers the 128 specific hazards recorded in the Review of Wolgan Gap Slope Hazards, 2022 (WSP-Golder 2023). As discussed in that report, 37 of those hazards were considered active at the time of the 15th November 2022 aerial survey. An active landslide is one that has undergone (or is still undergoing) significant displacement and/or material loss and has not yet reached a state of equilibrium. Those hazards have been assigned a Very High hazard descriptor and probability of landslide, (i.e. $P_{(H)}$) value between 0.1 p.a. and 1.0 p.a. for the purposes of the assessment contained herein.

Outside of the areas addressed by the 128 specific hazards identified, hazard categories H2.3 (i.e. Upslope debris flow/slide, general) and H3.3 (Downslope debris flow/slide, general) have been applied and assigned a hazard descriptor of Very Low (with an assumed probability of landslide, $P_{(H)}$ value of 0.01 p.a per km).

2.3.1.2 Temporal Spatial Probability ($P_{T:S}$) and Vulnerability ($V_{D:T}$)

Temporal spatial probability (i.e. $P_{(T:S)}$) for the EAR assessed herein has been calculated based upon a vehicular speed of 40 km/hr, the affected widths shown in Table B2 of Appendix B and the assumed number of vehicle passes described in Section 2.3.1 above.

Vulnerability (i.e. $V_{(D:T)}$) value of 0.3 has been adopted for hazards H1.1.1 (small rockfall), H2.3 (Upslope Debris Flow/Slide General), H3.3 (Downslope Debris Flow/Slide General) (H1.1.1) and selected specific hazards as shown in Table B2.

Vulnerability (i.e. $V_{(D:T)}$) value of 0.9 has been adopted for all other hazards.

2.3.2 Results of Loss of Life Risk Calculation

The loss of life risk calculation results for Cases 1, 2 and 3 described in Section 2.3 are presented below.

2.3.2.1 Loss of Life Risk Case 1 (Category 1, 2 and 3 Hazards)

The calculated annual loss of life risk for the EAR defined in Section 2.3.1 above, under Case 1 of Section 2.3 (i.e. for all the hazards nominated in the Review of Wolgan Gap Slope Hazards), is summarised in Table 3 below.

Table 3: Case 1 Loss of Life Risk Assessment

Individual Risk			Societal Risk		
Calculated $R_{(LOL)}$ p.a.	Tolerable $R_{(LOL)}$ p.a.	Calculated $R_{(LOL)}$ with respect to Section 1.2 threshold values	Calculated F for N ≥ 1 p.a.	Tolerable F for N ≥ 1 p.a.	Calculated F for N ≥ 1 p.a. with respect to Section 1.2 threshold values
2×10^{-3}	1×10^{-5}	Unacceptable	1×10^{-1}	1×10^{-4}	Unacceptable

The currently calculated individual annual loss of life risk for the PMAR under Case 1 is approximately 200 times greater than the tolerability limit (i.e. in the unacceptable range).

The calculated annual societal loss of life risk of one or more fatalities for the traffic count provided in section 2.3.1 above, under Case 1 of Section 2.3 (i.e. for all the hazards nominated in the Review of Wolgan Gap Slope Hazards, 2022 is 1×10^{-1} p.a. which is 1000 times greater than conventional industry tolerability thresholds for areas of existing landslide (i.e. in the unacceptable range).

2.3.2.2 Loss of Life Risk Case 2 (Category 2 and 3 Hazards Only)

The calculated annual loss of life risk for the EAR defined in section 2.3.1 above, under Case 2 of Section 2.3 (i.e. for Category 2 and 3 hazards nominated in the Review of Wolgan Gap Slope Hazards only), is summarized in Table 4 below.

Table 4: Case 2 Loss of Life Risk Assessment

Individual Risk			Societal Risk		
Calculated $R_{(LOL)}$ p.a.	Tolerable $R_{(LOL)}$ p.a.	Calculated $R_{(LOL)}$ with respect to Section 1.2 threshold values	Calculated F for N ≥ 1 p.a.	Tolerable F for N ≥ 1 p.a.	Calculated F for N ≥ 1 p.a. with respect to Section 1.2 threshold values
9×10^{-4}	1×10^{-5}	Unacceptable	5×10^{-2}	1×10^{-4}	Unacceptable

The calculated individual loss of life risk for the PMAR under Case 2 is nearly 100 times greater than the tolerability limit (i.e. in the unacceptable range).

The calculated annual societal loss of life risk of one or more fatalities for the traffic count provided in section 2.3.1 above, under Case 2 is 5×10^{-2} p.a. which is 500 times greater than conventional industry tolerability thresholds for areas of existing landslide (i.e. in the unacceptable range).

2.3.2.3 Loss of Life Risk Case 3 (Selected Category 3 Hazards Only)

The calculated annual loss of life risk for the EAR defined in section 2.3.1 above, under Case 3 of Section 2.3 (i.e. only selected Category 3 hazards remain un-remediated), is summarised in Table 5 below.

Table 5: Case 3 Loss of Life Risk Assessment

Individual Risk			Societal Risk		
Calculated $R_{(LOL)}$ p.a.	Tolerable $R_{(LOL)}$ p.a.	Calculated $R_{(LOL)}$ with respect to Section 1.2 threshold values	Calculated F for N ≥ 1 p.a.	Tolerable F for N ≥ 1 p.a.	Calculated F for N ≥ 1 p.a. with respect to Section 1.2 threshold values
2×10^{-6}	1×10^{-5}	Tolerable	9.6×10^{-5}	1×10^{-4}	Marginally Tolerable

The calculated annual loss of life risk for the EAR defined in section 2.3.1 above, for Category 3 hazards only is 9.7×10^{-6} p.a. The calculated annual societal loss of life risk of one or more fatalities for the traffic count provided in section 2.3.1 above, for Category 3 hazards only is 6×10^{-4} p.a. which is 6 times greater than

conventional industry tolerability thresholds for areas of existing landslide (i.e. in the unacceptable range). Thus, it is calculated that in order to meet conventional industry risk tolerability criteria for annual societal risk of one or more fatality for an existing landslide that in addition to Category 1 and 2 hazards being effectively remediated (such that residual risk from those hazards in conjunction with the remainder of Category 3 hazards met the societal risk tolerability criteria), the following hazards would also require remediation.

- H1.1.1 and H1.1.2 (i.e. small and large rockfall) in Domain 1 and 2.
- H1.2 (i.e. Rock Topple) with at least a High Hazard ranking in Domain 1.

As shown in Table 5 above, if in addition to exclusion of all Category 1 and Category 2 hazards, H1.1.1 and H1.1.2 hazards in Domain 1 and 2 and High hazard ranking H1.2 Hazards within Domain 1 are excluded the calculated annual societal loss of life risk of one or more fatalities for the traffic count provided in section 2.3.1 above, is 9.6×10^{-5} p.a. which is fractionally below the tolerability limit (i.e. in the tolerable range). For that case (i.e. Case 3 of Section 2.3 above), the calculated annual individual loss of life risk for the PMAR is 2×10^{-6} p.a. which is below the industry risk tolerability criteria (i.e. in the tolerable range).

2.4 2022 SRA Update for Property Risk

Annual property risk (i.e. the annual risk of loss of value) has been calculated in accordance with Equation 2 above, for the Cases 1, 2 and 3 described in Section 2.3 above. Property risk represents a loss of value risk and does not reflect actual costs to re-instate property damaged or lost which would include investigation, design and remediation costs.

The probability of landslide movement (i.e. $P_{(H)}$) and spatial impact probabilities (i.e. $P_{(S:H)}$) values of Section 2.3.1.1 have been applied in the property risk calculations herein. As the road is a static EAR, a temporal spatial probability (i.e. $P_{(T:S)}$) of 1 has been applied. Potential loss of value for individual hazards (i.e. the multiple of $V_{(Prop:S)}$ and E of Equation 2) has been calculated based upon the following assumptions.

1) Hazards which can result in debris accumulation on the road will require debris removal, the cost of which is considered a loss of value.
2) Hazard H1.1.1 (small rockfall) incurs a clean-up loss of value (i.e. a value of $V_{(Prop:S)} = 1$ is applied to the clean-up cost) but will only incur a road barrier loss of value in 10% of rockfalls (i.e. a value of $V_{(Prop:S)} = 0.1$ is applied to the barrier loss of value).
3) Hazard H1.1.2 (large rockfall) incurs a clean-up loss of value, a barrier replacement loss of value and a pavement damage loss of value.
4) For upslope hazards H1.2 (Rock Topple), H1.3 (Rock Slide), H2.1 (Upslope Debris Flow) and H2.2 (Upslope Debris Slide) an estimate has been made of the volume of material expected to remain at road level following failure (and thus requiring clean-up). In addition, pavement and barrier damage losses of value have been included where the magnitude of the hazard is deemed likely to cause damage to those structures.
5) Hazard H2.3 (Upslope Debris Flow/Slide, general) incurs a clean-up loss of value only.
6) Hazard H3.1 (Downslope Debris Flow), H3.2 (Downslope Debris Slide), H3.3. (Downslope Debris Flow/Slide, general) and Hazard H4.1 (Retention Element Failure) do not incur a clean-up loss of value (as the displaced material is expected to be able to be left downslope of the landslide) but do incur an earthworks loss of value (i.e. the value of the lost road embankment/earthworks volume, not the cost to replace the lost road embankment which may require significant investigation, design and remediation costs to be expended for re-instatement to be achieved), a pavement loss of value and a barrier loss of value.

7) Hazard H4.2 (Drainage Element Failure) incurs a culvert loss of value (i.e. the value of the culvert length, not the cost to replace embankment which may be lost around the culvert depending on the manner of the culvert's failure and which may require significant investigation, design and remediation costs to be expended for re-instatement to be achieved).

The following preliminary high-level road construction cost estimates provided to us by Public Works Advisory (Ref. 22232, Issue 1, dated 15.12.22) and typical wet hire equipment rates based on our recent experience have been applied to calculate the property loss values described above.

a) Traffic barrier - $500/m

b) Pipes under road - $1,100/m

c) Headwalls - $3,000 each

d) Inlet Pits in drainage channel - $5,000 each

e) Road pavement - $90/$m^2$

f) Embankment Material (delivered and compacted conventionally without retention) - $230/$m^3$

g) Hazard H1.1.1 clean-up - $1,000 (assumes individual mobilization and material relocated free of charge)

h) Hazard H1.1.2 clean-up - $1,400 (assumes individual mobilization and material relocated free of charge)

i) Hazard clean-up (other than H1.1.1 and H1.1.2) - $35/tonne (assumes minimum 50 tonnes and material re-located free of charge)

The above loss of value estimates do not include the following:

i) Costs associated with any investigation, design, planning or approvals that may be required to re-instate damaged road (e.g. embankment, pavement and surfacing) to the condition it was in prior to the loss of value resultant from the hazard.

ii) Any costs associated with construction or construction phase technical services or testing of remediation measures (e.g. horizontal drains, rock anchors, rock bolts, soil nails, drape mesh, rockfall catch fence, canopies or attenuators, piling or retentions systems).

iii) Removal and replacement of materials including any hazardous materials should they be present e.g. asbestos and contaminated soil.

iv) Excavation, removal and replacement of building rubble, in-ground structures etc.

v) Excavation, removal and replacement of soft spots.

vi) Nightworks or Out of hours works.

vii) Traffic control

Table B6, Table B7 and Table B9 of Appendix B summarise the property risk calculations for the assessed hazards and Case 1, Case 2 and Case 3 respectively of Section 2.3. Table B8 of Appendix B summarises the property risk calculations for Category 3 hazards only. The results of the property risk analysis for Cases 1, 2 and 3 described in Section 2.3 are presented in Section 2.4.1, Section 2.4.2 and Section 2.4.3 respectively below.

The actual loss of value experienced in any given year may be significantly more (i.e. up to the full value of the property) or significantly less (i.e. potential zero) than the calculated annual property risk.

2.4.1 Property Risk Case 1 (Category 1, 2 and 3 Hazards)

Based on reference to construction cost estimates provided to us by Public Works Advisory (Ref. 22232, Issue 1, dated 15.12.22) and our experience of typical road construction costs we have adopted an asset Value of $20 million dollars for the 2.7 km length of Wolgan Road assessed herein. By the method of property risk calculation expressed in Equation 2 above it is not possible to calculate a property risk greater than the adopted value of the property (i.e. in this case $20 million). However, the cost to re-instate lost or damaged property can far exceed the original value of the property. Council should make their own determination of the asset value.

The calculated annual loss of value property risk for Case 1 as per Section 2.4 (i.e. for all the hazards nominated in the Review of Wolgan Gap Slope Hazards, 2022) is summarized in Table 6 below.

Table 6: Case 1 Annual Loss of Property Value

Calculated $R_{(Prop)}$ p.a. (Annual Loss of Property Value)	Equivalent Percentage of Asset Value Loss Per Year	Property Risk Level	AGS Recommended Risk Evaluation
$6.2M	> 30%	Very High	Unacceptable

The calculated annual property risk (i.e. loss of value risk) for Case 1 is $6.2M p.a. That represents an annual loss of value risk of approximately 30% of the value of the asset, per year. With reference to Table 2, that annual property risk would be ranked as Very High and evaluated as in the Unacceptable range. Some of the $6.2M annualised value of property loss calculated for Case 1 has already been realized. That is some hazards have already incurred a significant loss of value because they have already impacted serviceability of the road and require cost to remediate. Those hazards will continue to experience additional loss of value unless effectively remediated such that no residual property risk exists in relation to them.

As an example, by the methods outlined in Section 2.4 above, Site 2B alone can be calculated to have experienced a loss of value of $193,500 over the period June 2022 to December 2022 (i.e. a 6 month period). Site 2B is active (i.e. the landslide continues to move) and enlarging and the calculated annualized loss of value property risk for that hazard is $1.5 million (of which a loss of value of $193,500 has already been realized in accordance with the method of calculation adopted herein). Further details regarding Site 2B are provided in WSP-Golder 2023. The actual cost to safely investigate, design and implement an effective long-term remediation may be significantly greater than the calculated loss of value for that hazard. Aerial photogrammetric and LiDAR derived hillshade views of Hazard 2B are shown in Figures 1 and 2 below respectively. Figure 3 shows a close-up of vertical displacement at Hazard 2B taken on 10th October 2022.

Figure 1: Aerial photogrammetric view of Hazard 2B below Hazard 2H from 15.11.2022 Aerial Survey

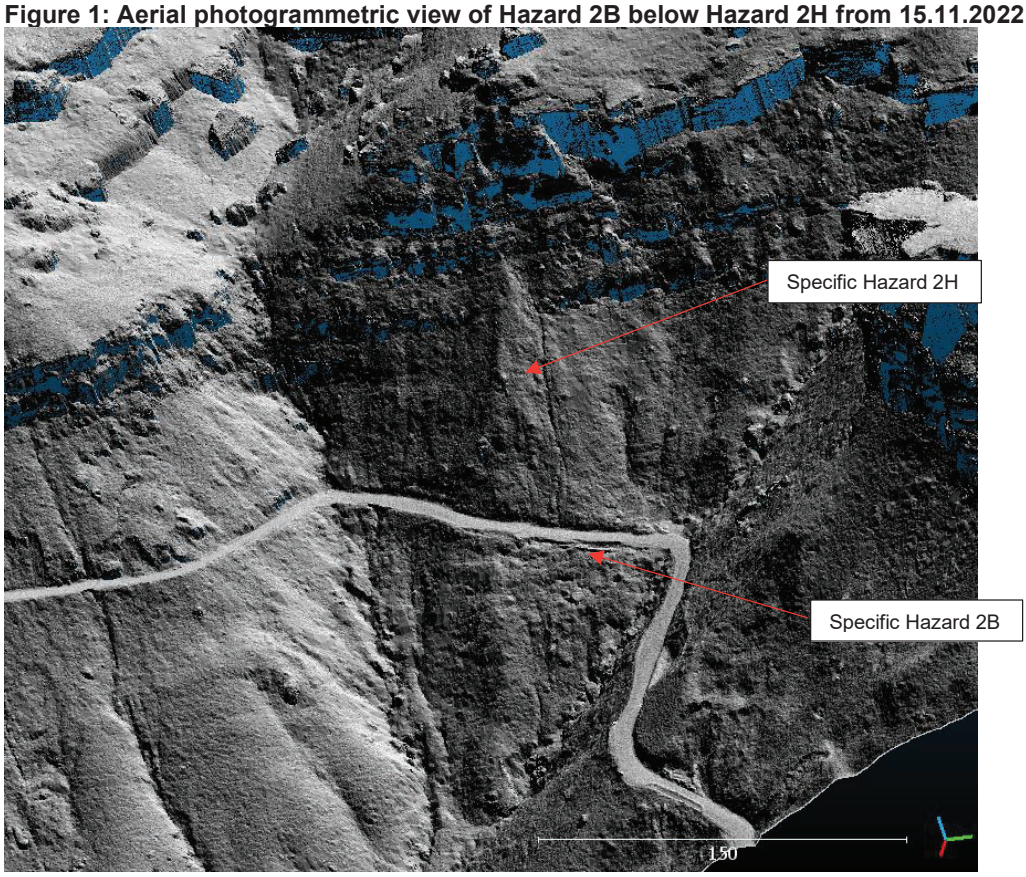

Figure 2: Aerial perspective view of Hazard 2B below Hazard 2H from 15.11.22 LiDAR derived hillshade

Figure 3: Looking south at Hazard 2B, photograph taken 10th October 2022

2.4.2 Property Risk Case 2 (Category 2 and 3 Hazards Only)

Case 2 calculation of property risk assumes effective remediation of Category 1 hazards, meaning that Case 2 considers only the risk to Wolgan Road for remaining Category 2 and 3 hazards.

For the extent of Category 2 and 3 hazards identified, 86% of the 2.7 km of Wolgan Road assessed would remain at risk of a loss of property value due to hazards other than rockfall following implementation of remediation of Category 1 hazards. The full length of the road would remain at risk of small and large rockfall under this Case 2 scenario.

The calculated annual loss of value property risk for Case 2 as per Section 2.4 (i.e. for Category 2 and 3 hazards) is summarized in Table 7 below.

Table 7: Case 2 Annual Loss of Property Value

Calculated $R_{(Prop)}$ p.a. (Annual Loss of Property Value)	Equivalent Percentage of Asset Value Loss Per Year	Property Risk Level	AGS Recommended Risk Evaluation
$2.1M	> 10%	Very High	Unacceptable

The calculated annual property risk (i.e. loss of value risk) for Case 2 is $2.1M p.a. That represents an annual loss of value risk of more than 10% of the value of the asset, per year. With reference to Table 2, that annual property risk would be ranked as Very High and evaluated as in the Unacceptable range.

2.4.3 Property Risk Case 3 (Selected Category 3 Hazards Only)

Case 3 calculation of property risk assumes effective remediation of Category 1 and 2 and some Category 3 hazards, meaning that this assessment considers only the risk to Wolgan Road for remaining Category 3 hazards.

Following effective remediation of Category 1 and 2 hazards, the remaining Category 3 hazards affect over half of the 2.7 km length of Wolgan Road assessed and this length of road remains at risk of a loss of property value from hazards other than rockfall. The full length of the road would remain at risk of small and large rockfall with only Category 1 and Category 2 hazards remediated.

As noted in Section 2.3.2.3, in order to meet industry annual loss of life tolerability criteria for one or more fatality for a site subject to existing landslides and remediation measures, in addition to Category 3 hazards, small and large rockfall (i.e. hazards H1.1.1 and H1.1.2) and rock topple (i.e. hazard H1.2) with a High hazard ranking within Domain 1 would require remediation.

The calculated annual loss of value property risk for Case 3 as per Section 2.4 (i.e. where only selected Category 3 hazards remain) is summarized in Table 8 below.

Table 8: Case 3 Annual Loss of Property Value

Calculated $R_{(Prop)}$ p.a. (Annual Loss of Property Value)	Equivalent Percentage of Asset Value Loss Per Year	Property Risk Level	AGS Recommended Risk Evaluation
$3k	0.02%	Low	Acceptable

The calculated annual property risk (i.e. loss of value risk) for Case 3 is $3k p.a. That represents an annual loss of value risk of approximately 0.02% of the value of the asset, per year. With reference to Table 2, that annual property risk would be ranked as Low and evaluated as in the Acceptable range.

3.0 INDICATIVE REMEDIAL WORKS COSTS VERSUS RISK

As discussed in Section 2.3 above, the current loss of life risk presented by slope hazards identified in WSP-Golder 2023 is in the unacceptable range and remediation would be required to re-open the 2.7 km length of Wolgan Road assessed.

Due to the active nature of many of the slope hazards, requirements for safe access and staging of investigation, design and implementation of remediation measures would require review on an on-going basis. However, as a minimum, the Category 1 hazards nominated herein are expected to require remediation before any of the remainder of the site could even be accessed for investigation and remediation works.

If remediation of the slope hazards identified in Sections 2.4.1, 2.4.2 and 2.4.3 above were to be pursued, the costs associated with those remediations are expected to significantly exceed the loss of value estimates. For example, a property risk (i.e. potential loss of value) of $1.5M has been calculated for specific hazard 2B (shown on Figure 1 and Figure 2 of Section 2.4.1). Temporary support would be required before the downslope embankment could be safely remediated and the downslope remediation will need to expose suitable foundation material before the new road embankment can be re-built. The re-built road embankment would likely need to be permanently supported (such as via permanent soil nails and facing to meet the geometric constraints of the very steep slope on which it would be situated). A preliminary indicative cost estimate to provide an effective long-term remediation of specific hazard 2B of $4M is calculated. That compares to a calculated loss of value incurred to date for specific hazard 2B of $193,500 as discussed in Section 2.4.1 above.

In our experience, remediation costs can be an order of magnitude higher than original construction costs, where significant investigation, design and temporary support is required for large (say greater than 50 m) lengths of road embankment on very steep slopes and slope hazards which are difficult to access. Remediation cost estimates are further detailed below.

3.1 Category 1 Hazard Remediation

The number and type of Category 1 hazards identified are summarized in Table 9 below.

Table 9: Summary of Identified Category 1 Hazards

Hazard Type	Number of Category 1 Hazards Identified
H2.1 Upslope Debris Flow	3
H2.2 Upslope Debris Slide	1
H3.1 Downslope Debris Flow	4
H3.2 Downslope Debris Slide	2
H4.2 Drainage Element Failure	3

Table B6 of Appendix B includes a preliminary high-level indicative estimate of the potential scale of costs which might apply for remediation of these hazards based on typical linear and square metre rates from other projects. The actual costs to remediate the above hazards will vary significantly depending on a number factors including.

- The nature of the specific hazard
- Remediation method
- Availability of resources, materials and technical expertise
- Design life adopted
- Durability of materials
- Allowances made regarding maintenance, repair and replacement
- Staging of the works required for remediation of an individual hazard
- Staging of the works required for remediation across multiple hazards (i.e. to what extent works can be undertaken concurrently across the entire site)

Due to the scale, access challenges and complexity of some Category 1 hazards, relatively complex bespoke remediation options may be required. Remediation concepts would require development in order to refine cost estimation. The development of those concepts would require investigation and the investigation and design costs alone would be substantial.

The preliminary high-level calculation of Table B6, results in a preliminary indicative high-level estimated cost of $21 million for remediation of Category 1 hazards.

3.2 Category 2 Hazards Remediation

The number and type of Category 2 hazards are summarized in Table 10 below.

Table 10: Summary of Category 2 Hazards

Hazard Type	Number of Category 2 Hazards
H2.1 Upslope Debris Flow	24
H2.2 Upslope Debris Slide	19

Hazard Type	Number of Category 2 Hazards
H3.1 Downslope Debris Flow	9
H3.2 Downslope Debris Slide	7
H4.1 Retention Element Failure	2
H4.2 Drainage Element Failure	5

The preliminary high-level calculation of Table B7, results in a preliminary indicative high-level estimated cost of $30 million for remediation of Category 2 hazards. As such the preliminary indicative high-level estimated cost for the cumulative remediation of Category 1 and Category 2 hazards is over $50 million.

3.3 Selected Category 3 Hazard Remediation

In addition to the costs to investigate, design and implement remediation of Category 1 and Category 2 hazards, based on the QRA contained herein, to target a tolerable societal risk level. additional budget would be required to remediate the following Category 3 hazards.

- H1.1.1 and H1.1.2 (i.e. small and large rockfall) Domain 1 and 2.
- High (or greater) hazard ranking H1.2 (i.e. Rock Topple) hazards in Domain 1.

The cost to remediate H1.1.1 and H1.1.2 (i.e. small and large rockfall) hazards in both Domain 1 and Domain 2 is likely to be significant (i.e. in the millions of dollars range).

Council has undertaken targeted remediation of H1.1.1 and H1.1.2 hazards for a portion of the upslope area at Wolgan Road previously. Monitoring only of H1.2 rock topple hazards was proposed at that time.

Remediation works to mitigate the risk to road users from hazards H1.1.1 and H1.1.2 were undertaken in 2009 over an approximately 240 m upslope section of Wolgan Road immediately north of the Wolgan Gap lookout, following a rockfall event which occurred in Domain 1 (Domain boundaries are shown in Figure A2 of Appendix A) on 8th September 2008. Figure 4 below shows some of the debris left on the road following the 8th September 2008 rockfall within Domain 1.

Figure 4: Looking north on 9th September 2008 after Domain 1 rockfall event.

The works proposed to mitigate H1.1.1 and H1.1.2 hazards over the immediate upslope area along the approximately 240 m length of Wolgan Road included a combination of items 1 to 5 below.

1) Spot rock bolting
2) Rockfall mesh
3) Scaling
4) Rockfall catch fences
5) Installation of permanent monitoring points for selected

Following an options assessment at that time, Council decided to proceed with a refined scope of work targeting specific hazards and portions of the overall 240 m length, comprising items 1 (i.e. spot rock bolting), 3 (i.e. scaling) and 5 (i.e. installation of permanent survey markers on selected hazards for on-going monitoring). For details of the remediation works undertaken at that time reference can be made to Golder 2009b and Golder 2009c. The decision to undertake the refined scope of work took into consideration the relatively low reported traffic count of 57 vehicles per day at that time.

As noted in Section 2.3.1 above, a traffic count of 114 vehicles per day has been applied for the slope risk assessment herein and on that basis mitigation of H1.1.1 and H1.1.2 hazards throughout Domain 1 and Domain 2 is calculated as being required to target a tolerable annual societal risk. That remediation would likely require a combination of items 1 to 4 listed above.

At the time of the 2009 remediation referred to above, the contractor's cost estimate to target all H1.1.1 and H1.1.2 hazards over an approximately 240 m length was $511,300 (Ex GST). Indexing that estimate at 2% p.a. for increases in construction costs over the intervening years up to the time of this report, results in a potential preliminary high-level cost estimate of $2.8 million per km for remediation of hazards H1.1.1 and H1.1.2.

It is estimated that an approximate length of 1.5 km of rock escarpment situated above the 2.7 km of road assessed poses a loss of life risk to road users due to the hazard of primary rockfall (i.e. rockfall initiating as a kinematic release from an existing rock face). There is also a risk of secondary rockfall (e.g. re-mobilisation of rock blocks which have come to rest on rock ledges, colluvial slopes or at cutting crests) along the majority of the 2.7 km length assessed herein. Applying a rate of $2.8 million per km over a nominal 2 km length results in a preliminary high-level estimate of over $5 million to remediate the H1.1.1 and H1.1.2 hazards. That estimate is based upon up-lift for inflation of a single 2009 cost estimate for construction and material costs only to suit the specific hazards in one area of the site and does not include other costs which would apply including investigation, design and construction phase geotechnical input. As such, that estimate should be considered a preliminary order of magnitude estimate only.

The actual cost of remediation options would vary depending on numerous factors including those outlined in Section 3.1 above. Furthermore, the 2009 budget estimate was for a relatively small area of typically exposed or shallow rock and included a length of 3 m high, 250 kJ catch fence. Implementation of a rockfall catch fence in areas of deep colluvium would need to consider the potential for on-going creep movement of the colluvial slope and the potential for loss of alignment and/or height of a catch fence (or attenuator) system in that area. In addition, the design energy levels, height of impact and acceptable residual deflections would need to be carefully considered in the design of catch fence or attenuator remediation options. Maintenance, repair and replacement assumptions and budgets would need to take into consideration the potential for impacts that could load the system beyond its serviceability state, as well as the potential for accumulation of debris load behind the fence from the mobilization of other hazard types (e.g. rock topple, rock slide, upslope debris flows and slides).

Remediation of High hazard category H1.2 type hazards would likely require higher capacity measures than remediation for rockfall (e.g. longer, high capacity anchors and mesh in combination with spot bolting as well as shotcreting of underlying weaker seams which typically weather preferentially to the overlying stronger rock which form potential rock topples). As such the cost to remediate those hazards in Domain 1 is likely to be in the millions of dollars range.

Depending on the nature and extent of investigation, design and documentation, construction supervision, quality control and testing, design life adopted, maintenance, repair and replacement budget allowed for, it is possible that a budget of $10M or more would be required to remediate rockfall hazards (i.e. H1.1.1 and H1.1.2) across the entire 2.7 km length of Wolgan Road assessed and high hazard ranking rock topple (i.e. H1.2) hazards within Domain 1 to target a tolerable annual societal risk.

Remediation of Category 1, 2 and the above additional rockfall and rock topple hazards is calculated to result in an annual societal risk of one or more fatality of 9.6×10^{-5} p.a. which is only marginally less than 1×10^{-4} p.a.

3.4 Residual Risk Versus Indicative Remediation Costs

Calculated annual individual loss of life risk values versus the indicative remediation costs presented in Table B6 of Appendix B are summarized in Figure 5 below.

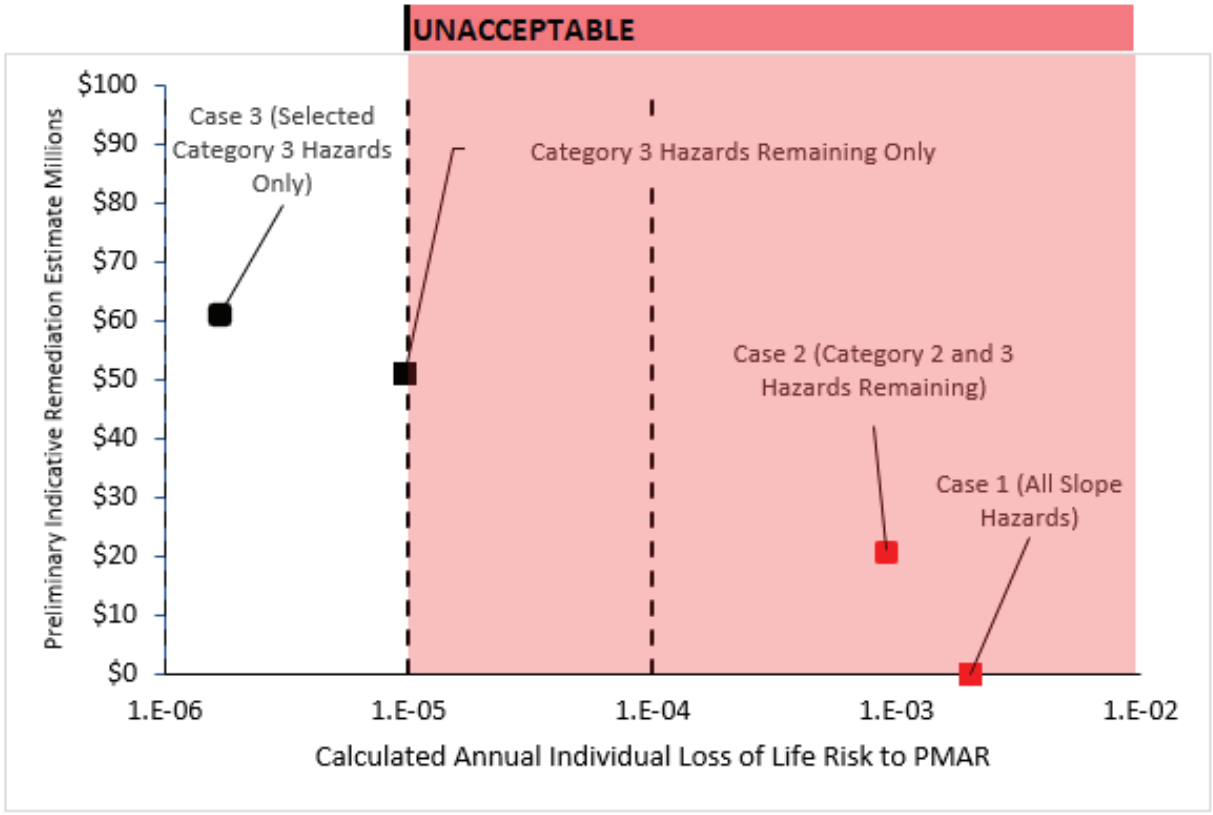

Figure 5: Change in Calculated Annual Individual Loss of Life Risk for PMAR Between Cases

Calculated residual annual societal loss of life risk of one or more fatalities (for each of the cases considered) and the indicative remediation costs are show on Figure 6 below.

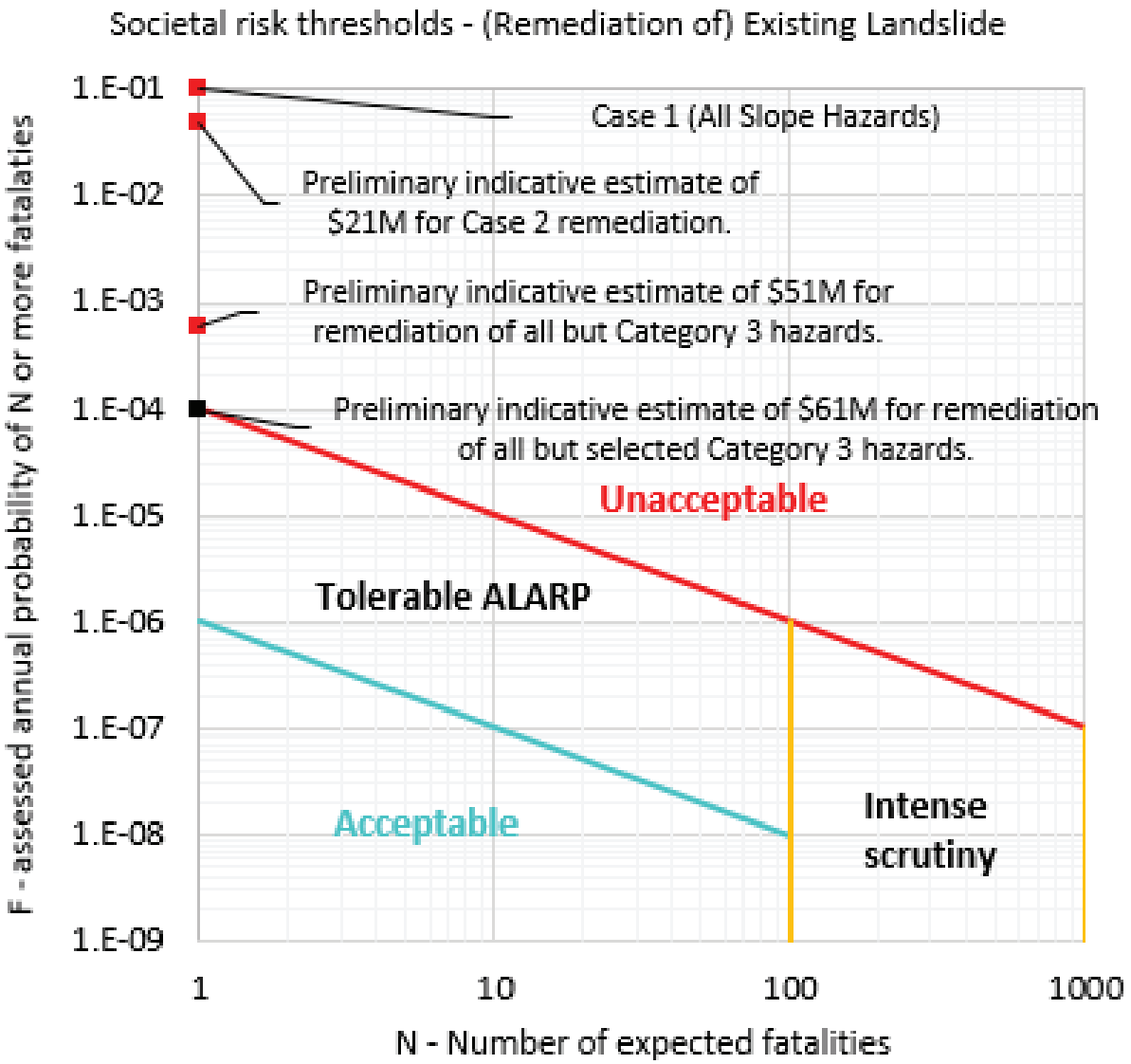

Figure 6: Change in calculated annual Societal risk of one or more fatality (i.e. N ≥ 1) between Cases (adapted from NSW NPWS 2019)

Calculated residual annual property (i.e. loss of value) risk versus the indicative remediation costs are shown on Figure 7 below.

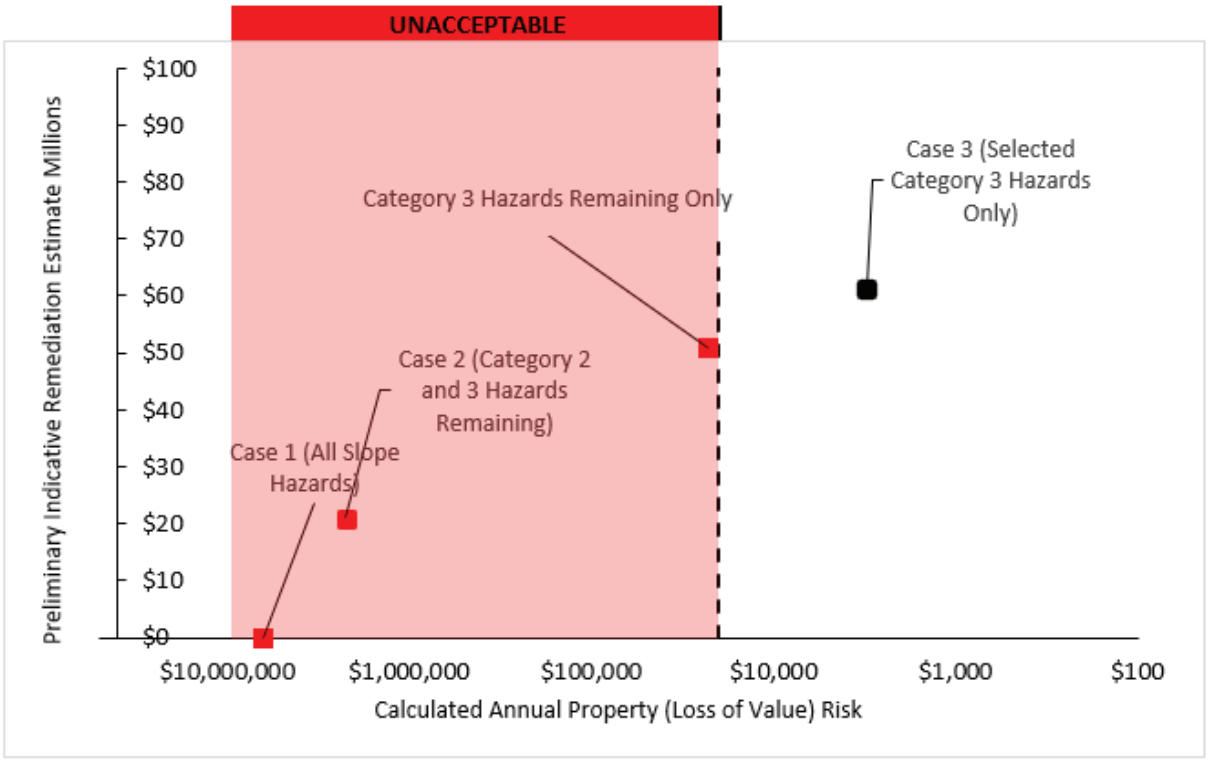

Figure 7: Change in calculated annual property (i.e. loss of value) risk between Cases

As shown in Figure 5 above, the indicative preliminary cost to remediate Category 1 hazards (i.e. Case 2) exceeds the assumed asset value for the road of $20 million. Even with that level of expenditure, as shown in Figure 5 and Figure 6 respectively, calculated annual individual loss of life risk and calculated annual societal loss of life risk remain in the unacceptable range, as does annual property (i.e. loss of value) risk which is calculated to remain over $2 million p.a. as shown in Figure 7.

Remediation of both Category 1 and Category 2 hazards is estimated to reduce the annual individual loss of life risk for the PMAR to marginally within the tolerable range as shown in Figure 5 above. However, with Category 1 and 2 hazards remediated, the annual societal and property (i.e. loss of value) risk remain in the unacceptable range as shown in Figure 6 and Figure 7 respectively. For the calculated residual annual societal risk of one or more fatality and annual property (loss of value) risk to be within the acceptable range (i.e. below 1×10^{-4} p.a and 0.1% of the assumed asset value), Category 1, 2 and the selected Category 3 Hazards described under Case 3 of Section 3.3 must be excluded from the calculation (i.e. effectively remediated), for which a preliminary indicative cost of over $60 million has been calculated in Table B6 of Appendix B (i.e. more than 3 times the assumed value of the asset).

Although remediation of the hazards identified in Section 3.1, Section 3.2 and Section 3.3 would significantly reduce the calculated annual loss of life and annual property risk, further remediation could be required following implementation of those remedial measures in response to changes in slope conditions.

4.0 ON-GOING COSTS

If the 2.7 km of Wolgan Road assessed herein were to be re-opened, in addition to the costs associated with remediation of hazards described above, budget would be required for the following items which are discussed in Sections 4.1 to 4.4 inclusive below.

- On-going periodic inspection and monitoring
- Maintenance
- Repair
- Replacement

Taking into consideration the level of remediation implemented, an annual budget allowance would also be needed for additional remediation in response to changes in slope conditions as discussed further in Section 4.5, and the potential for the development of additional future hazards not identified herein.

4.1 On-going Periodic Inspection and Monitoring

Wolgan Road at Wolgan Gap has been subject to on-going monitoring as part of management of slope risk at the site since 2006. Over those 17 years, in accordance with the Instability Management Plan re-assessment of Slope Risk has been undertaken in response to changing slope conditions, increased rockfalls and has included implementation of remedial work. Prior to 2019, the length of road subject to on-going monitoring was approximately 240 m. Based on the results of the 2019 periodic monitoring, Council approved a recommendation to increase the length of road subject to on-going periodic inspection (Golder 2019b). Changes in slope conditions which have occurred during 2022 (WSP-Golder 2023) would require the length of road subject to on-going periodic inspection and monitoring to include the full 2.7 km length assessed herein. Council would need to ensure sufficient annual budget allowance for that increase in the extent of Wolgan Road which would require on-going periodic inspection and monitoring were it to be re-opened. Remediation measures would need to be designed and implemented such that they are accessible for periodic inspection and monitoring.

4.2 Maintenance

If re-opened, Council's annual maintenance budget for the 2.7 km length of Wolgan Road would need to be significantly higher than the general maintenance allowance (e.g. for weed control, line marking and re-surfacing) which Council might make for a 2.7 km road not affected by slope hazards and which does not incorporate extensive remediation measures.

The annual maintenance budget would need to include allowance for maintenance inspections (e.g. by Council staff) at a higher frequency than the on-going periodic geotechnical inspections previously carried out. Maintenance inspections would need to include access and inspection of drains and remedial measures such as catch fences would need to be adequately maintained and cleaned of fallen debris. The magnitude of additional maintenance required will depend on the nature and extent of remedial measures installed.

In addition to management of maintenance issues such as accumulation of slope debris behind catch fences, sufficient allowance would need to be made for vegetation maintenance such that the effective performance of remedial measures and drains are not impeded.

Remediation measures would need to be designed and implemented so that they are safely accessible for on-going maintenance.

4.3 Repair

Council could refer to their records of repairs (e.g. for pavement patching and barrier repairs due to impact from rockfall) from the period 2006 to 2021 for a baseline of road and road furniture repairs in the absence of significant damage due to hazard types H2.1, H2.2, H2.3, H3.1, H3.2, H3.3 and H4.1.

The mobilization of slope hazards in 2022 (WSP-Golder 2023) has resulted in significant damage to Wolgan Road. On-going annual budget requirements for repairs of the road and road furniture will depend on the nature and extent of remediation measures implemented. Reference can be made to Figure 7 above for the calculated on-going property (i.e. loss of value) risk with and without inclusion of particular hazard categories. As the property risk represents a loss of value rather than a repair cost (which may require additional remediation), it could be considered a lower bound value of which the actual repair or replacement cost could be many times greater.

In addition to the potential for repairs of the road and road furniture (e.g. barriers), there would be a potential need for repair of remediation measures, depending what those remediation measures are and how effectively they are maintained and how they perform. For example, the occurrence of a rock topple which impacts a catch fence designed for a lower energy level (e.g. for rockfall rather than rock topple) may require repair or replacement of part or all of the catch fence over the impacted extent. An example of some debris which was left on Wolgan Road following a 2016 rock topple within Domain 1 is shown in Figure 8 below.

Figure 8: Debris left on road following rock topple within Domain 1 in June 2016.

Potential for such events would need to be considered in the development of remediation designs and establishment of on-going annual repair budgets. Additionally, if remediation measures such as catch fences are not adequately maintained (e.g. via removal of accumulated debris) then there would be a risk of damage, occurring due to the cumulative effect of multiple events, even where those individual events are below the design energy level for the fence. Thus, annual repair budgets would need to be developed in consideration of

the annual maintenance budget and the expected frequency and effectiveness of maintenance inspections and operations.

4.4 Replacement

If the currently closed section of Wolgan Road was remediated and re-opened, an annual budget allowance for replacement would be needed to account for the eventual need to replace remedial measures. In addition to natural on-going slope process associated with the hazards of Section 2.1 above, there is the potential for damage or destruction of the road and remedial measures from other hazards including tree fall (e.g. which could impact catch fences or attenuator systems were they adopted) and the effects of bushfire. Figure 9 below shows the condition of Wolgan Road within Domain 1 in the aftermath of the December 2019 bushfire.

Figure 9: Looking south in Domain 1 during clean-up following December 2019 bushfire.

Development of an annual budget for complete replacement of portions of the road, its furniture and/or remedial measures would need to consider the extent and nature of remedial measures adopted.

4.5 Additional Remediation in Response to Slope Condition Changes

Remediation envisaged by Section 3.3 above, does not include all hazards which affect the 2.7 km length of Wolgan Road assessed herein. With respect to upslope and downslope debris flows and slides (i.e. hazards H2.1, H2.2, H2.3, H3.1, H3.2 and H3.3) remediation of all Category 1, 2 and selected Category 3 hazards would leave approximately 60% of the upslope length of the 2.7 km and 75% of the downslope length of the 2.7 km un-remediated. Over that un-remediated length there would remain a risk of future changes in slope conditions resulting in a need for remediation in addition to that envisaged in Table B6 of Appendix B. Retention elements and culverts (i.e. hazards H4.1 and H4.2) also have a risk of failure within their design life, which may result in a need for replacement and invoke the need for additional remediation works within the surrounding road and embankment. The remediation described in Section 3.3 excludes replacement of 16 of the 24 culverts over the area assessed.

If the currently closed section of Wolgan Road was remediated and re-opened, an annual budget allowance for additional remedial measures would be required and would need to be developed in consideration of the extent and nature of remedial measures adopted.

5.0 EFFECT OF CHANGES IN TRAFFIC COUNT ON SRA

The assessment undertaken herein has been based upon the Council supplied traffic count of 114 vehicles per day. We note that traffic count has increased since the 2006 assessment for which a traffic count of 57 vehicles per day was supplied by Council along with an envisaged vehicle count of 87 vehicles per day for the post development case with respect to the Emirates Resort (which at that time was yet to be opened).

Remediation of Category 1, 2 and selected Category 3 hazards is calculated to result in an annual societal risk for one or more fatality of 9.6×10^{-5} p.a. If Council adopted a risk tolerability threshold value of 1×10^{-4} p.a. for an existing landslide (and 'new' development comprising remediation of that existing landslide site) then for a count of 114 vehicles per day the calculated value for annual societal risk of one or more fatality is only marginally within the acceptable range. The remediation cost has been broadly estimated to be in the vicinity of $60M. If the applied traffic count was to increase by a modest 3 % (i.e. an additional 3 cars per day or approximately 1248 cars per year) then the calculated annual societal risk of one or more fatality would be $> 1 \times 10^{-4}$ p.a. (i.e. in the ***unacceptable*** range) and remediation of additional hazards would be necessary to maintain tolerable risk. The development of future hazards not identified herein could also negatively affect the residual risk values presented.

Given the high anticipated cost of remediation required to meet risk tolerability criteria, Council should obtain a review of expected future traffic volumes at Wolgan Road. If remediation to enable re-opening of the currently closed section of Wolgan Road were to be pursued, the SRA contained herein would need to be updated to incorporate an appropriate long-term vehicle count.

6.0 SUMMARY AND NEXT STEPS

Following protracted above average rainfall during 2022, landslides resulted in extensive damage to Wolgan road, it's furniture (e.g. barriers) and embedded elements such as culverts, but no fatalities. Many of those landslides remain active (i.e. movement is on-going).

The potential for a complex landslide of medium magnitude (i.e. 50,000 m^3 to 250,000 m^3) was identified at Site 1I within Domain 1 due to the proximity of upslope and downslope landslides, their on-going movement and enlarging nature.

Wolgan Road at Wolgan Gap was closed to all traffic on 11th November 2022, due to the loss of life risk to road users presented by the identified slope hazards.

This 2022 periodic Slope Risk Assessment Update has calculated that for the risk values to be below industry thresholds, remediation of 79 specific slope hazard locations (including 8 culverts) and numerous active landslides comprising thousands of cubic metres of material would be required. An indicative preliminary cost of over $50 million (i.e. more than twice the assumed value of the road asset) has been broadly estimated for slope remediation to achieve an annual individual loss of life risk value below the industry tolerability threshold. However, to reduce the societal risk value to below industry tolerability threshold, additional remediation measures are required to those described above. The additional remediation measures include mitigation of small and large rockfall (both primary rockfall with a source in the rock cliffs above the road and secondary rockfall which could remobilise from the colluvial slopes above the road) and high hazard category rock topple hazards within Domain 1. Costs estimated for the additional remediation increases the indicative preliminary cost estimate to over $60 million. The remediation required to achieve loss of life risk values (individual and societal) below industry thresholds is envisaged to comprise.

- Remediation of the upslope of approximately 40 % of the road's length (i.e. approximately 1 km).
- Remediation of the downslope over 25% of its length (i.e. approximately 700 m).
- Rockfall mitigation over an approximately 2 km length.
- Remediation of specific rock topple hazards within Domain 1.
- Replacement of 8 culverts.

Based on the current condition of the pavement, it is likely that on completion of remediation works, new pavement would be required over the majority of the 2.7 km length. However a cost for pavement replacement has not been allowed for explicitly in the preliminary high level indicative cost calculations for remediation which have been based on typical costs per metre or square metre of remediation only.

Remediation works, if pursued, would need to be carefully staged due to the numerous slope hazards and the loss of life risk they would present to investigation and remediation workers and assets. It is likely that the time-frames necessary for investigation, design and implementation of remediation would require lengthy continued closure of Wolgan Road at Wolgan Gap to the public.

The actual level of risk which workers would be exposed to during investigation and construction would depend upon a number of factors including the methods of investigation and remediation construction adopted, the staging of the works, the time period over which workers were exposed to the hazards and the prevailing weather and slope conditions at the time of the works.

As a minimum it is expected that the Category 1 hazards referred to herein would require carefully staged remediation before access to the rest of the site could be safely achieved. Practically that means that Category 1 hazards might need to be remediated sequentially rather than concurrently and delivery of material

and removal of spoil may only be possible from the outside edges of the hazards rather than with thoroughfare past the hazards. It is possible that relatively specialized equipment, (e.g. remote control machinery, such as those with long 'umbilical' cords) would be required. The implication of those challenges is a potential increase in costs to undertake the remediation compared to where thoroughfare is possible during remediation. The duration for remediation works would also be greater than if the hazards were able to be safely remediated concurrently.

The preliminary indicative estimate for remediation of Category 1 hazards only is more than the assumed value of the road itself (i.e. greater than $20 million). However, whilst thoroughfare for on-going remediation activities could potentially be established following completion of remediation of Category 1 hazards, annual loss of life risk values (individual and societal) for public road users would remain in the unacceptable range. In addition, it is calculated that an annual property (i.e. loss of value) risk of over $2 million p.a. would remain on completion of remediation of Category 1 hazards.

With Category 1, Category 2, rockfall and selected additional hazards within Domain 1 excluded, the calculated annual societal risk of one or more fatality is only marginally in the tolerable range (i.e. a value of 9.6×10^{-5} p.a. is calculated) and consideration would need to be given to whether in light of the very large capital expense of remediation, a higher vehicle count should be adopted to allow for increases in usage over the design life of a remediated road.

Even with Category 1, Category 2, rockfall and selected additional hazards within Domain 1 excluded to target calculated annual risk values below industry risk tolerability thresholds, some loss of life and property risk will remain. Annual budgetary allowance would be required for on-going periodic inspections and monitoring, maintenance inspections and maintenance operations, repairs, replacement and additional remediation which may be required in areas which have not been remediated.

Wolgan Road at the Gap has been in use for over a century. If the currently closed section is to be re-opened, relatively lengthy design lives for remediation measures should be considered (which will have cost implications and may present some technical challenges depending on the nature of the remediation adopted). Even with relatively long design lives adopted for remediation measures, annual budgetary allowances should take into consideration the eventual need for replacement of remediation measures as well as contingency for the risk of damage or destruction within their design life.

As discussed above, there are significant safety challenges to remediating the currently closed section of Wolgan Road to meet industry loss of life risk threshold criteria for road users and the preliminary indicative costs are very high (more than 3 times the assumed value of the road itself). Council may wish to consider options for an alternative primary access to Wolgan Valley.

A slope hazard susceptibility assessment for the Wolgan Valley (WSP-Golder 2022) has recently been provided to Council. That hazard susceptibility assessment could be used by Council should they chose to investigate alternative permanent access routes to Wolgan Valley which may not require as significant slope risk mitigation and management measures as the currently closed portion of Wolgan Road would if it were to be re-opened.

7.0 REFERENCES

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Signature Page

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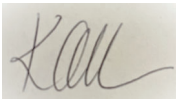

Karen Allan
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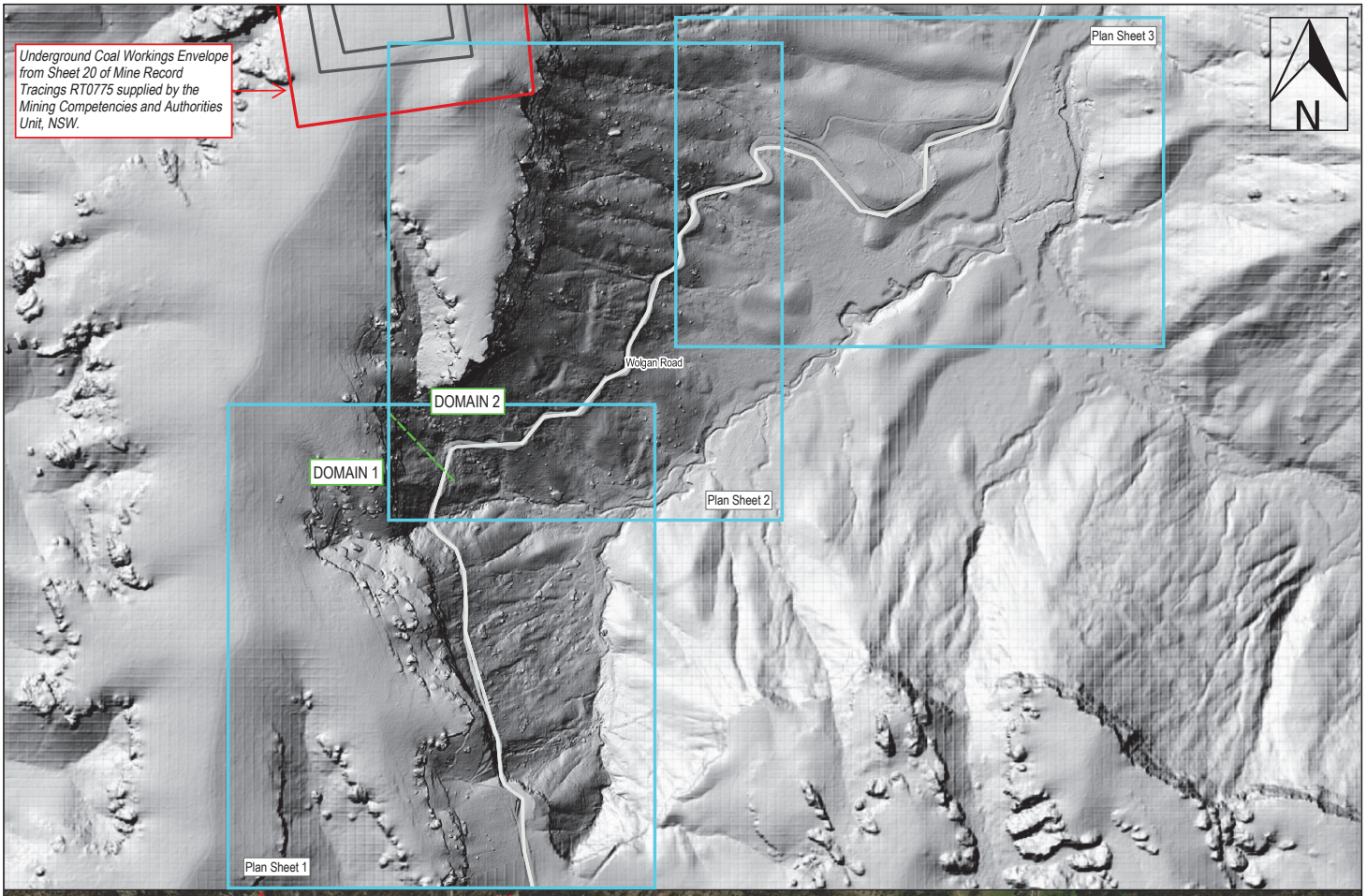
APPENDIX A

Overview Figures



References:
Coal tracings - RT0775.R10000783.RT775 Sheets 15&20
LiDAR - Combined
1) State wide LiDAR dataset 'Wallerawang 201704-LID2-AHD-2m' and
2) detailed LiDAR '221115_22AU072_Wolgan Gap_DTM25cm' (Diospatial 15.11.22)
Aerial imagery - Aerial orthophoto 2cm pixel resolution (Diospatial 15.11.22)

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PREPARED	GW
REVIEWED	GKS
APPROVED	GKS

PROJECT
Wolgan Gap

TITLE
Wolgan Gap, Wolgan Road 2022
Slope Risk Assessment Update - Overview plans

PROJECT NO	DOC	REV.	FIGURE
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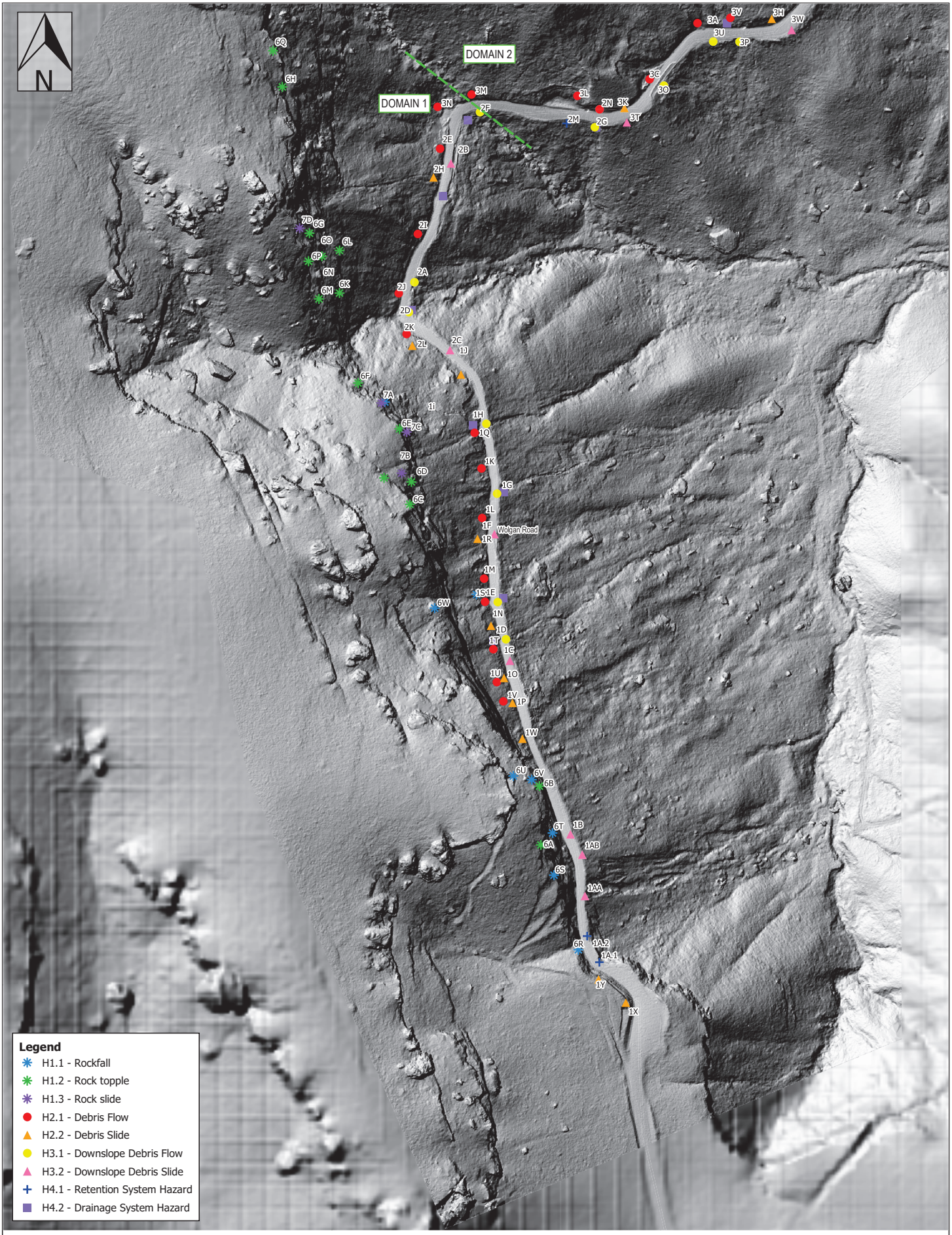

References
LiDAR - Combined
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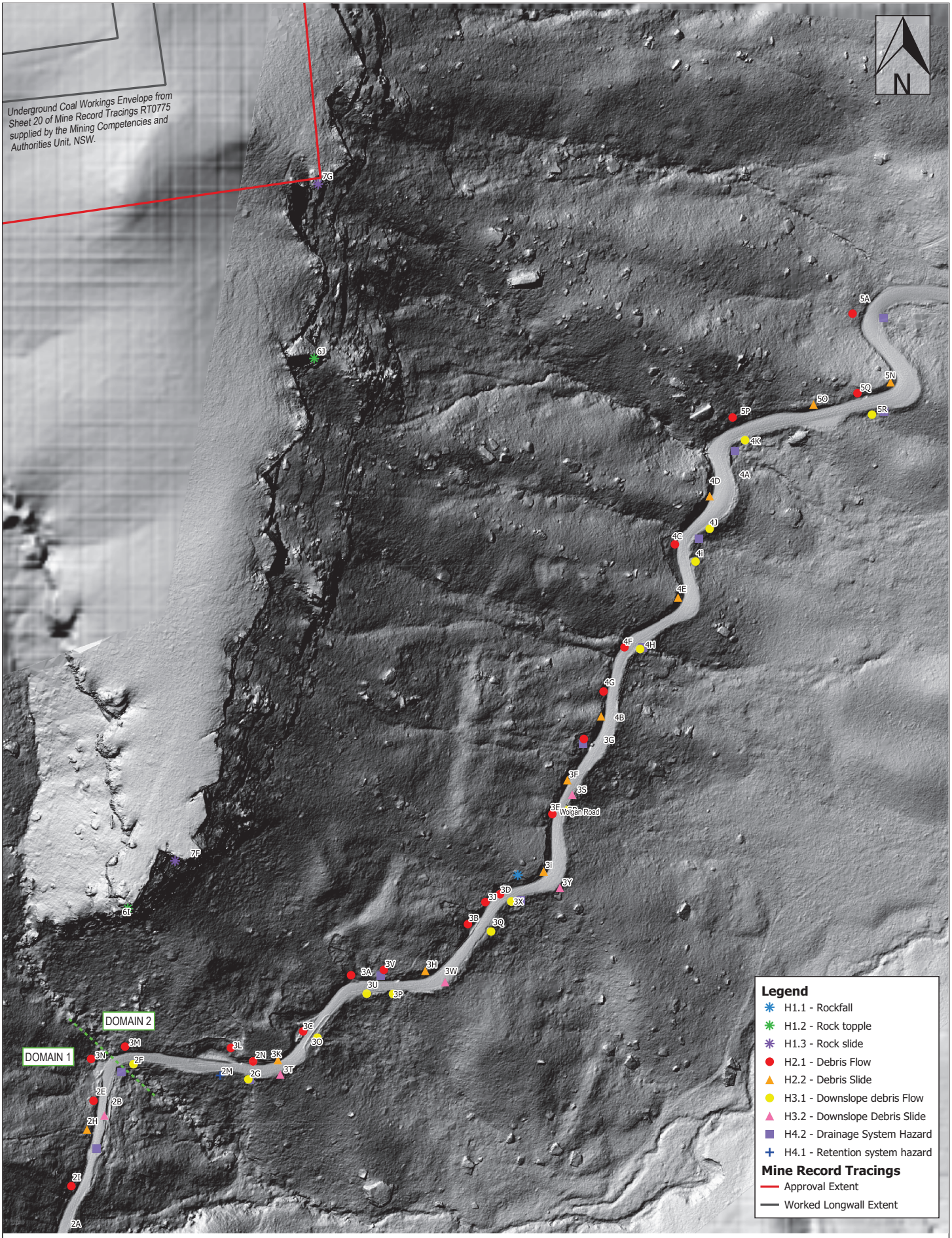

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Coal tracings - *RT0775.R10000783.RT775 Sheets 15&20*

LIDAR - Combined

1) State wide LiDAR dataset 'Wallerawang 201704-LID2-AHD-2m' and
2) detailed LiDAR '221115_22AU072_Wolgan

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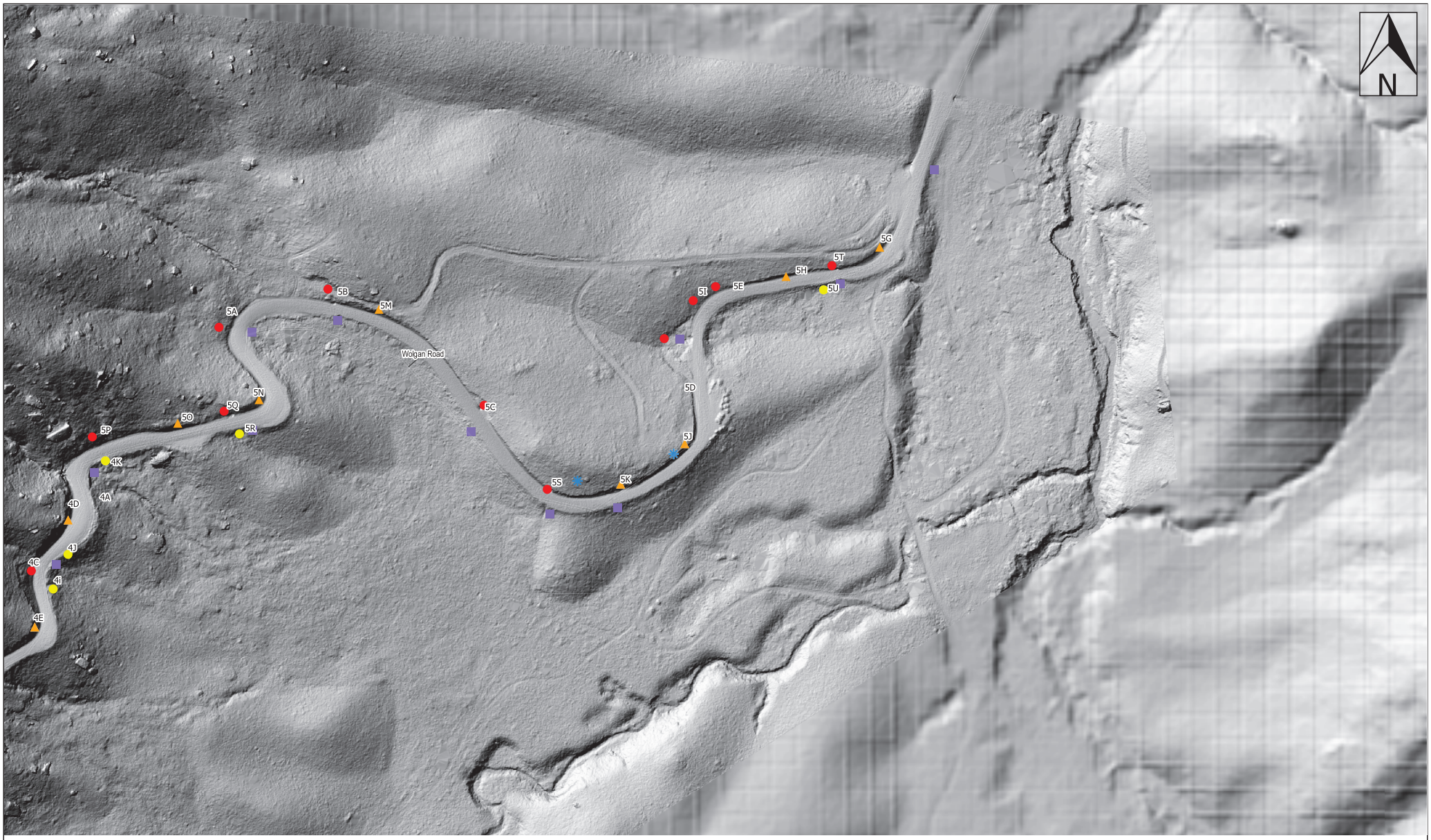

Legend

- H1.1 - Rockfall
- H1.2 - Rock topple
- H1.3 - Rock slide
- H2.1 - Debris Flow
- H2.2 - Debris Slide
- H3.1 - Downslope debris Flow
- H3.2 - Downslope Debris Slide
- H4.2 - Drainage System Hazard
- H4.1B - Retention System Hazard

References
LiDAR - Combined
1) State wide LiDAR dataset 'Wallerawang 201704-LID2-AHD-2m' and
2) detailed LiDAR '221115_22AU072_Wolgan

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APPENDIX B

QRA Summary Tables

Table B1: Summary of Number of Hazards within each Descriptor Category in Domain 1 and Domain 2

Hazard Type	Hazard Category[1]	Domain 1					Domain 2				
		VH	H	M	L	VL	VH	H	M	L	VL
H1.1.1 Small Rockfall	1 and 2	-	-	-	-	-	-	-	-	-	-
	3	See Note 2									
H1.1.2 Large Rockfall	1 and 2	-	-	-	-	-	-	-	-	-	-
	3	See Note 3									
H1.2 – Rock Topple.	1 and 2	-	-	-	-	-	-	-	-	-	-
	3	-	7	8	-	-	-	-	2	-	-
H1.3 – Rock Slide	1 and 2	-	-	-	-	-	-	-	-	-	-
	3	-	-	1	3	-	-	-	2	-	-
H2.1 – Upslope Debris Flow, specific	1	2	1	-	-	-	-	-	-	-	-
	2	5	4	-	-	-	8	5	1	-	-
	3	-	-	-	-	-	-	2	5	-	-
H2.2 – Upslope Debris Slide, specific	1	1	-	-	-	-	-	-	-	-	-
	2	1	8	-	-	-	6	4	-	-	-
	3	-	-	-	-	-	-	-	3	1	-
H2.3 – Upslope Debris Flow/Slide, general	1 and 2	-	-	-	-	-	-	-	-	-	-
	3	See Note 4									
H3.1 – Downslope Debris Flow, specific	1	3	-	-	-	-	1	-	-	-	-
	2	1	-	-	-	-	6	2	-	-	-
	3	-	-	-	-	-	-	-	1	-	-
H3.2 – Downslope Debris Slide specific	1	2	-	-	-	-	-	-	-	-	-
	2	4	2	-	-	-	1	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-
H3.3. – Downslope Debris Slide/Flow, general	1 and 2	-	-	-	-	-	-	-	-	-	-
	3	See Note 4									
H4.1 – Retention Element Failure	1	-	-	-	-	-	-	-	-	-	-
	2	1	-	-	-	-	1	-	-	-	-
	3	-	-	-	-	-	-	-	-	-	-
H4.2 – Drainage Element Failure	1	3	-	-	-	-	-	-	-	-	-
	2	2	-	-	-	-	3	-	-	-	-
	3	-	2	-	-	-	-	13	-	-	-

1. Refer to Section 2.3 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of categories.
2. A VH hazard descriptor has been assigned to H1.1.1 hazards, refer Section 2.3.1 of this report for further detail.
3. A H hazard descriptor has been assigned to H1.1.2 hazards refer Section 2.3.1 of this report for further detail.
4. A VL hazard descriptor has been assigned to H2.3 and H3.3 hazards refer Section 2.3.1 of this report for further detail.

Table B2: Annual Loss of Life QRA Calculation Table: Category 1, Category 2 and Category 3 Hazards

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
1	H1: ROCK									
1	H1.1.1 Small Rockfall	N/A	3	VH	1.0	1	0.5	1.43E-09	0.3	1.23E-09
1	H1.1.2 Large Rockfall	N/A	3	VH	0.3	1	3	8.56E-09	0.9	2.22E-09
1	H1.2 – Rock Topple	6A	3	H	0.01	1	30	8.56E-08	0.9	7.71E-10
		6B	3	M	0.001	1	65	1.86E-07	0.9	1.67E-10
		6C	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6D	3	H	0.01	1	15	4.28E-08	0.9	3.85E-10
		6E	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6F	3	H	0.01	1	15	4.28E-08	0.9	3.85E-10
		6G	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		6H	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		6K	3	H	0.01	1	20	5.71E-08	0.9	5.14E-10
		6L	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		6M	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6N	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		6O	3	M	0.001	1	15	4.28E-08	0.9	3.85E-11
		6P	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6Q	3	M	0.001	0.25	25	7.13E-08	0.9	1.61E-11
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		7B	3	L	0.0001	1	30	8.56E-08	0.9	7.71E-12
		7C	3	L	0.0001	1	35	9.99E-08	0.9	8.99E-12
		7D	3	L	0.0001	1	50	1.43E-07	0.9	1.28E-11
1	H2: DEBRIS (UPSLOPE)									
1	H2.1 Debris Flow	1L	2	VH	0.1	1	15	4.28E-08	0.9	3.85E-09
		1Q	1	VH	1	1	25	7.13E-08	0.9	6.42E-08
		1S	2	VH	0.1	0.5	10	2.85E-08	0.9	1.28E-09
		1T	2	VH	0.1	0.5	10	2.85E-08	0.9	1.28E-09
		2E	1	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		2I	1	VH	0.1	1	30	8.56E-08	0.9	7.71E-09
		1K	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10
		2J	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		2K	2	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		1M	2	VH	0.1	1	30	8.56E-08	0.9	7.71E-09
		1U	2	VH	0.1	1	15	4.28E-08	0.9	3.85E-09
		1V	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
1	H2.2 Debris Slide	1I	1	VH	1	1	60	1.71E-07	0.9	1.54E-07
		2H	2	VH	0.1	1	50	1.43E-07	0.9	1.28E-08
		2L	2	H	0.01	1	20	5.71E-08	0.9	5.14E-10
		1R	2	H	0.01	1	30	8.56E-08	0.9	7.71E-10
		1N	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10
		1O	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
		1P	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		1W	2	H	0.01	1	20	5.71E-08	0.9	5.14E-10
		1X	2	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		1Y	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	1.43E-08	0.3	5.78E-12
1	H3: DEBRIS (DOWNSLOPE)									
		2A	1	VH	1	1	40	1.14E-07	0.9	1.03E-07
		1G	1	VH	1	1	25	7.13E-08	0.9	6.42E-08
		1H	1	VH	1	1	50	1.43E-07	0.9	1.28E-07
		2D	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
		1AA	2	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		1AB	2	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
1	H3.2 Debris Flow	1B	2	VH	1	0.5	20	5.71E-08	0.9	2.57E-08
		1C	2	VH	1	1	25	7.13E-08	0.9	6.42E-08
		1A.2	2	VH	0.1	0.5	25	7.13E-08	0.9	3.21E-09
		1F	2	VH	1	1	50	1.43E-07	0.9	1.28E-07
		1J	1	VH	1	1	60	1.71E-07	0.9	1.54E-07
		2B	1	VH	1	1	100	2.85E-07	0.9	2.57E-07
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	1.43E-08	0.3	6.42E-12
1	H4: RETENTION OR DRAINAGE ELEMENTS									
1	H4.1 Retention Element	1A.1	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
		Culvert 01	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		Culvert 02	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		Culvert 03	1	VH	1	1	15	4.28E-08	0.9	3.85E-08
1	H4.2 Drainage Element	Culvert 04	1	VH	1	1	15	4.28E-08	0.9	3.85E-08
		Culvert 05	2	VH	1	0.5	25	7.13E-08	0.9	3.21E-08
		Culvert 06	1	VH	1	1	15	4.28E-08	0.9	3.85E-08
		Culvert 07	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
2	H1: ROCK									
2	H1.1.1 Small Rockfall	N/A	3	VH	1	0.5	0.5	1.43E-09	0.3	1.71E-09
2	H1.1.2 Large Rockfall	N/A	3	VH	0.8	0.5	3	8.56E-09	0.9	3.08E-09
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6J	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	1.43E-07	0.9	1.28E-10
		7G	3	M	0.001	0.5	50	1.43E-07	0.9	6.42E-11
2	H2: DEBRIS (UPSLOPE)									
		3C	2	VH	1	1	40	1.14E-07	0.9	1.03E-07
2	H2.1 Debris Flow	3A	2	VH	1	1	15	4.28E-08	0.9	3.85E-08
		3B	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
		3D	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		3E	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08
		3F	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08
		3G	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		3J	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		4C	2	VH	1	1	45	1.28E-07	0.9	1.16E-07
		5A	3	M	0.001	0.5	20	5.71E-08	0.3	8.56E-12
		5B	3	H	0.01	0.5	20	5.71E-08	0.3	8.56E-11
		5C	3	H	0.01	0.5	25	7.13E-08	0.3	1.07E-10
		5D	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12
		2N	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
		3L	2	M	0.001	0.5	10	2.85E-08	0.9	1.28E-11
		5I	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12
		5P	2	H	0.01	1	30	8.56E-08	0.9	7.71E-10
		4F	2	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		4G	2	VH	1	1	20	5.71E-08	0.9	5.14E-08
		3M	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		3N	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
2	H2.2 Debris Slide	3K	2	VH	0.1	1	30	8.56E-08	0.9	7.71E-09
		4B	2	VH	1	1	25	7.13E-08	0.9	6.42E-08
		4D	2	VH	1	1	40	1.14E-07	0.9	1.03E-07
		3H	2	VH	1	1	70	2.00E-07	0.9	1.80E-07
		5J	2	H	0.01	0.5	25	7.13E-08	0.3	1.07E-10
		5K	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10
		5M	2	H	0.01	0.5	20	5.71E-08	0.3	8.56E-11
		5N	2	H	0.01	0.5	15	4.28E-08	0.9	1.93E-10
		4E	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
		3I	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
		5E	3	L	0.0001	0.5	10	2.85E-08	0.3	4.28E-13
		5G	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
		5H	3	M	0.001	0.5	10	2.85E-08	0.9	1.28E-11
		5O	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	1.43E-08	0.3	2.73E-11
2	H3: DEBRIS (DOWNSLOPE)									
		2F	2	H	0.01	0.5	30	8.56E-08	0.9	3.85E-10
		2G	2	VH	0.1	0.5	5	1.43E-08	0.3	2.14E-10
		3O	1	VH	1	1	50	1.43E-07	0.9	1.28E-07
2	H3.1 Debris Flow	3P	2	VH	1	0.5	30	8.56E-08	0.9	3.85E-08
		3Q	2	VH	1	1	45	1.28E-07	0.9	1.16E-07
		3R	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08
		4H	2	H	0.01	0.5	30	8.56E-08	0.9	3.85E-10

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
		4I	2	VH	1	0.5	20	5.71E-08	0.9	2.57E-08
		4J	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
		4K	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H3.2 Debris Slide	3S	2	VH	1	1	25	7.13E-08	0.9	6.42E-08
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	1.43E-08	0.3	3.66E-11
2	H4: RETENTION OR DRAINAGE ELEMENTS									
2	H4.1 Retention Element	2M	2	VH	0.1	1	30	8.56E-08	0.9	7.71E-09
2	H4.2 Drainage Element	Culvert 08	2	VH	0.1	1	15	4.28E-08	0.9	3.85E-09
		Culvert 09	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
		Culvert 10	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 11	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		Culvert 12	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		Culvert 13	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 14	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 15	2	VH	0.1	0.5	5	1.43E-08	0.3	2.14E-10
		Culvert 16	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 17	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 18	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 19	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 20	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 21	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 23	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 24	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11

1. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.

Table B3: Annual Loss of Life QRA Calculation Table: Category 2 and Category 3 Hazards

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
1	H1: ROCK									
1	H1.1.1 Small Rockfall	N/A	3	VH	1.0	1	0.5	1.43E-09	0.3	1.23E-09
1	H1.1.2 Large Rockfall	N/A	3	VH	0.3	1	3	8.56E-09	0.9	2.22E-09
1	H1.2 – Rock Topple	6A	3	H	0.01	1	30	8.56E-08	0.9	7.71E-10
		6B	3	M	0.001	1	65	1.86E-07	0.9	1.67E-10
		6C	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6D	3	H	0.01	1	15	4.28E-08	0.9	3.85E-10
		6E	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6F	3	H	0.01	1	15	4.28E-08	0.9	3.85E-10
		6G	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		6H	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		6K	3	H	0.01	1	20	5.71E-08	0.9	5.14E-10
		6L	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		6M	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6N	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		6O	3	M	0.001	1	15	4.28E-08	0.9	3.85E-11
		6P	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6Q	3	M	0.001	0.25	25	7.13E-08	0.9	1.61E-11
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		7B	3	L	0.0001	1	30	8.56E-08	0.9	7.71E-12
		7C	3	L	0.0001	1	35	9.99E-08	0.9	8.99E-12
		7D	3	L	0.0001	1	50	1.43E-07	0.9	1.28E-11
1	H2: DEBRIS (UPSLOPE)									
1	H2.1 Debris Flow	1L	2	VH	0.1	1	15	4.28E-08	0.9	3.85E-09
		1S	2	VH	0.1	0.5	10	2.85E-08	0.9	1.28E-09
		1T	2	VH	0.1	0.5	10	2.85E-08	0.9	1.28E-09
		1K	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10
		2J	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		2K	2	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		1M	2	VH	0.1	1	30	8.56E-08	0.9	7.71E-09
		1U	2	VH	0.1	1	15	4.28E-08	0.9	3.85E-09
		1V	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		2H	2	VH	0.1	1	50	1.43E-07	0.9	1.28E-08
		2L	2	H	0.01	1	20	5.71E-08	0.9	5.14E-10
		1R	2	H	0.01	1	30	8.56E-08	0.9	7.71E-10
		1N	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10
		1O	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		1P	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		1W	2	H	0.01	1	20	5.71E-08	0.9	5.14E-10
		1X	2	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		1Y	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	1.43E-08	0.3	5.78E-12
1	H3: DEBRIS (DOWNSLOPE)									
		2D	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
		1AA	2	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		1AB	2	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		1B	2	VH	1	0.5	20	5.71E-08	0.9	2.57E-08
		1C	2	VH	1	1	25	7.13E-08	0.9	6.42E-08
		1A.2	2	VH	0.1	0.5	25	7.13E-08	0.9	3.21E-09
		1F	2	VH	1	1	50	1.43E-07	0.9	1.28E-07
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	1.43E-08	0.3	6.42E-12
1	H4: RETENTION OR DRAINAGE ELEMENTS									
1	H4.1 Retention Element	1A.1	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
1	H4.2 Drainage Element	Culvert 01	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		Culvert 02	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		Culvert 05	2	VH	1	0.5	25	7.13E-08	0.9	3.21E-08
		Culvert 07	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
2	H1: ROCK									
2	H1.1.1 Small Rockfall	N/A	3	VH	1	0.5	0.5	1.43E-09	0.3	1.71E-09
2	H1.1.2 Large Rockfall	N/A	3	VH	0.8	0.5	3	8.56E-09	0.9	3.08E-09
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6J	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	1.43E-07	0.9	1.28E-10
		7G	3	M	0.001	0.5	50	1.43E-07	0.9	6.42E-11
2	H2: DEBRIS (UPSLOPE)									
2	H2.1 Debris Flow	3C	2	VH	1	1	40	1.14E-07	0.9	1.03E-07
		3A	2	VH	1	1	15	4.28E-08	0.9	3.85E-08
		3B	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08
		3D	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		3E	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08
		3F	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08
		3G	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		3J	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		4C	2	VH	1	1	45	1.28E-07	0.9	1.16E-07
		5A	3	M	0.001	0.5	20	5.71E-08	0.3	8.56E-12
		5B	3	H	0.01	0.5	20	5.71E-08	0.3	8.56E-11
		5C	3	H	0.01	0.5	25	7.13E-08	0.3	1.07E-10
		5D	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12
		2N	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
		3L	2	M	0.001	0.5	10	2.85E-08	0.9	1.28E-11
		5I	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
		5P	2	H	0.01	1	30	8.56E-08	0.9	7.71E-10
		4F	2	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		4G	2	VH	1	1	20	5.71E-08	0.9	5.14E-08
		3M	2	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		3N	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
2	H2.2 Debris Slide	3K	2	VH	0.1	1	30	8.56E-08	0.9	7.71E-09
		4B	2	VH	1	1	25	7.13E-08	0.9	6.42E-08
		4D	2	VH	1	1	40	1.14E-07	0.9	1.03E-07
		3H	2	VH	1	1	70	2.00E-07	0.9	1.80E-07
		5J	2	H	0.01	0.5	25	7.13E-08	0.3	1.07E-10
		5K	2	H	0.01	1	25	7.13E-08	0.9	6.42E-10
		5M	2	H	0.01	0.5	20	5.71E-08	0.3	8.56E-11
		5N	2	H	0.01	0.5	15	4.28E-08	0.9	1.93E-10
		4E	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
		3I	2	VH	0.1	1	20	5.71E-08	0.9	5.14E-09
		5E	3	L	0.0001	0.5	10	2.85E-08	0.3	4.28E-13
		5G	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
		5H	3	M	0.001	0.5	10	2.85E-08	0.9	1.28E-11
		5O	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	1.43E-08	0.3	2.73E-11
2	H3: DEBRIS (DOWNSLOPE)									
		2F	2	H	0.01	0.5	30	8.56E-08	0.9	3.85E-10
		2G	2	VH	0.1	0.5	5	1.43E-08	0.3	2.14E-10
		3P	2	VH	1	0.5	30	8.56E-08	0.9	3.85E-08
		3Q	2	VH	1	1	45	1.28E-07	0.9	1.16E-07
2	H3.1 Debris Flow	3R	2	VH	1	0.5	10	2.85E-08	0.9	1.28E-08
		4H	2	H	0.01	0.5	30	8.56E-08	0.9	3.85E-10
		4I	2	VH	1	0.5	20	5.71E-08	0.9	2.57E-08
		4J	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
		4K	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H3.2 Debris Slide	3S	2	VH	1	1	25	7.13E-08	0.9	6.42E-08
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	1.43E-08	0.3	3.66E-11
2	H4: RETENTION OR DRAINAGE ELEMENTS									
2	H4.1 Retention Element	2M	2	VH	0.1	1	30	8.56E-08	0.9	7.71E-09
		Culvert 08	2	VH	0.1	1	15	4.28E-08	0.9	3.85E-09
		Culvert 09	2	VH	0.1	0.5	15	4.28E-08	0.9	1.93E-09
2	H4.2 Drainage Element	Culvert 10	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 11	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		Culvert 12	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
		Culvert 13	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 14	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 15	2	VH	0.1	0.5	5	1.43E-08	0.3	2.14E-10
		Culvert 16	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 17	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 18	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 19	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 20	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 21	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 23	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 24	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11

1. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.

Table B4: Annual Loss of Life QRA Calculation Table: Category 3 Hazards Only

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
1	H1: ROCK									
1	H1.1.1 Small Rockfall	N/A	3	VH	1.0	1	0.5	1.43E-09	0.3	1.23E-09
1	H1.1.2 Large Rockfall	N/A	3	VH	0.3	1	3	8.56E-09	0.9	2.22E-09
1	H1.2 – Rock Topple	6A	3	H	0.01	1	30	8.56E-08	0.9	7.71E-10
		6B	3	M	0.001	1	65	1.86E-07	0.9	1.67E-10
		6C	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6D	3	H	0.01	1	15	4.28E-08	0.9	3.85E-10
		6E	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6F	3	H	0.01	1	15	4.28E-08	0.9	3.85E-10
		6G	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		6H	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		6K	3	H	0.01	1	20	5.71E-08	0.9	5.14E-10
		6L	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		6M	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6N	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		6O	3	M	0.001	1	15	4.28E-08	0.9	3.85E-11
		6P	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6Q	3	M	0.001	0.25	25	7.13E-08	0.9	1.61E-11
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		7B	3	L	0.0001	1	30	8.56E-08	0.9	7.71E-12
		7C	3	L	0.0001	1	35	9.99E-08	0.9	8.99E-12
		7D	3	L	0.0001	1	50	1.43E-07	0.9	1.28E-11
1	H2: DEBRIS (UPSLOPE)									
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	1.43E-08	0.3	5.78E-12
1	H3: DEBRIS (DOWNSLOPE)									
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	1.43E-08	0.3	6.42E-12
1	H4: RETENTION OR DRAINAGE ELEMENTS									
1	H4.2 Drainage Element	Culvert 01	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		Culvert 02	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
2	H1: ROCK									
2	H1.1.1 Small Rockfall	N/A	3	VH	1	0.5	0.5	1.43E-09	0.3	1.71E-09
2	H1.1.2 Large Rockfall	N/A	3	VH	0.8	0.5	3	8.56E-09	0.9	3.08E-09
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6J	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	1.43E-07	0.9	1.28E-10
		7G	3	M	0.001	0.5	50	1.43E-07	0.9	6.42E-11
2	H2: DEBRIS (UPSLOPE)									
2	H2.1 Debris Flow	5A	3	M	0.001	0.5	20	5.71E-08	0.3	8.56E-12
		5B	3	H	0.01	0.5	20	5.71E-08	0.3	8.56E-11
		5C	3	H	0.01	0.5	25	7.13E-08	0.3	1.07E-10

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
		5D	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12
		5I	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12
		3N	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
2	H2.2. Debris Slide	5E	3	L	0.0001	0.5	10	2.85E-08	0.3	4.28E-13
		5G	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
		5H	3	M	0.001	0.5	10	2.85E-08	0.9	1.28E-11
		5O	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	1.43E-08	0.3	2.73E-11
2	H3: DEBRIS (DOWNSLOPE)									
2	H3.1 Debris Flow	4K	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	1.43E-08	0.3	3.66E-11
2	H4: RETENTION OR DRAINAGE ELEMENTS									
2	H4.2 Drainage Element	Culvert 10	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 11	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		Culvert 12	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		Culvert 13	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 14	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 16	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 17	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 18	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 19	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 20	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 21	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 23	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 24	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11

2. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.

Table B5: Annual Loss of Life QRA Calculation Table: Selected Category 3 Hazards Only

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
1	H1: ROCK									
1	H1.2 Rock Topple	6B	3	M	0.001	1	65	1.86E-07	0.9	1.67E-10
		6C	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6E	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6L	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		6M	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6O	3	M	0.001	1	15	4.28E-08	0.9	3.85E-11
		6P	3	M	0.001	1	25	7.13E-08	0.9	6.42E-11
		6Q	3	M	0.001	0.25	25	7.13E-08	0.9	1.61E-11
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	5.71E-08	0.9	5.14E-11
		7B	3	L	0.0001	1	30	8.56E-08	0.9	7.71E-12
		7C	3	L	0.0001	1	35	9.99E-08	0.9	8.99E-12
		7D	3	L	0.0001	1	50	1.43E-07	0.9	1.28E-11
1	H2: DEBRIS (UPSLOPE)									
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	1.43E-08	0.3	5.78E-12
1	H3: DEBRIS (DOWNSLOPE)									
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	1.43E-08	0.3	6.42E-12
1	H4: RETENTION OR DRAINAGE ELEMENTS									
1	H4.2 Drainage Element	Culvert 01	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
		Culvert 02	3	H	0.01	0.5	10	2.85E-08	0.9	1.28E-10
2	H1: ROCK									
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	2.85E-08	0.9	2.57E-11
		6J	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	1.43E-07	0.9	1.28E-10
		7G	3	M	0.001	0.5	50	1.43E-07	0.9	6.42E-11
2	H2: DEBRIS (UPSLOPE)									
2	H2.1 Debris Flow	5A	3	M	0.001	0.5	20	5.71E-08	0.3	8.56E-12
		5B	3	H	0.01	0.5	20	5.71E-08	0.3	8.56E-11
		5C	3	H	0.01	0.5	25	7.13E-08	0.3	1.07E-10
		5D	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12
		5I	3	M	0.001	0.5	10	2.85E-08	0.3	4.28E-12
		3N	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
2	H2.2. Debris Slide	5E	3	L	0.0001	0.5	10	2.85E-08	0.3	4.28E-13
		5G	3	M	0.001	1	15	4.28E-08	0.3	1.28E-11
		5H	3	M	0.001	0.5	10	2.85E-08	0.9	1.28E-11
		5O	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	1.43E-08	0.3	2.73E-11
2	H3: DEBRIS (DOWNSLOPE)									
2	H3.1 Debris Flow	4K	3	M	0.001	0.5	30	8.56E-08	0.9	3.85E-11

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	$P_{(T:S)}$	$V_{(D:T)}$	One Pass $R_{(LoL)}$ p.a.
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	1.43E-08	0.3	3.66E-11
2	H4: RETENTION OR DRAINAGE ELEMENTS									
2	H4.2 Drainage Element	Culvert 10	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 11	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		Culvert 12	3	H	0.01	0.5	5	1.43E-08	0.9	6.42E-11
		Culvert 13	3	H	0.01	1	10	2.85E-08	0.9	2.57E-10
		Culvert 14	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 16	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 17	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 18	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 19	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 20	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 21	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 23	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11
		Culvert 24	3	H	0.01	0.5	5	1.43E-08	0.3	2.14E-11

1. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.

Table B6: Annual Property Risk (Loss of Value) Calculation Table with Preliminary Indicative Remediation Cost Estimate: Category 1, Category 2 and Category 3 Hazards

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
1	H1: ROCK													
1	H1.1.1 Small Rockfall	N/A	3	VH	1.0	1	0.5			0.125	1	$2,952	$2,952	$992,132
1	H1.1.2 Large Rockfall	N/A	3	VH	0.3	1	3			27	1	$3,710	$1,068	$992,132
1	H1.2 – Rock Topple	6A	3	H	0.01	1	30	10	10	3000	1	$157,200	$1,572	$1,200,000
		6B	3	M	0.001	1	65	10	10	6500	1	$340,600	$341	Not Calculated
		6C	3	M	0.001	1	25	10	10	2500	1	$131,000	$131	Not Calculated
		6D	3	H	0.01	1	15	5	10	750	1	$47,100	$471	$600,000
		6E	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6F	3	H	0.01	1	15	10	10	1500	1	$78,600	$786	$600,000
		6G	3	H	0.01	1	10	10	10	1000	1	$52,400	$524	$400,000
		6H	3	H	0.01	0.5	10	5	10	500	1	$57,800	$289	$400,000
		6K	3	H	0.01	1	20	5	10	1000	1	$62,800	$628	$800,000
		6L	3	M	0.001	1	20	5	10	1000	1	$62,800	$63	Not Calculated
		6M	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6N	3	H	0.01	1	10	5	10	500	1	$31,400	$314	$400,000
		6O	3	M	0.001	1	15	10	10	1500	1	$78,600	$79	Not Calculated
		6P	3	M	0.001	1	25	5	10	1250	1	$78,500	$79	Not Calculated
		6Q	3	M	0.001	0.25	25	10	20	5000	1	$906,500	$227	Not Calculated
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	10	20	4000	1	$188,800	$189	Not Calculated
		7B	3	L	0.0001	1	30	10	30	9000	1	$409,200	$41	Not Calculated
		7C	3	L	0.0001	1	35	10	20	7000	1	$330,400	$33	Not Calculated
		7D	3	L	0.0001	1	50	20	30	30000	1	$304,000	$30	Not Calculated
1	H2: DEBRIS (UPSLOPE)													
1	H2.1 Debris Flow	1L	2	VH	0.1	1	15	5	5	375	1	$31,500	3,150	$150,000
		1Q	1	VH	1	1	25	2	20	1000	1	$68,000	68,000	$1,000,000
		1S	2	VH	0.1	0.5	10	3	3	90	1	$15,120	756	$60,000
		1T	2	VH	0.1	0.5	10	3	3	90	1	$15,120	756	$60,000
		2E	1	H	0.01	0.5	10	2	20	400	1	$72,600	363	$400,000
		2I	1	VH	0.1	1	30	2	30	1800	1	$91,800	9,180	$1,800,000
		1K	2	H	0.01	1	25	5	10	1250	1	$52,500	525	$500,000
		2J	2	H	0.01	0.5	10	3	3	90	1	$15,120	76	$60,000
		2K	2	H	0.01	0.5	5	2.5	2.5	31.25	1	$5,250	26	$25,000

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		1M	2	VH	0.1	1	30	5	10	1500	1	$63,000	6,300	$600,000
		1U	2	VH	0.1	1	15	5	5	375	1	$31,500	3,150	$150,000
		1V	2	H	0.01	0.5	10	3	3	90	1	$15,120	76	$60,000
1	H2.2 Debris Slide	1I	1	VH	1	1	60	3	60	10800	1	$153,120	153,120	$7,200,000
		2H	2	VH	0.1	1	50	10	40	20000	1	$220,000	22,000	$4,000,000
		2L	2	H	0.01	1	20	5	10	1000	1	$94,800	948	$400,000
		1R	2	H	0.01	1	30	5	10	1500	1	$63,000	630	$600,000
		1N	2	H	0.01	1	25	5	10	1250	1	$52,500	525	$500,000
		1O	2	H	0.01	0.5	10	3	3	90	1	$7,560	38	$60,000
		1P	2	H	0.01	0.5	10	3	3	90	1	$7,560	38	$60,000
		1W	2	H	0.01	1	20	3	5	300	1	$25,200	252	$200,000
		1X	2	H	0.01	0.5	5	2.5	5	62.5	1	$5,250	26	$50,000
		1Y	2	H	0.01	1	25	3	10	750	1	$63,000	630	$500,000
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	2.5	2.5	31.25	1	$2,625	4	Not Calculated
1	H3: DEBRIS (DOWNSLOPE)													
		2A	1	VH	1	1	40	3	6	720	1	$196,400	196,400	$480,000
		1G	1	VH	1	1	25	3	3	225	1	$71,000	71,000	$150,000
		1H	1	VH	1	1	50	3	6	900	1	$245,500	245,500	$600,000
		2D	2	VH	0.1	0.5	15	3	3	135	1	$85,200	4,260	$90,000
		1AA	2	H	0.01	0.5	5	2.5	2.5	31.25	1	$21,625	108	$25,000
1	H3.2 Debris Flow	1AB	2	H	0.01	0.5	5	2.5	2.5	31.25	1	$21,625	108	$25,000
		1B	2	VH	1	0.5	20	3	5	300	1	$168,800	84,400	$200,000
		1C	2	VH	1	1	25	3	6	450	1	$122,750	122,750	$300,000
		1A.2	2	VH	0.1	0.5	25	3	5	375	1	$211,000	10,550	$250,000
		1F	2	VH	1	1	50	3	10	1500	1	$383,500	383,500	$1,000,000
		1J	1	VH	1	1	60	3	25	4500	1	$1,081,200	1,081,200	$3,000,000
		2B	1	VH	1	1	100	3	20	6000	1	$1,457,000	1,457,000	$4,000,000
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	2.5	2.5	31.25	1	$21,625	32	Not Calculated
1	H4: RETENTION OR DRAINAGE ELEMENTS													
1	H4.1 Retention Element	1A.1	2	VH	0.1	1	20	5	5	500	1	$134,000	13,400	$200,000
1	H4.2 Drainage Element	Culvert 01	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated
		Culvert 02	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated
		Culvert 03	1	VH	1	1	15				1	$28,500	28,500	$28,500

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		Culvert 04	1	VH	1	1	15				1	$28,500	28,500	$28,500
		Culvert 05	2	VH	1	0.5	25				1	$47,500	23,750	$47,500
		Culvert 06	1	VH	1	1	15				1	$28,500	28,500	$28,500
		Culvert 07	2	VH	0.1	0.5	15				1	$28,500	1,425	$28,500
2	H1: ROCK													
2	H1.1.1 Small Rockfall	N/A	3	VH	1	0.5	0.5			0.125	1	$16,200	8,100	$2,755,921
2	H1.1.2 Large Rockfall	N/A	3	VH	0.8	0.5	3			27	1	$5,920	2,368	$2,755,921
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	10	10	1000	1	$11,240	11	Not Calculated
		6J	3	M	0.001	0.5	30	30	30	27000	1	$49,920	25	Not Calculated
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	20	50	50000	1	$56,200	56	Not Calculated
		7G	3	M	0.001	0.5	50	15	40	30000	1	$83,200	42	Not Calculated
2	H2: DEBRIS (UPSLOPE)													
2	H2.1 Debris Flow	3C	2	VH	1	1	40	2	30	2400	1	$131,600	131,600	$2,400,000
		3A	2	VH	1	1	15	1	40	600	1	$5,310	5,310	$1,200,000
		3B	2	VH	1	0.5	10	1	40	400	1	$3,120	1,560	$800,000
		3D	2	H	0.01	0.5	10	1	15	150	1	$3,120	16	$300,000
		3E	2	VH	1	0.5	10	0.5	20	100	1	$3,120	1,560	$400,000
		3F	2	VH	1	0.5	10	1	10	100	1	$3,120	1,560	$200,000
		3G	2	H	0.01	0.5	10	0.5	10	50	1	$3,120	16	$200,000
		3J	2	H	0.01	0.5	10	0.5	10	50	1	$3,120	16	$200,000
		4C	2	VH	1	1	45	0.5	10	225	1	$15,930	15,930	$900,000
		5A	3	M	0.001	0.5	20	3	3	180	1	$15,120	8	Not Calculated
		5B	3	H	0.01	0.5	20	3	3	180	1	$15,120	76	Not Calculated
		5C	3	H	0.01	0.5	25	3	3	225	1	$18,900	95	Not Calculated
		5D	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated
		2N	2	VH	0.1	1	20	2	10	400	1	$54,400	5,440	$400,000
		3L	2	M	0.001	0.5	10	5	10	500	1	$42,000	21	$200,000
		5I	3	M	0.001	0.5	10	3	3	90	1	$7,560	4	Not Calculated
		5P	2	H	0.01	1	30	2	10	600	1	$81,600	816	$600,000
		4F	2	M	0.001	1	20	2	5	200	1	$37,600	38	$200,000
		4G	2	VH	1	1	20	2	10	400	1	$54,400	54,400	$400,000
		3M	2	H	0.01	0.5	10	1	10	100	1	$18,800	94	$200,000
		3N	3	M	0.001	1	15	5	5	375	1	$31,500	32	Not Calculated

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
2	H2.2 Debris Slide	3K	2	VH	0.1	1	30	2	40	2400	1	$132,000	13,200	$2,400,000
		4B	2	VH	1	1	25	5	20	2500	1	$131,000	131,000	$1,000,000
		4D	2	VH	1	1	40	5	10	2000	1	$125,600	125,600	$800,000
		3H	2	VH	1	1	70	5	20	7000	1	$366,800	366,800	$2,800,000
		5J	2	H	0.01	0.5	25	1	2	50	1	$4,200	21	$100,000
		5K	2	H	0.01	1	25	1	3	75	1	$6,300	63	$150,000
		5M	2	H	0.01	0.5	20	0.5	2	20	1	$1,680	8	$80,000
		5N	2	H	0.01	0.5	15	0.5	5	37.5	1	$3,150	16	$150,000
		4E	2	VH	0.1	1	20	2	20	800	1	$54,400	5,440	$800,000
		3I	2	VH	0.1	1	20	1	10	200	1	$16,800	1,680	$400,000
		5E	3	L	0.0001	0.5	10	3	3	90	1	$7,560	0	Not Calculated
		5G	3	M	0.001	1	15	2	2	60	1	$5,040	5	Not Calculated
		5H	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated
		5O	3	M	0.001	0.5	30	3	3	270	1	$22,680	11	Not Calculated
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	2.5	2.5	31.25	1	$2,625	17	Not Calculated
2	H3: DEBRIS (DOWNSLOPE)													
2	H3.1 Debris Flow	2F	2	H	0.01	0.5	30	3	5	450	1	$253,200	1,266	$300,000
		2G	2	VH	0.1	0.5	5	2	3	30	1	$20,600	1,030	$30,000
		3O	1	VH	1	1	50	3	20	3000	1	$728,500	728,500	$2,000,000
		3P	2	VH	1	0.5	30	3	5	450	1	$253,200	126,600	$300,000
		3Q	2	VH	1	1	45	3	5	675	1	$189,900	189,900	$450,000
		3R	2	VH	1	0.5	10	3	3	90	1	$56,800	28,400	$60,000
		4H	2	H	0.01	0.5	30	3	3	270	1	$170,400	852	$180,000
		4I	2	VH	1	0.5	20	3	3	180	1	$113,600	56,800	$120,000
		4J	2	VH	0.1	0.5	15	3	3	135	1	$85,200	4,260	$90,000
		4K	3	M	0.001	0.5	30	3	3	270	1	$170,400	85	Not Calculated
2	H3.2 Debris Slide	3S	2	VH	1	1	25	3	5	375	1	$105,500	105,500	$250,000
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	2.5	2.5	31.25	1	$21,625	185	Not Calculated
2	H4: RETENTION OR DRAINAGE ELEMENTS													
2	H4.1 Retention Element	2M	2	VH	0.1	1	30	3	6	540	1	$147,300	14,730	$360,000
2	H4.2 Drainage Element	Culvert 08	2	VH	0.1	1	15				1	$28,500	2,850	$28,500
		Culvert 09	2	VH	0.1	0.5	15				1	$28,500	1,425	$28,500

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		Culvert 10	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 11	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 12	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 13	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 14	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 15	2	VH	0.1	0.5	5				1	$9,500	475	$9,500
		Culvert 16	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 17	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 18	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 19	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 20	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 21	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 23	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 24	3	H	0.01	0.5	5	10	10		1	$9,500	48	Not Calculated

1. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.
2. Preliminary Indicative cost estimates for remediation have been calculated based upon a rate of $2,000/m^2$ for remediation of H2.1, H2.2, H2.3, H3.1, H3.2, H3.3 and H4.1 hazards. For hazard types H1.1.1 and H1.1.2, the indexed cost estimate from the 2009 remediation works has been applied at a rate of approximately $2,755 per lineal metre. For H1.2 hazards a rate of $4,000/m^2$ has been applied. For H4.2 hazards a rate of $1,900 per lineal metre has been applied.

Table B7: Annual Property Risk (Loss of Value) Calculation Table with Preliminary Indicative Remediation Cost Estimate: Category 2 and Category 3 Hazards

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
1	H1: ROCK													
1	H1.1.1 Small Rockfall	N/A	3	VH	1.0	1	0.5			0.125	1	$2,952	$2,952	$992,132
1	H1.1.2 Large Rockfall	N/A	3	VH	0.3	1	3			27	1	$3,710	$1,068	$992,132
1	H1.2 – Rock Topple	6A	3	H	0.01	1	30	10	10	3000	1	$157,200	$1,572	$1,200,000
		6B	3	M	0.001	1	65	10	10	6500	1	$340,600	$341	Not Calculated
		6C	3	M	0.001	1	25	10	10	2500	1	$131,000	$131	Not Calculated
		6D	3	H	0.01	1	15	5	10	750	1	$47,100	$471	$600,000
		6E	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6F	3	H	0.01	1	15	10	10	1500	1	$78,600	$786	$600,000
		6G	3	H	0.01	1	10	10	10	1000	1	$52,400	$524	$400,000
		6H	3	H	0.01	0.5	10	5	10	500	1	$57,800	$289	$400,000
		6K	3	H	0.01	1	20	5	10	1000	1	$62,800	$628	$800,000
		6L	3	M	0.001	1	20	5	10	1000	1	$62,800	$63	Not Calculated
		6M	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6N	3	H	0.01	1	10	5	10	500	1	$31,400	$314	$400,000
		6O	3	M	0.001	1	15	10	10	1500	1	$78,600	$79	Not Calculated
		6P	3	M	0.001	1	25	5	10	1250	1	$78,500	$79	Not Calculated
		6Q	3	M	0.001	0.25	25	10	20	5000	1	$906,500	$227	Not Calculated
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	10	20	4000	1	$188,800	$189	Not Calculated
		7B	3	L	0.0001	1	30	10	30	9000	1	$409,200	$41	Not Calculated
		7C	3	L	0.0001	1	35	10	20	7000	1	$330,400	$33	Not Calculated
		7D	3	L	0.0001	1	50	20	30	30000	1	$304,000	$30	Not Calculated
1	H2: DEBRIS (UPSLOPE)													
1	H2.1 Debris Flow	1L	2	VH	0.1	1	15	5	5	375	1	$31,500	3,150	$150,000
		1S	2	VH	0.1	0.5	10	3	3	90	1	$15,120	756	$60,000
		1T	2	VH	0.1	0.5	10	3	3	90	1	$15,120	756	$60,000
		1K	2	H	0.01	1	25	5	10	1250	1	$52,500	525	$500,000
		2J	2	H	0.01	0.5	10	3	3	90	1	$15,120	76	$60,000
		2K	2	H	0.01	0.5	5	2.5	2.5	31.25	1	$5,250	26	$25,000
		1M	2	VH	0.1	1	30	5	10	1500	1	$63,000	6,300	$600,000
		1U	2	VH	0.1	1	15	5	5	375	1	$31,500	3,150	$150,000
		1V	2	H	0.01	0.5	10	3	3	90	1	$15,120	76	$60,000

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		2H	2	VH	0.1	1	50	10	40	20000	1	$220,000	22,000	$4,000,000
		2L	2	H	0.01	1	20	5	10	1000	1	$94,800	948	$400,000
		1R	2	H	0.01	1	30	5	10	1500	1	$63,000	630	$600,000
		1N	2	H	0.01	1	25	5	10	1250	1	$52,500	525	$500,000
		1O	2	H	0.01	0.5	10	3	3	90	1	$7,560	38	$60,000
		1P	2	H	0.01	0.5	10	3	3	90	1	$7,560	38	$60,000
		1W	2	H	0.01	1	20	3	5	300	1	$25,200	252	$200,000
		1X	2	H	0.01	0.5	5	2.5	5	62.5	1	$5,250	26	$50,000
		1Y	2	H	0.01	1	25	3	10	750	1	$63,000	630	$500,000
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	2.5	2.5	31.25	1	$2,625	4	Not Calculated
1	H3: DEBRIS (DOWNSLOPE)													
1	H3.2 Debris Flow	2D	2	VH	0.1	0.5	15	3	3	135	1	$85,200	4,260	$90,000
		1AA	2	H	0.01	0.5	5	2.5	2.5	31.25	1	$21,625	108	$25,000
		1AB	2	H	0.01	0.5	5	2.5	2.5	31.25	1	$21,625	108	$25,000
		1B	2	VH	1	0.5	20	3	5	300	1	$168,800	84,400	$200,000
		1C	2	VH	1	1	25	3	6	450	1	$122,750	122,750	$300,000
		1A.2	2	VH	0.1	0.5	25	3	5	375	1	$211,000	10,550	$250,000
		1F	2	VH	1	1	50	3	10	1500	1	$383,500	383,500	$1,000,000
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	2.5	2.5	31.25	1	$21,625	32	Not Calculated
1	H4: RETENTION OR DRAINAGE ELEMENTS													
1	H4.1 Retention Element	1A.1	2	VH	0.1	1	20	5	5	500	1	$134,000	13,400	$200,000
1	H4.2 Drainage Element	Culvert 01	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated
		Culvert 02	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated
		Culvert 05	2	VH	1	0.5	25				1	$47,500	23,750	$47,500
		Culvert 07	2	VH	0.1	0.5	15				1	$28,500	1,425	$28,500
2	H1: ROCK													
2	H1.1.1 Small Rockfall	N/A	3	VH	1	0.5	0.5			0.125	1	$16,200	8,100	$2,755,921
2	H1.1.2 Large Rockfall	N/A	3	VH	0.8	0.5	3			27	1	$5,920	2,368	$2,755,921
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	10	10	1000	1	$11,240	11	Not Calculated
		6J	3	M	0.001	0.5	30	30	30	27000	1	$49,920	25	Not Calculated
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	20	50	50000	1	$56,200	56	Not Calculated

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		7G	3	M	0.001	0.5	50	15	40	30000	1	$83,200	42	Not Calculated
2	H2: DEBRIS (UPSLOPE)													
2	H2.1 Debris Flow	3C	2	VH	1	1	40	2	30	2400	1	$131,600	131,600	$2,400,000
		3A	2	VH	1	1	15	1	40	600	1	$5,310	5,310	$1,200,000
		3B	2	VH	1	0.5	10	1	40	400	1	$3,120	1,560	$800,000
		3D	2	H	0.01	0.5	10	1	15	150	1	$3,120	16	$300,000
		3E	2	VH	1	0.5	10	0.5	20	100	1	$3,120	1,560	$400,000
		3F	2	VH	1	0.5	10	1	10	100	1	$3,120	1,560	$200,000
		3G	2	H	0.01	0.5	10	0.5	10	50	1	$3,120	16	$200,000
		3J	2	H	0.01	0.5	10	0.5	10	50	1	$3,120	16	$200,000
		4C	2	VH	1	1	45	0.5	10	225	1	$15,930	15,930	$900,000
		5A	3	M	0.001	0.5	20	3	3	180	1	$15,120	8	Not Calculated
		5B	3	H	0.01	0.5	20	3	3	180	1	$15,120	76	Not Calculated
		5C	3	H	0.01	0.5	25	3	3	225	1	$18,900	95	Not Calculated
		5D	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated
		2N	2	VH	0.1	1	20	2	10	400	1	$54,400	5,440	$400,000
		3L	2	M	0.001	0.5	10	5	10	500	1	$42,000	21	$200,000
		5I	3	M	0.001	0.5	10	3	3	90	1	$7,560	4	Not Calculated
		5P	2	H	0.01	1	30	2	10	600	1	$81,600	816	$600,000
		4F	2	M	0.001	1	20	2	5	200	1	$37,600	38	$200,000
		4G	2	VH	1	1	20	2	10	400	1	$54,400	54,400	$400,000
		3M	2	H	0.01	0.5	10	1	10	100	1	$18,800	94	$200,000
		3N	3	M	0.001	1	15	5	5	375	1	$31,500	32	Not Calculated
2	H2.2 Debris Slide	3K	2	VH	0.1	1	30	2	40	2400	1	$132,000	13,200	$2,400,000
		4B	2	VH	1	1	25	5	20	2500	1	$131,000	131,000	$1,000,000
		4D	2	VH	1	1	40	5	10	2000	1	$125,600	125,600	$800,000
		3H	2	VH	1	1	70	5	20	7000	1	$366,800	366,800	$2,800,000
		5J	2	H	0.01	0.5	25	1	2	50	1	$4,200	21	$100,000
		5K	2	H	0.01	1	25	1	3	75	1	$6,300	63	$150,000
		5M	2	H	0.01	0.5	20	0.5	2	20	1	$1,680	8	$80,000
		5N	2	H	0.01	0.5	15	0.5	5	37.5	1	$3,150	16	$150,000
		4E	2	VH	0.1	1	20	2	20	800	1	$54,400	5,440	$800,000
		3I	2	VH	0.1	1	20	1	10	200	1	$16,800	1,680	$400,000
		5E	3	L	0.0001	0.5	10	3	3	90	1	$7,560	0	Not Calculated
		5G	3	M	0.001	1	15	2	2	60	1	$5,040	5	Not Calculated
		5H	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		5O	3	M	0.001	0.5	30	3	3	270	1	$22,680	11	Not Calculated
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	2.5	2.5	31.25	1	$2,625	17	Not Calculated
2	H3: DEBRIS (DOWNSLOPE)													
2	H3.1 Debris Flow	2F	2	H	0.01	0.5	30	3	5	450	1	$253,200	1,266	$300,000
		2G	2	VH	0.1	0.5	5	2	3	30	1	$20,600	1,030	$30,000
		3P	2	VH	1	0.5	30	3	5	450	1	$253,200	126,600	$300,000
		3Q	2	VH	1	1	45	3	5	675	1	$189,900	189,900	$450,000
		3R	2	VH	1	0.5	10	3	3	90	1	$56,800	28,400	$60,000
		4H	2	H	0.01	0.5	30	3	3	270	1	$170,400	852	$180,000
		4I	2	VH	1	0.5	20	3	3	180	1	$113,600	56,800	$120,000
		4J	2	VH	0.1	0.5	15	3	3	135	1	$85,200	4,260	$90,000
		4K	3	M	0.001	0.5	30	3	3	270	1	$170,400	85	Not Calculated
2	H3.2 Debris Slide	3S	2	VH	1	1	25	3	5	375	1	$105,500	105,500	$250,000
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	2.5	2.5	31.25	1	$21,625	185	Not Calculated
2	H4: RETENTION OR DRAINAGE ELEMENTS													
2	H4.1 Retention Element	2M	2	VH	0.1	1	30	3	6	540	1	$147,300	14,730	$360,000
2	H4.2 Drainage Element	Culvert 08	2	VH	0.1	1	15				1	$28,500	2,850	$28,500
		Culvert 09	2	VH	0.1	0.5	15				1	$28,500	1,425	$28,500
		Culvert 10	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 11	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 12	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 13	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 14	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 15	2	VH	0.1	0.5	5				1	$9,500	475	$9,500
		Culvert 16	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 17	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 18	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 19	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 20	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		Culvert 21	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 23	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 24	3	H	0.01	0.5	5	10	10		1	$9,500	48	Not Calculated

1. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.
2. Preliminary Indicative cost estimates for remediation have been calculated based upon a rate of $2,000/m^2$ for remediation of H2.1, H2.2, H2.3, H3.1, H3.2, H3.3 and H4.1 hazards. For hazard types H1.1.1 and H1.1.2, the indexed cost estimate from the 2009 remediation works has been applied at a rate of approximately $2,755 per lineal metre. For H1.2 hazards a rate of $4,000/m^2$ has been applied. For H4.2 hazards a rate of $1,900 per lineal metre has been applied.

Table B8: Annual Property Risk (Loss of Value) Calculation Table with Preliminary Indicative Remediation Cost Estimate: Category 3 Hazards

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
1	H1: ROCK													
1	H1.1.1 Small Rockfall	N/A	3	VH	1.0	1	0.5			0.125	1	$2,952	$2,952	$992,132
1	H1.1.2 Large Rockfall	N/A	3	VH	0.3	1	3			27	1	$3,710	$1,068	$992,132
1	H1.2 – Rock Topple	6A	3	H	0.01	1	30	10	10	3000	1	$157,200	$1,572	$1,200,000
		6B	3	M	0.001	1	65	10	10	6500	1	$340,600	$341	Not Calculated
		6C	3	M	0.001	1	25	10	10	2500	1	$131,000	$131	Not Calculated
		6D	3	H	0.01	1	15	5	10	750	1	$47,100	$471	$600,000
		6E	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6F	3	H	0.01	1	15	10	10	1500	1	$78,600	$786	$600,000
		6G	3	H	0.01	1	10	10	10	1000	1	$52,400	$524	$400,000
		6H	3	H	0.01	0.5	10	5	10	500	1	$57,800	$289	$400,000
		6K	3	H	0.01	1	20	5	10	1000	1	$62,800	$628	$800,000
		6L	3	M	0.001	1	20	5	10	1000	1	$62,800	$63	Not Calculated
		6M	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6N	3	H	0.01	1	10	5	10	500	1	$31,400	$314	$400,000
		6O	3	M	0.001	1	15	10	10	1500	1	$78,600	$79	Not Calculated
		6P	3	M	0.001	1	25	5	10	1250	1	$78,500	$79	Not Calculated
		6Q	3	M	0.001	0.25	25	10	20	5000	1	$906,500	$227	Not Calculated
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	10	20	4000	1	$188,800	$189	Not Calculated
		7B	3	L	0.0001	1	30	10	30	9000	1	$409,200	$41	Not Calculated
		7C	3	L	0.0001	1	35	10	20	7000	1	$330,400	$33	Not Calculated
		7D	3	L	0.0001	1	50	20	30	30000	1	$304,000	$30	Not Calculated
1	H2: DEBRIS (UPSLOPE)													
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	2.5	2.5	31.25	1	$2,625	4	Not Calculated
1	H3: DEBRIS (DOWNSLOPE)													
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	2.5	2.5	31.25	1	$21,625	32	Not Calculated
1	H4: RETENTION OR DRAINAGE ELEMENTS													
1		Culvert 01	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
	H4.2 Drainage Element	Culvert 02	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated
2	H1: ROCK													
2	H1.1.1 Small Rockfall	N/A	3	VH	1	0.5	0.5			0.125	1	$16,200	8,100	$2,755,921
2	H1.1.2 Large Rockfall	N/A	3	VH	0.8	0.5	3			27	1	$5,920	2,368	$2,755,921
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	10	10	1000	1	$11,240	11	Not Calculated
		6J	3	M	0.001	0.5	30	30	30	27000	1	$49,920	25	Not Calculated
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	20	50	50000	1	$56,200	56	Not Calculated
		7G	3	M	0.001	0.5	50	15	40	30000	1	$83,200	42	Not Calculated
2	H2: DEBRIS (UPSLOPE)													
2	H2.1 Debris Flow	5A	3	M	0.001	0.5	20	3	3	180	1	$15,120	8	Not Calculated
		5B	3	H	0.01	0.5	20	3	3	180	1	$15,120	76	Not Calculated
		5C	3	H	0.01	0.5	25	3	3	225	1	$18,900	95	Not Calculated
		5D	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated
		5I	3	M	0.001	0.5	10	3	3	90	1	$7,560	4	Not Calculated
		3N	3	M	0.001	1	15	5	5	375	1	$31,500	32	Not Calculated
		5E	3	L	0.0001	0.5	10	3	3	90	1	$7,560	0	Not Calculated
		5G	3	M	0.001	1	15	2	2	60	1	$5,040	5	Not Calculated
		5H	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated
		5O	3	M	0.001	0.5	30	3	3	270	1	$22,680	11	Not Calculated
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	2.5	2.5	31.25	1	$2,625	17	Not Calculated
2	H3: DEBRIS (DOWNSLOPE)													
2	H3.1 Debris Flow	4K	3	M	0.001	0.5	30	3	3	270	1	$170,400	85	Not Calculated
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	2.5	2.5	31.25	1	$21,625	185	Not Calculated
2	H4: RETENTION OR DRAINAGE ELEMENTS													
2	H4.2 Drainage Element	Culvert 10	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 11	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 12	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		Culvert 13	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 14	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 16	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 17	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 18	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 19	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 20	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 21	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 23	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 24	3	H	0.01	0.5	5	10	10		1	$9,500	48	Not Calculated

3. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.
4. Preliminary Indicative cost estimates for remediation have been calculated based upon a rate of $2,000/m^2$ for remediation of H2.1, H2.2, H2.3, H3.1, H3.2, H3.3 and H4.1 hazards. For hazard types H1.1.1 and H1.1.2, the indexed cost estimate from the 2009 remediation works has been applied at a rate of approximately $2,755 per lineal metre. For H1.2 hazards a rate of $4,000/m^2$ has been applied. For H4.2 hazards a rate of $1,900 per lineal metre has been applied.

Table B9: Annual Property Risk (Loss of Value) Calculation Table with Preliminary Indicative Remediation Cost Estimate: Selected Category 3 Hazards

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
1	H1: ROCK													
1	H1.2 – Rock Topple	6B	3	M	0.001	1	65	10	10	6500	1	$340,600	$341	Not Calculated
		6C	3	M	0.001	1	25	10	10	2500	1	$131,000	$131	Not Calculated
		6E	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6L	3	M	0.001	1	20	5	10	1000	1	$62,800	$63	Not Calculated
		6M	3	M	0.001	1	10	5	10	500	1	$31,400	$31	Not Calculated
		6O	3	M	0.001	1	15	10	10	1500	1	$78,600	$79	Not Calculated
		6P	3	M	0.001	1	25	5	10	1250	1	$78,500	$79	Not Calculated
		6Q	3	M	0.001	0.25	25	10	20	5000	1	$906,500	$227	Not Calculated
1	H1.3 – Rock Slide	7A	3	M	0.001	1	20	10	20	4000	1	$188,800	$189	Not Calculated
		7B	3	L	0.0001	1	30	10	30	9000	1	$409,200	$41	Not Calculated
		7C	3	L	0.0001	1	35	10	20	7000	1	$330,400	$33	Not Calculated
		7D	3	L	0.0001	1	50	20	30	30000	1	$304,000	$30	Not Calculated
1	H2: DEBRIS (UPSLOPE)													
1	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0027	0.5	5	2.5	2.5	31.25	1	$2,625	4	Not Calculated
1	H3: DEBRIS (DOWNSLOPE)													
1	H3.3 Debris Flow/Slide General	N/A	3	VL	0.003	0.5	5	2.5	2.5	31.25	1	$21,625	32	Not Calculated
1	H4: RETENTION OR DRAINAGE ELEMENTS													
1	H4.2 Drainage Element	Culvert 01	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated
		Culvert 02	3	H	0.01	0.5	10				1	$19,000	95	Not Calculated
2	H1: ROCK													
2	H1.2 Rock Topple	6I	3	M	0.001	1	10	10	10	1000	1	$11,240	11	Not Calculated
		6J	3	M	0.001	0.5	30	30	30	27000	1	$49,920	25	Not Calculated
2	H1.3 Rock Slide	7F	3	M	0.001	1	50	20	50	50000	1	$56,200	56	Not Calculated
		7G	3	M	0.001	0.5	50	15	40	30000	1	$83,200	42	Not Calculated
2	H2: DEBRIS (UPSLOPE)													
2	H2.1 Debris Flow	5A	3	M	0.001	0.5	20	3	3	180	1	$15,120	8	Not Calculated
		5B	3	H	0.01	0.5	20	3	3	180	1	$15,120	76	Not Calculated

Domain	Hazard Type	Specific Hazard Name	Hazard Category	Hazard descriptor	$P_{(H)}$	$P_{(S:H)}$	Hazard width m	Hazard Breadth m	Hazard Slope Height m	Volume m^3	$P_{(T:S)}$	Estimated Loss of Value (i.e. $E \times V_{(D:T)}$)	$R_{(Prop)}$ p.a.	Preliminary Indicative Remediation Cost Estimate
		5C	3	H	0.01	0.5	25	3	3	225	1	$18,900	95	Not Calculated
		5D	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated
		5I	3	M	0.001	0.5	10	3	3	90	1	$7,560	4	Not Calculated
		3N	3	M	0.001	1	15	5	5	375	1	$31,500	32	Not Calculated
		5E	3	L	0.0001	0.5	10	3	3	90	1	$7,560	0	Not Calculated
		5G	3	M	0.001	1	15	2	2	60	1	$5,040	5	Not Calculated
		5H	3	M	0.001	0.5	10	2	2	40	1	$3,360	2	Not Calculated
		5O	3	M	0.001	0.5	30	3	3	270	1	$22,680	11	Not Calculated
2	H2.3 Debris Flow/Slide General	N/A	3	VL	0.0128	0.5	5	2.5	2.5	31.25	1	$2,625	17	Not Calculated
2	H3: DEBRIS (DOWNSLOPE)													
2	H3.1 Debris Flow	4K	3	M	0.001	0.5	30	3	3	270	1	$170,400	85	Not Calculated
2	H3.3 Debris Flow/Slide General	N/A	3	VL	0.0171	0.5	5	2.5	2.5	31.25	1	$21,625	185	Not Calculated
2	H4: RETENTION OR DRAINAGE ELEMENTS													
2	H4.2 Drainage Element	Culvert 10	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 11	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 12	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 13	3	H	0.01	1	10				1	$19,000	190	Not Calculated
		Culvert 14	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 16	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 17	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 18	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 19	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 20	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 21	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 23	3	H	0.01	0.5	5				1	$9,500	48	Not Calculated
		Culvert 24	3	H	0.01	0.5	5	10	10		1	$9,500	48	Not Calculated

1. Refer to Section 2 of this report (WSP Golder Ref. PS129742-SYD-REP-002-REV 0) for a description of assumptions and calculation methodology.
2. Preliminary Indicative cost estimates for remediation have been calculated based upon a rate of $2,000/m^2 for remediation of H2.1, H2.2, H2.3, H3.1, H3.2, H3.3 and H4.1 hazards. For hazard types H1.1.1 and H1.1.2, the indexed cost estimate from the

2009 remediation works has been applied at a rate of approximately $2,755 per lineal metre. For H1.2 hazards a rate of $4,000/m^2 has been applied. For H4.2 hazards a rate of $1,900 per lineal metre has been applied.

APPENDIX C

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

LANDSLIDE RISK

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as *"a measure of the probability and severity of an adverse effect to health, property, or the environment."* This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

TABLE 2: LIKELIHOOD

Likelihood	Annual Probability
Almost Certain	1:10
Likely	1:100
Possible	1:1,000
Unlikely	1:10,000
Rare	1:100,000
Barely credible	1:1,000,000

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

TABLE 1: RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	**Unacceptable** without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low. May be too expensive and not practical. Work likely to cost more than the value of the property.
High	H	**Unacceptable** without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	**May be tolerated** in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as possible.
Low	L	**Usually acceptable** to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	**Acceptable**. Manage by normal slope maintenance procedures.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Risk to Life

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

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

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

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

TABLE 3: RISK TO LIFE

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

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

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

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

APPENDIX D

Important Information

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

This Report constitutes or is part of services ("Services") provided by Golder to its client ("Client") under and subject to a contract between Golder and its Client ("Contract"). The contents of this page are not intended to and do not alter Golder's obligations (including any limits on those obligations) to its Client under the Contract.

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The scope of Golder's Services and the period of time they relate to are determined by the Contract and are subject to restrictions and limitations set out in the Contract. If a service or other work is not expressly referred to in this Report, do not assume that it has been provided or performed. If a matter is not addressed in this Report, do not assume that any determination has been made by Golder in regards to it.

At any location relevant to the Services conditions may exist which were not detected by Golder, in particular due to the specific scope of the investigation Golder has been engaged to undertake. Conditions can only be verified at the exact location of any tests undertaken. Variations in conditions may occur between tested locations and there may be conditions which have not been revealed by the investigation and which have not therefore been taken into account in this Report.

Golder accepts no responsibility for and makes no representation as to the accuracy or completeness of the information provided to it by or on behalf of the Client or sourced from any third party. Golder has assumed that such information is correct unless otherwise stated and no responsibility is accepted by Golder for incomplete or inaccurate data supplied by its Client or any other person for whom Golder is not responsible. Golder has not taken account of matters that may have existed when the Report was prepared but which were only later disclosed to Golder.

Having regard to the matters referred to in the previous paragraphs on this page in particular, carrying out the Services has allowed Golder to form no more than an opinion as to the actual conditions at any relevant location. That opinion is necessarily constrained by the extent of the information collected by Golder or otherwise made available to Golder. Further, the passage of time may affect the accuracy, applicability or usefulness of the opinions, assessments or other information in this Report. This Report is based upon the information and other circumstances that existed and were known to Golder when the Services were performed and this Report was prepared. Golder has not considered the effect of any possible future developments including physical changes to any relevant location or changes to any laws or regulations relevant to such location.

Where permitted by the Contract, Golder may have retained subconsultants affiliated with Golder to provide some or all of the Services. However, it is Golder which remains solely responsible for the Services and there is no legal recourse against any of Golder's affiliated companies or the employees, officers or directors of any of them.

By date, or revision, the Report supersedes any prior report or other document issued by Golder dealing with any matter that is addressed in the Report.

Any uncertainty as to the extent to which this Report can be used or relied upon in any respect should be referred to Golder for clarification

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