



Wolgan Road

Landslide Risk Assessment

Lithgow City Council

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Executive summary

Lithgow City Council commissioned GHD to perform a landslide risk assessment for a 1.7 km section of Wolgan Road (colloquially known as “The Gap”) north of Lithgow, NSW. The aim of the GHD study was to quantify the landslide risk to road users following the closure of the road in 2022 due to landslide risks and associated road damage. This report documents GHD’s Quantitative Risk Assessment (QRA), providing an objective evaluation of landslide hazards, their likelihood, and the potential risk to life to road users. The findings of this assessment are intended to guide Council and stakeholders in understanding the severity of landslide risk issues on this vital access route.

Wolgan Road is a historic road, constructed by the Public Works Department in 1897 when transport moved away from the use of pack animals. From the lookout at the top of The Gap, Wolgan Road initially descends steeply into Wolgan Valley, passing directly below a sheer cliff that forms part of the natural escarpment. As the road descends further into the valley it traverses steep colluvial hillsides and progressively deviates away from the cliffs. Wolgan Road has been the sole vehicular access route into Wolgan Valley, serving residents, tourists, and the Emirates One&Only Resort for many years. In 2022 Wolgan Road was closed after heavy rains triggered landslides and caused damage to the road and has remained closed since. A steep 4WD-only alternative access along the historic “Donkey Steps” track was formalised and opened to residents, but due to its steep grades it is not a practical long-term solution.

Previous studies found landslide risks to be intolerable, using their adopted criteria concluding that re-opening the existing road was not economically feasible. However, independent peer reviews identified issues in those assessments and called for a comprehensive re-evaluation. In June 2025 Lithgow City Council engaged GHD to undertake a new risk assessment (this report).

This GHD study has divided the site into five geotechnical domains based on geology and geomorphology to assist in characterisation of the road to undertake appropriate risk assessments. Considerable efforts have been made to compile a landslide inventory, which is an important task for landslide risk assessments as it provides context on past events that can be used to identify the nature of the hazards and approximate predicted future landslide frequencies. The inventory has been compiled using many different data sources including but not limited to, Council records, historic newspaper articles and history provided by residents of Wolgan Valley. To help estimate frequencies for different hazards the inventory has been complimented with additional studies carried out by GHD including site inspections (both on foot and remotely by drone), geological and geomorphological interpretation, anecdotal evidence, rainfall assessments, development of a rockfall volume-frequency model and rockfall modelling.

The landslide hazards assessed at the site have been classified according to the internationally accepted scheme by Hungr et al. (2014). This assessment considered 11 different hazard types based on landslide volume and classification. The hazards include a range of different sized rockfalls, earthflows, debris flows and embankment slides. The distribution of the hazards varies across the site, and not all hazard types were found to be present in each domain.

Leading up to the road closure in 2022, the site experienced above average rainfall, and the year has been variously described in the media as “record breaking rainfall”. While 2022 was a wet period for the site, the rainfall recorded in the region was considerably less than the actual record-breaking rain received in other parts of New South Wales such as to the east in Sydney in the same year. The wet period at the site in 2022 fell into the top 10 wettest years on record for the area however, the rainfall was significantly less than that experienced in 1950. It should also be noted that if locally collected rainfall data is considered (i.e. unofficial data collected by a Wolgan Valley resident), the rainfall for 2022 would be only the 22nd highest since records began. We note that the denuding of the slopes of groundcover and vegetation on the slopes from the 2019-20 Black Summer bushfires, where over 80% of the Blue Mountains National Park was affected, may have exacerbated the effect of the rainfalls in 2022.

While the road was affected by numerous landslides and localised embankment instability during 2022, the available history for the road suggests these events were not unprecedented. The historical data indicates that similar or even greater landslide activity occurred during the record-breaking rainfall in 1950. This has been

corroborated by local residents who have provided anecdotal accounts of similar landslide events occurring in 'wet' years.

Landslide risks at the site have been assessed using the Australian Geomechanics Society Landslide Risk Management Guidelines (AGS, 2007), which are recognised both nationally and internationally as world-leading practice. These guidelines have since been further adapted in the NSW National Parks and Wildlife Service Guidelines for Quantitative Risk Assessment (NPWS, 2024). Risk has been estimated for "the individual most at risk" (individual risk estimate) and an individual within the exposed population (societal risk estimate, i.e. society as a whole). The person most at risk is typically an identifiable / named individual who undertakes a particular travel pattern. Estimates of risk have been made for:

- Each hazard type in each domain (individual risk)
- Overall risk in each domain by combining individual risks from each hazard (individual risk)
- Overall risk for a journey from start to finish incorporating combined risk in every domain across the site (individual risk)
- Overall risk in each domain (societal risk)
- Overall risk for a journey from start to finish incorporating combined risk in every domain across the site (societal risk)

In addition, risk estimates have also been carried out for each hazard type in each domain using the Transport for New South Wales (TfNSW) Guide to Slope Risk Analysis to determine an Assessed Risk Level (ARL).

As the regulator / responsible authority, Council has the responsibility for setting the risk acceptance criteria with which to evaluate the level of risk acceptable for Wolgan Road. The choice of what boundaries and thresholds constitutes acceptable or tolerable risk are not absolute and different organisations may adopt different criteria. The role of the consultant is to estimate the levels of risk in accordance with the available data and state of knowledge within stated limitations and uncertainty but cannot advise on acceptability or otherwise of such risk levels for a particular client or organisation.

AGS (2007) provides suggested tolerable risk criteria for the person most at risk for two scenarios; 'Existing slope / existing development' and 'New constructed slope / new development / existing landslide'. Using the AGS suggested criteria as a guide only the estimated loss of life risks for each hazard type and in each domain (i.e. combined individual risks from each hazard in each domain) are all lower than the AGS suggested tolerable levels for both scenarios. The estimated overall risk for a journey from start to finish incorporating combined risk in every domain across the site slightly exceeds the AGS suggested tolerable level for the person most at risk for a new development. However, where the AGS criteria for an 'existing slope' are applied the risk levels are within the tolerable range.

AGS (2007) is not definitive when it comes to circumstances when societal risks should be considered because the focus of the AGS guidelines was largely on residential development. NPWS (2024) proposes two suggested societal risk thresholds; 'existing developments' and 'new developments'. Using the NPWS criteria for 'existing developments' as a guide, the risks for loss of life to the total population would be considered tolerable across every domain and for a journey from start to finish incorporating combined risk in every domain. However, using the NPWS criteria for 'new developments' as a guide, the societal risks estimated for Domain 1 would be considered not tolerable and for a journey from start to finish incorporating combined risk in every domain would also be considered not tolerable (because of the potential hazards in Domain 1).

Using the TfNSW risk methodology, risks assessed at the site range from ARL2 to ARL5. TfNSW does not publicly publish their risk tolerability criteria.

It is noteworthy that the highest assessed risks at the site using each of the risk estimation methods are associated with hazards in Domains 1 and 2. Assessed risks for Domains 3, 4 and 5 are all below the AGS (2007) suggested Tolerable or Acceptable risk criteria for both the individual most at risk and societal criteria.

It must be acknowledged that there are numerous forms of landslides along Wolgan Road that have occurred in the past and will inevitably occur in the future. Risk assessment allows us to postulate the nature of those hazards, how frequent they may be and what impact they may potentially have on road users through estimations of both spatial and temporal exposures. It is important to note that any risk estimate has inherent uncertainty and limitations, and discussion has been included in this assessment to provide a more realistic understanding to the

risk assessment process. Based on our assessment of uncertainty, the risk levels are within a range of typically +/- half to one order of magnitude.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 1.3 and the assumptions and qualifications contained throughout the Report.

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1. Introduction

1.1 Purpose of this report

GHD has been engaged by Lithgow City Council (Council) to carry out a quantitative landslide risk assessment (QRA) for a section of Wolgan Road on route to Wolgan Valley north of Lithgow, NSW. This report provides an overview of our research, methodology, modelling and assessments carried out at the site including our landslide risk assessment carried out to estimate loss of life risks to persons using Wolgan Road.

The work was carried out in accordance with our proposal dated 3 June 2025 (Ref: RFQ Number SCM0005 / SCM1191).

1.2 Background

Wolgan Road was closed to traffic in 2022 by Lithgow City Council due to landslide risks and associated road damage. Wolgan Road is an important access route for the Wolgan Valley community and provides access to the Emirates One&Only Resort. The road closure has resulted in the closure of the resort. Council has constructed an interim alternate access road along the eastern side of the Wolgan Gap, following the route of the historic 'Donkey Steps' track. However, this route is primarily limited to four-wheel drive vehicles and is constructed at very steep grades.

Updated in 2023, WSP conducted a landslide risk assessment for Wolgan Road (WSP, 2023b). These assessments concluded that landslide risks are intolerable, and that restoration and remediation of the existing road are not practical or cost-effective options. Currently, the recommended option involves constructing a new road on the opposite side of the valley. Previous risk assessments carried out for the site by Golder Associates in 2006 found the risks to be Acceptable according to the AGS (2007) suggested tolerable levels for the person most at risk (Golder 2006).

GHD (2025) undertook an independent review of the WSP landslide risk assessment found that the assessment lacked sufficient clarity, sensitivity and transparency of method. There was an absence of review against longer term history landslide history along the road with some of the assigned probabilities not reflecting observed events over the years. Other assigned probability values such as vulnerability were also found to be very high, having a significant impact on the overall risk calculations. Another review of the WSP landslide risk assessment conducted by Krogh (2024) identified the same issues. It was recommended in both reviews that Council undertake a comprehensive independent revision of the landslide risk assessment for Wolgan Road. In April 2025, Transport for NSW (TfNSW) and NSW Reconstruction Authority advised that they support Lithgow City Council in undertaking an independent Slope Risk Assessment for the closed section of Wolgan Road under the Disaster Recovery Funding Arrangement.

1.3 Scope and limitations

The scope of this work was to prepare an independent landslide risk assessment for the site in general accordance with the Australian Geomechanics Society Landslide Risk Management Guidelines (AGS 2007) as outlined in our proposal dated 3 June 2025. This report does not present recommendations for risk mitigation works or risk management advice.

GHD undertook reconnaissance level site walkovers along Wolgan Road in July 2025. The inspections were carried out across the site area between the locked gate at Wolgan Valley Lookout and the bottom of the pass at the intersection with the Donkey Steps' track. The site visits were carried out by a Senior Technical Director Engineering Geologist and a Technical Director Geotechnical Engineer. The site visits included both observations from road level as well as traverses of selected areas of steep colluvial slopes above the road. Remote viewing was also undertaken using a UAV/drone to provide a broader visual perspective.

This report has been prepared by GHD for Lithgow City Council and may only be used and relied on by Lithgow City Council for the purpose agreed between GHD and Lithgow City Council as set out in section 1.3 of this report.

GHD otherwise disclaims responsibility to any person other than Lithgow City Council arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

Accessibility of documents

If this report is required to be accessible in any other format, this can be provided by GHD upon request and at an additional cost if necessary.

2. Data sources

GHD has undertaken a background review of available data and historical information available for the site. A summary of the data sources is provided below:

- Publicly available geological maps;
- Publicly available aerial photographs dating from 1969 onwards;
- Historical consultant reports provided by Council. The reports made available by Council are summarised in Table 1;
- A limited inventory of rockfall / landslide events and maintenance ‘callouts’ provided by Council (earliest record dated 2012);
- In-person feedback and information provided by participants during a community consultation meeting held in Lithgow on 3 July 2025;
- Data including historical site photographs and photographs of landslides / rockfalls provided by the Wolgan Valley Community Association. This also includes verbal discussions and accounts of events and incidents that have affected the road over its history;
- Results of an online community survey undertaken by Council to gather information on landslides / rockfalls. GHD provided input into the questionnaire to gather information on the nature of the landslide history at the site. The results of the survey are included in Appendix D;
- Lidar and photogrammetry survey data provided by Council. Six datasets were supplied, with collection dates ranging from February 2020 to March 2024.

Table 1 Consultant reports provided by Council

Author / Reference	Date	Document Title	Content Overview
Golder Associates/ 01622472/029	9 May 2006	Wolgan Gap – Geotechnical Risk Assessment	Risk assessment to road users using RTA (TfNSW) and AGS guidelines
Golder Associates/ 087622115/003 Rev1	17 March 2009	Road Slope Instability Risk Management Plan	Risk management plan for rockfall above Wolgan Road
Golder Associates /097622078/002 Rev 0	08 September 2009	Slope Remediation Design Report	Work plan for slope stability remedial measures
Golder Associates /097622078/005 Rev 0	05 November 2009	Slope Remediation Completion Report	Remedial work results and as-built drawings
Golder Associates /097622078/011 Rev 0	02 July 2018	Embankment Slip Remediation Investigation	Geotechnical investigation and concept design
Golder Associates /097622078-R-013-Rev0	17 July 2019	Periodic Inspection Report – Slope Face 1 to 4	Results of February 2019 inspection
Golder Associates /097622078-003-R-Rev2	31 July 2019	Road Slope Instability Risk Management Plan (Update)	Update of previous risk management plan
Golder Associates /097622078-014-R-Rev0	22 January 2020	Geotechnical Investigation and Remediation Concept Report	Recommended remedial works for distressed pavement
Golder Associates/ 097622078-M-Rev 0	20 December 2021	Technical Memorandum – Wolgan Gap December 2021 Instability Event	Site visit and response measures
WSP/Golder	23 January 2023	Review of Wolgan Gap Slope Hazards 2022	Summary of slope hazards and emergency response
WSP/Golder, PS129742-SYD-GEO-REP-002-REV 0	17 February 2023	Slope Risk Assessment Update 2022 – Domain 1 and 2	Updated geotechnical slope hazards

Author / Reference	Date	Document Title	Content Overview
WSP/PS217104-WSP-SYD-GEO-LTR-Rev0	24 June 2025	Wolgan Road Project - Gap Slope Risk Assessment	Summary of WSP 2023 risk assessment and reply to GHD 2025 review report
Environmental Data Analysis Pty Ltd.	2 March 2024	Wolgan Valley Road Risk Assessment and Road Closure	Review of WSP risk assessment

3. Definitions and terminology

3.1 Landslide risk terminology

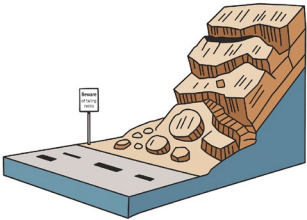

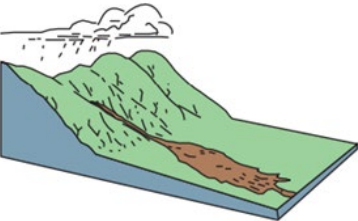
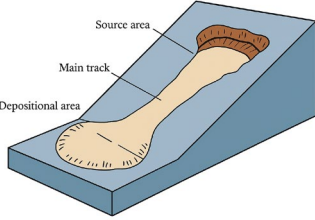
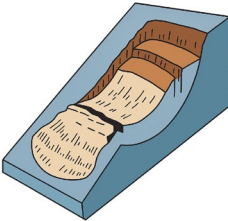
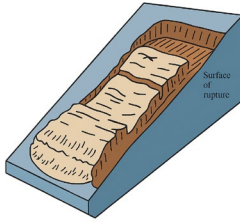
The terms used to describe landslide risk throughout this report are as defined by AGS (2007c). For ease of reference, the main terms that are used throughout their report and their AGS definitions, are presented below.

- **Acceptable risk:** A risk for which, for the purposes of life or work, we are prepared to accept as it is with no regard to its management. Society does not generally consider expenditure in further reducing such risks justifiable.
- **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.
- **Elements at risk:** The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by the landslide hazard.
- **Frequency:** A measure of likelihood expressed as the number of occurrences of an event in a given time. See also Likelihood and Probability.
- **Hazard:** A condition with the potential for causing an undesirable consequence (the landslide). The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material and the probability of their occurrence within a given period of time. Landslide hazard includes landslides which have their source in the area or may have their source outside the area but may travel on to or regress into the area.
- **Individual risk to life:** The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide; or who follows a particular pattern of life that might subject him or her to the consequences of the landslide.
- **Landslide:** The movement of a mass of rock, debris, or earth (soil) down a slope. The AGS landslide risk management publications use the term 'landslide' to broadly describe all forms of mass movement.
- **Likelihood:** Used as a qualitative description of probability or frequency.
- **Quantitative risk analysis (assessment):** An analysis based on numerical values of the probability, vulnerability and consequences and resulting in a numerical value of the risk.
- **The regulator:** The responsible body / authority for setting acceptable / tolerable risk criteria to be adopted for the community / region / activity, which will be the basis for setting levels for acceptable and tolerable risk in the application of the risk assessment guidelines.
- **Risk:** A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability and consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.
Risk is further defined as:
 - 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 annualised loss taking account of the elements at risk, their temporal spatial probability and vulnerability.
- **Societal risk:** The risk of multiple fatalities or injuries in society as a whole: one where society would have to carry the burden of a landslide causing a number of deaths, injuries, financial, environmental and other losses.
- **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.

3.2 Landslide nomenclature

The classification of landslides in this report typically follows the scheme of Cruden and Varnes (1996) and associated updates made by Hungr et al. (2014). The landslides commonly referred to in this report are listed in Table 2:

Table 2 *Landslide types commonly referred to in this report*

Landslide Type	Description ¹	Schematic Illustration ²
Rockfall	Detachment, fall, rolling and bouncing of rock fragments. May occur singly or in clusters, but there is little dynamic interaction between moving fragments, which interact mainly with the substrate (path).	
Rock avalanche	Extremely rapid, massive, flow-like motion of fragmented rock from a large rock slide or rockfall.	
Debris flow	Very rapid to extremely rapid surging flow of saturated non-plastic debris in a steep channel. Strong entrainment of material and water from the flow path.	
Earth flow	Rapid or slower, intermittent flowlike movement of plastic, clayey soil, facilitated by a combination of sliding along multiple discrete shear surfaces, and internal shear strains.	
Clay/silt rotational slide ("soil slump")	Sliding of a mass of (homogeneous and usually cohesive) soil on a cylindrical or ellipsoidal rupture surface. Little internal deformation. Normally slow, but may be extremely rapid in sensitive or collapsible soils.	
Clay/silt translational slide	Sliding of a block of cohesive soil on an inclined planar rupture surface, formed by a weak layer (usually pre-sheared). The head of the slide mass separates from stable soil along a deep tension crack (no active wedge). May be slow or rapid.	

¹Descriptions from Hungr et al. (2014). ² Illustrations from Highland (2004) with the exception being the 'rock avalanche' photo of the 2025 rock avalanche at Carne Wall, Grose Valley, Blue Mountains, NSW.

Terms used to describe specific features associated with landslides are based on Varnes (1978), as illustrated in Figure 1.

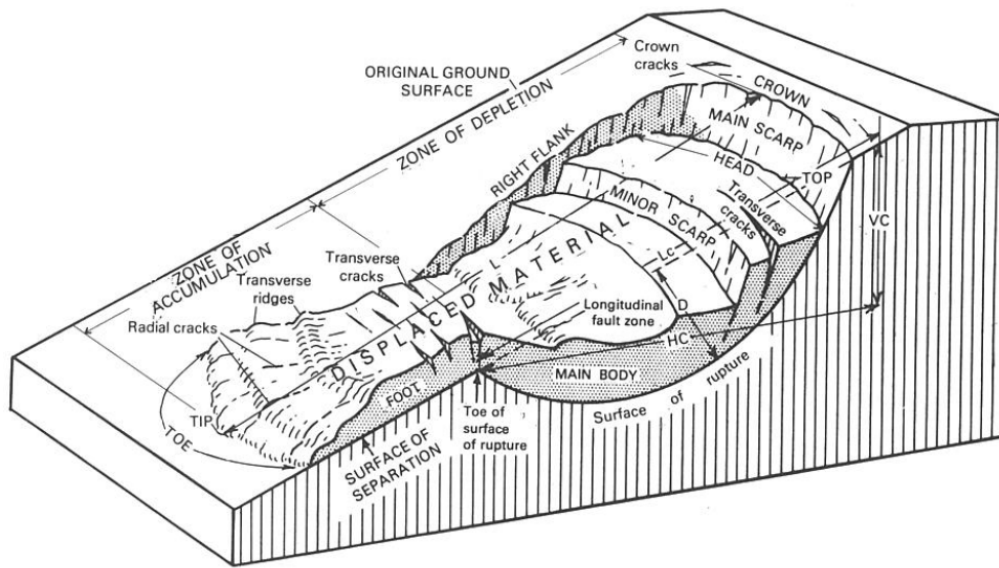


Figure 1 Block diagram of idealised landslide showing common features and associated terms (Varnes 1978).

4. Site description

Wolgan Road at Wolgan Gap is located about 23 km north of Lithgow, NSW on the edge of the UNESCO-listed Greater Blue Mountains World Heritage Area. The section of Wolgan Road that is the subject of this study is approximately 1.7 km long, beginning at the locked gate near the Wolgan Valley Lookout and ending near the intersection with the Donkey Steps track towards the toe of the escarpment (i.e. 'the site'). This section of road has been colloquially referred to as "The Gap" for many decades (i.e. generations). Plans of the study area are presented in Figures A1, A2 and A3 in Appendix A and an oblique aerial photograph of the site is presented in Figure 2.

From the lookout, the initial section of the road descends steeply towards the north, passing directly below a steep rock cutting and the natural escarpment capping cliff-line. Over the next approximately 500 m of the decent, the road traverses steep colluvial hillsides, progressively deviating away from the cliffs. The road then crosses two prominent gullies and winds its way down the lower escarpment hillsides towards the valley floor. This section of road has a near-continuous series of upslope road cuttings ranging from less than 1 m to about 11 m in height.

All the slopes above the road are densely covered by dry sclerophyll forests, typical of the vegetation commonly developed on the Triassic and Permian aged sedimentary rock strata in the Blue Mountains region. The forest understorey is commonly grassy with intermittent shrubs.



Figure 2 View of Wolgan Road looking north. Donkey Steps track on right.

5. Brief history of Wolgan Road

Krogh (2024) provides a good summary of the early history of Wolgan Road and some of the following section has been sourced from that report. The original access road / trail into Wolgan Valley is now known as the Donkey Steps, which has recently been upgraded following the 2022 closure of Wolgan Road to provide temporary access into the valley. Like many pioneering trails, the construction date of the Donkey Steps is uncertain, but thought to date back to the 1820's as the first bullock trail into the valley. It is known that Charles Darwin travelled to Wolgan Valley via the Donkey Steps during his 1836 visit to Australia.

The present Wolgan Road was constructed in 1897 when transport moved away from pack animals (Wolgan Valley Homestead Complex - Conservation Management Plan, Conybeare Morrison International, 2006.). Breckwoldt (1977) stated that: Transport to and from Newnes was first via Lidsdale by a road constructed by the Public Works Department in 1897. The "Coach Road" from Newnes Junction was suggested to have come later, with the railway from Newnes Junction to Newnes commencing in April 1906 and being completed in November 1907 (Breckwoldt 1977). Figure 3 presents a photograph taken circa 1920 near the top of "The Gap" indicating that the road alignment has remained essentially unchanged since construction.



Figure 3 Wolgan Gap pictured circa 1920 (Source: Breckwoldt (1977))

The original road alignment at the top of The Gap was narrow and the road passed beneath a section of overhanging cliff known as 'The Overhang'. Figure 4 presents a photograph taken around 1960 showing a bus passing below the overhang where the road is only one lane wide. Members of the Wolgan Valley community have informed GHD that this section of cliff was removed to widen the road in either 1962 or 1963 (Michael Coates & Nigel Webb, personal communication, 5 August 2025). The blasting was carried out by personnel from the Portland Cement Works who were apparently quite liberal with the use of explosives. Consequently, the blasting was more extensive than planned and damaged a section of road that subsequently needed to be rebuilt. The road was closed for a number of weeks following.

Figure 5 presents an aerial photograph taken in 1969 (i.e. about 6 years after the blast). The blasted rock left a very large scar in the landscape, with rubble travelling hundreds of metres down the slopes below the road. The freshly exposed rock in the newly created cutting is also clearly visible over a length of about 100 metres of the

road. The rubble strewn slope below the road remained visible in aerial photographs for many decades following the blast (Figure 6).

The widened section of the rockface remains clearly discernible to this day due to its 'fresher' less weathered appearance and absence of iron-stained, case-hardened patina common to the adjacent natural cliff face to the north (Figure 7). 'Half barrel' drill holes can be seen in this section of the rockface.



Figure 4 Photograph provided by the Wolgan Valley Community Association showing 'The Overhang' prior to road widening.

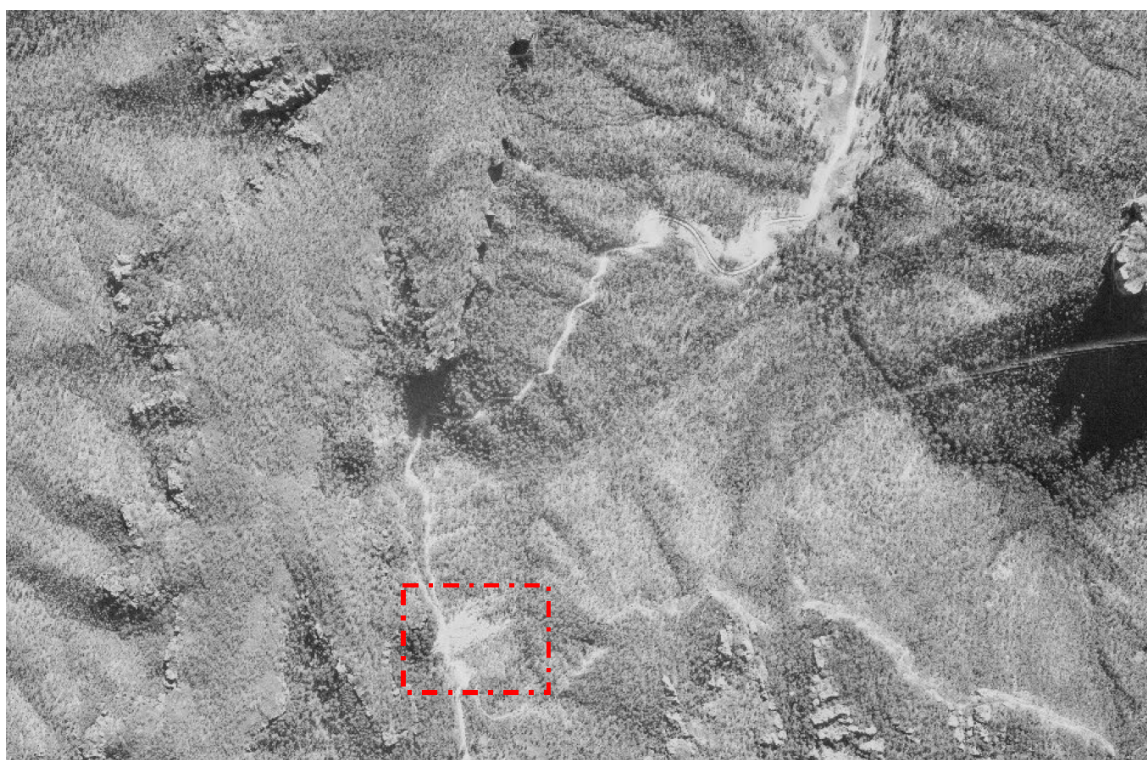


Figure 5 Aerial photograph taken 25 May 1969. Red outline shows blast damage from road widening in 1962/1963



Figure 6 *Aerial photograph taken 24 September 1991. Blast damage from road widening in 1962/1963 remains visible in the landscape (centre).*



Figure 7 *Drone / UAV photograph acquired by GHD showing (red outline) the approximate extent of the cliff removed / widened by blasting in 1962/1963.*

The road has been subject to many landslide events and over its history, which is documented in detail in Section 7. These hazards are to be expected on old, steep mountain pass roads. Similar landslide hazards occur on comparable roads across NSW, including many within the Sydney Basin.

Over the years various parties have undertaken remedial works, pavement repairs, conducted risk assessments, and options assessments for Wolgan Road. Risk assessments carried out for the site by Golder Associates (now WSP) in 2006 found the risks to be Acceptable according to the AGS (2007) suggested tolerable levels for the person most at risk (Golder 2006).

Wolgan Road was affected by numerous landslides and localised embankment instability during a period of wet weather in 2022. WSP (2023b) subsequently conducted a quantitative landslide risk assessment for the road. The WSP report stated *“The slope hazards currently pose an annual individual loss of life risk of more than 200 times greater than industry tolerable limits (2×10^{-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).”* The WSP report concluded that landslide risks are intolerable, and that restoration and remediation of the existing road are not practical or cost-effective options. Council subsequently closed the road to traffic in November 2022, and the road has remained closed since this time.

6. Geological setting

6.1 Regional geology

Wolgan Valley is situated near the western edge of the Sydney Basin within the Blue Mountains Plateau. The Sydney Basin is a major structural basin extending from southern New South Wales to central coastal Queensland. The Sydney Basin sedimentary strata range in age from Carboniferous to Triassic. The stratigraphic units present in the Blue Mountains are summarised in Figure 8 below.

PERIOD	GROUP	SUB-GROUP	FORMATION (maximum thickness in metres)	MEMBER	LITHOLOGY	
TRIASSIC	Wianamatta Group		Ashfield Shale (55)		Dark-grey shale with thin sandstone bands	
			Mittagong Formation		Interbedded shale and sandstone	
			Hawkesbury Sandstone (62)		Quartzose sandstone, massive and crossbedded	
	Narrabeen Group (265.9)	Grose Sub-Group (238)		Burralow Formation (6)		Shale/sandstone laminite
				Banks Wall Sandstone (114.6)	Wentworth Falls Claystone Member (9)	Quartzose sandstone, friable
				Mount York Claystone (13.1)		Red-brown claystone, and sandstone
			Burra-Moko Head Sandstone (112)		Sandstone	
		Caley Formation (46.6)			Hartley Vale Claystone Member (7.9)	Claystone, shale, fine-grained sandstone
					Govetts Leap Sandstone Member (16.4)	Quartz-lithic sandstone
					Victoria Pass Claystone Member (8.2)	Claystone, shale
			Clwydd Sandstone Member (13.4)	Quartz-lithic sandstone		
PERMIAN	Illawarra Coal Measures (231.5)	Charbon Sub-Group (184.7)	Not formally named	Katoomba seam (2.4)	Claystone, sandstone/shale laminite, sandstone, torbanite, conglomerate, coal	
			Burrarorang Claystone (13.0)	Middle River seam (12)		
			Not formally named	Lithgow seam (6.9)		
		Marrangaroo Conglomerate (46)		Sandstone, conglomerate, fine siltstone		
		Nile Sub-Group (50.1)		Gundangaroo Formation (23.5)		Coal, carbonaceous shale, shale, sandstone
			Coorongoba Creek Sandstone (18.9)		Medium lithic sandstone, minor conglomerate, fossil wood	
			Mount Marsden Claystone (19.1)		Dolomite, limestone, claystone, chert, conglomerate (silicified), fine lithic sandstone	
	Shoalhaven Group (250)	Cenjala Sub-Group		Berry Siltstone (210)		Micaceous siltstone, limestone, with minor evaporites
				Snapper Point Formation (90)		Lithic sandstone, basal conglomerate, minor shale

Figure 8 Permo-Triassic stratigraphic nomenclature for the western Blue Mountains (Bembrick, 1980)

The route of Wolgan Road traverses geological formations from both the Narrabeen Group and the Illawarra Coal Measures (see Figure A3). The approximate extent of each geological unit with respect to the road alignment is summarized in Table 3 based on publicly available geological data (NSW Seamless Geology data package). The site is located within an area broadly known as the Western Coalfield in the Lithgow region. The Western Coalfield

contains minimal structural disturbance, with a regional dip in the Lithgow area of less than one degree with a dip direction towards approximately 65 degrees.

Table 3 Summary of geological units along Wolgan Road

Group	Formation	Description	Section of Wolgan Road
Narrabeen (Grose Subgroup)	Banks Wall Sandstone	Fine- to coarse-grained, cross-bedded quartz sandstone with numerous lenticular grey-green claystone bands.	Prominent cliff forming unit at the top of Wolgan Road (i.e. cliffs adjacent to road near the lookout)
Narrabeen (Grose Subgroup)	Burra-Moko Head Sandstone	Quartzose to quartz-lithic sandstone with common cross-bedding. Minor green to grey claystone horizons.	Prominent cliff forming unit at the top of Wolgan Road (i.e. cliffs adjacent to road near the lookout)
Narrabeen	Caley Formation	Claystone, shale, fine- to coarse-grained, quartz-lithic sandstone with common cross-bedding.	Only exposed in lower few metres of cliff near the top of "The Gap". This unit is then covered by colluvium above the road and not exposed.
Illawarra Coal Measures - Cullen Bullen Subgroup, Charbon Subgroup & Wallerawang Subgroup	NA	Mudstone, siltstone, claystone, sandstone, conglomerate, coal, torbanite, siliceous claystone.	Wolgan Road is directly underlain by this unit for the majority of the site area, starting from the upper section of the road, before the first gully. Unit is exposed in numerous upslope road cuts, particularly along the lower section of the road.

The Grose Subgroup is undifferentiated in the publicly available geological mapping, meaning that the contact between the Banks Wall Sandstone and the Burra-Moko Head Sandstone is not known. The Mount York Claystone unit is typically located between the two abovementioned sandstone units however the presence of this unit at the site is uncertain. It is possible the Mount York Claystone is exposed near the crest of the prominent near-vertical cliff face at the top of The Gap where thinly bedded reddish claystone units form a recessive horizon beneath a thickly bedded sandstone unit that caps the cliff.

The Banks Wall Sandstone is reported to have a maximum thickness of about 115 m and typically comprises quartzose sandstone with a small percentage of lithic fragments. It contains numerous lenticular greenish claystone horizons. Near surface exposures of the Banks Wall Sandstone are often described as 'friable' due to unusual behaviour whereby the sandstone rapidly breaks down following excavation. TfNSW have experienced this behaviour following the construction of cuttings that have been laid back at shallow angles. The sandstone exposed in the cuttings reportedly breaks down and is prone to erosion. Consequently, we understand TfNSW funded a research project into the behaviour of the Banks Wall Sandstone with some of the results published in Khoshini et al. (2020).

Khoshini et al. (2020) studied the upper parts of the Banks Wall Sandstone which they describe as a very weak and friable sandstone comprising mostly of sub-rounded to sub-angular quartz grains embedded in a clay matrix reacted with lime with occasional yellow iron oxidation. Mineralogically it is reported to be composed of 84 to 91% of quartz, 7 to 12% of Kaolinite and 2 to -4% of Aragonite.

The Mt York Claystone is the lowermost widespread 'redbed' unit in the Narrabeen Group. The maximum reported thickness is up to about 13 m. The claystone usually comprises two red-brown claystone layers separated by a quartz-lithic sandstone, however in some locations only one claystone layer is present. The claystone typically comprises a red-brown siltstone and claystone that is mottled green and grey in parts.

The literature also suggests that the claystone can be laterally quite variable with any variations to the general appearance and make-up of the claystone. At some locations the Mt York Claystone may not be present at all. McHugh (2013) notes that the average thickness of the Mt York Claystone in the vicinity of the nearby Spingvale Colliery is about 22 m and the unit has a gradational lower boundary with the Burra-Moko Sandstone below. That

is, thick claystone bands also occur within the underlying formation and it is sometimes debatable where the boundary should be defined.

The Burra-Moko Head Sandstone is the most prominent cliff forming unit in the Blue Mountains. It is typically cross bedded and displays well developed jointing. It comprises medium to coarse grained quartzose to quartz-lithic sandstones. Claystone horizons are reported to be common but thick claystone beds are rare.

The Caley Formation is made up of five members of alternating fine and coarse-grained units and has a reported maximum thickness of up to about 46 m. The sandstones of the Caley Formation are fine to coarse grained and quartz lithic with some lithic pebbles. The claystone units consist of grey and greenish grey claystone with interbedded shale and siltstone.

The Illawarra Coal Measures have a reported maximum thickness of up to about 230 m and are divided into two subgroups in the project area, the Nile Sub-Group and the Charbon Sub-Group. The Nile Sub-Group comprises various interbedded sedimentary units including coal, sandstone, claystone, shale and conglomerate. The Charbon Sub-Group comprises siltstone, claystone and major coal seams such as the Katoomba Seam. Coal seam thicknesses vary markedly and are reported to have thicknesses of between 2 m and 12.5 m.

6.2 Site geology

As discussed in Table 3, the prominent cliffs that cap the escarpment above Wolgan Road are formed in both Banks Wall Sandstone and Burra-Moko Head Sandstone. Both units commonly form cliffs in the Blue Mountains area.

The sandstone beds exposed in the cliffs range in thickness from about 0.5 m to 3 m. Claystone and siltstone interbeds are common and in some areas are up to 3 m thick, however are more commonly less than about 0.5 m thick. The claystone and siltstone beds are recessive due to their low strength, erodible nature and are commonly observed to be associated with spalling and erosion. The dominant joint set that has strongly influenced and controlled the formation of the cliffs above the upper section of The Gap is orientated at approximately 337°. The joints range from near vertical to steeply dipping to the north-east. The lateral persistence of this joint set extends for hundreds of metres based on available lidar data. The vertical persistence of the joints based on site observations ranges from a few metres to tens of metres. The spacing of the joints is variable, ranging from about 0.5 m to 1.5 m. A second, less dominant joint set is oriented approximately orthogonal to the dominant joint set. This joint set has more variation in trend, with an average orientation of about 055°. The variability of the less dominant joint set is reflected in the more irregular, stepped geometry of the cliffs above the lower section of the road.

A small profile of the upper section of the Caley Formation is exposed at the toe of the cliff near the top of “The Gap”. The unit predominantly comprises interbedded siltstones and claystones. Downslope of this exposure the unit becomes covered by colluvium above the road and is only exposed in the lower portions of the cliffs that cap the escarpments above the site.

An unusual lateritic soil profile is exposed in the roadside cutting at the top of the Gap adjacent to the lookout. The soil is indurated and is subject to preferential erosion and gulying. Photos provided in Golder (2009a) indicate the cutting has previously been groomed and reprofiled. Due to the nature of the material and its limited occurrence it is not particularly significant to this project.

The Illawarra Coal measures are exposed in a near-continuous series of upslope road cuttings along the lower section of the road, beginning near the second major bend and extending to the northern end of the site. The exposures in the cuttings comprise thinly interbedded sequences of siltstone, claystone, sandstone and coal. The rock is typically highly to extremely weathered and prone to exfoliation and spalling.

6.3 Geomorphology

6.3.1 Overview

The escarpment geomorphology is strongly influenced by the underlying geology, reflecting the varying competencies of the underlying sedimentary units. The site has been divided into five distinct geotechnical domains (GD1 in the south to GD5 in the north) based on the geomorphology, as shown in Figures A1, A2 and A3

in Appendix A. The nature of the landslide hazards at the site, which will be discussed later in this report, vary considerably depending on the local geomorphology. Reference to the geotechnical domains is therefore made throughout this report for communication and discussion purposes. A summary of the key geomorphic features of each domain is provided in the following sections.

6.3.2 Geotechnical Domain 1 (GD1)

Geotechnical Domain 1 is located at the top of The Gap and covers the section of road directly adjacent to the prominent, escarpment capping cliff-line (Figure 9). Typical geological and geomorphological features present in this domain are presented in Figure B1 in Appendix B.

The initial approximately 120 m of the road, commencing from the lookout, is located adjacent to very steep to near-vertical rock cuttings that were constructed by blast methods in the 1960s as discussed in Section 5. The cutting then transitions into a natural, sheer cliff face that reaches heights of up to about 65 m above road level. Discrete areas of the cliff face have been previously treated with rock bolts. The area above the cliff comprises a steep but short length of colluvial slope that extends to a smaller cliff-line that forms the upper plateau. Small rockfall fragments were observed on the road during the GHD site visit (Figure 10).

The depth of fill materials in the road embankment appears to be variable, with natural rock ledges and outcrops visible at varying elevations below the downslope road shoulder. Localised drilling investigations presented in Golder (2020) found rock to be located at a depth of approximately 5 m below the downslope lane. Rock is expected to be at shallow depths below the upslope lane given the road appears to be constructed in cut.

A small downslope failure of a 'drystone' retaining wall near the top of the pass was observed during our site visit and appears to have been temporarily treated with shotcrete. The extent of drystone walls below the road in this area is unclear.



Figure 9 View to south of cliff and rock cuttings in Domain 1.



Figure 10 Extremely small rockfall fragments on road below cliff in Domain 1.

6.3.3 Geotechnical Domain 2 (GD2)

Geotechnical Domain 2 traverses a section of steep colluvial slopes as the road deviates away from the cliff-line, extending to the first major gully (Figure 11 and Figure 12). Typical geological and geomorphological features present in this domain are presented in Figure B2 in Appendix B.

There is a near-continuous series of steep cuttings in colluvium and talus along the upslope side of the road, ranging from less than 1 m to several metres in height. Several upslope failures (slide scarps) in these soil materials are apparent along this section of the road. Blocks of talus up to a few metres in diameter are commonly exposed in the colluvium.

The largest upslope landslide observed during our site visits is located near the northern end of the domain (referred to as Site 1I in WSP (2023a)). The crown / head scarp of the slide is about 1.5 m high and located approximately 25 m above road level (Figure 13). We have been advised that the slumped material at road level has been partly removed a number of times following the initial failure of the slide and the debris exposed above the road has been reprofiled / cut back. At the time of our site visits the debris was confined to the road shoulder and edge of the upslope road pavement (Figure 14). There were no features observed that would suggest the slide surface extends below the road, i.e. at the time of the site visit no transverse cracks or ridges in the road pavement. Furthermore, bedrock (highly to extremely weathered rock from the Caley Formation) is exposed in a cutting immediately to the north of the landslide and extends to the major gully at the end of this domain.

Above the cuttings, steep colluvial slopes extend upwards to the toe of the escarpment-capping cliff-line. These slopes are typically inclined at approximately 40°. The slopes are strewn with various sized blocks of talus and rock scree. The cliff-line at the crest of the escarpment ranges from about 30 m to 50 m in height and comprises both sheer, vertical faces and areas of stepped and craggy rock faces.

The road appears to be constructed with relatively limited side-cast embankment fill. Rock shelves are visible on the downslope side at several locations below the road. Localised tension cracking and settlement of the pavement was observed in the downslope lane at some locations across this length of road, suggestive of instability of the fill embankments. Localised shallow failures (slides) in the downslope road shoulder were also

observed at a few locations (Figure 15). No prominent tension cracks suggestive of large-scale, deep-seated landsliding were observed in the pavement.

At the time of our site visits, many of the culvert inlets along this section of road were full of debris and appear to be at least partially blocked.



Figure 11 View to north of cliffs and colluvial slopes in Domain 2.



Figure 12 View to south of cliffs and colluvial slopes in Domain 2. Domain 1 cliffs on left at top of The Gap.



Figure 13 *Landslide crown / head scarp on colluvial slope above road.*



Figure 14 *Toe of landslide in colluvium*



Figure 15 Shallow downslope road shoulder failure.

6.3.4 Geotechnical Domain 3 (GD3)

Geotechnical Domain 3 comprises a natural amphitheatre flanked by large cliffs on all sides (Figure 16). Typical geological and geomorphological features present in this domain are presented in Figure B3 in Appendix B. The road crosses two major gullies, each located at prominent bends in the road.

There is a near-continuous series of steep cuttings in colluvium and talus along the upslope side of the road, however the cuttings are lower than those in Domain 2. The cuttings range from less than 1 m to a few metres in height. Several small historical upslope failures (slide scarps) in these soil materials were observed and one recent failure was observed near the second gully.

Above the cuttings, steep colluvial slopes extend upwards to the toe of the escarpment-capping cliffs. These slopes are typically inclined at between 30° and 40°. The slopes are strewn with various sized blocks of talus and rock scree. Smaller, intermediate cliffs are located at various elevations across the colluvial slopes. The cliffs at the crest of the escarpment reach heights of up to about 80 m, comprising both sheer, vertical faces and areas of stepped and craggy rock faces.

Both gullies appear to have significant catchments, commencing from the plateau slopes above the escapement and draining areas of the colluvial slopes. Parts of the accessible parts of the gullies near road level have been incised into bedrock. Both gullies, and the gully banks contain appreciable amounts of rock debris ranging from gravel to boulder sized as well as vegetation matter.

Between the two gullies the road has experienced a series of coalescing downslope embankment failures that extend along an approximately 100 m length of road (Figure 17). The failures appear to have involved retrogressive slumping of the outer side-cast embankment fill. It appears that this could have been due to scouring exacerbated by poor road drainage. Based on feedback received from the local community we understand the culvert inlet for the gully above the failure was full of debris for an extended period prior to the failure. It is important to note that the failures have only affected the downslope lane, with the upslope lane still trafficable. The failures appear to be shallow and have only occurred in fill materials, with the upslope lane likely constructed at or near grade. The upslope pavement was not observed to contain obvious tension cracks.



Figure 16 Typical view to north of Domain 1 (first gully is left of photograph – not shown).



Figure 17 Embankment slide comprising slumping of fill materials below downslope lane. Upslope lane remains trafficable.

6.3.5 Geotechnical Domain 4 (GD4)

Geotechnical Domain 4 comprises the winding section of road that traverses steep colluvial slopes leading down to the valley (Figure 18). The road progressively deviates away from upper cliffs during the descent. Typical geological and geomorphological features present in this domain are presented in Figure B4 in Appendix B..

There is a continuous series of steep cuttings in colluvium and weathered rock (Illawarra Coal Measures that is typically highly weathered). The cuttings range from a few metres to about 10 m in height. Several of the cuttings have experienced recent failures, understood to have occurred in 2022 (refer to Section 7). The failures appear to have comprised relatively shallow translational and rotational slides in colluvium and weathered rock. Bedrock is exposed in the failure scarps, again suggesting the thickness of colluvium and talus is relatively shallow.

Above the cuttings, steep colluvial slopes extend upwards to the toe of the escarpment-capping cliffs. These slopes are typically inclined at between 30° and 35°. The slopes are strewn with various sized blocks of talus and rock scree. Smaller, intermediate cliffs are located at various elevations across the colluvial slopes. The cliffs at the crest of the escarpment reach heights of up to about 80 m, comprising both sheer, vertical faces and areas of stepped and craggy rock faces. The cliff exhibits characteristic, case-hardened patinas, typical of a Sydney Basin escarpment associated with infrequent, episodic rockfall events.

Many sections of the road pavement and some of the base layers across this domain has been removed. We understand this was to supply material to sheet the Donkey Steps track. Despite this, the road and remaining sections of pavement appear to be in apparent good condition (Figure 20), with no tension cracking or other obvious signs of instability observed.



Figure 18 Typical view to northwest of Domain 4



Figure 19 *Example of upslope batter failure in colluvium, talus and weathered bedrock*



Figure 20 *Example of lower section of Wolgan Road in apparent good condition. Asphalt and subbase removed for reuse on Donkey Steps track.*

6.3.6 Geotechnical Domain 5 (GD5)

Geotechnical Domain 5 comprises the lower winding section of road that traverses the lower colluvial slopes of the escarpment (Figure 18). The road progressively deviates away from upper cliffs during the descent. Typical geological and geomorphological features present in this domain are presented in Figure B5 in Appendix B.

The colluvial slopes and escarpment-capping cliffs are essentially geomorphically similar to Domain 4, however the road is further from the cliffs. In addition, the continuous series of cuttings on the upslope side of the road are typically smaller, often less than a few metres in height and exhibited fewer signs of previous instability.



Figure 21 Typical view of Domain 5

7. Landslide inventory

7.1 Methodology and information sources

Compilation of a landslide inventory is an essential task for any landslide risk assessment as it provides an overall summary of information of the known events and historic records that can be used to approximate predicted future landslide frequencies. This is often paraphrased as ‘the past and present are keys to the future’. However, inventories and historical observations invariably have limitations. Some of these are summarised below:

- Inventories are almost always incomplete because landslide data is rarely collected by managing authorities;
- Data is often biased towards large events that had a significant impact on people or property;
- Larger events are more likely to be ‘remembered’, or reported by media, while smaller events often go unnoticed and undocumented;
- Data is often biased towards more recent events. For example, recent, somewhat more detailed data at this site has been collected and compiled over the last approximately 20 years;
- Landslide frequency, size and intensity may differ from past performance where altered trigger events are introduced, e.g. due to human-made changes, bushfires or climate change. In addition, other factors (such as periodic or seasonal wetting and drying cycles resulting in soil creep, cyclic degradation and strength loss) can also result in failures after relatively “normal” rainfall events;
- Landslide features may be observed in the landscape however there is no recorded historical precedent for the events.

The issues listed above are commonly encountered on most projects.

The landslide inventory compiled for this project is presented in Appendix C, including photographs of landslide events where available. It was compiled by systematically reviewing each data source outlined in Section 2. Any mention of a landslide or rockfall event within each of the sources was assigned a separate entry into the inventory. All entries into the inventory were accompanied by the date the mentioned event occurred, or else a qualifier signifying the proximity of the date recorded to the actual event (e.g., circa, prior to, on). Additionally, if known, the location of the event was included along with the observed failure mechanism, a description of the debris on the road, and an estimation of the volume of the event.

Following the initial compilation, the entries were cross-referenced and merged, and each unique event was assigned a distinct ‘Event ID’. The number of individual reports for each event was also recorded. The events contained within the inventory date between 1889 and 2025; and come from many sources. For example, the National Library of Australia digitizes and makes available online newspapers published before 1955. However, it must be noted that due to copyright restrictions imposed by the National Library of Australia, public access to newspaper records post-1954 are restricted. Unfortunately, this means that newspapers published after 1954 are generally still under copyright and are not digitised for online access. As such the inventory contains few entries for the period between 1954 and 2009, with 2009 being the year Council began recording landslide events.

Volumes of each rockfall, landslide, or debris flow event were derived from the available sources. The degree of confidence in determining the volumes of each event varied with the quality of the sources available. Whilst some events had photographic evidence of the impact on the road, others were limited to qualitative descriptions. This varying degree of certainty was captured by assigning each event with a confidence rating (e.g., low, medium, high). In the inventory, a distinction has also been made between the total displaced volume and the volume of debris that reached (i.e. accumulated on) the road, based on the nature of the evidence available.

For events where photographic evidence of road impact was available, volume estimates were calculated using geometric approximations, supported by the photogrammetry survey data. These models enabled reasonable measurements of road width and surrounding features, improving the precision of volume calculations.

7.2 Anecdotal landslide history of Wolgan Road

To assist the assessment of landslide frequency for this project an online community survey was undertaken by Council to gather information on the nature of landslides and rockfalls at the site from a community perspective.

GHD provided input into the questionnaire and the results of the survey are included in Appendix D. The Wolgan Valley Community Association independently undertook a similar survey of which there were 25 respondents. Several of the respondents grew up in the valley and therefore have unique knowledge of the road stretching back over many decades. GHD also attended an in-person community consultation meeting in Lithgow on 3 July 2025 where residents and representatives from Emirates One&Only Resort were able to provide in-person accounts and stories of the landslide history of the road.

During the meeting participants were asked to 'mark-up' the location of landslides / rockfalls on a map of the road. A compilation of these notes as provided by Council is presented in Figure 22. There is good agreement with many of the features presented on this map and the inventory information compiled in Appendix C. A summary of some of the pertinent in-person accounts and survey results is discussed below.

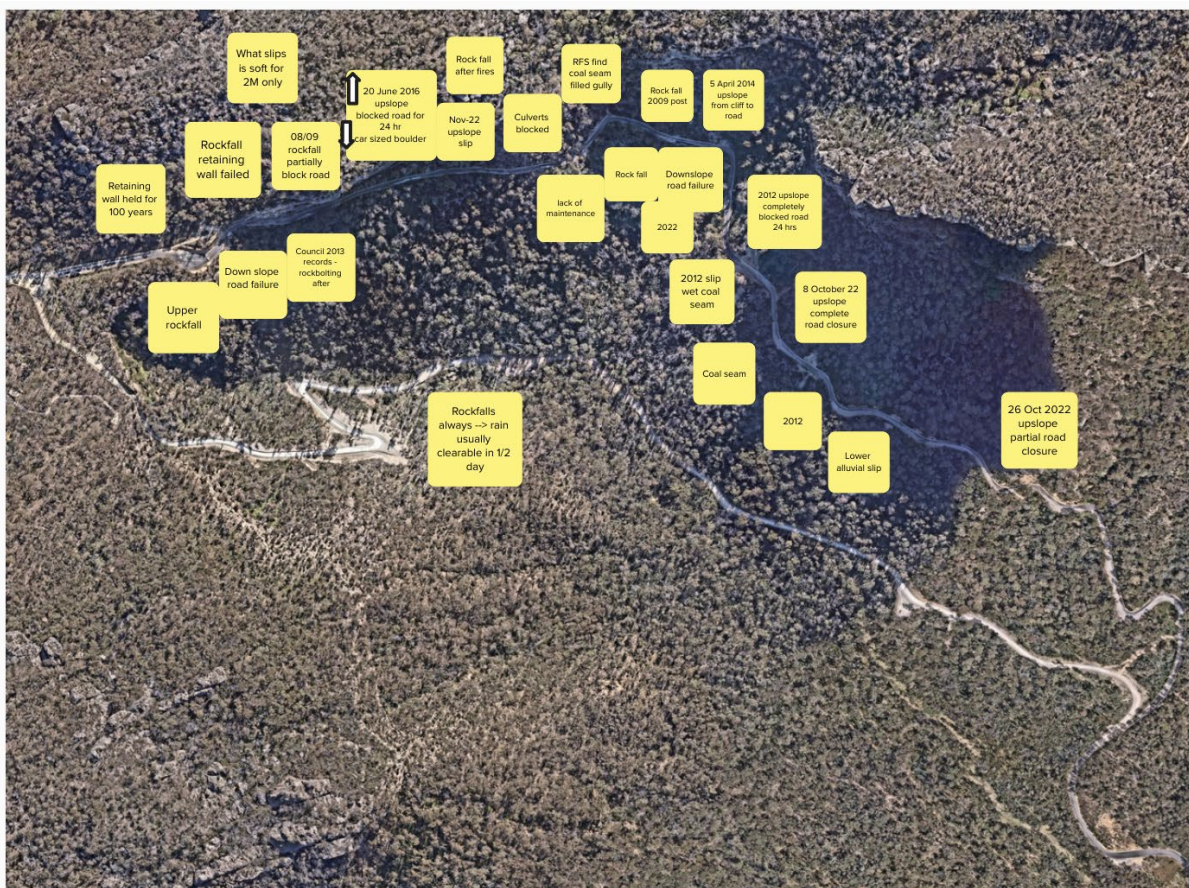


Figure 22 Map of landslides / rockfalls and other features reported by residents during community consultation meeting

The majority of the survey results indicate that 'large' rockfalls occur less frequently than once every ten years (Figure 23). In-person conversations with long-term residents Nigel Webb and Michael Coates, both of whom grew up in the valley are also in general agreement with these observations. Michael Coates noted that apart from the large rockfalls that occurred in 2008 and 2016, neither he nor his family members were aware of previous rockfalls that were large enough to block the road. Nigel Webb echoed a similar sentiment however he recalled a large rockfall (about the size of a car) that occurred in 1990 in the vicinity of the first major gully (i.e. Domain 3). The rock was large enough to block one lane. Prior to this rockfall Mr Webb could not recall any comparable rockfalls in his lifetime.

The survey and in-person discussions both indicated that 'small' rockfalls occurred frequently, mainly along the top section of the road (i.e. Domains 1 and 2). These rockfalls typically comprise one or multiple small fragments of rock (i.e. less than about 0.4 m diameter). Several of these rockfalls were noted to occur each year. Due to the small size of these rockfalls, traffic is typically not adversely affected so they do not appear to have been incorporated into the Council inventory.

Michael Coates noted that since the road was closed in 2022, he has routinely inspected the road (i.e. most weeks). Over this period, he has observed three rocks on the road that were too large to be moved by hand.

These were typically less than about 0.5 m diameter and occurred in the vicinity of the first major gully (i.e. Domain 3). GHD has incorporated these rockfalls into the inventory in Appendix C.

Question 3.

For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

22 responses

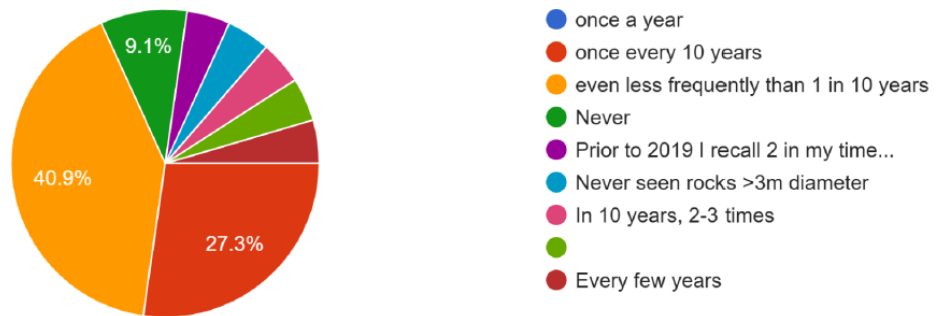


Figure 23 Community survey result summary for frequency of large rockfalls reaching Wolgan Road

The majority of the survey results also indicate that “landslips” (i.e. landslides in colluvium or weathered rock originating from upslope cut batters or natural slopes) occur less frequently than once every ten years (Figure 24). In-person conversations with long-term residents corroborated these results. Residents routinely commented that these modes of landslides usually occurred during periods of prolonged wet weather. Usually, these landslides only affect one lane however occasionally they have been large enough to block both lanes. The years 1986 and 1990 were often mentioned as having particularly wet periods that were associated with a few upslope landslides.

Residents also provided important observations on the behaviour of the upslope landslides that occur in colluvium (i.e. soil materials). The landslides were routinely described as ‘slow moving’, with residents explaining that they had observed the wet soils ‘creeping’ over the road over a period of a few hours. Some residents even described walking across the moving soil materials.

Whilst the anecdotal evidence gathered by the survey and in-person discussions is important, a degree of caution has been also applied to the results when integrating these observations with other forms of inventory data.

Question 7

For large Landslips, how often would you estimate that these have occurred in the past?

22 responses



Figure 24 Community survey result summary for frequency of large “landslips” reaching Wolgan Road

8. Review of rainfall data and relationship to landsliding

8.1 Daily rainfall

Bureau of Meteorology (BoM) stations in Lidsdale (1 station, 8km away) and Lithgow (3 stations, ~18km away) were used to assess rainfall history across the site and its relevance to landslide initiation. The four stations: Lidsdale (Maddox Lane, 063132), Lithgow (Coerwull, 063226), Lithgow (Birdwood St, 063224), Lithgow (Newnes Forest Centre, 063062), captured daily rainfall records that have been applied to the site dating from 1890 to 2025. The earliest landslide event recorded in the inventory occurred in 1889; however no complete record of rainfall could be located for that year. Using this data, one-day, two-day, and seven-day cumulative rainfall depths were assigned for each event (where possible). These amounts could be determined and used in conjunction with an Intensity-Frequency-Duration (IFD) plot.

For this project a rainfall Intensity-Frequency-Duration (IFD) plot was created for the site using the BoM Design Rainfall Data System (2016) (see Figure 25). An IFD plot is a graphical representation of the historical frequency and duration of rainfall events. IFD plots are used to assess the intensity (i.e. 'heaviness') of rainfall events and can be used to evaluate the influence of rainfall events on recorded landslides. For rainfall triggered landslide events, the triggering rainfall is often presented as a relationship between intensity and duration. By plotting both the intensity and duration at varying Annual Exceedance Probabilities (AEP) it is sometimes possible to assess potential triggering thresholds for historical landslide events. The AEP can be defined as the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. The average recurrence interval (ARI) is the average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that the periods between exceedances are generally random.

Label:Wolgan Gap

Requested coordinate Easting: 231156.5400 Northing: 6309644.4200 Zone: 56
Nearest grid cell Latitude: 33.3125 (S) Longitude: 150.1125 (E)

IFD Design Rainfall Depth (mm)

Issued: 04 July 2025

Rainfall depth in millimetres for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).

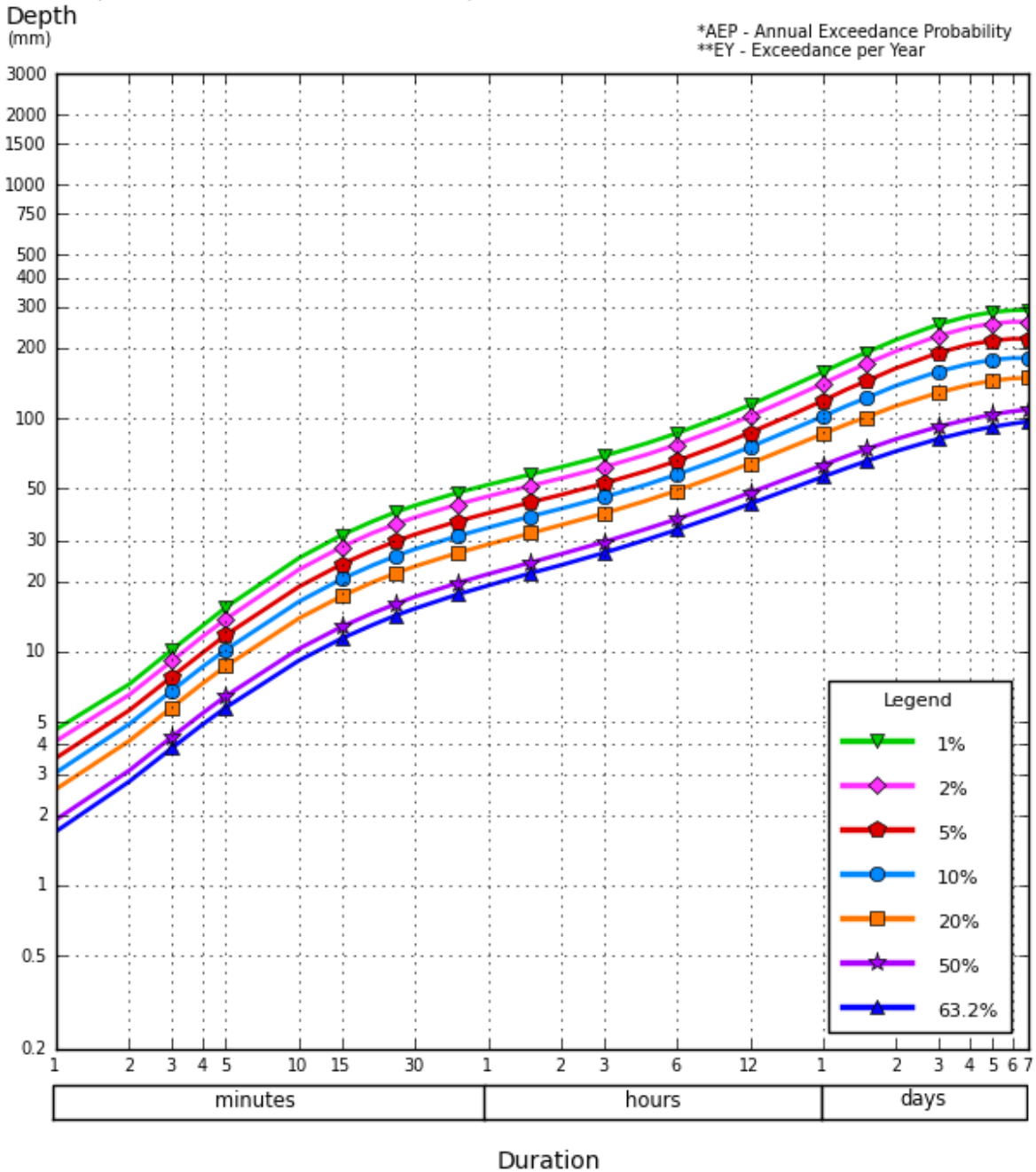


Figure 25 IFD Curve for Wolgan Rd, produced for the site using the BoM Design Rainfall Data System.

Where possible, an AEP was assigned for each rainfall event interpreted to be associated rockfall and landslide events in the inventory. A summary of the findings is presented below:

- Interestingly, of all the landslide events in the inventory, only 11 events experienced rainfall within the week leading up to the event that was considered either a 1 in 1-year event or more severe (AEP of 63.2% or less).

- One event was assigned an AEP based on daily rainfall totals. That event occurred on the 21 April 2015 and experienced a 1 in 2-year (AEP of 50%) rainfall event.
- One event was assigned an AEP based on two-day rainfall totals. That event occurred on the 3 April 1950 and experienced a 1 in 1-year (AEP of 63.2%) rainfall event.
- Five 1 in 1-year rainfall events (AEP of 63.2%) were recorded across seven-day periods leading up to events on 22 July 1950, 26 November 2011, 11 January 2015, 21 April 2015, and 23 March 2021.
- Three 1 in 2-year rainfall events (AEP of 50%) were recorded across seven-day periods leading up to events on 2 April 1950, 9 March 2021, and 11 March 2021.
- The most severe AEPs recorded for any of the events in the inventory were found across seven-day periods leading up to events on 3 April 1950, 6 December 2010, and 3 March 2012. These were all found to be 1 in 5-year (AEP of 20%) rainfall events.

These results are also presented in Appendix C. The inventory data suggests that many rockfalls appear to be associated with relatively frequent ARI events and in some cases do not have a clear relationship to rainfall at all, suggesting that other causal factors are at play.

8.2 Annual and Cumulative rainfall

Figure 26 below presents the yearly rainfall totals for the site and highlights the years where substantial rainfall occurred, most notably in 1950, 1892, and 1984. The figure is composed of combined data from the four BoM sites mentioned earlier, as well as supplementary rainfall monthly rainfall data collected by a Wolgan Valley resident (Michael Coates).

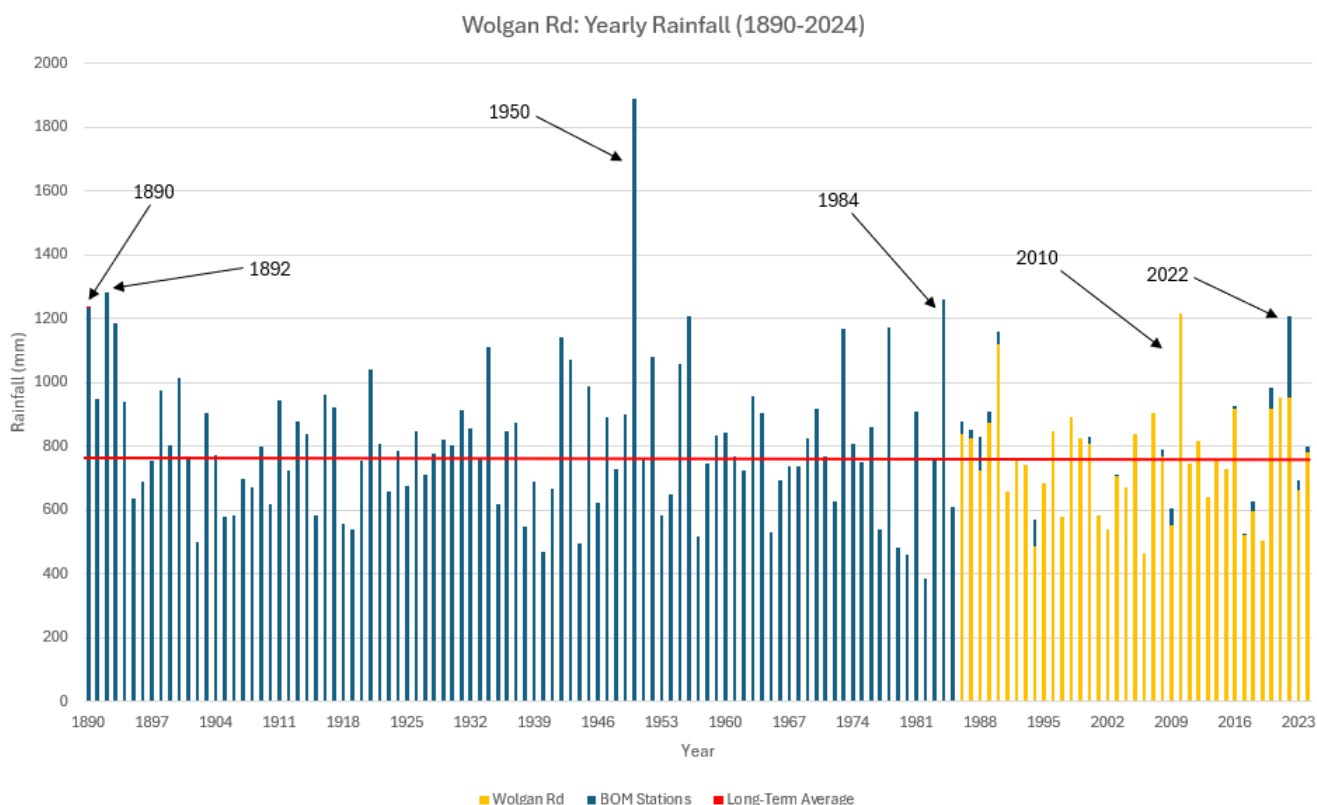


Figure 26 Yearly rainfall totals for Wolgan Rd; data collected from BoM records (blue) and a Davis vantage pro 2 Weather Station (yellow) owned by Michael Coates (1180 Wolgan Rd). The six highest rainfall totals are annotated.

The BoM and Wolgan Valley data is generally in agreement notwithstanding minor differences that would be expected given the geographic distance between the two locations. However, 2022 represents an unusual difference between the two recorded rainfalls and suggests that rainfall at the site in 2022 was approximately 254 mm less than recorded at the Lidsdale station, which is about 8 km from the site. The reason for this difference is not clear given the landslide activity that occurred at the site in November 2022.

Cumulative rainfall (being the running cumulative total of daily rainfall over any year) was also investigated using the data from BoM and is presented in Figure 27. 1950 clearly experienced the highest rainfall since records began and experienced significant rainfall from June onwards. Other years such as 1890 and 1956 also had well above average yearly rainfalls. Meanwhile, based on the available data, 2022 experienced the 6th highest rainfall for the area since records began. However, if the locally collected rainfall data is considered, the rainfall for 2022 would be the 22nd highest since records began.

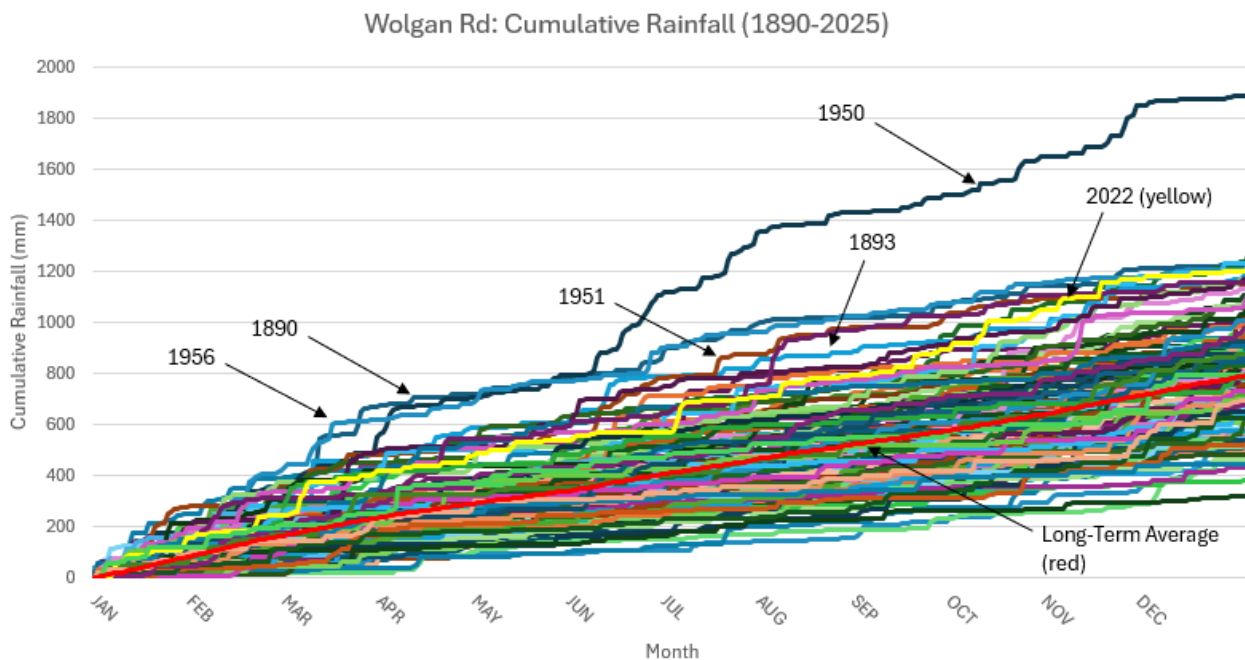


Figure 27 Cumulative rainfall for Wolgan Rd between 1890-2025; data collected from BoM records.

8.3 Monthly rainfall

Monthly rainfall, as presented in Figure 28, provides more insight into historical rainfall at the site. The rainfall has been plotted against rockfall and landslide events as recorded within the inventory, however, the data is strongly biased towards increased inventory data collection post 2012, the year Council began keeping records of rockfall and landslide occurrences. It is important to note we have only plotted events wherein we have a high level of confidence in the date of occurrence. This makes it difficult to compare with earlier records. The monthly rainfall is also plotted in Figure 29 for the period including 2008 to 2025 where more landslide records are available.

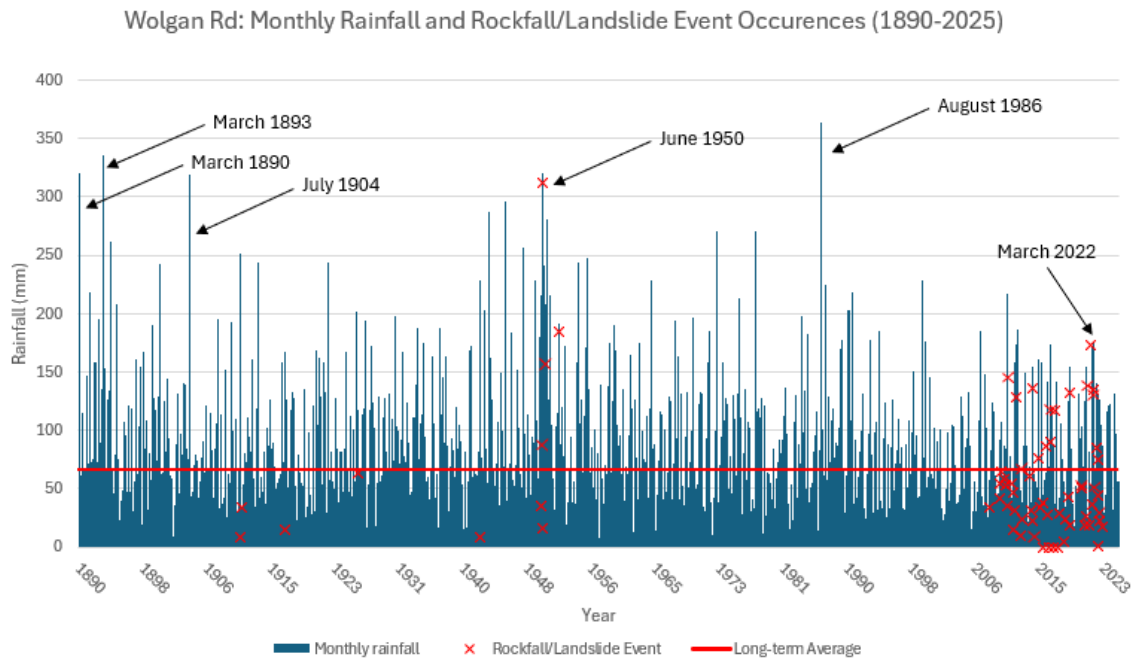


Figure 28 Monthly rainfall data for Wolgan Rd plotted against rockfall/landslide inventory event occurrences from 1890-2025; data collected from BoM records.

The highest monthly rainfall on record was in August 1986. March 1893, June 1950, July 1940, and March 1890 complete the top 5 highest monthly rainfalls. March 2022 represents the greatest rainfall of that year and is well above the long-term average but is still significantly less than numerous other monthly totals over the decades. Although many landslide events were reported in November 2022, the month's rainfall (about 120 mm) was less than recorded in March, although still above the monthly average. This is postulated to be reflective of the influence of significant previous antecedent rainfall and suggests a complex interplay of various causal factors.

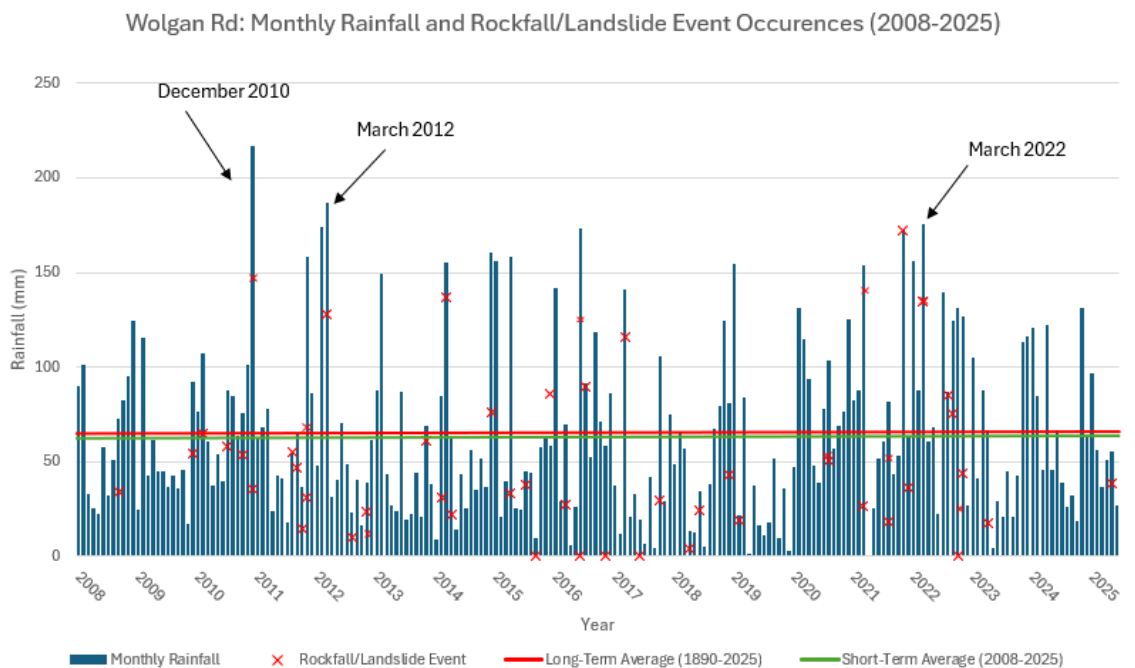


Figure 29 Monthly rainfall data for Wolgan Rd plotted against rockfall/landslide inventory event occurrences from 2008-2025; data collected from BoM records.

Comparison between the long-term (66 mm) and short-term (64 mm) monthly averages indicates that rainfall over the short-term history (i.e. since 2008) of the site has been relatively similar across the 135 years reviewed in this report. Whilst many rockslide and landslide events are recorded in this time, correlation with specific rainfall events is problematic as the majority of events do not appear to be associated with intense rainfall events based on the daily rainfall data available.

8.4 Discussion on rainfall relationships

Whilst 2022 rainfall totals at the site were high, they were nowhere as anomalous as totals in the early 1950's. It is also noted that the rainfall experienced across parts of Australia during 2022 was commonly anecdotally referred to in the media as being "record breaking", indeed even recent media articles for Wolgan Road describe landslides being triggered by "record rainfall" in 2022 (Oataway 2025).

While parts of Sydney recorded the highest rainfall on record, as discussed above 2022 at the site ranks as only the 6th wettest year for the site (since records began). BoM (2023) notes that for the country as a whole, 2022 was the ninth-wettest year on record since 1900 with considerable variation across regions. The 11 wettest years on record in eastern Australia were all influenced by La Niña (cold phase of the El Niño Southern Oscillation (ENSO)) (BoM 2024). BoM (2023) states that the level of ENSO activity over the past 50 years is higher, with more significant El Niño and La Niña events than in the years between 1920 and 1970. However, BoM (2023) also states that there is no clear indication that the recent rainfall activity levels are outside the long-term range of variability, with evidence of high levels of ENSO activity in the late 19th and early 20th centuries.

This suggests that there is potentially a complex groundwater regime at the site that would require further study to better understand the relationship between rainfall, groundwater levels and landsliding. Conceptually it appears that prolonged rainfall may be responsible for charging aquifers within the Illawarra Coal Measures, a unit known to be a porous rock groundwater system. Elevated porewater pressures are then likely to develop beneath colluvium, particularly towards the lower sections of the escarpment. These conditions are likely to be more pronounced where highly permeable units such as coal and highly jointed rocks intersect the colluvium. These materials were observed in Domain 4, where many slides occurred in and above cuttings in colluvium and weathered rock.

Years that experienced periods of prolonged rainfall such as 1950, 1986 and 2022 also experienced upslope slides in colluvium, often at multiple locations across the site. It is likely that there could be a considerable time lag between the rainfall events and landslide events due to the complexities of the groundwater system discussed above. Unfortunately, due to gaps in the inventory after the 1950's it has not been possible to correlate any other similar colluvial slide events with rainfall. It is also important to note that there does not appear to be a strong correlation between rainfall and rockfalls at the site with many recorded rockfalls occurring on days of relatively low rainfall (AEPs of 63.2% to 50 %).

9. Landslide hazards and processes

9.1 Landslide volume classification

The magnitudes of landslides discussed in this report have been classified according to the estimated volume of material reaching or passing the road. This is because the nature of the material reaching the road is critical to understanding the hazard and the inventory has largely been compiled using data collected at road level. For this project half order of magnitude categories have been used to reflect the range of hazard sizes in the inventory. A breakdown of the classification is presented in Table 4. The approximate equivalent volume classification according to the TfNSW Guide to Slope Risk Analysis (TfNSW, 2012) is also shown in Table 4.

Table 4 Landslide volume classification

Volume of Debris Reaching or Passing Road (m ³)	Project Volume Classification	Equivalent TfNSW Scale of Failure		Qualitative description	
		Block size	Debris Volume	Debris	Rockfalls
< 0.3	Extremely Small	S3 – S5	S5	NA	Single blocks of rock up to about 0.4 m across and / or multiple smaller rock fragments (such as Figure 10 and Event 90)
0.3 - 1	Very Small	S2	S5	Superficial soil slides reaching road shoulder	Single blocks of rock up to about 0.6 m across and / or multiple smaller rock fragments (such as Event 88).
1 - 3	Small	S1 – S2	S5	Shallow depths of soil reaching road shoulder or edge of lane	Single blocks of rock up to about 1 to 1.5 m across and / or multiple smaller rock fragments (such as Event 72).
3 - 10	Medium	S1	S5	Shallow depths of soil reaching closest lane, likely < 0.5 m thick (such as Event 66).	Multiple rock fragments of various sizes, single block could exceed 1 m diameter (such as Event 36).
10 - 30	Large	S1	S4 - S5	Mixed soil and rock debris across one or both lanes, likely up to about 1 m thick (such as Event 69).	Multiple rock fragments of various sizes, single block could exceed 1 m diameter (such as Event 16).
30 - 100	Very Large	S1	S3 – S4	Mixed soil and rock debris across one or both lanes, likely about 1 m thick or more (such as Event 71).	Multiple rock fragments of various sizes, single blocks could exceed 1 m diameter
> 100	Extremely Large	S1	S3 – S1	Multiple individual slides. Mixed soil and rock debris across both lanes, likely >1 m thick (such as Event 76).	Multiple rock fragments of various sizes, single blocks could exceed 1 m diameter (such as Event 46).

9.2 Rockfall volume frequency model

Records of past landslides can provide some information on what has happened but are invariably incomplete. The limitations of the landslide inventory compiled for this project are discussed in Section 7. Slope models can be used to support judgements about what might happen which go beyond the limitations of the historical record. Although slope models provide simplified views of reality, they enable prediction, and they can be tested and updated with local and regional knowledge and relevant knowledge from elsewhere.

For the purpose of this project, we have developed a rockfall volume frequency model (Figure 30) which predicts the long term average number and volume of rockfalls detaching from the main escarpment cliff-lines across Domains 1 and 2 each year that reach or pass the road. The model was developed for the section of road in Domain 1 and 2 because the rockfall data compiled in the inventory was primarily within this section of the road. Using knowledge about rockfall reach probability, the model can also be used more broadly to estimate the likelihood of rockfalls reaching the road for Domains 3 to 5 given the geological conditions of the escarpment cliffs are similar. There was insufficient data in the inventory to develop size-frequency relationships for landslides associated with the colluvial slopes or downslope embankment slides.

The approach to developing and using landslide volume frequency models is given in Moon et al. (2005). The model is based on knowledge and interpretation of evidence on:

- The geological and geomorphological history of the region;
- Rockfalls in the landslide inventory and anecdotal information provided by community members
- Cliff retreat rates in the region and elsewhere;
- Observed landslide failure mechanisms and site observations in general.

Average annual number of landslides, category volume and average annual volume per year in each volume category

Yearly Rockfalls	Extremely Small	Very Small	Small	Medium	Large	Very Large	Extremely Large	Totals
Volume (m ³)	1.73	0.55	0.70	0.90	1.15	2.57	5.77	11.72
Number	10	1	0.407	0.165	0.067	0.047	0.033	15

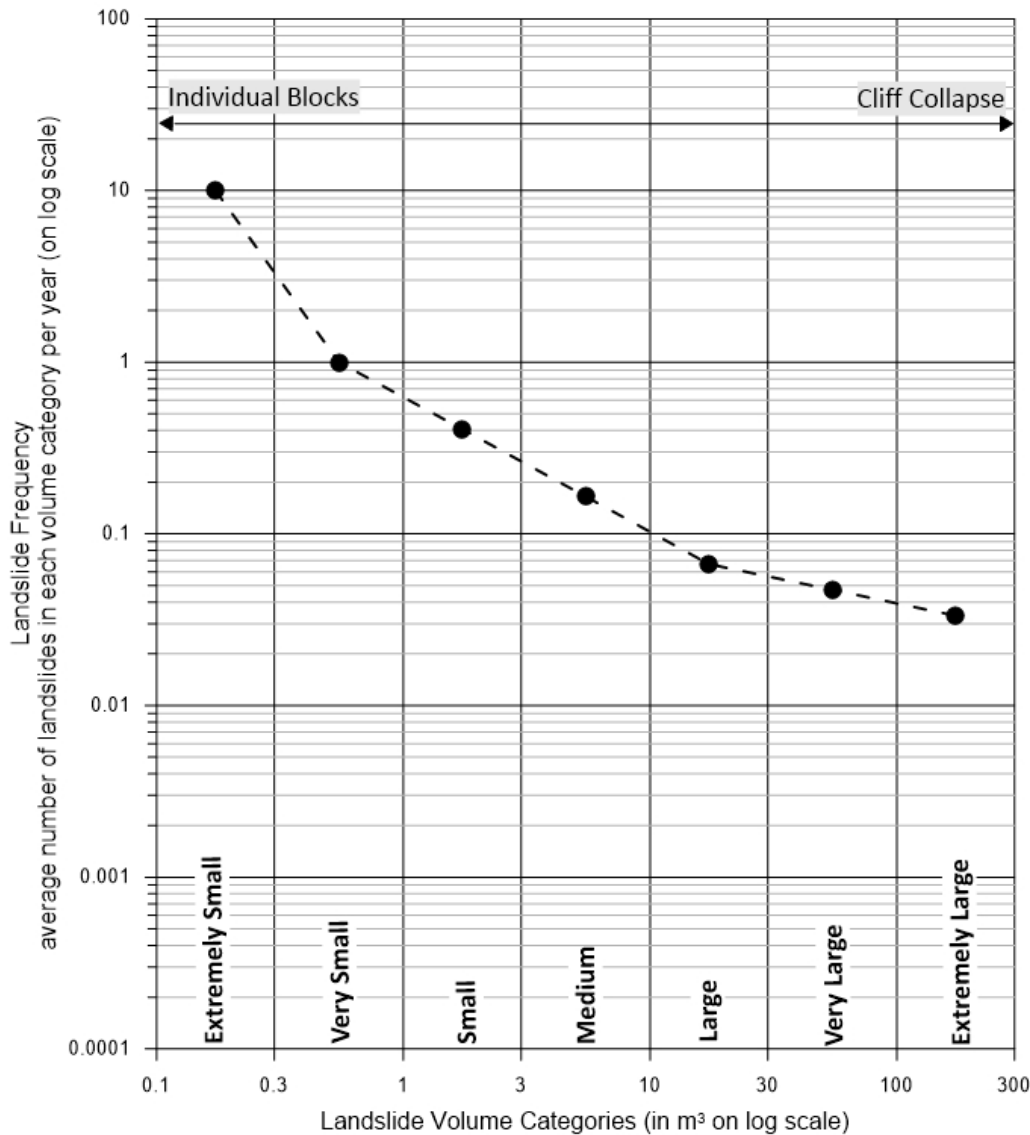


Figure 30 Landslide volume frequency model for rockfalls originating from main escarpment cliffs (Domains 1 and 2)

The model implies a cliff retreat rate (process rate calculated as the area under the curve) of about 0.3 m every 1000 years. This rate is similar to other published escarpment retreat rates for south-eastern Australia (Hunter et al. 2025).

It is important to recognise that the model has not considered the 'maximum credible landslide event'. For this site the 'maximum credible landslide event' is likely to involve a large cliff collapse that transitions into a rock avalanche. The size of a 'maximum credible landslide event' is typically controlled by geological and geomorphological factors such as cliff heights, rock defect characteristics and associated kinematic mechanisms. While it would be possible to estimate the size of such an event using analogies from the broader Blue Mountains region, there is no evidence in the landscape at the site (i.e. boulder fields / extensive rock debris in the lidar) of a comparable event. Therefore, estimates of event frequencies would be 'order of magnitude' estimates with a high

degree of uncertainty. If the model was to consider the 'maximum credible landslide event' the process rate would increase, however it would still be comparable to published estimated for south-east Australian escarpments.

9.3 Assessed hazards

Slope hazards vary across the site depending on the local geomorphology in each Geotechnical Domain. A summary of the credible hazards at the site considered in the risk assessment is presented in Table 5. The hazards are also presented illustratively on the cross sections presented in Appendix B (Figures B6 to B10). The table should be read in conjunction with the cross sections.

Table 5 Summary of credible hazards considered in the risk assessment

Hazard ID ¹	Landslide Type ²	Project landslide volume classification ³	Relevant location
H1a / H1b	Rockfall	Extremely Small	All domains ⁴
H2a / H2b	Rockfall	Very Small	All domains ^{4, 5}
H3	Rockfall	Small - Medium	All domains
H4	Rockfall (tending to be multiple blocks)	Large - Very Large	All domains
H5	Rockfall (tending to be multiple blocks)	Extremely Large	All domains
H6	Earth flow (originating from upslope slides, typically associated with cuttings)	Small - Medium	Domains: 2, 3 & 4.
H7	Earth flow (originating from upslope slides, typically associated with cuttings)	Large – Very Large	Domains: 2, 3 & 4.
H8	Earth flow (originating from upslope slides, typically associated with cuttings)	Extremely Large	Domains: 2, 3 & 4.
H9	Debris Flow	Large - Extremely Large	Domain 3
H10	Downslope embankment failure (rotational & translational)	Large – Very Large	All domains
H11	Downslope embankment failure (rotational & translational)	Extremely Large	All domains

¹ Note: suffix "a" denotes rockfalls originating from escarpments and suffix "b" denotes rockfalls originating from upslope cuttings. ² Refer to Section for landslide 3.2 nomenclature. ³ Refer to Section 9.1 for landslide volume classification. ⁴ In Domain 1, H1a & H1b are coincident and H2a & H2b are coincident. ⁵ H2b not present in Domain 5.

10. Rockfall modelling

To inform the risk assessment presented in this report, particularly in areas where inventory data is incomplete, GHD carried out both two-dimensional (2D) and three-dimensional (3D) rockfall modelling to estimate the travel distance (spatial / reach probability) and three-dimensional (spatial) flow directions of falling rocks originating from the escarpment cliffs.

10.1 Two-dimensional rockfall modelling

The 2D rockfall modelling was carried out using RocFall™ produced by Rocscience Inc, a 2D statistical analysis program for the prediction of rockfall behaviour on slopes. The modelling was carried out at four cross section profiles across the site (Sections B-B', C-C', D-D' and E-E'), the location of which are shown in Figures A1 and A2 in Appendix A. Modelling was not carried out for Domain 1 because the escarpment cliffs located directly adjacent to the road, it is almost certain rockfalls will reach the road.

The modelling involved simulating 1,000 rockfalls at each section line. The modelled rockfall block sizes are presented in Table 6. The rockfalls were initiated from the highest point of the cliffs, which is a conservative approach. A summary of the rockfall modelling is presented in Appendix E.

Table 6 Modelled block sizes – two-dimensional modelling

Volume category	Nominal dimensions (m)	Mass (kg)
Very small	0.6 x 0.4 x 0.4	236
Large	2 x 1.5 x 1.5	13,854

It should be recognised that there are a number of limitations with 2D rockfall modelling and the process is a statistical approximation of rockfall behaviour. The modelling does not consider the fragmentation of rockfalls or obstacles such as large blocks of talus or trees. The modelling also does not consider that rockfalls may change directions and take different paths. The results could therefore be considered conservative. A summary of the outputs for the modelling is provided in Table 7.

Table 7 Summary of two-dimensional rockfall modelling

Domain	Volume category	Comments
2 (Section B-B')	Very small	Approximately 75% of rockfalls modelled to reach road
	Large	Approximately 70% of rockfalls modelled to reach road
3 (Section C-C')	Very small	Approximately 71% of rockfalls modelled to reach road
	Large	Approximately 71% of rockfalls modelled to reach road
4 (Section D-D')	Very small	< 1 % of rockfalls modelled to reach road
	Large	< 1 % of rockfalls modelled to reach road
5 (Section E-E')	Very small	No rockfalls modelled to reach road
	Large	No rockfalls modelled to reach road

10.2 Three-dimensional rockfall modelling

The rockfall modelling was carried out using the software application 'Rockyfor3D'. Rockyfor3D is a simulation model that calculates trajectories of individual falling rocks, in three dimensions. When large numbers of block trajectories are simulated from all the rockfall source cells within a site, a three-dimensional, statistical "runout" model can be generated. Using this runout modelling, rockfall susceptibility can be estimated along Wolgan Road. The effectiveness of these methods for assessing rockfall susceptibility on similar Sydney Basin escarpments above roads was demonstrated by Field and Hunter (2024). Based on the results of this study and other work in similar geological and geomorphological settings, we have found that the results of this specific 3D rockfall

modelling methodology provides a more reliable estimate of travel distance than can be produced using 2D methods. The reader is advised to consult this paper for further details on the methodology.

It is important that an accurate ground surface or “terrain” model of the site be used, as this heavily influences the rockfall travel paths. For this model, the March 2024 lidar survey supplied by Council was used for the ground surface geometry in the model (Figure A2).

Input parameters such as soil and rock properties and surface roughness were estimated using observations from our site visits. Two different block sizes were modelled in two independent scenarios: Very Small and Large. The dimensions of the two block sizes adopted are presented in Table 8. These are the same as were used in the two-dimensional rockfall modelling, but it is worth noting that the masses are less, due to slight differences in the shape of the blocks simulated in each software package.

Table 8 *Modelled block sizes – three-dimensional modelling*

Volume category	Nominal dimensions (m)	Mass (kg)
Very small	0.6 x 0.4 x 0.4	230
Large	2 x 1.5 x 1.5	10,800

While Wolgan Road itself features prominently in the terrain model, and specific “asphalt” parameters were assigned to it, the modelling does not consider the effects of other human-made structures (such as road furniture). Also, in the interest of conservatism, slope vegetation has not been incorporated.

The results of the 3D modelling are presented in Figures F1 to F6 in Appendix F. The modelling outputs presented in the figures comprise:

- Rockfall susceptibility: the probability of a modelled rock block reaching each cell within the modelling area, given that it is possible for it to reach that location;
- Energy: the 95th percentile of the simulated rockfall energy of blocks passing through each cell within the model area;
- Block depositions: the number of rock blocks that have settled within each cell within the model area.

11. Quantitative landslide risk assessment

11.1 Landslide risk management framework

11.1.1 Background

The 1998 Thredbo landslide, in which 18 people were killed, highlighted the challenges faced from building upon steep slopes and led to the development of the Australian Geomechanics Society Landslide Risk Management Guidelines, initially published in 2000 and revised and re-published in 2007 and now commonly referred to as AGS (2007). The suite of guidelines is recognised nationally (Australia) and internationally as world-leading practice. The reader of this report is encouraged to consult the freely available Landslide Risk Management guidelines (LRM) resources which can be accessed at: <https://geomechanics.org.au/downloads/#dILRM2007>.

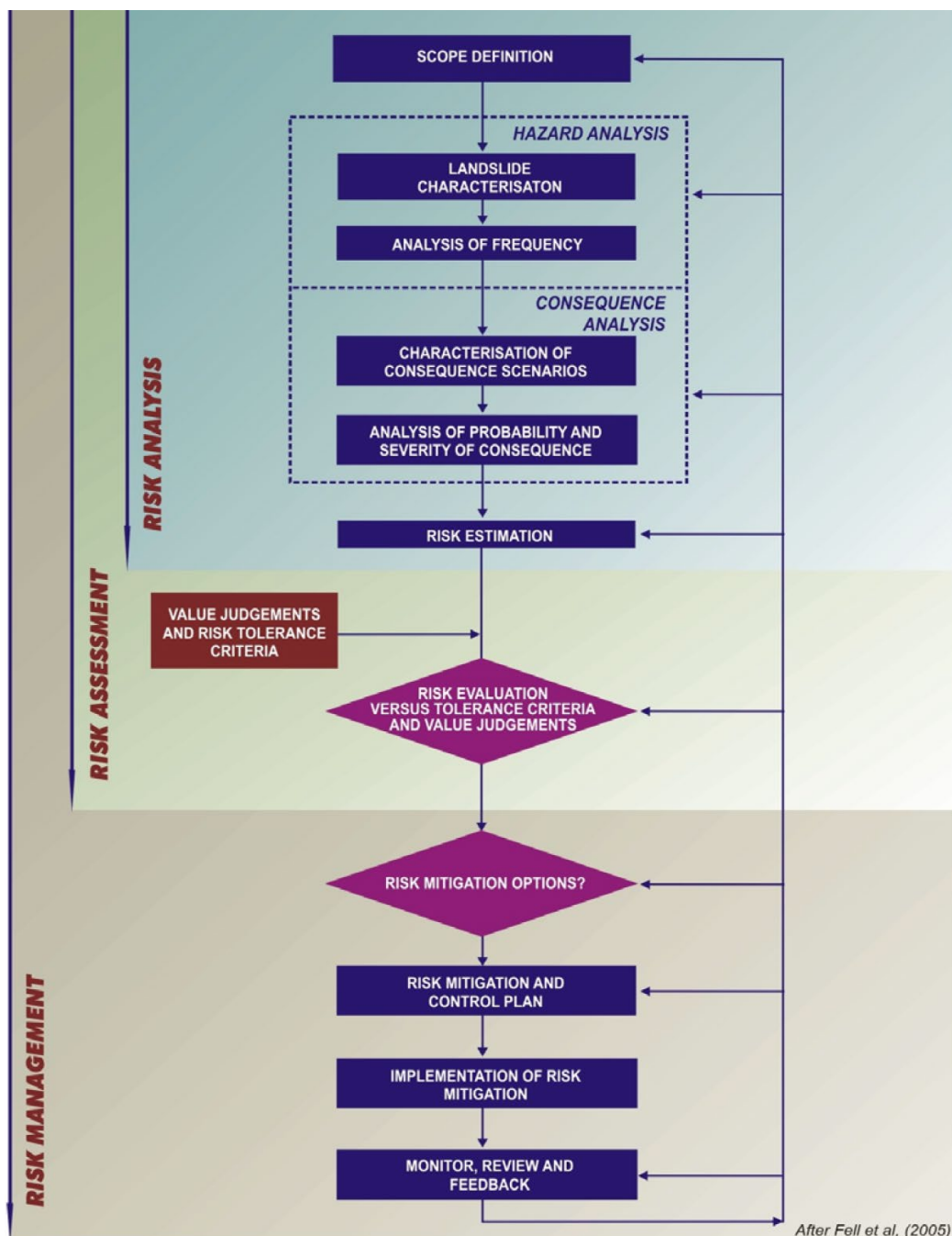


Figure 31 Risk assessment framework from AGS 2007

After Fell et al. (2005)

The 'Practice Note Guidelines for Landslide Risk Management' (AGS 2007c), provides technical guidance in relation to the processes and tasks undertaken by geotechnical practitioners who prepare LRM reports including appropriate methods and techniques. The Practice Note is a statement of what constitutes good practice by a competent practitioner for LRM, including defensible and up to date methodologies and provides guidance on the quality of assessment and reporting, including the outcomes to be achieved and how they are to be achieved.

The framework for landslide risk management from AGS2007 is presented in Figure 31 and represents a framework widely used internationally.

Following the publication of AGS (2007), The New South Wales National Parks and Wildlife Service (NPWS) subsequently produced in 2020 and updated in 2024, further guidance and policy for assessment and management of risk associated with landslides in NSW national parks (NPWS, 2024). The NPWS guidelines are based on the AGS (2007) guidelines but provide a somewhat broader range of hazard scenarios including the assessment of mobile elements at risk such as walkers on a track or vehicles on a road. As a result, the NPWS guidelines have particular application to the Wolgan Road risk assessment as they maintain adherence to AGS (2007) but provide specific application to road users.

11.1.2 Risk estimation methodology

In this assessment, the most critical elements at risk are road users which represent the particular case designated as "a mobile element at risk". The risk methodology for 'loss-of-life' for mobile elements has been estimated using guidance provided in the New South Wales National Parks and Wildlife Service Guidelines for Quantitative Risk to Life Calculations for Landslides (2024).

The NPWS guidelines are based on the concepts and premises detailed in AGS (2007) which includes a fundamental equation for calculation of the annual probability of loss of life for an individual which incorporates four separate conditional probability terms relating to hazard occurrence, spatial, temporal and human vulnerability factors.

As such, the annual risk of loss of life of the individual most at risk is defined in AGS 2007c by equation 1.

$$R_{(LoL)} = P_{(H)} \times P_{(S:H)} \times P_{(T:S)} \times V_{(D:T)} \quad (1)$$

Where:

R_(LoL) is the risk or annual probability of loss of life of the individual most at risk. This is usually the individual who is exposed to the hazard for the greatest duration.

P_(H) is the annual probability that a landslide or rockfall occurs.

P_(S:H) is the probability of spatial impact of the landslide impacting a mobile element at risk taking into account the travel distance and direction of the landslide or rockfall.

P_(T:S) the temporal spatial probability (e.g. of the individual being in an area subject to landslide) given the spatial probability and allowing for evacuation if there is warning of the landslide or rockfall event.

V_(D:T) is the vulnerability of the individual given they are impacted.

In the context of mobile elements at risk and particularly vehicles on a road, the NPWS approach further defines some of these factors as described in Appendix C of NPWS (2024) as follows:

$$P_{(S:H)} = P_{(t)} \text{ w.d/l} \quad (2)$$

Where:

P_(t) is the probability that the boulder or debris reaches the track after detaching

- w** is the proportion of the width of the road or track affected by the landslide and ranges between 0 (none of track affected) to 1 (full width of the track affected). For example, $w = 0.5$ indicates a person has a 50% chance on being on the side of the track impacted by the landslide hazard. If unsure, $w = 1$
- d** is the length of a track / road that could be impacted by the landslide. For rockfall, $d =$ the boulder diameter and for a landslide $d =$ the width of the landslide
- l** is the length of the track / road within the area subjected to the hazard and in this case the length of the Domain.

$$P_{(T:S)} = f \cdot n_i \cdot l / (1000 \cdot s_i) / (24 \times 365) \quad (3)$$

Where:

- f** is a reduction factor of between 0 and 1 and relates to the probability of a person being present when the landslide is triggered. For example, if the landslide trigger is heavy rain, and it is assumed that the individual is half as likely to be exposed to the hazard during heavy rain than at other times, $f = 0.5$. The guidance recommends if there is any uncertainty a factor of 1 should be used. A factor of 1 has been adopted for this assessment.
- n_i** is the number of traverses the individual most at risk makes within a year.
- s_i** is the speed in km/hr that the individual most at risk moves through the area subject to the hazard. For estimating risk to the individual most at risk, s_i applies to the individual expected to move through the zone at risk at the slowest speed.

Hence substituting the expanded definition for $P_{(S:H)}$ and $P_{(T:S)}$ into Equation 1, the consolidated final equation as per the NPWS methodology is as follows:

$$R_{(LOL)} = P_{(H)} P_{(t)} V_{(D:T)} \cdot n_i w f d \times 1.1 \times 10^{-7} / s_i \quad (4)$$

11.2 Elements at risk

A range of potential elements at risk have been assessed as users of Wolgan Rd and these include:

- Community members/residents of the Wolgan Valley
- Contractors delivering supplies and transporting stock and goods
- Staff members of the Emirates One&Only Wolgan Valley resort
- Visitors / tourists
- Council maintenance crews and workers
- Geotechnical consultants undertaking monitoring and review

Note this assessment is only considering those elements at risk that have exposure to hazards with a potential “loss of life” and does not consider property and infrastructure elements.

11.3 Individual most at risk

AGS (2007d) recommends that risks be assessed only for the person most at risk, and not for the average person. For example, the person most at risk is typically an identifiable / named individual who undertakes a particular travel pattern. Based on discussions and feedback during community consultation sessions, in the case of users of Wolgan Road, the individual most at risk has been assessed to be represented by an Emirates staff member collecting guests who may make 3 x return trips a day, over 5 days of the week assuming weekends are taken off. Given they may also take 4 weeks holiday off a year, the total number of trips or traverses made by this individual is as follows:

$$n_i = 3 \times 2 \times 5 \times 48 = 1,440 \text{ trips per year}$$

It should be recognised that other individuals, such as members of the community who undertake a similar number of trips along Wolgan Road each year will be exposed to similar risk levels.

11.4 Societal Risk

The concept of societal risk involves consideration of probability of loss of life to the total population exposed to one or more hazards. In the case of Wolgan Road, total population exposure relates to the total number of traverses by individuals made in a year. Council provided GHD with traffic count data recorded in 2021/2022 that assessed the annual average daily traffic (AADT) as being 95 vehicles per day. The total annual number of vehicle traverses is taken as $95 \times 365 = 34,675$.

The NPWS approach undertakes an assessment of societal risk which requires the calculation of what is termed an F-N pair where F= the probability of impact to the element at risk and N is N or more fatalities.

For mobile elements at risk F is estimated as follows:

$$F = 1 - (1 - AvR_{(LoL)})^n \quad (5)$$

Where:

AvR_(LoL) is the average individual risk across the exposed population for a single traverse through the area at risk. (Note that AvR_(LoL) is further defined as follows $AvR_{(LoL)} = \sum si R(iol) / ni.s$ where si, R(iol) and ni are as has been defined in Section 11.1.2 and s = average speed of the exposed population)

n = the total number of traverses made annually through the area at risk by a mobile element at risk (i.e. a vehicle)

11.5 Landslide likelihood P_(H)

The estimation of hazard likelihood P(H) is a critical component of any risk assessment and yet is generally one of the most difficult and challenging tasks. There are several ways of estimating likelihood as noted by Fell et al. (2005) and AGS (2007) which may include:

- Gathering local and historical knowledge of slope performance and landslide characteristics and occurrence. The resulting inventory enables assessment of frequency (known as a frequentist approach).
- Relationships to geomorphology and geology.
- Relationship to frequency and intensity of triggering events such as rainfall, earthquakes and bushfires.
- Development of observation-based volume - frequency models to estimate a broader range of likelihood for different sized events.
- Use of knowledge based expert judgement or “degree of belief” method which combines experience, expertise and general principles.

Incomplete knowledge and inherent uncertainty require a broad approach to likelihood estimation which by necessity, involves a combination of the above methods.

The frequentist’ approach largely assumes that the historical record is a guide to the future and that future probability can be estimated using statistical analysis of past landslide records such as inventory data. While this approach is commonly and widely used, like most methods there are inherent limitations and drawbacks. For example, the focus is solely on the statistical analysis rather than interpretation of conditions that led to landslide events such as geology and rainfall. Furthermore, where there are gaps in the data set such as incomplete inventories, the recorded frequency of landsliding may be an imprecise guide to future probability of landsliding. In addition, can often be too short to contain evidence for all forms of landsliding the site may experience.

The rockfall volume frequency model in Section 0 forms the basis for the estimated probability of occurrence for the rockfall hazards at the site across Domains 1 and 2 (i.e. likelihood of rockfalls reaching the road). The model has also been used more broadly to estimate the detachment probability for rockfalls detaching from the escarpment cliffs in Domains 3 to 5 given the geological conditions of the escarpment cliffs are similar. As discussed in Section 11.6, these probabilities are then further multiplied by spatial probabilities informed by the rockfall modelling to estimate the annual probability of rockfalls reaching the road.

As discussed, there was insufficient data in the inventory to develop size-frequency relationships for landslides associated with the colluvial slopes or downslope embankment slide. The likelihoods for these hazards have therefore been estimated using a combination of the 'frequentist' and 'degree of belief' approaches as defined by Lee and Jones (2023).

The 'degree of belief' approach is based on a practitioners belief or confidence in the outcome according to their state of knowledge at the time to estimate the probability of an uncertain event. This approach is often viewed as being subjective as it involves judgement being made based on the available information and experience of the practitioner. The focus of the 'degree of belief' approach is typically on understanding the causes and triggering factors for landslides, thus introducing understanding of geomorphology and geology, and requires specialist knowledge. This approach has been used estimate likelihoods for events that may have limited representation in the inventory but are likely to be triggered by observed processes and certain rainfall conditions.

As discussed in Section 8, while Australia as a whole experienced the ninth-wettest year on record since 1900, there was considerable variation across regions. For example, while parts of Sydney recorded the highest rainfall on record, the rainfall experienced in the Lithgow area was lower, ranking as only the 6th wettest year for the site (since records began). It is postulated that the combined effect of the local bushfire in 2019 with the high 2022 rainfall may represent a more significant overall preparatory and triggering event than if either were taken as single separate events. Literature generally suggests that a bushfire impacted landscape may take between 4 to 10 years to recover to pre-bushfire state (Colls & Miner, 2021). Hence the use of a frequentist approach to likelihood and site performance may not always be totally applicable and it may be reasonable to presume that the site may respond in a less significant way to potential triggers in the future as the site recovers.

Section 8 highlighted that there does not appear to be a strong correlation between rainfall and rockfalls at the site with many recorded rockfalls occurring on days of relatively low rainfall (AEPs of 63.2% to 50 %). This is because, depending on the source location, rockfalls can be triggered by a number of processes such as;

- Root-jacking (i.e. expansion of tree roots growing in open joints);
- Wind induced movements associated with trees growing on the cliffs;
- Seismic activity;
- Gradual erosion / weathering of underlying rock leading to the development of rock overhangs and subsequent tensile failures;
- Softening and/or expansion of clay infilled rock defects;
- Elevated pore pressures due to rainfall, noting there may be significant delay following rainfall due to the complex nature of the groundwater systems at the site;
- Reduction in the tensile strength of rocks due to wetting.

Table 9 Adopted landslide likelihood values

Hazard ID	Domain	Likelihood	Comments
H1a	All domains	1	Rockfalls originating from escarpments. Inventory and rockfall volume frequency model.
H1b	2, 3, 4, 5	1	Small rockfalls originating from upslope cuttings in colluvium and weathered rock. Observations, anecdotal history, Google Street View imagery.
H2a	All domains	1	Rockfalls originating from escarpments. Inventory and rockfall volume frequency model.
H2b	2, 3, 4	0.1	Rockfalls originating from upslope cuttings in colluvium and weathered rock. Inventory and observations.
H3	All domains	0.3	Rockfalls originating from escarpments. Inventory and rockfall volume frequency model.
H4	All domains	0.06	Rockfalls originating from escarpments. Inventory and rockfall volume frequency model.

Hazard ID	Domain	Likelihood	Comments
H5	All domains	0.03	Rockfalls originating from escarpments. Inventory and rockfall volume frequency model.
H6	2, 3, 4	0.5	Inventory
H7	2, 3, 4	0.1	Inventory
H8	2, 3, 4	0.05	Inventory and degree of belief approach based on knowledge of preparatory causal factors (rainfall).
H9	3	0.02	Very limited inventory entries necessitate a degree of belief approach based on knowledge of preparatory causal factors (i.e. presence of gullies, landscape impacted by bushfire) and triggering causal factors (observed rainfall).
H10	All domains	0.05	Inventory
H11	All domains	0.02	Very limited inventory entries for hazards of this magnitude necessitates a degree of belief approach based on knowledge of preparatory causal factors (i.e. blocked drains / culverts above failure) and triggering causal factors (observed rainfall). Adopted likelihood assumes road maintenance will be carried out.

11.6 Probability of spatial impact P(S:H)

The AGS (2007c) definition of spatial probability is represented by single term $P_{(S:H)}$ and is described as the probability of spatial impact by the landslide on the element at risk, given the landslide occurs and taking into account the travel direction and travel distance or reach. As previously defined, the NPWS approach further subdivides $P(S:H)$ into $P(t)$ the probability that if a hazard occurs it reaches the road and w , the proportion of the road the hazard travels onto.

For this project the spatial probability values are based on a combination of methods including inventory data, observations and the rockfall modelling presented in 10. The spatial probability values are presented in Table 10. Factors for 'w' (the proportion of the width of the road affected by the landslide) are presented in Table 11.

Table 10 Likelihood of landslide reaching Road - $P(t)$

Hazard ID	Domain	Likelihood of landslide reaching Road - $P(t)$	Comments
H1a	1, 2	1	Inventory and observations.
H1a	3	0.05	Rockfall modelling
H1a	4	0.025	Rockfall modelling
H1b	2, 3, 4, 5	1	Observations, degree of belief approach
H2a	1, 2	1	Inventory and observations.
H2a	3	0.05	Rockfall modelling
H2a	4	0.025	Rockfall modelling
H2a	5	0	Rockfall modelling
H2b	2, 3, 4	1	Observations, degree of belief approach
H3	1, 2	1	Inventory and observations.
H3	3	0.05	Rockfall modelling
H3	4	0.05	Rockfall modelling
H3	5	0.005	Scaled between rockfall modelling values of H2 & H4
H4	1, 2	1	Inventory and observations.
H4	3	0.05	Rockfall modelling

Hazard ID	Domain	Likelihood of landslide reaching Road - P(t)	Comments
H4	4	0.075	Rockfall modelling
H4	5	0.01	Rockfall modelling
H5	1, 2	1	Inventory and observations.
H5	3	0.075	Rockfall modelling
H5	4	0.1	Rockfall modelling
H5	5	0.02	Rockfall modelling
H6	2, 3, 4	1	Inventory and degree of belief approach
H7	2, 3, 4	1	Inventory and degree of belief approach
H8	2, 3, 4	1	Inventory and degree of belief approach
H9	3	1	Inventory and degree of belief approach
H10	1, 2, 3, 4, 5	1	Inventory and degree of belief approach
H11	1, 2, 3, 4, 5	1	Inventory and degree of belief approach

Table 11 'w' - Proportion of the width of the road affected by the landslide

Hazard ID	Domain	Proportion of road impacted, w	Comments
H1a	1, 2	1	Inventory and observations.
H1a	3, 4, 5	0.5	Inventory and observations.
H1b	2	1	Inventory and observations.
H1b	3, 4, 5	0.5	Inventory and observations.
H2a	1, 2	1	Inventory and observations.
H2a	3, 4, 5	0.5	Inventory and observations, TfNSW travel distance method.
H2b	2	1	Inventory and observations.
H2b	3, 4	0.5	Inventory and observations, TfNSW travel distance method.
H3	1, 2	1	Inventory and observations.
H3	3, 4, 5	0.5	Inventory and observations.
H4	All domains	1	Inventory and observations.
H5	All domains	1	Inventory and observations.
H6	2, 3, 4	0.5	Inventory and observations.
H7	2, 3, 4	1	Inventory and observations.
H8	2, 3, 4	1	Inventory and observations.
H9	3	1	Inventory and observations.
H10	All domains	0.5	Inventory and observations.
H11	All domains	0.5	Inventory and observations.

11.7 Temporal probability P(T:S)

The temporal probability for mobile elements is governed by the travel speed, v_i . While the posted speed limit for the site is 50 km/ hr, given the road conditions it is likely most vehicles will be travelling slower than 50 km/ hr. Consequently, a travel speed of 40 km/ hr has been used in this assessment.

11.8 Vulnerability $V_{(D:T)}$

AGS (2007c) provides indicative examples of vulnerability values and general qualitative guidance on the assessment of consequences based on published literature. One of the most widely referenced papers on vulnerability is by Finlay et al (1999), who presents a review of landslide fatality incidents in Hong Kong and presented a range of vulnerability values for different hazards and various inundation and building damage scenarios. Other literature we have examined to inform the assessment of vulnerability include:

- Bunce et. al (1997): *Assessment of the hazard from rock fall on a highway*
- TfNSW (2012): *TfNSW Guide to Slope Risk Analysis*
- Wilson et al. (2005): *Application of quantitative risk assessment to the Lawrence Hargrave Drive Project, New South Wales, Australia*

It is important to note that most literature on vulnerability include ranges rather than specific values, which is reflective of the uncertainty and subjectivity of consequence assessment. The above references have been used as a guide and expert judgement has been applied to select a value within the range of values where appropriate on a site-specific basis. It has also been assumed that the speed of a typical vehicle using the road at the site is 40 km/hr or less.

It is also important to recognise that the same hazard type can result in different consequences (vulnerability), depending on the location. For example, a rock falling vertically from the cliff in Domain 1 will have a much higher vulnerability than the same sized rock bouncing or rolling across the road in Domain 5. This is because the rock falling vertically is travelling at high velocity and may penetrate or crush a vehicle, whereas a rock rolling across the road has significantly lower entrained energy, meaning that it may hit the side of the vehicle and not penetrate it.

The vulnerability values adopted for this project are presented in Table 12.

Table 12 Adopted vulnerability values

Hazard ID	Domain	Vulnerability $V_{(D:T)}$	Comments
H1a / H1b	1	0.1	Rocks falling vertically onto vehicle
	2, 3, 4	0.05	Rocks bouncing / rolling horizontally – likely to hit side of vehicle
	5	0.001	Rocks rolling horizontally from very low cuttings – likely to hit side of vehicle
H2a / H2b	1	0.3	Rocks falling vertically onto vehicle
	2, 3, 4	0.1	Rocks bouncing / rolling horizontally – likely to hit side of vehicle
	5	0.005	Rocks rolling horizontally from very low cuttings – likely to hit side of vehicle
H3	1	0.5	Rocks falling vertically onto vehicle
	2, 3, 4, 5	0.3	Rocks bouncing / rolling horizontally – likely to hit side of vehicle
H4	1	1	Rocks falling vertically onto vehicle
	2, 3, 4, 5	0.8	Rocks bouncing / rolling horizontally – likely to hit side of vehicle
H5	1	1	Rocks falling vertically onto vehicle
	2, 3, 4, 5	1	Rocks bouncing / rolling horizontally – likely to hit side of vehicle
H6	2, 3, 4	0.001	Shallow, slow moving earth flow slide hits side of vehicle
H7	2, 3, 4	0.01	Shallow, slow moving earth flow slide hits side of vehicle
H8	2, 3, 4	0.1	Slow moving earth flow slide hits side of vehicle
H9	3	0.05	Distal end of shallow debris flow hits side of vehicle. Guardrail may prevent a vehicle from leaving the road.
H10	All domains	0.001	Vehicle traversing an irregular surface formed by a developing embankment failure. Guardrail may prevent a vehicle from leaving the road.

Hazard ID	Domain	Vulnerability $V_{(D:T)}$	Comments
H11	All domains	0.05	Vehicle traversing a developing embankment failure and impacting a deep void. Guardrail may prevent a vehicle from leaving the road.

11.9 Risk estimation

11.9.1 Individual most at risk

The risk estimation results for the conceivable hazards assessed in this report are presented in Appendix G. Estimates of risk have been made for:

- Each hazard type in each domain (see Appendix G).
- Overall risk in each domain by combining individual risks from each hazard (see Table 13).
- Overall risk for a journey from start to finish incorporating combined risk in every domain across the site (see Table 13).

Table 13 Risk of Loss of life for individual most at risk across each domain

Domain	$R_{(LOLC)}$
1	5.1×10^{-06}
2	4.2×10^{-06}
3	8.8×10^{-07}
4	8.7×10^{-07}
5	7.7×10^{-08}
All Domains	1.1×10^{-05}

11.9.2 Societal risk

The concept of societal risk involves consideration of probability of loss of life to the total population exposed to one or more hazards, that is society as a whole. The assessed F – N pairings are presented in Table 14, where F is the probability of impact to the element at risk and N is N or more fatalities. The pairings include:

- Overall risk in each domain
- Overall risk for a journey from start to finish incorporating combined risk in every domain across the site

F – N pairings are typically plotted on 'F-N' charts to compare risks with risk tolerance criteria. The 'F-N' charts are presented in Figure 32 to Figure 35.

Table 14 F-N pairings across each domain

Domain	F	N
1	1.2×10^{-04}	1
2	1.0×10^{-04}	
3	2.1×10^{-05}	
4	2.1×10^{-05}	
5	1.9×10^{-06}	
All Domains	2.7×10^{-04}	

11.9.3 Uncertainty assessment

The process of risk assessment involves estimation of likelihood, consequence and risks based on available information for the study site. By its very nature, much of the data, including historical and current inventories, may be incomplete whilst an understanding of the triggering events has a degree of uncertainty attached to it.

Judgement is required to estimate the nature and size of potential hazards, their frequency of occurrence and their impact on a variety of elements at risk. As these judgements are based on the knowledge, experience and understanding of the assessor, it is not unusual for different assessors to make different judgements about the level of risk.

While the basis for the judgements contained in this report are well documented, and the levels of risk considered to be good representations of reality, the accuracy and precision of the process should not be overestimated and should always be used in an appropriate manner in combination with risk management including mitigation and treatment options.

Methods for communicating uncertainty associated with quantitative risk assessment is a developing field and approaches can vary from qualitative descriptions where information may be limited to more detailed quantitative descriptions where past knowledge is well known and key data sets including inventory are extensive and the nature and extent of the project is confined.

Paul and Miner (2025) provided a range of numerical methodologies for describing uncertainty associated with quantitative risk assessment to provide a more transparent approach to communicate the limitations and uncertainty associated with a risk estimation.

For the Wolgan Road project, a Tier1 approach is considered appropriate where uncertainty is communicated initially as an index using concepts of both epistemic and aleatory knowledge. This index is then more readily communicated and understood as a qualitative descriptor.

Based on the Tier 1 approach which incorporates the state of knowledge for epistemic certainty (the Index, **le** which includes consideration of the key risk estimation factors of likelihood, spatial, temporal and vulnerability) as well as an estimate of the aleatory knowledge (the Index, **la**) the following index estimates were made on the basis of the information and understanding presented in this report:

- State of knowledge score= Likelihood=6 + Spatial=5 + Temporal=5 + Vulnerability=3 giving a total S=21.
- $le = 0.714$ and $la = 0.85$

This then allows the calculation of what is known as the **Uncertainty Index Ic** where:

- $Ic = le \times la = 0.61$.

Generally, this uncertainty index Ic indicates a **Moderate, tending to High** level of confidence which is indicative of a quantitative risk estimate within a range of typically +/- half to one order of magnitude.

11.10 Risk Evaluation

The main objectives of risk evaluation are typically to compare the assessed risk to risk levels that are acceptable or tolerable to the community, and therefore to decide whether to accept, tolerate or treat the risks and to set priorities for remediation. The regulator / responsible authority usually has the sole responsibility (commensurate with organisational priorities and risk tolerance) for setting their own risk acceptance criteria with which to evaluate the levels of risk estimated in this report. The role of the consultant is to estimate the levels of risk in accordance with the available data and state of knowledge within stated limitations and uncertainty but cannot advise on acceptability or otherwise of such risk levels.

Where a regulator / responsible authority does not have fully incorporated risk acceptance criteria, as guidance only, the AGS recommendations for Tolerable and Acceptable risk can be used as a useful starting point for consideration of risk evaluation and acceptance criteria. AGS (2007d) provides discussion and gives the AGS recommendations in relation to tolerable risk for loss of life. The AGS recommended levels are summarised in Table 15.

In some circumstances, a regulator / responsible authority may choose other combinations of risk levels and risk acceptance. As such, the authority may deem a higher level of risk as Tolerable where it is not practical or economically feasible to significantly reduce risk. However, such a decision would need to be made with full knowledge and transparency to all stakeholders that in order to achieve a community of organisational benefit, a higher level of risk than is being tolerated than might otherwise be generally adopted.

Table 15 AGS-suggested tolerable loss of life risk - individual risk

Situation	Suggested Tolerable Loss of Life Risk for the person most at risk
Existing slope / existing development	10 ⁻⁴ per annum (1E-4 pa) or 1 in 10,000 pa
New constructed slope / new development / existing landslide	10 ⁻⁵ per annum (1E-5 pa) or 1 in 100,000 pa

It is important to distinguish between “acceptable risks” and “tolerable risks”. AGS (2007c) provides the following definitions for these risks:

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

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

The estimated loss of life risks for the person most at risk for each individual hazard type across the site are all lower than the AGS suggested tolerable levels for ‘New constructed slope / new development / existing landslide’ (see Appendix G). The estimated loss of life risks in each domain (i.e. combined individual risks from each hazard in each domain) are also all lower than the AGS suggested tolerable levels. The estimated overall risk for a journey from start to finish incorporating combined risk in every domain across the site slightly exceeds the AGS suggested tolerable level.

AGS (2007) is not definitive when it comes to circumstances when societal risks should be considered because the focus of the AGS guidelines was largely on residential development. For example, AGS (2007) states:

“Societal risk should be evaluated for buildings having high numbers of occupants, such as schools, hospitals, hotels or motels where many lives are at risk. This then addresses society’s aversion to loss of many lives from single landslide events.”

AGS (2007c) and AGS (2007d) both suggest that methods outlined in Fell et al. (2005) and ANCOLD (2003) be used if societal risks need to be considered. The use of ‘F-N’ charts to evaluate societal risk was developed in Hong Kong by the Geotechnical Engineering Office (1998). Fell et al. (2005) notes that the use of the F-N method is not universal and has been trialled on an interim basis to assist landslide risk management of natural hillside hazards. The Fell et al. (2005) paper also notes that:

“tolerable risk criteria are themselves not absolute boundaries. Society shows a wide range of tolerance to risk, and the risk criteria are only a mathematical expression of the assessment of general societal opinion”

The F-N evaluation criteria presented in NPWS (2024) was based on the concepts in both Fell et al. (2005) and ANCOLD (2003). NPWS (2024) proposes two suggested societal risk thresholds; ‘existing developments’ and ‘new developments’. The NPWS (2024) criteria for ‘existing developments’ is the same F-N risk criteria as Fell et al. (2005). The NPWS (2024) criteria for ‘new developments’ has lower risk thresholds to reflect scenarios such as new buildings and new roads where there has not been any on the site before. The societal risks for the site are presented on the ‘F-N’ charts in Figure 32 to Figure 35.

Societal Risk Thresholds (New Development, Domains 1-5)

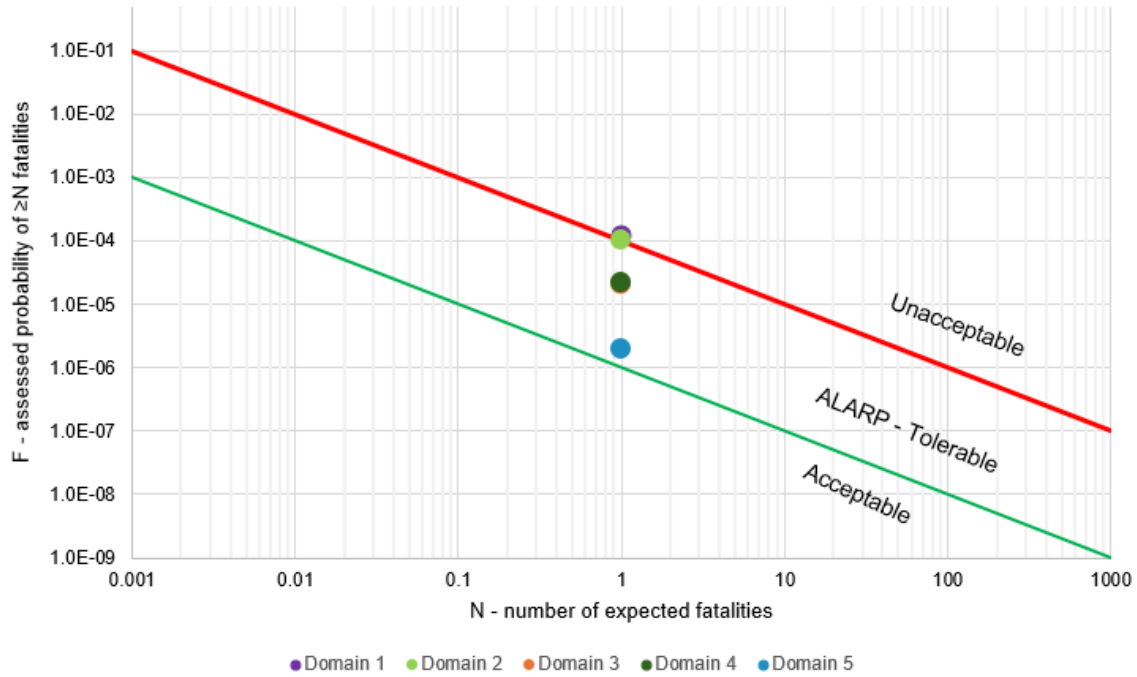


Figure 32 F-N chart presenting societal risk thresholds for New Developments (NPWS criteria) in Domains 1 to 5

Societal Risk Thresholds (New Development, All Domains Combined)

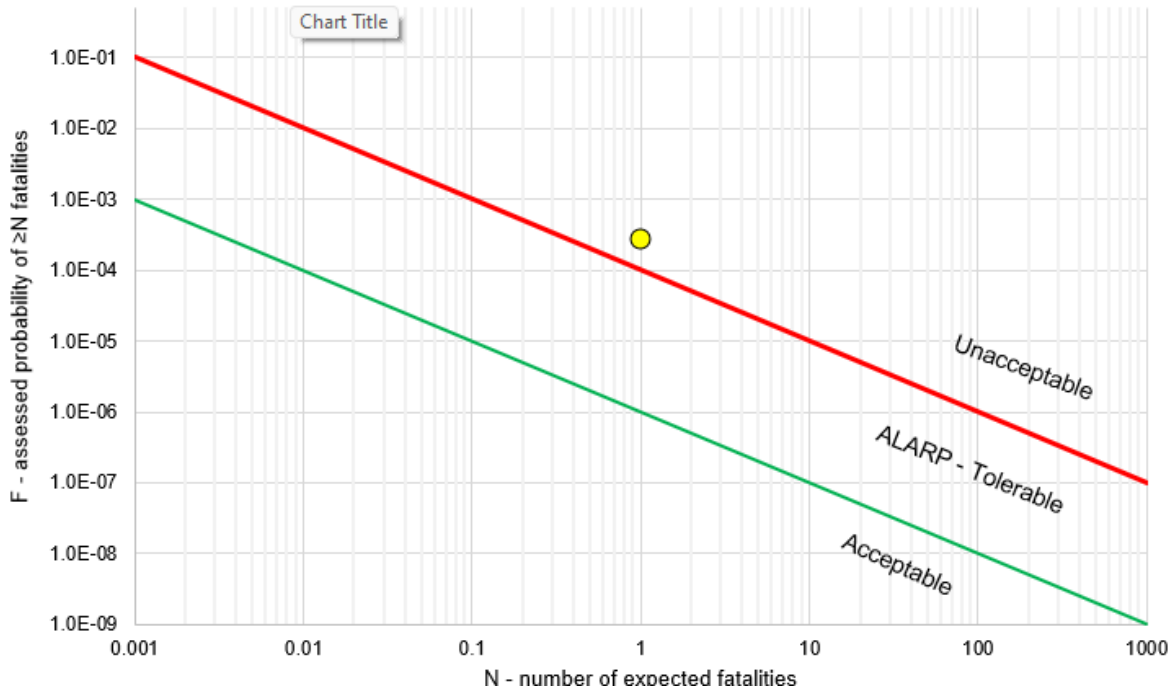


Figure 33 F-N chart representing societal risk thresholds for New Developments (NPWS criteria) combining Domains 1 to 5

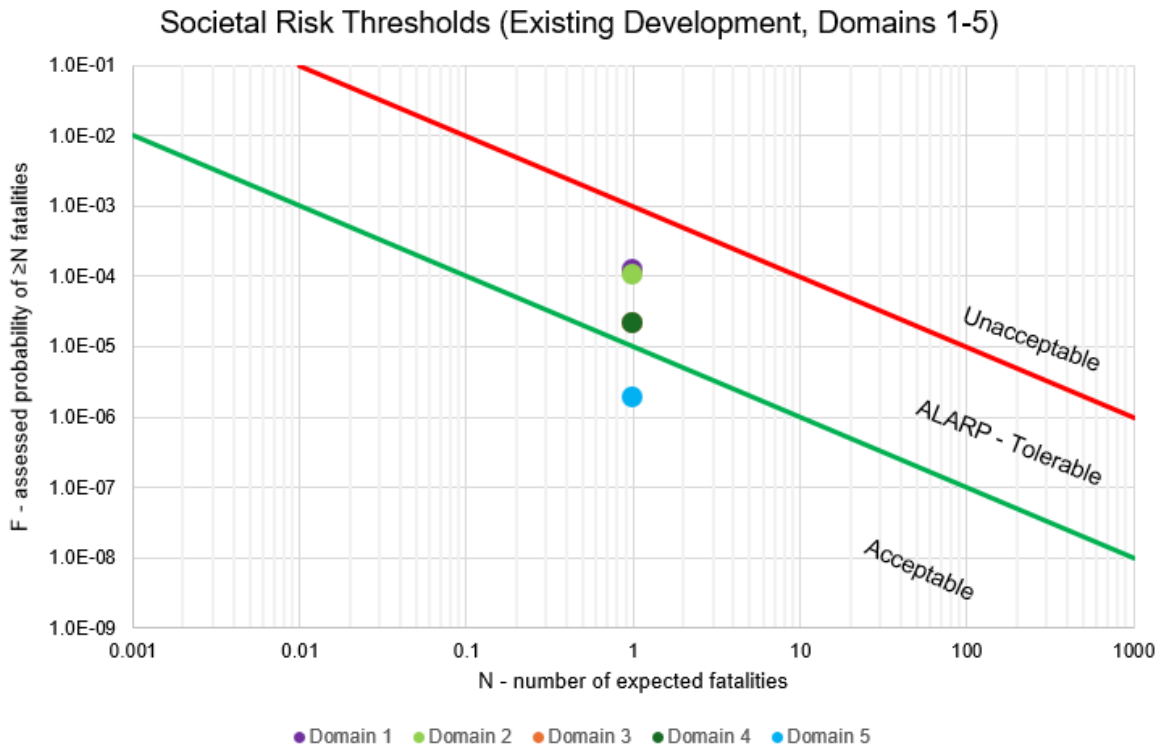


Figure 34 F-N chart representing societal risk thresholds for Existing Developments (NPWS Criteria) in Domains 1 to 5

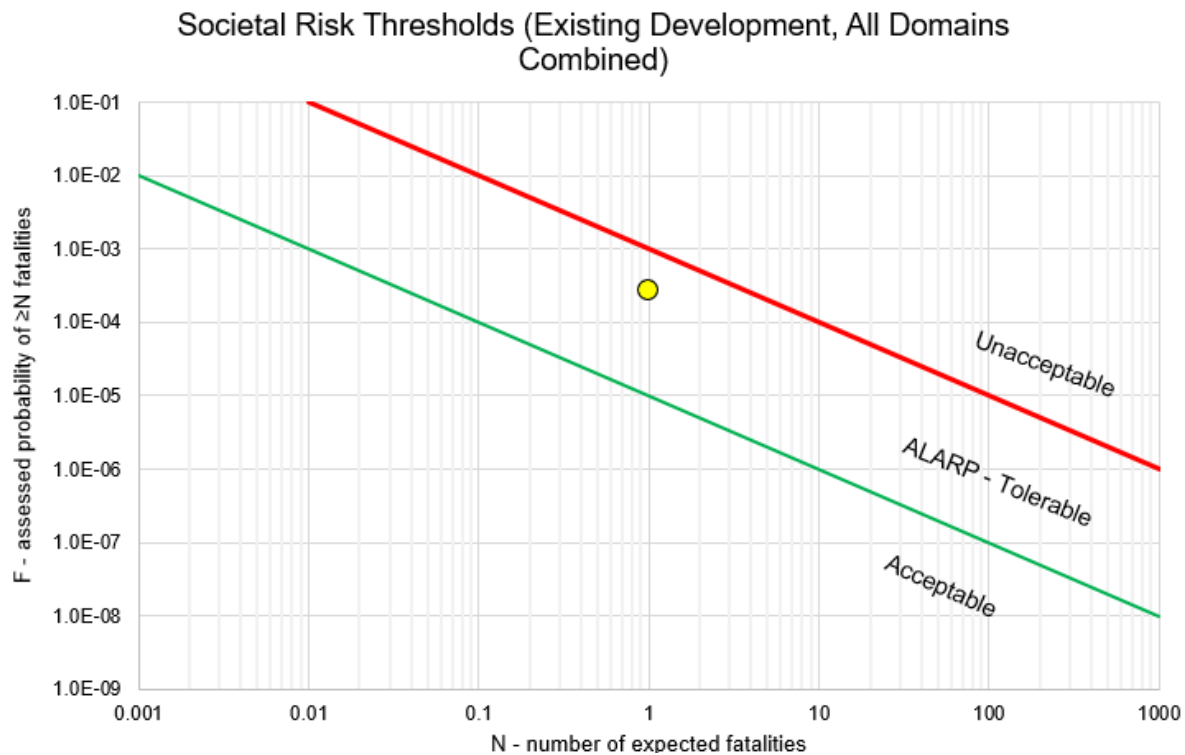


Figure 35 F-N chart representing societal risk thresholds for Existing Developments (NPWS Criteria) combining Domains 1 to 5

Using the NPWS criteria for 'existing developments' as a guide, the risks for loss of life to the total population would be considered tolerable across every domain and for a journey from start to finish incorporating combined risk in every domain. However, using the NPWS criteria for 'new developments' as a guide, the societal risks estimated for Domain 1 would be considered not tolerable and for a journey from start to finish incorporating combined risk in every domain would also be considered not tolerable.

It should be noted that the 'tolerable' region of the 'F-N' charts includes reference to the 'ALARP' principle ("As Low As Reasonably Practicable"). The term ALARP originated from work health and safety legislation in the United Kingdom in the 1970's. The usage and interpretation of the principle varies from country to country and between industries. Lee and Jones (2023) discuss the usage of the ALARP principle by hazardous industries such as nuclear and offshore oil and gas whereby a cornerstone of risk management is the concept that there is a degree of risk that is tolerable and this can be defined through the use of three categories of risk acceptance criteria or thresholds as follows:

- Above a certain threshold the risk might be considered intolerable or unacceptable
- Below a much lower risk level, the risk is considered so small that is broadly acceptable
- A zone between acceptable and unacceptable is considered a tolerable region where the level of risk is typical of the risk posed by activities or development that people are willing to live with in order to secure certain benefits

The ALARP principle has common usage and wide application in dam safety risk assessments and has also been applied to landslide risk evaluation (Fell et al. 2005, AGS, 2007).

In the tolerable region, Lee and Jones (2023) note that it is generally expected that the level of risk should be reduced to a level that *is as low as reasonably practicable*. The ALARP or tolerable region includes a continuous spectrum of conditions ranging from where the cost of risk reduction would exceed the improvement gained adjacent to a lower boundary, to where the risk is only tolerable if risk reduction is impracticable or if the cost of risk reduction is grossly disproportionate to the improvement gained.

In the context of landslide risk management, both Fell (2005) and AGS (2007c) provide discussion on when the principle should apply. The following definition and commentary is provided in AGS (2007c):

"In many cases, the ALARP principle may apply so that reduction to a tolerable level is a pragmatic result since reduction to acceptable levels is not viable in the context of the cost to the individual or community. In other cases, good practice may suggest that risk reduction be applied since it is relatively cheap or cost effective to implement even though risk levels are assessed to already be at acceptable levels. In other words, risk minimization should be a governing feature or tenet of Landslide Risk Management."

12. Transport for NSW slope risk assessment

The TfNSW system has been used extensively to assess slopes adjacent to roads in New South Wales and Queensland and has more recently been adopted for use on New Zealand's State Highways. This form of risk analysis is used to rapidly analyse the risk to life and property associated with cut/ fill slopes and soil retaining structures adjacent to roads. The procedure is based primarily on visual assessment, however additional supporting data / information can be used when available. The risk analysis provides information for use in setting priorities for investigation, monitoring and remediation of such slopes and structures. The system is generally used as a prioritisation tool (i.e. for remediation, monitoring, investigation etc.) for individual sites and is not generally used as a measure of the combined or total risk along a longer or extended stretch of road.

The procedure has been progressively established since 1999 to allow TfNSW to rank landslide hazards on severity of risk to life. It is based on an underlying quantitative framework and was developed to systematically analyse geotechnical risks associated with slopes adjacent to roads in NSW. The framework was primarily based on landslide risk literature available at the time including the Australian Geomechanics Society Landslide Risk Management guidelines. TfNSW-trained practitioners select defined ratings based on field observations that are then incorporated into a risk matrix to generate an Assessed Risk Level (ARL). There are five ARL levels ranging from ARL1 (highest risk level) to ARL5 (lowest risk level). Baynes, Lee and Stewart (2002) provide the following commentary on the TfNSW risk assessment system with respect to risk to life:

“the median quantitative probability of loss of life implied by the five ARL levels are roughly one order of magnitude apart, with the highest risk level (ARL1) roughly equating to an annual risk of loss of life of $>10^{-3}$ ” (i.e. an annual risk of about 1 in 1000) “and the lowest risk level (ARL5) roughly equating to an annual risk of loss of life of $<10^{-6}$ ” (i.e. an annual risk of about 1 in 1,000,000)”.

Is it also noteworthy that the TfNSW system does not have a process for combining hazards, instead the system prioritises management of slopes based on their individual ratings. The reported risk levels for sites are based on the hazard with the highest risk level. The TfNSW doesn't combine risks from multiple hazards within a site, nor does it combine risks from multiple sites along a length of road (i.e. a “journey rating”). If a “journey rating” approach was applied to roads and highways, many roads in Australia would eventually be unacceptable simply due to the fact if a vehicle travelled far enough, it would encounter enough hazards to exceed the threshold of risk tolerability or acceptability. This is particularly important to consider in the context of Wolgan Road.

TfNSW risk sites typically comprise a single road cutting or embankment and are usually less than about 500 m in length. A length of roadway such as the Wolgan Road at the site would ordinarily be divided into numerous sites covering both upslope and downslope areas. For consistency in this report, we have assessed risks for each domain, with the assessed risk levels presented in Table 16.

Due to the sheer cliffs directly adjacent to the road in Domain 1, the TfNSW method to assess rockfalls directly impacting a moving vehicle has been applied.

Table 16 TfNSW Risk Assessment Summary

Domain	Hazard ID	Likelihood (L)			Temporal Probability (T)	Vulnerability (V)	Consequence (C)	Assessed Risk Level (ARL)
		P(d)	P(t)	L				
1	H1a	1	1	L1	T4	V5	C5	ARL3
	H1a (direct impact method)	1	1	L1	T5	V1	C4	ARL2
	H2a	1	1	L1	T4	V4	C5	ARL3
	H2a (direct impact method)	1	1	L1	T5	V1	C4	ARL2
	H3	0.3	1	L1	T4	V3	C4	ARL2
	H4	0.06	1	L2	T4	V3	C4	ARL3

Domain	Hazard ID	Likelihood (L)			Temporal Probability (T)	Vulnerability (V)	Consequence (C)	Assessed Risk Level (ARL)
		P(d)	P(t)	L				
2	H5	0.03	1	L3	T4	V3	C4	ARL4
	H10	0.05	1	L2	T4	V5	C5	ARL4
	H11	0.02	1	L3	T4	V3	C4	ARL4
	H1b	1	1	L1	T4	V5	C5	ARL3
	H2a	1	1	L1	T4	V4	C5	ARL3
	H2b	1	1	L1	T4	V4	C5	ARL3
	H3	0.3	1	L1	T4	V3	C4	ARL2
	H4	0.06	1	L2	T4	V3	C4	ARL3
	H5	0.03	1	L3	T4	V3	C4	ARL4
	H6	0.5	1	L1	T4	V5	C5	ARL3
	H7	0.1	1	L2	T4	V5	C5	ARL4
	H8	0.05	1	L2	T4	V5	C5	ARL4
	H10	0.05	1	L2	T4	V5	C5	ARL4
H11	0.02	1	L3	T4	V3	C4	ARL4	
3	H1a	1	0.05	L2	T4	V5	C5	ARL4
	H1b	1	1	L1	T4	V5	C5	ARL3
	H2a	1	0.05	L2	T4	V4	C5	ARL4
	H2b	1	1	L1	T4	V4	C5	ARL3
	H3	0.3	0.05	L3	T4	V3	C4	ARL4
	H4	0.06	0.05	L4	T4	V3	C4	ARL5
	H5	0.03	0.075	L4	T4	V3	C4	ARL5
	H6	0.5	1	L1	T4	V5	C5	ARL3
	H7	0.1	1	L2	T4	V5	C5	ARL4
	H8	0.05	1	L2	T4	V5	C5	ARL4
	H9	0.02	1	L3	T4	V5	C5	ARL5
	H10	0.05	1	L2	T4	V5	C5	ARL4
H11	0.02	1	L3	T4	V3	C4	ARL4	
4	H1a	1	0.025	L3	T4	V5	C5	ARL5
	H1b	1	1	L1	T4	V5	C5	ARL3
	H2a	1	0.015	L3	T4	V4	C5	ARL5
	H2b	1	1	L1	T4	V4	C5	ARL3
	H3	0.3	0.05	L3	T4	V3	C4	ARL4
	H4	0.06	0.075	L4	T4	V3	C4	ARL5
	H5	0.03	0.1	L4	T4	V3	C4	ARL5
	H6	0.5	1	L1	T4	V5	C5	ARL3
	H7	0.1	1	L2	T4	V5	C5	ARL4
	H8	0.05	1	L2	T4	V5	C5	ARL4
	H10	0.05	1	L2	T4	V5	C5	ARL4
	H11	0.02	1	L3	T4	V3	C4	ARL4

Domain	Hazard ID	Likelihood (L)			Temporal Probability (T)	Vulnerability (V)	Consequence (C)	Assessed Risk Level (ARL)
		P(d)	P(t)	L				
5	H1b	1	1	L1	T4	V5	C5	ARL3
	H3	0.3	0.005	L4	T4	V3	C4	ARL5
	H4	0.06	0.01	L4	T4	V3	C4	ARL5
	H5	0.03	0.02	L4	T4	V3	C4	ARL5
	H10	0.05	1	L2	T4	V5	C5	ARL4
	H11	0.02	1	L3	T4	V3	C4	ARL4

The terms and abbreviations used in the above table are in accordance with those outlined in 'The TfNSW Guide to Slope Risk Analysis, Version 4 (TfNSW, 2012). Vulnerability values have been adopted based on methods outlined in TfNSW (2012) and differ slightly from Table 12. Consequence analysis is for loss of life; damage to property and consequential (social/economic impact) effects has not been considered.

13. Discussion

This study has used geotechnical domains based on geology and geomorphology to assist in characterisation of the site in order to undertake appropriate risk assessments. Considerable efforts have been made to compile a landslide inventory for the site, which is an essential task for any landslide risk assessment as it provides context on past events that can be used to approximate predicted future landslide frequencies. This was compiled using many different data sources including but not limited to, Council records, historic newspaper articles and oral history provided by residents of Wolgan Valley.

Despite the extensive effort devoted to assembling an inventory, by its very nature it must still be viewed as somewhat incomplete given data availability, which is a common issue in landslide studies. As such the use of anecdotal evidence, site observations, rockfall volume-frequency models and geological/ geomorphological interpretation have complimented the inventory to help estimate frequencies for different hazards.

Leading up to the road closure in 2022, the site experienced above average rainfall however the rainfall was considerably less than the record-breaking rain received to the east in Sydney in the same year. While 2022 was a wet period, with the year falling into the top 10 wettest years on records, the rainfall was significantly less than that experienced in 1950. March 2022 recorded the greatest monthly rainfall total rainfall of that year and was above the long-term average but still significantly less than numerous other monthly totals over the decades. It should also be noted that if the locally collected rainfall data is considered (i.e. collected by a Wolgan Valley resident), the rainfall for 2022 would be only the 22nd highest since records began.

While the road was affected by numerous landslides and localised embankment instability during 2022, the available history for the road suggests these events were not unprecedented. The historical data indicates that similar or even greater landslide activity occurred during the record-breaking rainfall in 1950. This has been corroborated by local residents who have provided anecdotal accounts of similar landslide events occurring in 'wet' years. It is postulated that the combined effect of the local bushfire in 2019 with the above average rainfall in 2022 rainfall may represent a more significant overall preparatory and triggering event than if either were taken as single separate events.

The landslide hazards at the site have been classified according to the internationally accepted scheme by Hungr et al. (2014). This assessment considered 11 different hazard types based on volume and the landslide classification. The hazards include a range of rockfall sizes, earthflows, debris flows and embankment slides. Rockfall modelling was carried out to estimate the travel distance (spatial / reach probability) and three-dimensional (spatial) flow directions of falling rocks originating from the escarpment cliffs.

Risk has been estimated for the individual most at risk (individual risk estimate) and an individual within the exposed population (societal risk estimate). Estimates of risk have been made for:

- Each hazard type in each domain (individual risk)
- Overall risk in each domain by combining individual risks from each hazard (individual risk)
- Overall risk for a journey from start to finish incorporating combined risk in every domain across the site (individual risk)
- Overall risk in each domain (societal risk)
- Overall risk for a journey from start to finish incorporating combined risk in every domain across the site (societal risk)

Risk estimates have also been carried out for each hazard type in each domain using the TfNSW Guide to Slope Risk Analysis to determine an Assessed Risk Level (ARL).

Using the AGS recommendations for Tolerable risk criteria as a guide only, the estimated loss of life risks for each hazard type and in each domain (i.e. combined individual risks from each hazard in each domain) are all lower than the AGS suggested tolerable levels. The estimated overall risk for a journey from start to finish incorporating combined risk in every domain across the site slightly exceeds the AGS suggested tolerable level for the person most at risk for a new development. However, where the AGS criteria for an 'existing slope' are applied the risk levels are within the tolerable range.

In terms of societal risks, using the risk criteria typically recommended by AGS (2007) and NPWS (2024) as a guide ('existing developments'), the risks for loss of life to the total population would be considered tolerable. If more conservative risk criteria were applied such as proposed by NPWS (2024) for 'new developments', the estimates of risk for Domains 1 and 2 would be considered above the tolerable levels however the other domains remain either tolerable or acceptable.

Using the TfNSW risk methodology, risks assessed at the site range from ARL2 to ARL5. The loss of life risks implied by each ARL level correlate reasonably well with the societal risks presented in Section 11.9.2. The highest Assessed Risk Level is ARL2 which is associated with Extremely Small to Medium sized rockfall hazard types in Domains 1 and 2. All other domains have assessed risk levels ranging from ARL3 to ARL5. TfNSW does not publicly publish their risk tolerability criteria. We recommend Council seek advice from TfNSW on risk tolerability criteria that would be typically adopted for similar roads.

It is noteworthy that the highest assessed risks at the site using each of the risk estimation methods are associated with hazards in Domains 1 and 2. Assessed risks for Domains 3, 4 and 5 are all below the AGS (2007) suggested Tolerable or Acceptable risk criteria. This may be important for future decision making.

It is important to note that any risk estimate has inherent uncertainty and limitations and discussion has been included in this assessment to provide a more realistic understanding to the risk assessment process. The risk estimates presented in this report should be considered in the context of limitations and uncertainty associated with risk estimation. Based on our assessment of uncertainty presented in Section 11.9.3, the risk levels are within a range of typically +/- half to one order of magnitude.

It must be acknowledged that there are numerous forms of hazards along Wolgan Road that have occurred in the past and will inevitably occur in the future. Risk assessment allows us to postulate the nature of those hazards, how frequent they may be and what impact they may potentially have on road users through estimations of both spatial and temporal exposures. However, the process is an extrapolation of past and current observations into future behaviour, and it carries inherent uncertainties and limitations that must be acknowledged. Estimated risks are the results of judgement based on all the available data and observation that rely on the state of knowledge of a number of diverse factors but are also limited by gaps in that knowledge.

As the regulator / responsible authority, Council has the responsibility for setting the risk acceptance criteria with which to evaluate the levels of risk estimated in this report. Guidance on risk evaluation can be gained through reference to industry publications such as the Australian Geomechanics Society Landslide Risk Management Guidelines (AGS, 2007) and NSW National Parks and Wildlife Service Guidelines for Quantitative Risk to Life Calculations for Landslides (NPWS, 2024). It must be noted that the choice of what boundaries and thresholds constitutes acceptable or tolerable risk are not absolute and different organisations may adopt different criteria. It is acknowledged that risk assessment is only one input to the overall decision-making process. Owners, society and regulators may also consider political, social and legal issues in their assessments and as such the community affected by hazards may also play a role in such decisions (adapted from Fell et al. 2005).

Aspects of risk management and treatment, and how these might affect risk levels, are beyond the agreed scope of works for this assessment.

14. Closure

This report outlines our observations of geological and geotechnical site features and our assessment of landslide hazards observable at the time that the observations were made. Note that natural features will change and may deteriorate over time, that could change existing hazards or create new ones. In that situation, additional investigations may be required to further assess landslide hazards, all in the context of landslide risk management. Further information on the landslide risk management process is presented in Appendix H.

The risk assessment presented in this report has relied on historical landslide inventory data for the site provided by Council as well as available information obtained from other sources as outlined herein. Changes to site usage (i.e. traffic volumes, traffic speeds etc) will change the risk levels. Should these conditions change, we recommend that this risk assessment be updated. Furthermore, should Council become aware of any landslides and/or rockfalls, particularly large events, we recommend that Council inventory records continue to be maintained and a geotechnical practitioner be requested to undertake further assessment.

We would like to thank Council for the opportunity to undertake this project. Should Council have any queries regarding the contents of this report, please contact the authors of this report as named.

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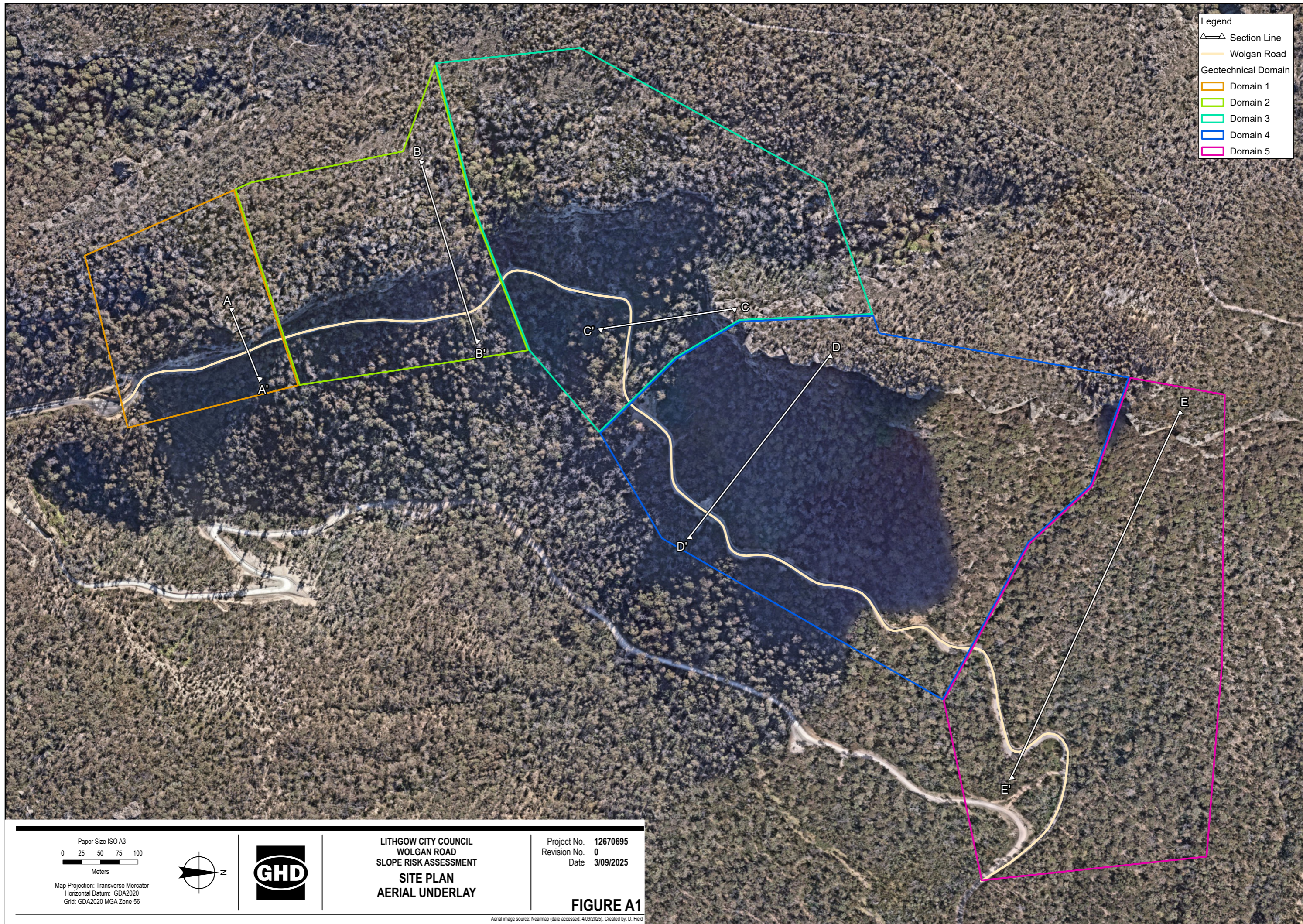
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WSP Pty Ltd. (2025). Letter – Wolgan Road Project: Gap Slope Risk Assessment.

Appendices

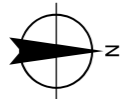
Appendix A

Figures



- Legend**
- △—△ Section Line
 - Wolgan Road
 - Geotechnical Domain**
 - Domain 1
 - Domain 2
 - Domain 3
 - Domain 4
 - Domain 5

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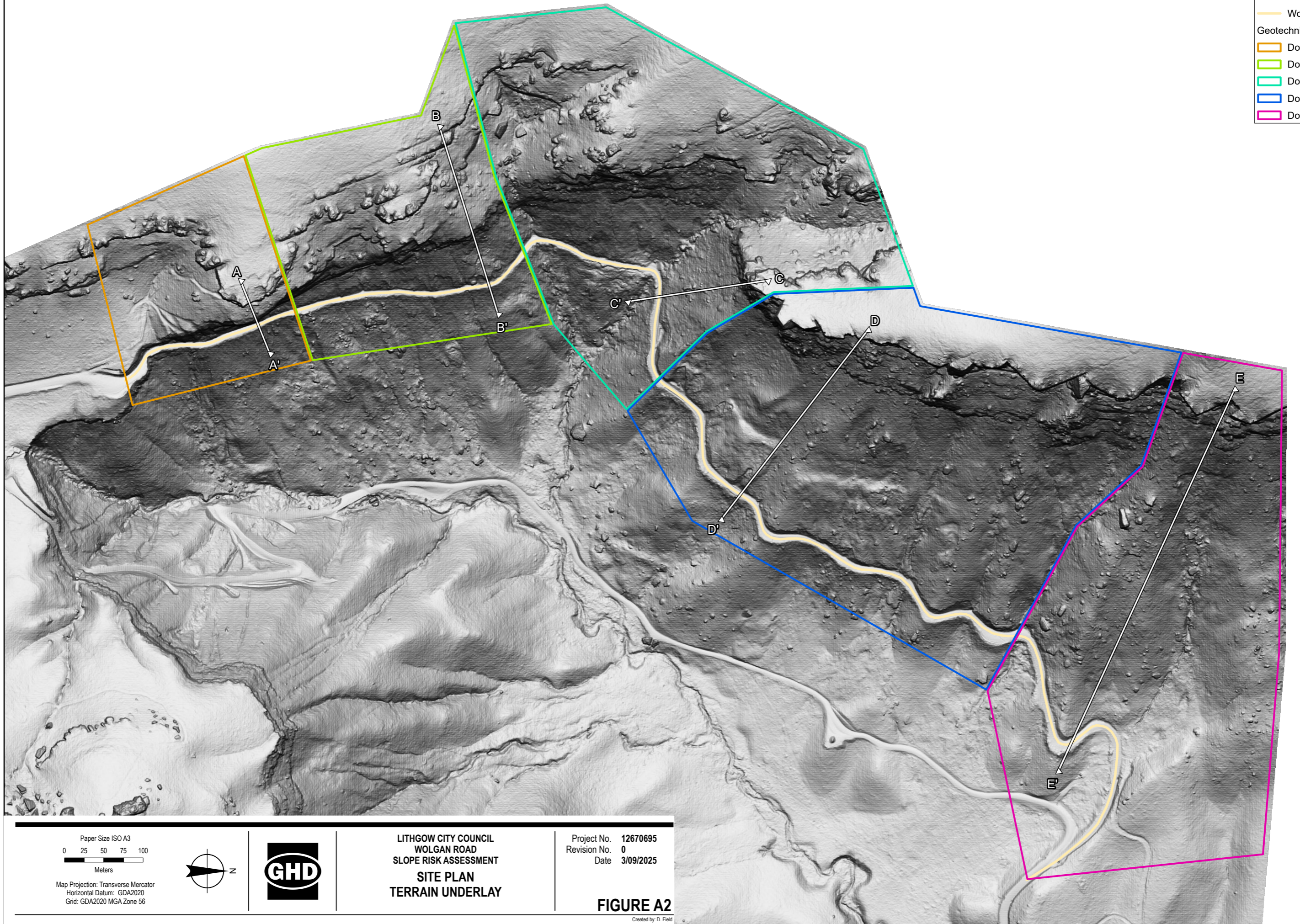
LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
 SITE PLAN
 AERIAL UNDERLAY

Project No. 12670695
 Revision No. 0
 Date 3/09/2025

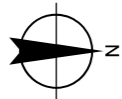
FIGURE A1

Aerial image source: Nearmap (date accessed: 4/09/2025). Created by: D. Field

- Legend**
- △—△ Section Line
 - Wolgan Road
 - Geotechnical Domain**
 - Domain 1
 - Domain 2
 - Domain 3
 - Domain 4
 - Domain 5



Paper Size ISO A3
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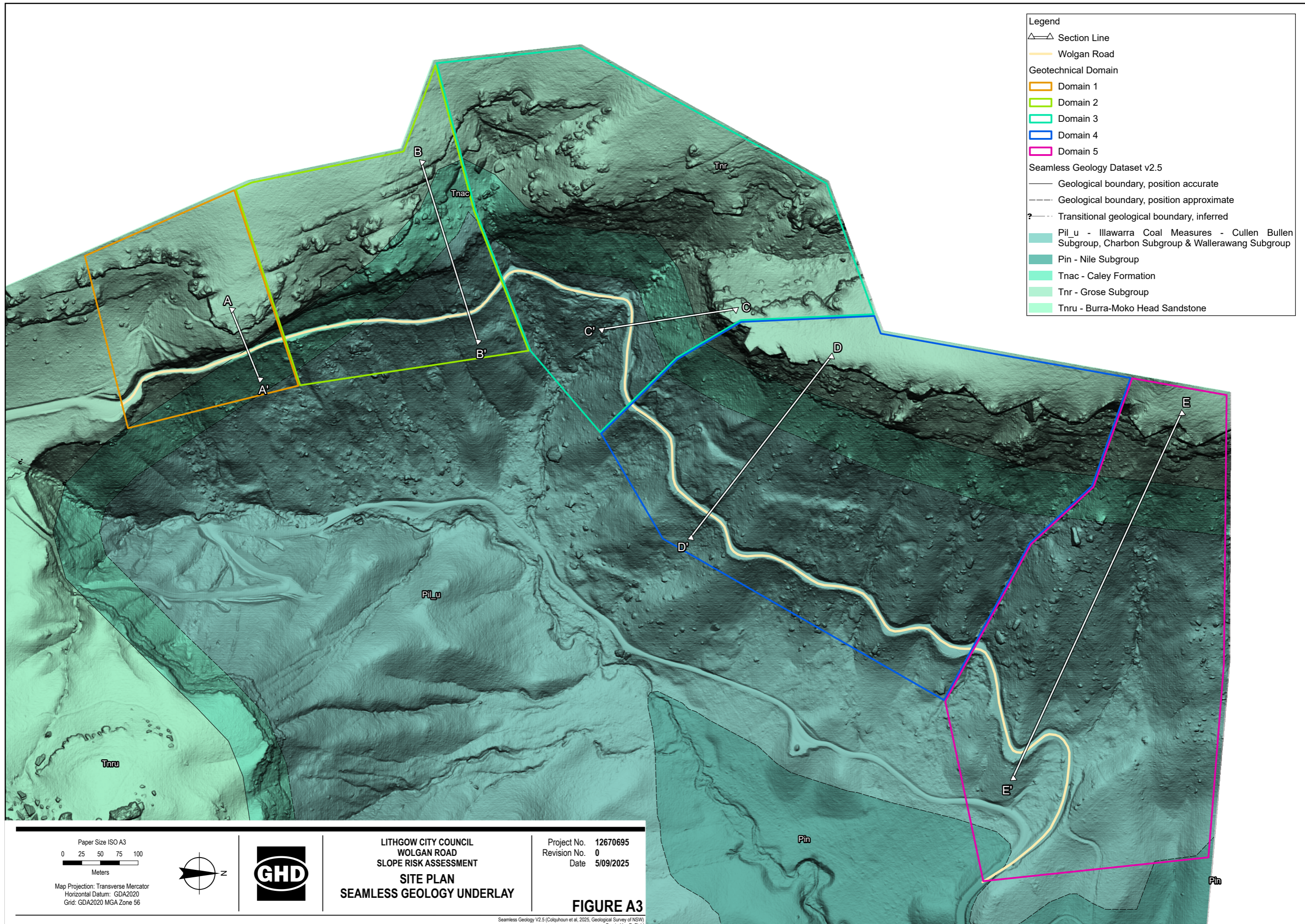
LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
 SITE PLAN
 TERRAIN UNDERLAY

Project No. 12670695
 Revision No. 0
 Date 3/09/2025

FIGURE A2

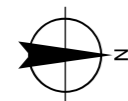
Created by: D. Field

Map Projection: Transverse Mercator
 Horizontal Datum: GDA2020
 Grid: GDA2020 MGA Zone 56



- Legend**
- △ Section Line
 - Wolgan Road
 - Geotechnical Domain**
 - Domain 1
 - Domain 2
 - Domain 3
 - Domain 4
 - Domain 5
 - Seamless Geology Dataset v2.5**
 - Geological boundary, position accurate
 - - - Geological boundary, position approximate
 - ? - - - Transitional geological boundary, inferred
 - Pil_u - Illawarra Coal Measures - Cullen Bullen Subgroup, Charbon Subgroup & Wallerawang Subgroup
 - Pin - Nile Subgroup
 - Tnac - Caley Formation
 - Tnr - Grose Subgroup
 - Tnr_u - Burra-Moko Head Sandstone

Paper Size ISO A3
 0 25 50 75 100
 Meters



LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
SITE PLAN
SEAMLESS GEOLOGY UNDERLAY

Project No. 12670695
 Revision No. 0
 Date 5/09/2025

FIGURE A3

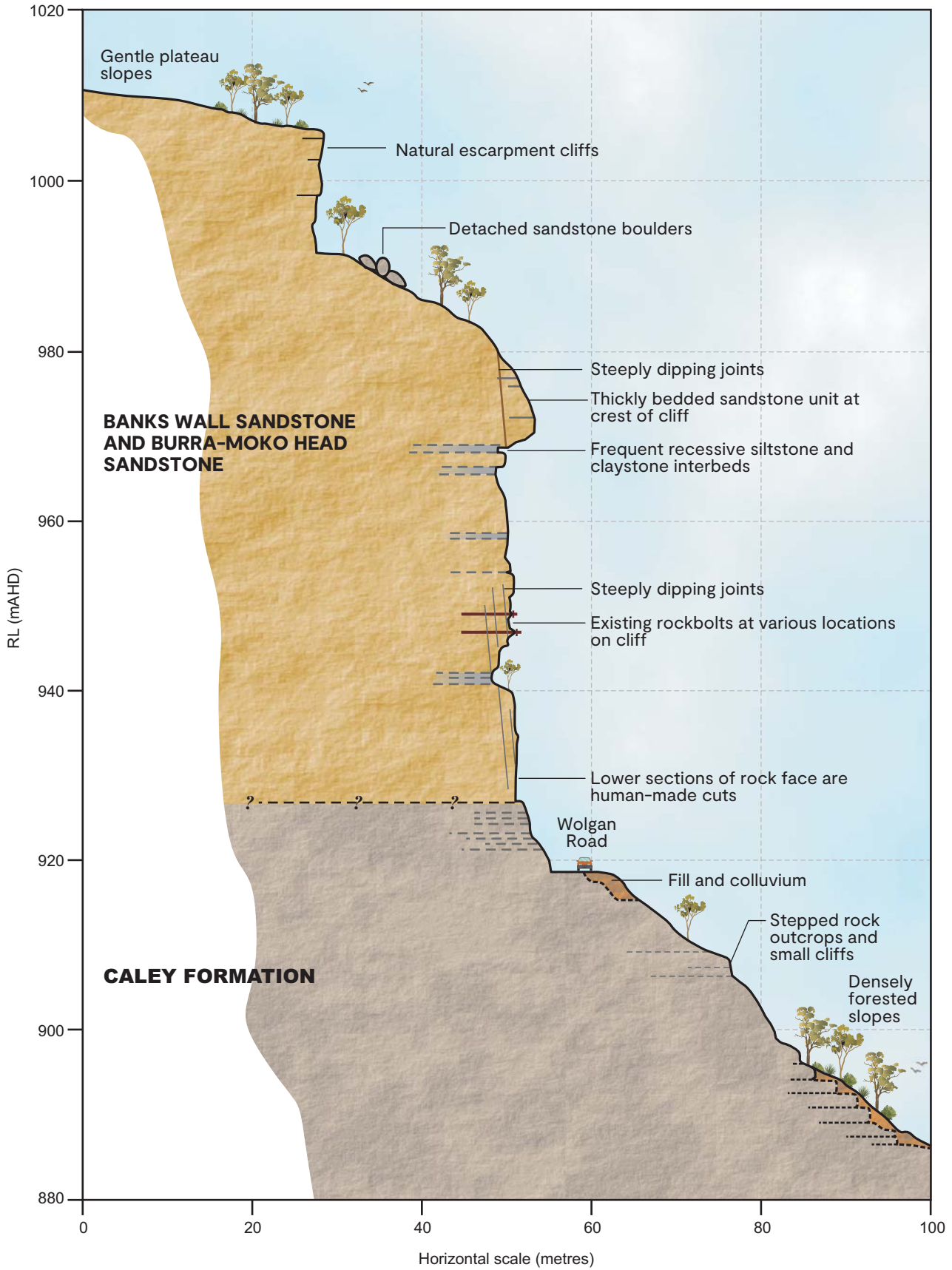
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Seamless Geology V2.5 (Colquhoun et al., 2025, Geological Survey of NSW) Created by: D. Field

Appendix B

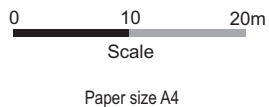
Illustrative cross sections

SECTION 1



NOTES

1. This figure is for illustrative purposes only.
2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate. Regional dip of strata is less than 1 degree towards northeast (not shown).



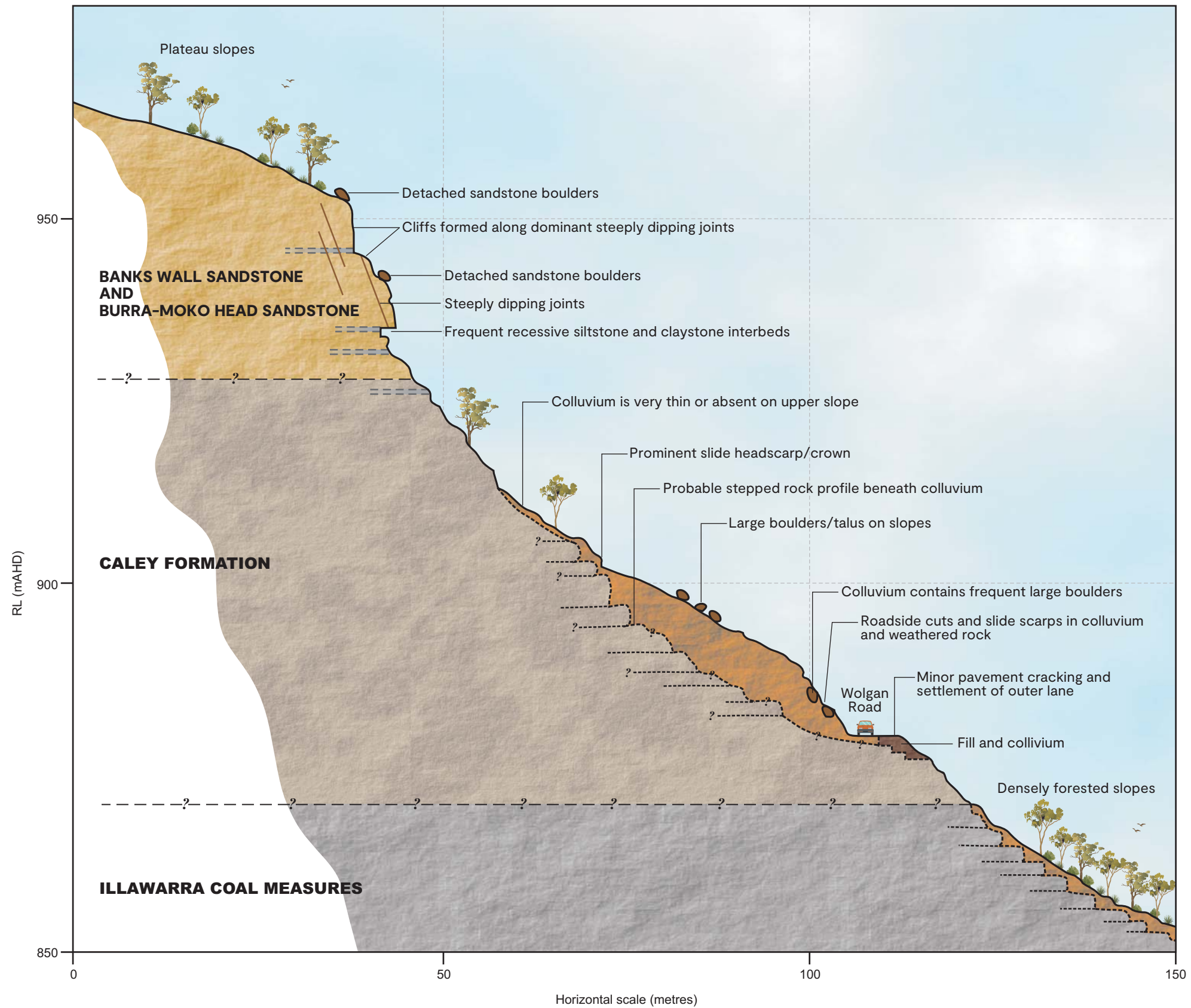
Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section A-A'
(Geotechnical Domain 1)

Project No. 12670695
Revision No. 0
Date 12/08/2025

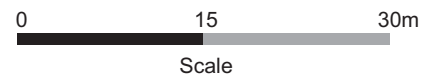
FIGURE B1

SECTION 2



NOTES

1. This figure is for illustrative purposes only.
2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate. Regional dip of strata is less than 1 degree towards northeast (not shown).



Paper size A3



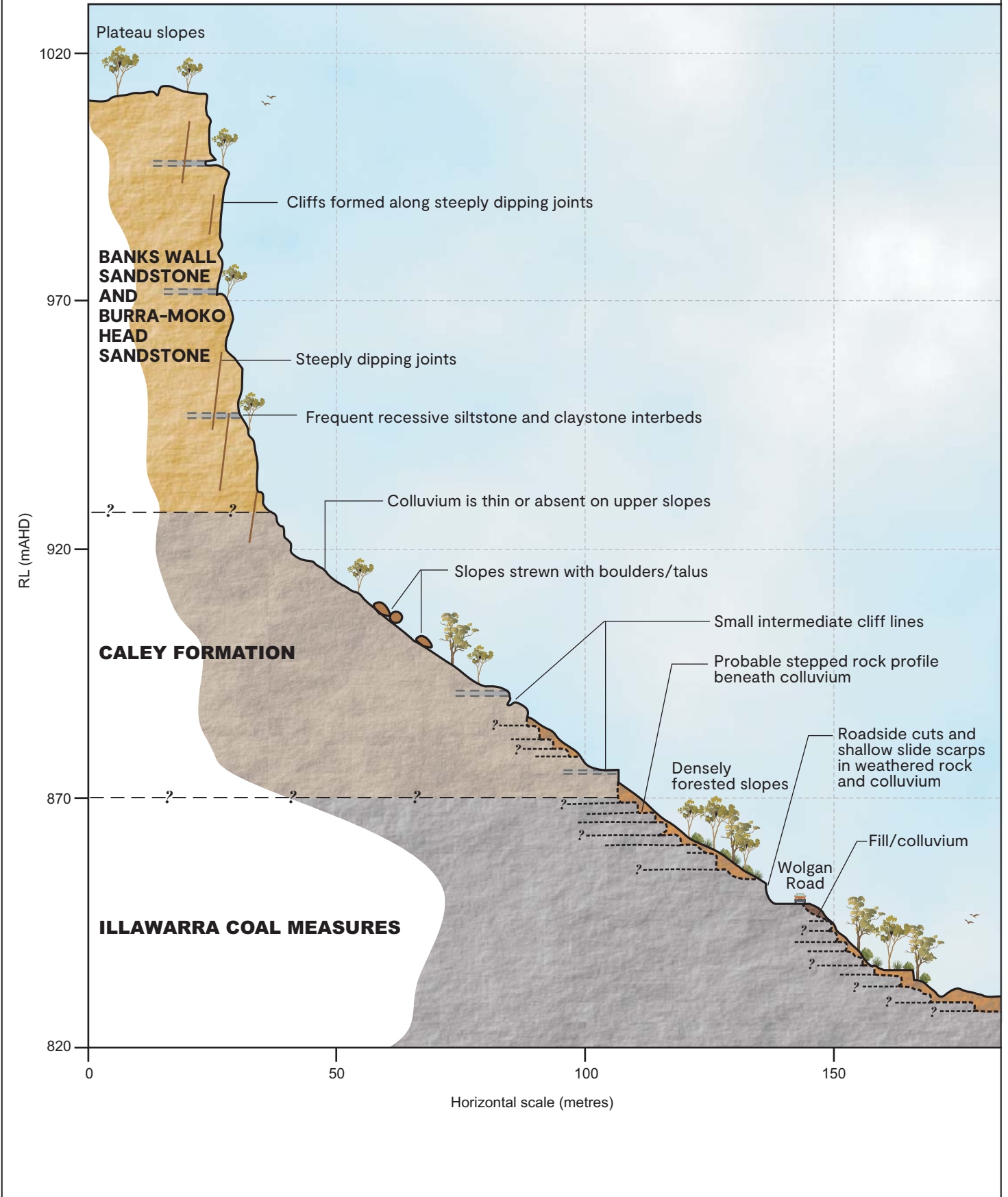
Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section B-B'
(Geotechnical Domain 2)

Project No. 12670695
Revision No. A
Date 12/08/2025

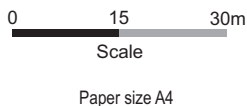
FIGURE B2

SECTION 3



NOTES

1. This figure is for illustrative purposes only.
2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate. Regional dip of strata is less than 1 degree towards northeast (not shown).



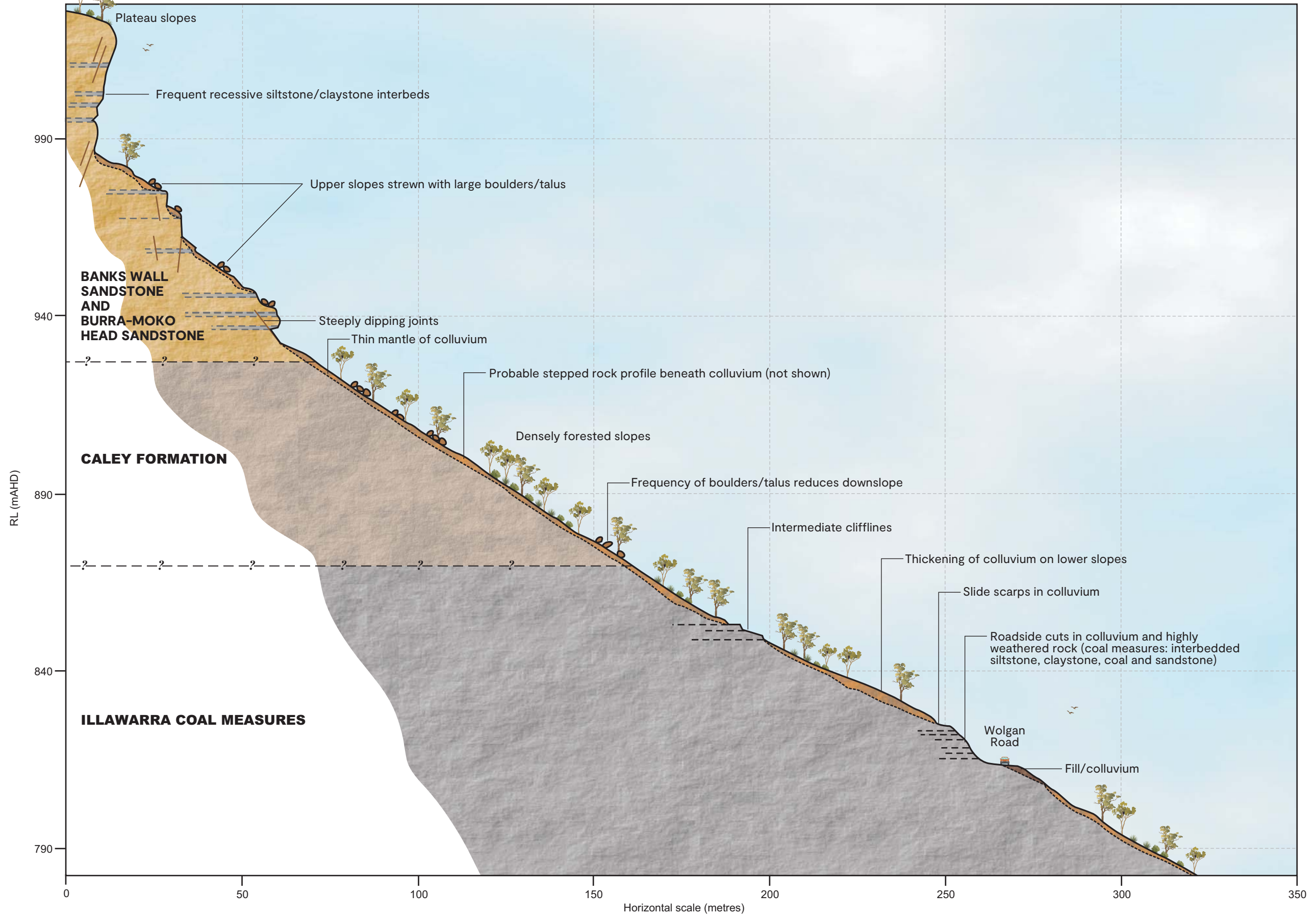
Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section C-C'
(Geotechnical Domain 3)

Project No. 12670695
Revision No. 0
Date 12/08/2025

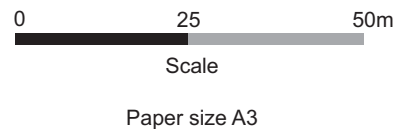
FIGURE B3

SECTION 4



NOTES

1. This figure is for illustrative purposes only.
2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate. Regional dip of strata is less than 1 degree towards northeast (not shown).



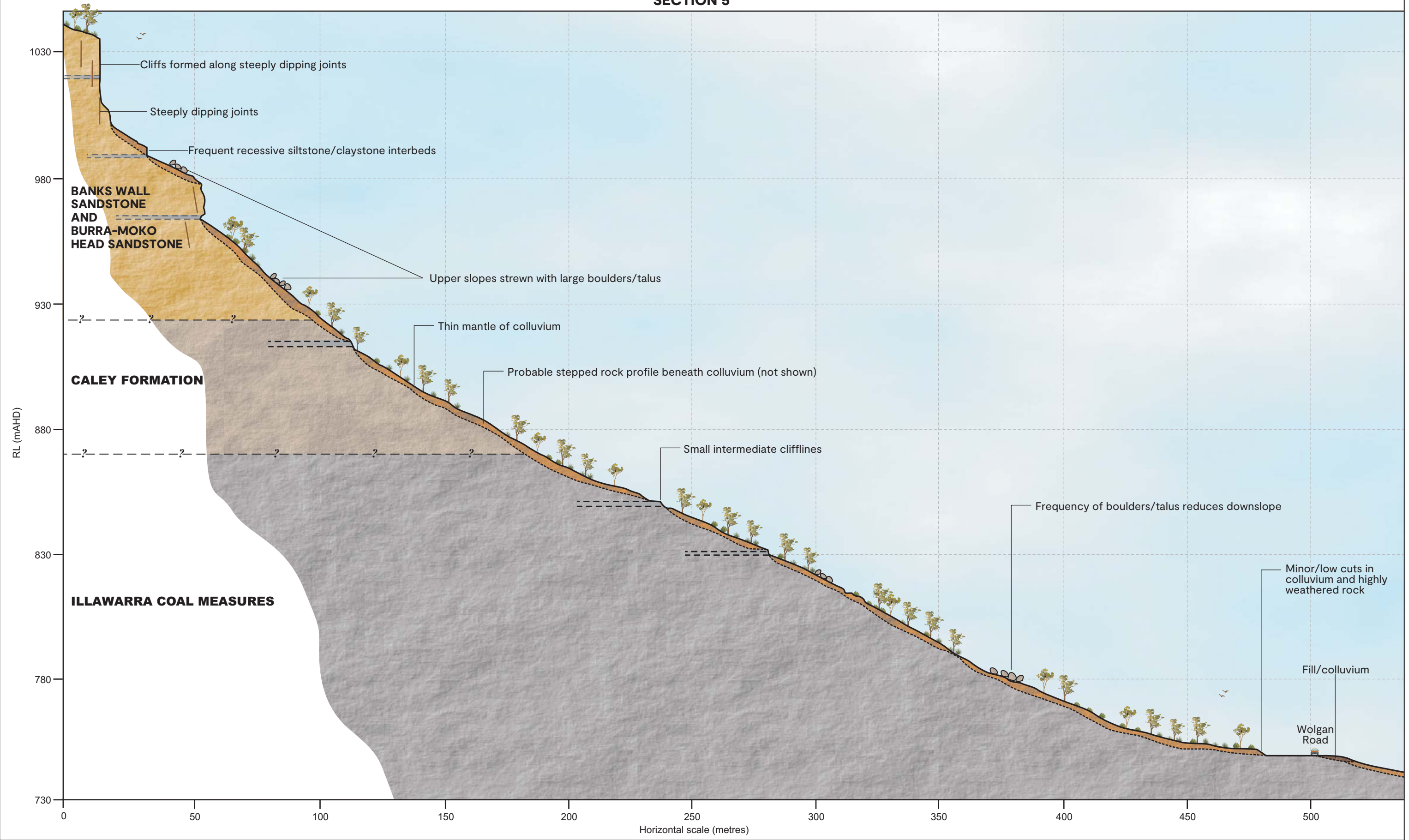
Lithgow City Council
Worgan Road Slope Risk Assessment

Project No. 12670695
Revision No. A
Date 12/08/2025

**Illustrative Geotechnical Section D-D'
(Geotechnical Domain 4)**

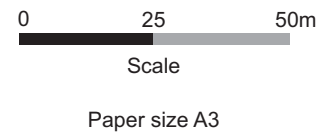
FIGURE B4

SECTION 5



NOTES

1. This figure is for illustrative purposes only.
2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate. Regional dip of strata is less than 1 degree towards northeast (not shown).



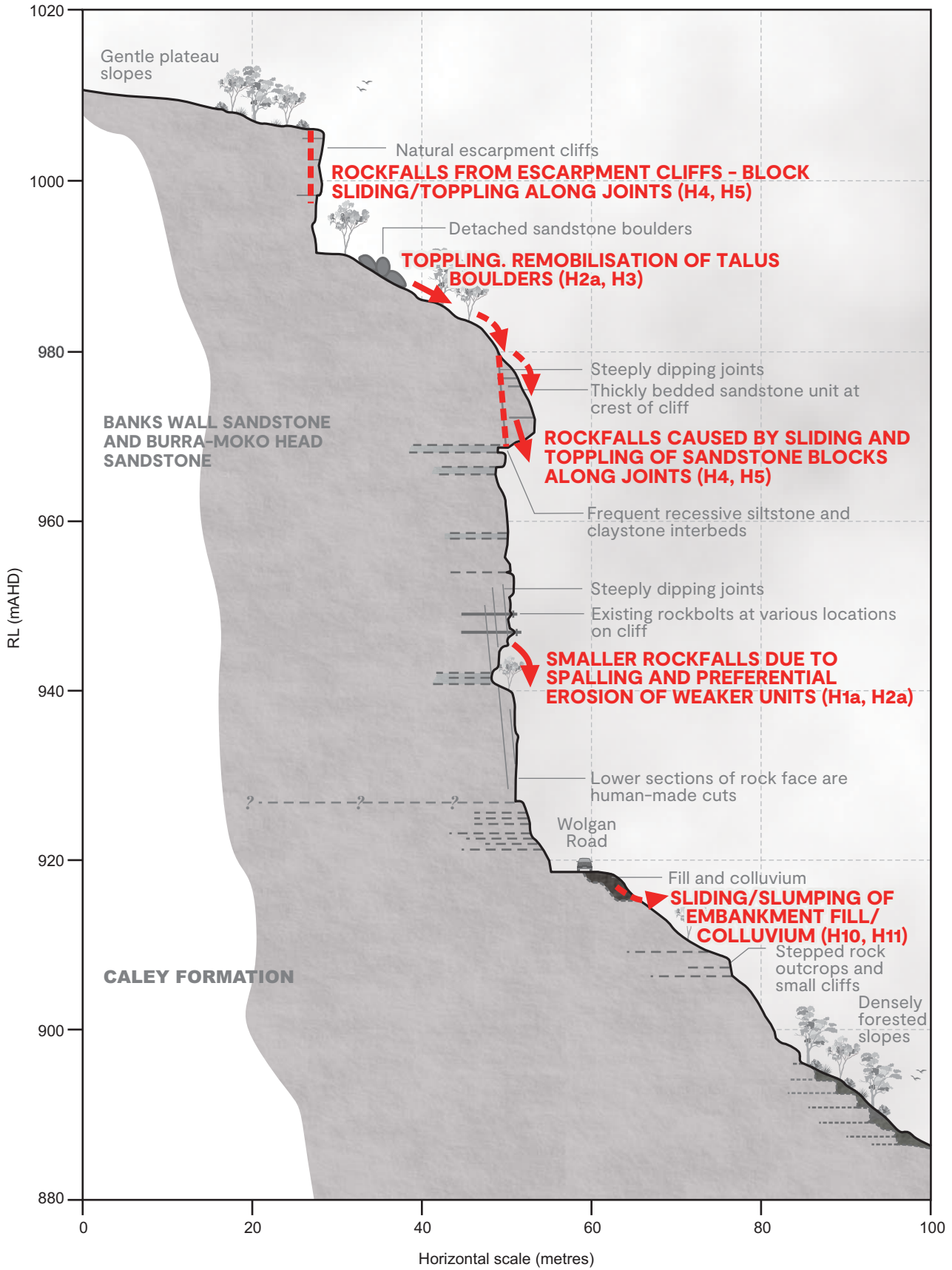
Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section E-E'
(Geotechnical Domain 5)

Project No. 12670695
Revision No. A
Date 12/08/2025

FIGURE B5

SECTION 1

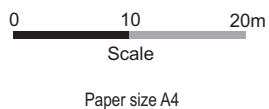


LEGEND

H2, H3 Hazard ID (Refer to accompanying GHD report)

NOTES

1. This figure is for illustrative purposes only.
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3. Geological stratigraphic boundaries are approximate. Regional dip of strata is less than 1 degree towards northeast (not shown).



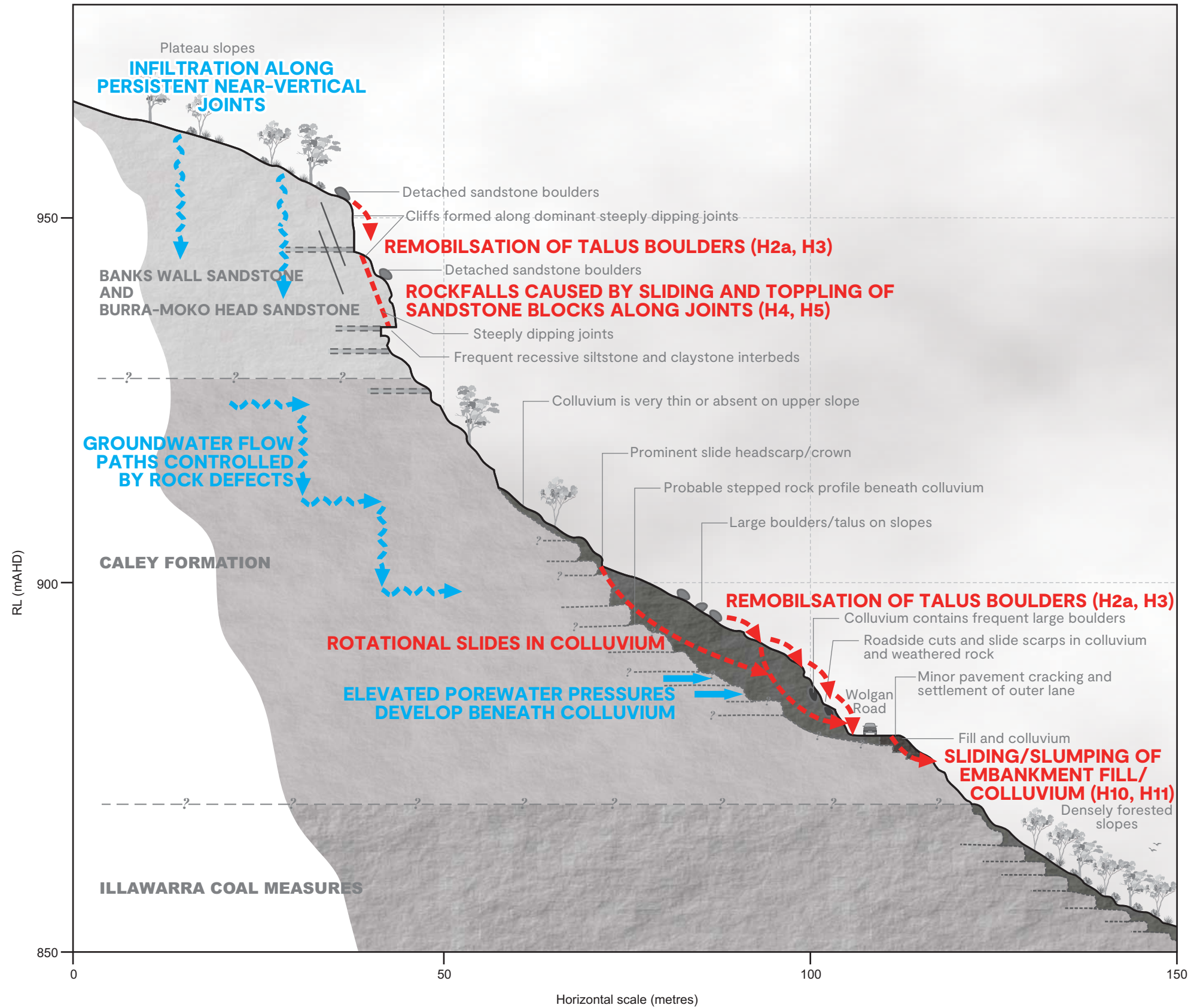
Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section A-A'
depicting landslide hazards

Project No. 12670695
Revision No. 0
Date 12/08/2025

FIGURE B6

SECTION 2

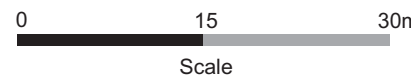


NOTES

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2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate.
Regional dip of strata is less than 1 degree towards northeast (not shown).

LEGEND

H2, H3 Hazard ID (Refer to accompanying GHD report)



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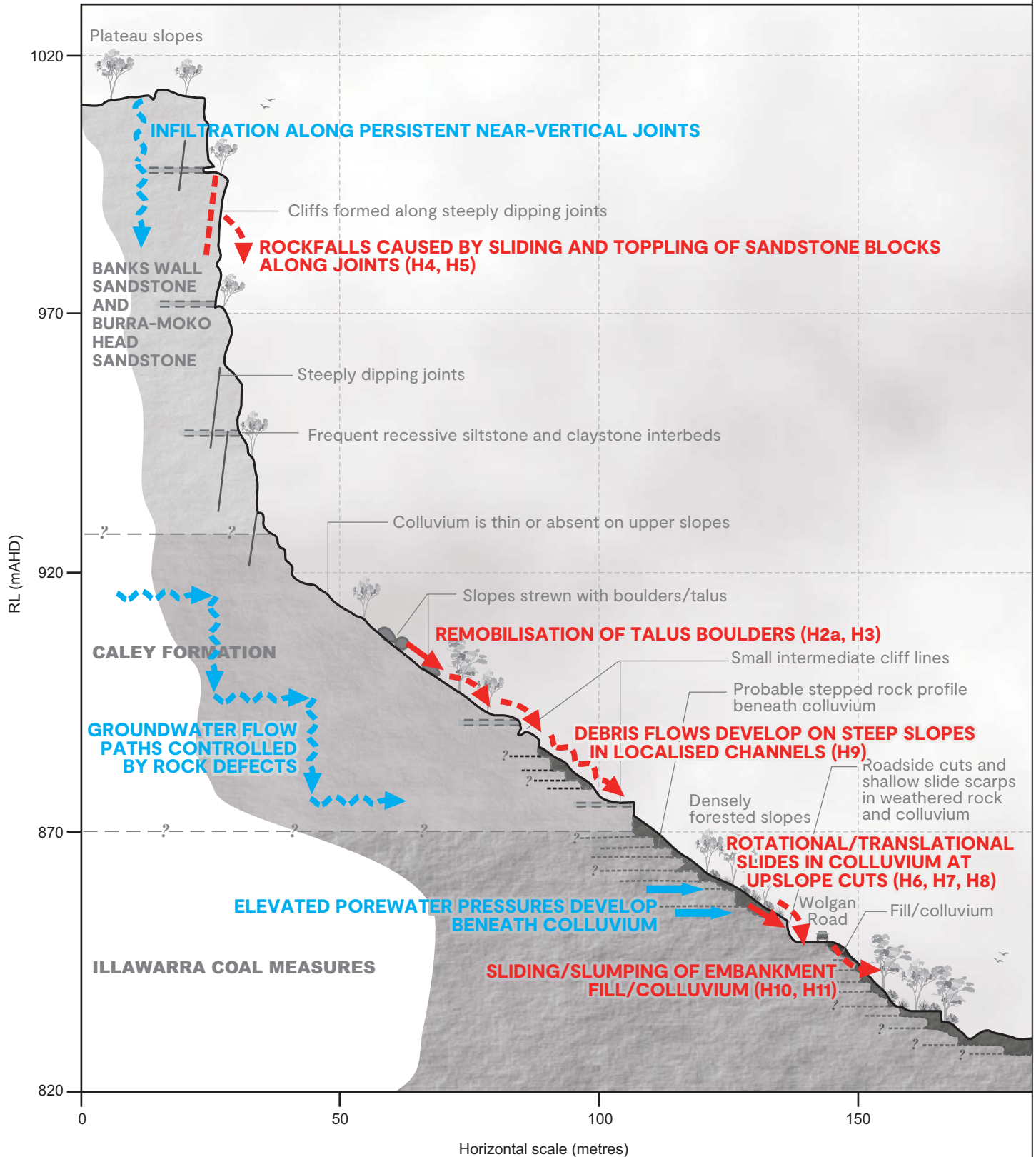
Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section B-B'
depicting landslide hazards

Project No. 12670695
Revision No. A
Date 12/08/2025

FIGURE B7

SECTION 3

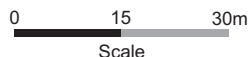


LEGEND

H2, H3 Hazard ID (Refer to accompanying GHD report)

NOTES

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2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate. Regional dip of strata is less than 1 degree towards northeast (not shown).



Paper size A4



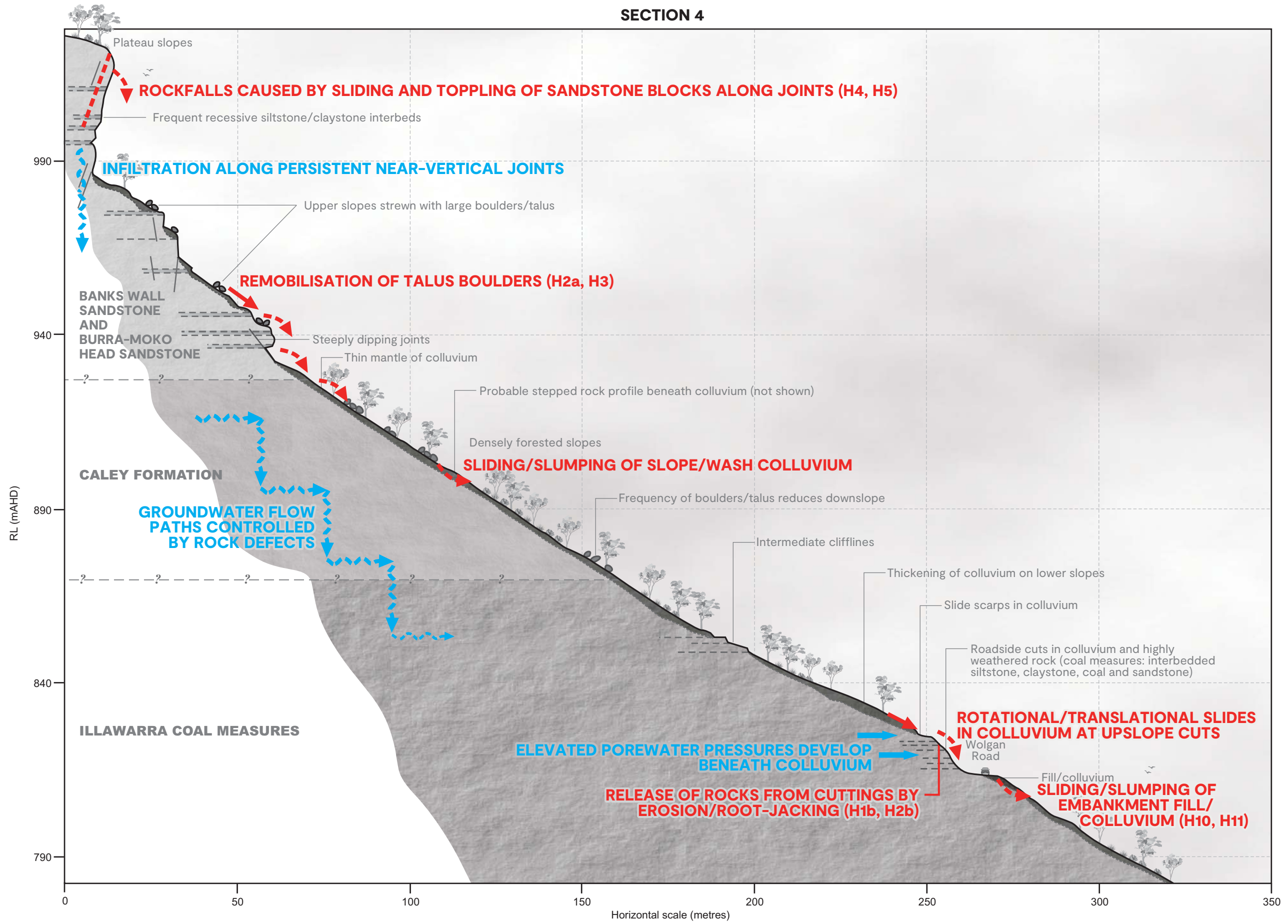
Lithgow City Council
Wolgan Road Slope Risk Assessment

Project No. 12670695
Revision No. 0
Date 12/08/2025

Illustrative Geotechnical Section C-C'
depicting landslide hazards

FIGURE B8

SECTION 4

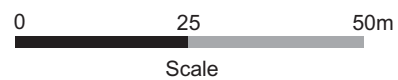


NOTES

1. This figure is for illustrative purposes only.
2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate.
Regional dip of strata is less than 1 degree towards northeast (not shown).

LEGEND

H2, H3 Hazard ID (Refer to accompanying GHD report)



Paper size A3



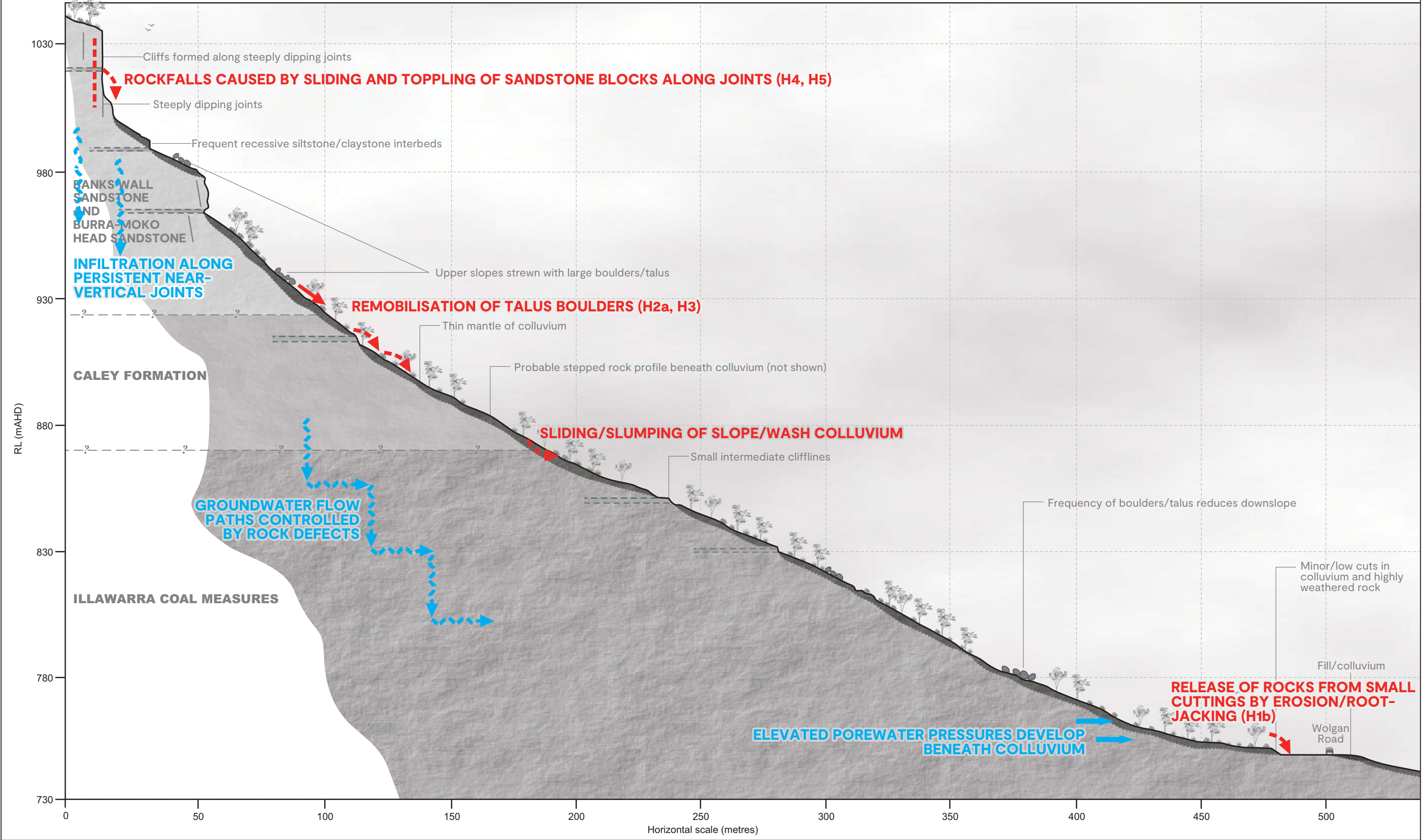
Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section D-D'
depicting landslide hazards

Project No. 12670695
Revision No. A
Date 12/08/2025

FIGURE B9

SECTION 5

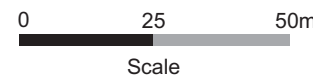


NOTES

1. This figure is for illustrative purposes only.
2. Refer to Figure A1 for location of section.
3. Geological stratigraphic boundaries are approximate.
Regional dip of strata is less than 1 degree towards northeast (not shown).

LEGEND

H2, H3 Hazard ID (Refer to accompanying GHD report)



Paper size A3



Lithgow City Council
Wolgan Road Slope Risk Assessment

Illustrative Geotechnical Section E-E'
depicting landslide hazards

Project No. 12670695
Revision No. A
Date 12/08/2025

FIGURE B10

Appendix C

Landslide inventory

Appendix C - Landslide Inventory

CLIENT: Lithgow City Council
 PROJECT: Wolgan Road Slope Risk Assessment
 PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
 DATE: 3/09/2025



Event ID	# of Reports	Qualifier	Day	Month	Year	Locality	Failure Mechanism	Debris Description	Dimension of Largest Rock (m)	Volume On Road (m ³)	Volume Displaced (m ³)	Scale of Failure (TfNSW)	Confidence	Source Reference
1	1	Circa	31	March	1889	-	Landslide	-	-	-	-	-	Low	(Sydney Morning Herald, 1989)
2	2	Circa	6	March	1911	-	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow Mercury, 1911)
3	3	Circa	13	May	1911	22 miles from Deanes depot on	Rockfall	Rocks - single	-	-	-	-	Low	(Sydney Morning Herald, 1911)
4	4	Circa	15	January	1917	-	Landslide	-	-	-	-	-	Low	(Lithgow Mercury, 1917)
5	2	On	28	July	1926	Near the top	Landslide	Earth	-	-	-	-	Low	(Lithgow Mercury, 1926), (Mudgee Guardian, 1926)
6	5	Circa	8	May	1942	-33.3157442673633, 150.1114;	Rockfall	Rock - multiple	-	-	-	-	Low	(Lithgow Mercury, 1942a), (Lithgow Mercury, 1942b), (Lithgow Mercury, 1942c), (Lithgow Mercury, 1942d), (Lithgow Mercury, 1942e)
7	1	On	2	April	1950	The Gap	Landslide	-	-	-	-	-	Low	(Lithgow Mercury, 1950a)
8	1	On	3	April	1950	The Gap	Landslide	-	-	-	-	-	Low	(Lithgow Mercury, 1950a)
9	1	On	28	June	1950	The Gap	Landslide	-	-	-	-	-	Low	(Lithgow Mercury, 1950b)
10	2	Circa	4	July	1950	Wolgan Gap Rd	Landslide	Earth and rocks	-	500	-	S3	Medium	(WSP Golder, 2025), (Keats, 2022)
11	3	Circa	22	July	1950	The Gap	Landslide	-	-	-	-	-	Low	(Sydney Morning Herald, 1950), (WSP Golder, 2025), (Lithgow Mercury, 1950c)
12	1	Circa	20	August	1952	The Gap	Landslide	-	-	-	-	-	Low	(Lithgow Mercury, 1952)
13	1	Circa	-	September	1986	The Gap	Landslide	Rocks and earth	-	-	-	-	Low	(Golder, 2006), (Coates, 2025c)
14	1	Circa	-	-	1990	-	Rockfall	Rocks - single	-	-	-	-	Low	(WVA, 2025b)
15	1	Circa	-	-	2002	-	Rockfall	Rocks - multiple	-	-	-	-	Low	(WVA, 2025b)
16	1	On	9	September	2008	Domain 1 (WSP Golder)	Rockfall	Rocks - multiple	1x1x1	30	-	S2	High	(WSP Golder, 2022a)
17	1	On	28	December	2009	The Gap	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023a)
18	1	On	27	January	2010	New Section of Road	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023b)
19	1	Circa	-	-	2010	Chainage 1300	Landslide	-	-	-	-	-	Low	(Wolgan Valley Community, 2025)
20	5	On	12	February	2010	The Gap	Landslide	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023c), (Lithgow City Council, 2023d), (Lithgow City Council, 2023e), (Lithgow City Council, 2023f), (Lithgow City Council, 2023g)
21	1	On	29	July	2010	Wolgan Rd	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023h)
22	1	On	21	October	2010	Top of The Gap	Rockfall	Rocks- multiple	1	0.5	-	S5	Medium	(Lithgow City Council, 2023i)
23	1	On	1	December	2010	The Gap	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023j)
24	3	On	6	December	2010	400m from the top	Landslide	Rocks and earth	-	-	-	-	Low	(Lithgow City Council, 2023k), (Lithgow City Council, 2023l), (Lithgow City Council, 2023m)
25	1	On	21	August	2011	-33.315043394609106, 150.11'	Rockfall	Rock - single	-	-	-	-	Low	(Lithgow City Council, 2023n)
26	1	On	29	September	2011	First corner of the gap	Rockfall	-	-	-	-	-	Low	(Lithgow City Council, 2012), (Lithgow City Council, 2023o)
27	2	On	6	October	2011	First corner of the gap	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023p), (Lithgow City Council, 2023q)
28	1	On	6	November	2011	Top of the Gap	Landslide	-	-	-	-	-	Low	(Lithgow City Council, 2023r)
29	1	On	26	November	2011	6kn from the intersection of the	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023s)
30	1	On	3	March	2012	Bottom of Gap Rd	-	-	-	-	-	-	Low	(Lithgow City Council, 2023t)
31	1	On	23	August	2012	The Gap	Rockfall	Rocks - multiple	>0.3x0.3x0.3	0.1	-	S5	Low	(Lithgow City Council, 2019a)
32	1	On	16	November	2012	Top of the Pass	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023u)
33	1	On	20	November	2012	Top of the pass	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019b)
34	1	On	22	November	2013	Top of The Gap	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019c)
35	3	On	17	February	2014	Top of the pass	Rockfall	Rocks - multiple	>0.3x0.3x0.3	0.1	-	S3	Medium	(Lithgow City Council, 2019d), (Lithgow City Council, 2019e), (Lithgow City Council, 2019f)
36	1	On	27	March	2014	-33.31115316811381, 150.109'	Rockfall	Rocks - multiple	-	4	144	S4	Medium	(Lithgow City Council, 2019g), (Diospatial, 2019)
37	1	On	4	April	2014	-33.30975825488106, 150.110'	Rockfall	-	3	-	-	-	Low	(Lithgow City Council, 2019h), (Lithgow City Council, 2023v), (Lithgow City Council, 2023w), (Lithgow City Council, 2023x)
38	1	On	7	December	2014	30 km from road to resort	Landslide	-	-	-	-	-	Low	(Lithgow City Council, 2019i)
39	1	On	11	January	2015	Wolgan Valley Road heading to	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019j)
40	1	On	21	April	2015	500m down the gap	Rockfall	Rocks - single	-	-	-	-	Low	(Lithgow City Council, 2023y)
41	1	On	18	July	2015	Past lidsdale tip	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023z)
42	1	On	1	September	2015	Woglan Rd on the windy part of	Landslide	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019k)
43	1	On	28	December	2015	The Gap	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019l)
44	1	On	11	March	2016	On the Pass	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019m)
45	1	On	2	June	2016	The Gap	Rockfall	Earth and rocks	-	-	-	-	Low	(Lithgow City Council, 2019n)
46	5	On	19	June	2016	-33.312810399871346, 150.11'	Rockfall	Rocks - multiple	11x5x2	130.41	145	S1	High	(Golder, 2019), (Beeh, 2016), (Diospatial, 2019), (Keats, 2022), (Lithgow City Council, 2019o), (Lithgow City Council, 2019p), (Lithgow City Council, 2019q), (WVA, 2025a)
47	1	On	26	July	2016	Half way down the Gap	Rockfall	Rocks - single	-	-	-	-	Low	(Lithgow City Council, 2023aa)
48	2	On	8	November	2016	Windy part of the road	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023ab), (Lithgow City Council, 2023ac)
49	1	On	30	March	2017	The Gap	Rockfall	Rocks and Trees	-	-	-	-	Low	(Lithgow City Council, 2019r)
50	2	On	4	June	2017	Just past the gap lookout	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019s), (Lithgow City Council, 2019t)
51	1	On	20	October	2017	Down from the lookout	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019u)
52	1	Prior	-	November	2017	-33.29927693713694, 150.123'	Embankment Failure	Earth and rocks	-	-	16	S5	High	(Golder, 2018)
53	1	Circa	-	-	2018	-33.31554925545117, 150.111'	Rockfall	Rockfall - single	0.3x0.3x0.3	0.3	-	S3	Medium	(WVA, 2025b)
54	2	On	19	April	2018	-33.314587070017474, 150.11'	Rockfall	Rocks - multiple	>0.3x0.3x0.3	7	-	S3	Low	(Lithgow City Council, 2019v), (Golder, 2019), (Lithgow City Council, 2019w)
55	1	On	28	June	2018	-33.315043394609106, 150.11'	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023ad)
56	1	On	17	December	2018	The Gap	Rockfall	Rocks and Trees	-	-	-	-	Low	(Lithgow City Council, 2019x)
57	1	On	24	January	2019	-	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019y)
58	1	On	20	February	2019	Closer to Lidsdale	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2019z)
59	2	Circa	11	August	2020	113012111256, 150.109937947	Rockfall	Rocks - multiple	0.8x0.8x0.8	12	-	S2	High	(WSP Golder, 2025), (Unknown Author, 2020), (Lithgow City Council, 2023ae)
60	2	On	4	January	2021	Wolgan Rd	Landslide	Rocks and earth	-	-	-	-	Low	(Lithgow City Council, 2023af), (Lithgow City Council, 2023ag)
61	1	Circa	12	March	2021	1671553356466, 150.11053580'	Rockfall	Rocks and earth	0.2x0.2x0.2	0.3	-	S5	Low	(Bowers, 2021a)
62	2	Circa	12	March	2021	1116316675798, 150.10992193'	Debris Flow	Rocks and earth	0.4x0.4x0.4	236	-	S3	High	(Bowers, 2021a), (Coates, 2025)
63	1	Circa	12	March	2021	?	Rockfall	Rocks - multiple	0.1x0.1x0.1	0.1	-	S4	Low	(Bowers, 2021a)

Appendix C - Landslide Inventory

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025




Event ID	# of Reports	Qualifier	Day	Month	Year	Locality	Failure Mechanism	Debris Description	Dimension of Largest Rock (m)	Volume On Road (m ³)	Volume Displaced (m ³)	Scale of Failure (TfNSW)	Confidence	Source Reference
64	2	On	23	March	2021	Wolgan Rd	Rockfall	Rocks - multiple	-	-	-	-	Low	(Lithgow City Council, 2023ah), (Lithgow City Council, 2023ai)
65	1	Prior	15	August	2021	300m from top	Rockfall	Rocks- multiple	-	-	-	-	Low	(Ebersoll, 2021)
66	1	On	24	August	2021	Face 5 (Golder)	Landslide	Rocks and earth	0.7x0.4x0.4	5	5	S5	High	(Lithgow City Council, 2021), (Lithgow City Council, 2023aj)
67	1	Circa	29	November	2021	1751669761624, 150.110693031	Landslide	Earth	-	-	6	S5	High	(Bowers, 2021b)
68	2	Circa	10	December	2021	15678718058635, 150.11132621	Embankment Failure	Rocks and earth	-	-	31	S5	High	(Golder, 2021), (Diospatial, 2021), (Lithgow City Council, 2023ak)
69	2	Circa	10	December	2021	894197758412, 150.113439901	Landslide	Rocks and earth	-	-	11	S5	High	(Golder, 2021), (Lithgow City Council, 2023al)
70	1	Circa	10	December	2021	1012583745594, 150.10998170	Embankment Failure	Rocks and earth	-	-	16	S5	High	(Diospatial, 2021)
71	2	On	9	March	2022	193140759039, 150.112427402	Landslide	Rocks and earth	-	39	79	S5	High	(Diospatial, 2022a), (Bowers, 2022a)
72	1	Circa	11	March	2022	985628113783, 150.111648926	Rockfall	Rocks and earth	0.4x0.2x0.1	2	2	S5	High	(Bowers, 2022b)
73	1	Circa	June	2022	98999704932, 150.110441987	Embankment Failure	Rocks and earth	-	-	-	230	S3	High	(WSP Golder, 2022a), (GHD, 2025), (Diospatial, 2022a)
74	1	Prior	29	August	2022	894197758412, 150.113439901	Landslide	Rocks and earth	-	-	113	S4	High	(Diospatial, 2022a)
75	1	On	16	September	2022	4575961765414, 150.11115268	Embankment Failure	Rocks and earth	-	-	0.2	S5	Medium	(Lithgow City Council, 2023am)
76	5	On	3	October	2022	196766092244, 150.112012741	Landslide	Rocks and earth	3.5x3x0.9	200	1100	S3	High	(Beeh, 2022b), (Bowers, 2022d), (Diospatial, 2022b), (Keats, 2022), (Lithgow City Council, 2023an), (Lithgow City Council, 2023ao), (Lithgow City Council, 2023ap)
77	1	Circa	5	November	2022	193140759039, 150.112427402	Landslide	Rocks and earth	-	-	66	S4	High	(Bowers, 2022c), (Diospatial, 2022b)
78	1	Circa	5	November	2022	894197758412, 150.113439901	Landslide	Rocks and earth	-	-	345	S3	High	(Diospatial, 2022b)
79	1	Circa	5	November	2022	9857875313114, 150.11044978	Landslide	Rocks and earth	1.3x0.7x0.7	-	67	S4	High	(Diospatial, 2022b)
80	1	Circa	5	November	2022	820176238678, 150.114063885	Landslide	Rocks and earth	-	-	15	S5	High	(Diospatial, 2022b)
81	1	Circa	5	November	2022	798302521563, 150.114221304	Landslide	Rocks and earth	-	-	141	S4	High	(Diospatial, 2022b)
82	1	Circa	5	November	2022	753762390974, 150.114532347	Landslide	Rocks and earth	-	-	13	S5	High	(Diospatial, 2022b)
83	1	Circa	5	November	2022	0646294519713, 150.11517150	Landslide	Rocks and earth	-	-	82	S4	High	(Diospatial, 2022b)
84	1	Circa	5	November	2022	1603814228713, 150.115454091	Landslide	Rocks and earth	-	-	63	S4	High	(Diospatial, 2022b)
85	1	On	5	November	2022	180907563373, 150.110443651	Landslide	Rocks, earth, trees	5x5x5	-	10000	S2	High	(WSP Golder, 2025), (WSP Golder, 2022b), (Beeh, 2022c), (Diospatial, 2022b)
86	1	Circa	4	January	2023	-	Landslide	-	-	-	-	-	Low	(Lithgow City Council, 2023aq)
87	1	Circa	13	April	2023	-	Landslide	-	-	-	-	-	Low	(Lithgow City Council, 2023ar)
88	1	On	23	May	2025	973248747987, 150.110844292	Rockfall	Rockfall - single	1.4x0.6x0.4	0.3	-	S2	High	(Coates, 2025)
89	1				11/22-07/25	156263653763, 150.111306831	Rockfall	Rockfall - multiple	0.7x0.3x0.3	0.3	-	S3	High	(Coates, 2025)
90	1				11/22-07/25	-	Rockfall	Rockfall - single	0.5x0.4x0.3	0.1	-	S4	High	(Coates, 2022-2025)
91	1				11/22-07/25	-	Rockfall	Rockfall - multiple	0.7x0.5x0.2	0.1	-	S4	High	(Unknown Author, 2022-2025)
BF2019	1	Post		December	2019		Bushfires	-	-	-	-	-	-	(WSP Golder, 2022a)
BL1969	1	Circa	-	-	1962		Blasting	-	-	-	-	-	-	(Chalk, 2025), (WSP Golder, 2025)

The weather having now cleared, a better idea of the damage done through the late heavy rainfall may be gathered. Heavy landslips on the roads at Hartley Vale and Wolgan Gap have occurred, and gangs of men are now engaged effecting repairs. Near

Event 1 - Newspaper Cut-out from Sydney Morning Herald, 31/03/1889.

Some rather serious falls of rock occurred along the Wolgan Gap road during the recent wet weather. In consequence, the shire maintenance men were kept busy seeing that the traffic was not impeded.

Event 2 - Newspaper Cut-out from Lithgow Mercury, 06/03/1911.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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At one place in the middle part of the track, a solitary spike left embedded in the perpendicular cliff face, some 30ft above the rails, marks the spot where a young fellow, during the construction of the line, fell headlong, and was instantly killed, the rock having broken away from under him. At other

Event 3 - Newspaper Cut-out from Sydney Morning Herald, 13/05/1911.

ENGINEER'S REPORT.

The engineer (Mr. G. F. Allman) reported having inspected roads in the following localities during the past month:—Mt. Victoria, Hartley, Brown's Gap, Hassan's Walls, Hartley Vale, Bowenfels, Newnes, Thompson's Creek, Portland, and the new dam, Portland water works. The surfaces of the roads generally had improved, except, perhaps, at Wolgan Gap, and in one or two other parts, where violent storms occurred, undoing much of the repairs recently effected. In fact, throughout the year the unprecedented rainfall and storms

Event 4 - Newspaper Cut-out from Lithgow Mercury, 15/01/1917.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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WOLGAN COLLIERY DEVELOPMENT.


A WORKMAN INJURED.

On Wednesday afternoon a serious accident befel James Murray, who was employed at No. 2 Vale of Clwydd colliery at mental work when he was struck by a fall-Wolgan Gap. He was engaged in developing stone. When he was extricated it was found that his left leg was fractured. The ambulance removed him to Lithgow hospital.

Event 5 - Newspaper Cut-out from Lithgow Mercury, 28/07/1926.

A man named James Murray, was struck by falling earth at Wolgan Gap, last week, and sustained a fractured leg.

Event 5 - Newspaper Cut-out from Mudgee Guardian, 05/08/1926.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
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Portion Of Wolgan Gap Road May Collapse

A fall of rock from the cliff on the Wolgan Gap road has made portion of the road, 50 yards from the top, dangerous to users, with the result that Blaxland Shire Council has advertised it as being unsafe. It warns that persons using the road do so at their own risk.

When the road was first constructed it was built around the face of the cliff, a wooden revetment, or retaining wall, having to be put in. Mr. H. Bursill, shire engineer, states that a fall of rock has swept away

part of this revetment, and it is feared that if any more of the cliff face, which is in a very fractured state, breaks it may sweep away the whole of this portion of the road. If this should occur it will cause the Wolgan Valley people considerable hardship, as the road is their only means of egress.

Mr. Bursill has been instructed to further investigate the position, and a detailed report will be submitted to a meeting of the Shire Council to be held on Wednesday next.

Event 6 - Newspaper Cut-out from Lithgow Mercury, 08/05/1942.

Wolgan Gap Landslide Difficult Problem

In reporting on the serious landslide on the Wolgan Gap road which occurred last week, the assistant engineer (Mr. H. Bursill) informed the Blaxland Shire Council that a section of the wooden revetment, about 50 yards from the top of the cliff, had been swept away. The road width is dangerous, and the position is further aggravated by the prospect of some overhanging rock likely to fall at any time.

...ed to fall on the road. It also outlines the road back as well. In regard to the revetment, he would be a party to putting a stick of dynamite in it. People were living there and must get in and out of the road and Council could not foot the bill. What would be the Council's responsibility if a heavy lorry slid off the cliff into the valley?

Mr. Riley said National Road Board would be willing to assist the Council if possible.

Event 6 - Newspaper Cut-out from Lithgow Mercury, 14/05/1942.



Client: **Lithgow City Council**
 Project: **Wolgan Road Slope Risk Assessment**
 Project #: **12670695**
 Location: **Wolgan Rd, NSW**

Author: **JB**
 Date: **26/08/2025**
 Checked: **AJH**
 Date: **3/09/2025**

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Wolgan Gap Road Fall Is Costly

Following on Blaxland Shire Council's recent representations to Mr. H. Knight, M.L.A., re the bad slip on the Wolgan Gap, a joint inspection was made by the district works engineer and the Blaxland Shire engineer. The taking down of the entire cliff face was recognised as the only all-time solution, but in view of the heavy expenditure involved and the lack of plant to do the job, it was decided that the best way out would be to dislodge the dangerous overhanging rocks and then re-build in stone the broken-away wooden revetment. Even this job was considered to be of considerable magnitude, and it was estimated that the cost would be in the vicinity of £600. Warning signs have been placed in position at the top and bottom of the pass, but otherwise no remedial measures of any kind have been attempted by the Council.

roads in the shire, and if they took £200 out of that sum there would be £11 8/4 for the remaining six months of the financial year.

The engineer said this was something that the Council had not budgeted for.

Cr. Baaner: We need £2,000 for the roads down Hartley way alone.

Cr. Kremer: One has no need to go to Luna Park for thrills. All he would have to do would be to take a trip over Cullen-road. (Laughter).


Cr. Baaner moved that they accept the £400 grant offered by the Government and spend it on Wolgan Gap. Seconded by Cr. Morris and carried.

Cr. Neubeck suggested asking the National Oil Pty. for a grant, and Cr. Kremer then moved that Council ask the company for a subsidy of £50 towards remaking the road. Seconded by Cr. Morris and carried.

Event 6 - Newspaper Cut-out from Lithgow Mercury, 12/06/1942.

Following the landslide at Wolgan Gap some months ago repairs are to be effected, commencing on Monday week. The work is being financed partly by the Shire, National Oil and the Government. From that date until further notice the road will be closed to vehicular traffic, but special journeys may be made subject to the ganger in charge giving his consent.

Event 6 - Newspaper Cut-out from Lithgow Mercury, 21/08/1942.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
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Nash's gang has been mainly engaged on Department of Main Roads work. The Wolgan Gap slip has been repaired by Butfield's gang: at present they are engaged in putting in a large pipe culvert in lieu of a damaged wooden one, on the Wang-Portland road. Other work carried out

Event 6 - Newspaper Cut-out from Lithgow Mercury, 12/11/1942.

The greatest damage is on the Wolgan Gap, with landslides over a distance of 600 yards. This is a serious matter for the residents of the Valley. One large poultry farm will have to go out of business if the road is not soon made traffickable as no feed is available.

Mr. J. Dornier, jr., and his wife, were caught in their utility between two landslides on the Gap on Sunday evening. They had to abandon the utility and walk to Lidsdale.

Event 7 - Newspaper Cut-out from Lithgow Mercury, 02/04/1950.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
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On Monday morning Mr. Dorner walked back down the Gap to try to get his truck and take it back to his father's place down the valley.

However he found the mountain side behind the truck had given way as well and the truck is now between two landslides.


Event 8 - Newspaper Cut-out from Lithgow Mercury, 03/04/1950.

Reporting on the Wolgan-road, he gave an outline of the enormous damage caused by flood rains. Following extensive landslides at the Gap early in April, a heavy dozing unit had been hired and was put into operation when the wather cleared. The Gap was cleared by April 15, but restoration of the collapsed retaining wall and flood damage in other parts of the shire were financially beyond the Council.

No reply has yet been received to an application to the Government for financial assistance. The application was lodged after Mr. Kenna and an officer of the Public Works Department had completed an inspection of damage.

Mr. Kenna said that on June 28 a further landslide occurred. Because of the rain and snow it was not possible to use earth-moving equipment until July 4. A track was cleared around the toe of the slide by the evening of that day, and the balance of the material removed on the following day.

Event 9 - Newspaper Cut-out from Lithgow Mercury, 12/07/1950.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
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Battle Imminent in Korea

Russian-built armor and American-made the latest anti-tank weapons on each other for a showdown

may well decide whether the protracted, says A.A.P. Reuters Arthur last night announced still holding the key town of Seoul, the east flank of which is Korean Communist columns.

South Koreans, before the arrival of American reinforcements

Wolgan's Plight-- Road Blocked, Food Needed

Marooned when a thousand tons of earth and rock avalanched down the mountainside, blocking their only access road, six families in the Wolgan Valley township of Newnes are running desperately short of food.

REJECT UNION WITH MINERS

NEWCASTLE, Mon. The Mining Mechanics' Association has again rejected a proposal to amalgamate with the Miners' Federation.

The decision made by a two to one majority, was announced to-day by the returning officer, Miss S. Wilson.

The mechanics first rejected amalgamation in 1947 following conferences between their officials and the central executive of the Miners' Federation.

The Federation favored amalgamation as part of a plan to establish one union in the coal industry. The decision to take a second ballot last week was made by the delegate board of the Mechanics' Association. Officials expected that amalgamation would be accepted.

Some officials said to-day that the decision against amalgamation was

Event 10 - Newspaper Cut-out from Lithgow Mercury, 04/07/1950.

Warren police expect the Macleay River will reach its peak on Sunday or Monday. The level to-night was 30ft. 10in.

over the decking of the bridge, which is the only normal access to Glen Davis.

Newnes Cut Off by Landslides

Two residents of Wolgan Valley reached Lithgow to-day after struggling over miles of road cut off by landslides.

The men are Messrs. R. W. Webb and A. Cartledge. They said landslides on the Gap Road had again cut off Newnes township. The valley was isolated only a fortnight ago by a landslide.

the watershed of the Macleay River, further flooding of Kempsey can be expected.

There was a three foot rise in the Macleay at Kempsey to-day, but it caused no damage.

Large sheets of water still cover vast areas of land in Kempsey following recent floods.

At Coff's Harbour, which has had nearly 26 inches this week, six homes near the railway sta-

Event 11 - Newspaper Cut-out from Lithgow Mercury, 22/07/1950.



Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Project #: 12670695
 Location: Wolgan Rd, NSW

Author: JB
 Date: 26/08/2025
 Checked: AJH
 Date: 3/09/2025

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Landslides have isolated the former shale oil township of Newnes for the second time in a fortnight.

A farmer, Jim Dormer, is ill in bed after being washed from his truck when trying to cross the flooded Wolgan River. He was trying to take feed over the river to LINDI fowls.


The truck is now submerged in the flooded river.

Event 11 - Newspaper Cut-out from Sydney Morning Herald, 22/07/1950.

Since July 14, conditioins at Wolgan Gap have rapidly deteriorated. Outlining the position at today's monthly meeting of Blaxland Shire Council, the engineer, Mr. Arthur Kenna declared:

"Further landslides have occurred and the collapse of the retaining walls of the hill side of the road are much more extensive. Cracks in the pavement at 'Hanging Rock' indicate that a further fall at this point is imminent."

Event 11 - Newspaper Cut-out from Lithgow Mercury, 09/08/1950.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
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Reports of the biggest flood in living memory in Wolgan Valley's ghost town of Newnes reached Lithgow yesterday afternoon when a valley farmer, Mr. J. Dormer, reached the city after clearing a landslide on the Wolgan-road Gap to get through by jeep.

Event 12 - Newspaper Cut-out from Lithgow Mercury, 20/08/1952.



Event BL1969 - Aerial Imagery of debris caused by Blasting in 1962/63, captured 1969.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
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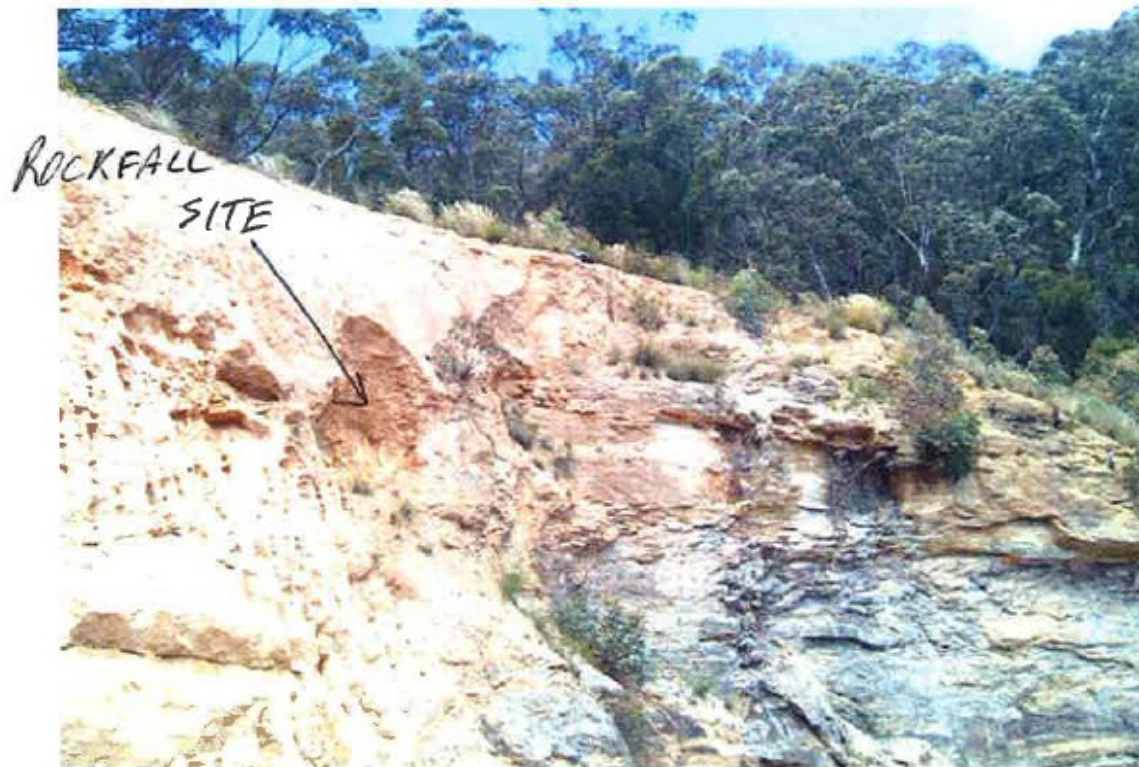


Event BL1969 - Aerial Imagery of debris caused by Blasting in 1962/63, captured 1969.



Event 16 - Photo of rockfall debris, taken 09/09/2008.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
		Checked: AJH Date: 3/09/2025
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Event 26 - Photo from Golder report showing evidence of rockfall on 29/9/2011, taken 2/2/12.



Event 36 - Aerial Photogrammetry of rockfall, captured 21/02/2019.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
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Event 36 - Aerial Photogrammetry of rockfall, captured 21/02/2019.



Event 46 - Aerial Photogrammetry of rockfall, captured 21/02/2019.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
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Event 46 - Aerial Photogrammetry of rockfall, captured 21/02/2019.



Event 46 - Resident's photo of rockfall, taken 20/06/2016.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 46 - Resident's photo of rockfall, taken 20/06/2016.



Event 46 - Resident's photo of rockfall, taken 20/06/2016.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
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Event 52 - Photo of Embankment Failure, taken from Golder remediation report, 2018.



Event 52 - Photo of Embankment Failure, taken from Golder remediation report, 2018.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 54 - Council photo taken post rockfall clean-up, rockfall occurred 19/04/2018.



Event BF2019 - Photo taken amidst road clean-up after 2019 bushfires.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
		Checked: AJH Date: 3/09/2025
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Event 59 - Council photos of rockfall debris, taken around 11/08/2020.



Event 59 - Council photos of rockfall debris, taken around 11/08/2020.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
		Checked: AJH Date: 3/09/2025
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Event 61 - Resident's photo showing remenants of rockfall debris, taken 12/03/2021.



Event 62 - Resident's photo showing debris flow event, taken 12/03/2021.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 63 - Resident's photo showing remnants of rockfall debris, taken 12/03/2021.



Event 66 - Council photo showing landslide that occurred on 24/8/2021.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
		Checked: AJH Date: 3/09/2025
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Event 66 - Council photo showing landslide that occurred on 24/8/2021.



Event 67 - Resident's photo showing embankment failure, taken 29/11/2021.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 68 - Aerial Photogrammetry showing embankment failure, captured 13/12/2021.



Event 68 - Aerial Photogrammetry showing embankment failure, captured 13/12/2021.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 69 - Photo from Golder Report showing landslide, taken 13/12/2021.



Event 69 - Aerial photogrammetry showing embankment failure, captured 13/12/2021.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 70 - Aerial photogrammetry showing embankment failure, captured 13/12/2021.



Event 71 - Aerial photogrammetry showing landslide, captured 29/08/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 71 - Resident's photo showing landslide, taken 09/03/2022.



Event 71 - Resident's photo showing landslide, taken 11/03/2022.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
		Checked: AJH Date: 3/09/2025
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Event 72 - Resident's photo showing rockfall, taken 11/03/2022.



Event 73 - Aerial photogrammetry showing embankment failure, captured 29/08/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 73 - Aerial photogrammetry showing embankment failure, captured 29/08/2022



Event 73 - Photo from Golder report showing embankment failure, taken 10/10/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 73 - Photo from GHD report showing embankment failure, taken 18/02/2025.



Event 74 - Aerial photogrammetry showing landslide, captured on 29/08/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 74 - Aerial photogrammetry showing landslide, captured on 29/08/2022.



Event 76 - Aerial photogrammetry showing landslide, captured on 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 76 - Aerial photogrammetry showing landslide, taken 15/11/2022.



Event 76 - Resident's photo showing landslide debris on road, taken 06/10/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 76 - Resident's photo taken after clean-up, taken 19/10/2022.



Event 76 - Resident's dashcam footage taken after clean-up, taken 08/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 77 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 77 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 77 - Resident's dashcam footage taken after clean-up, taken 08/11/2022.



Event 78 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 78 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 79 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 79 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 80 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 80 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 81 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 81 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 82 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 82 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 83 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 83 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 84 - Aerial photogrammetry showing landslide, captured 15/11/2022.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 84 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Event 85 - Aerial photogrammetry showing landslide, captured 15/11/2022.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 85 - Aerial photogrammetry showing landslide, captured 15/11/2022.



Date & Time: Thu, 10 Nov 2022, 12:57:19 AEDT
 Position: 56 H 230969 6310454 ($\pm 200.0m$)
 Altitude: 893m ($\pm 60.2m$)
 Datum: WGS-84
 Azimuth/Bearing: 119° S61E 2116mils Magnetic ($\pm 16^\circ$)
 Elevation Angle: +07.2°
 Tilt/roll Angle: -00.3°
 Zoom: 1.0X
 Return

Event 85 - Photo of landslide from WSP report, taken 10/11/2022.


	Client: Lithgow City Council Project: Wolgan Road Slope Risk Assessment Project #: 12670695 Location: Wolgan Rd, NSW	Author: JB Date: 26/08/2025
		Checked: AJH Date: 3/09/2025
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Event 85 - Resident's photo of landslide, taken 09/11/2022.



Event 88 - Photo of rockfall taken from Short Video made by resident, taken 23/05/2025.


	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 89 - Resident's photo of rockfall, taken post road closure (11/2025), exact date unknown.




Event 90 - Resident's photo of rockfall, taken post road closure (11/2025), exact date unknown.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Event 91 - Resident's photo of rockfall, taken post road closure (11/2025), exact date unknown.

	Client: Lithgow City Council	Author: JB
	Project: Wolgan Road Slope Risk Assessment	Date: 26/08/2025
	Project #: 12670695	Checked: AJH
	Location: Wolgan Rd, NSW	Date: 3/09/2025
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Appendix C - Landslide Inventory Rainfall Data



CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025

Event ID	Qualifier	Day	Month	Year	Date Confidence	BOM Station	Quality Controlled	Rainfall (mm)			AEP		
								Daily	2-day	7-day	Daily	2-day	7-day
1	Circa	31	3	1889	Medium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2	Circa	6	3	1911	Medium	Lithgow (Cooerwull)	☑	0	0	8.6	-	-	-
3	Circa	13	5	1911	Medium	Lithgow (Cooerwull)	☑	0.5	7.6	12.7	-	-	-
4	Circa	15	1	1917	Medium	Lithgow (Cooerwull)	☑	0.8	0.8	5.7	-	-	-
5	On	28	7	1926	High	Lithgow (Cooerwull)	☑	0.3	0.6	25.7	-	-	-
6	Circa	8	5	1942	Medium	Lithgow (Cooerwull)	☑	0	0	4.1	-	-	-
7	On	2	4	1950	High	Lithgow (Newnes Forest Centre)	☑	27.7	35.6	110.1	-	-	1in2Y
8	On	3	4	1950	High	Lithgow (Newnes Forest Centre)	☑	44.7	72.4	154	-	1in1Y	1in5Y
9	On	28	6	1950	High	Lithgow (Cooerwull)	☑	12.8	20.5	80	-	-	-
10	Circa	4	7	1950	Medium	Lithgow (Cooerwull)	☑	0	10.2	35	-	-	-
11	Circa	22	7	1950	Medium	Lithgow (Cooerwull)	☑	10.2	15.3	91.3	-	-	1in1Y
12	Circa	20	8	1952	Medium	Lithgow (Cooerwull)	☑	0	4.6	56.1	-	-	-
13	Circa	-	9	1986	Very Low	-	-	-	-	-	-	-	-
14	Circa	-	-	1990	Very Low	-	-	-	-	-	-	-	-
15	Circa	-	-	2002	Very Low	-	-	-	-	-	-	-	-
16	On	9	9	2008	High	Lidsdale (Maddox Lane)	☑	0	0	25.4	-	-	-
17	On	28	12	2009	High	Lidsdale (Maddox Lane)	☑	6.2	6.2	24.2	-	-	-
18	On	27	1	2010	High	Lidsdale (Maddox Lane)	☑	0	0	0	-	-	-
19	Circa	-	-	2010	Very Low	-	-	-	-	-	-	-	-
20	On	12	2	2010	High	Lidsdale (Maddox Lane)	☑	0	0	51.8	-	-	-
21	On	29	7	2010	High	Lidsdale (Maddox Lane)	☑	9.6	9.6	12.6	-	-	-
22	On	21	10	2010	High	Lidsdale (Maddox Lane)	☑	0	0	42.2	-	-	-
23	On	1	12	2010	High	Lidsdale (Maddox Lane)	☑	35.8	56	68.8	-	-	-
24	On	6	12	2010	High	Lidsdale (Maddox Lane)	☑	0.4	24.6	167	-	-	1in5Y
25	On	21	8	2011	High	Lidsdale (Maddox Lane)	☑	1.6	9	37.2	-	-	-
26	On	29	9	2011	High	Lidsdale (Maddox Lane)	☑	19.6	19.6	27.8	-	-	-
27	On	6	10	2011	High	Lidsdale (Maddox Lane)	☑	3.4	3.4	63.6	-	-	-
28	On	6	11	2011	High	Lidsdale (Maddox Lane)	☑	0	0	0	-	-	-
29	On	26	11	2011	High	Lidsdale (Maddox Lane)	☑	25.2	36.4	102.2	-	-	1in1Y
30	On	3	3	2012	High	Lidsdale (Maddox Lane)	☑	37.4	59.4	146.6	-	-	1in5Y
31	On	23	8	2012	High	Lidsdale (Maddox Lane)	☑	0.6	0.6	7.8	-	-	-
32	On	16	11	2012	High	Lidsdale (Maddox Lane)	☑	7.8	7.8	8.2	-	-	-
33	On	20	11	2012	High	Lidsdale (Maddox Lane)	☑	0.2	0.2	8.4	-	-	-
34	On	22	11	2013	High	Lidsdale (Maddox Lane)	☑	13.4	13.4	30.4	-	-	-
35	On	17	2	2014	High	Lidsdale (Maddox Lane)	☑	9	19.8	31.4	-	-	-
36	On	27	3	2014	High	Lidsdale (Maddox Lane)	☑	25.6	25.8	38	-	-	-
37	On	4	4	2014	High	Lidsdale (Maddox Lane)	☑	22	22	38.6	-	-	-
38	On	7	12	2014	High	Lidsdale (Maddox Lane)	☑	23.4	34.2	75.8	-	-	-
39	On	11	1	2015	High	Lidsdale (Maddox Lane)	☑	18.6	44.8	87.4	-	-	1in1Y
40	On	21	4	2015	High	Lidsdale (Maddox Lane)	☑	60.6	65.4	87.4	1in2Y	-	1in1Y
41	On	18	7	2015	High	Lidsdale (Maddox Lane)	☑	0	5	30.4	-	-	-
42	On	1	9	2015	High	Lidsdale (Maddox Lane)	☑	0	0	0	-	-	-
43	On	28	12	2015	High	Lidsdale (Maddox Lane)	☑	0	9.4	48.4	-	-	-
44	On	11	3	2016	High	Lidsdale (Maddox Lane)	☑	27.6	27.6	27.6	-	-	-
45	On	2	6	2016	High	Lidsdale (Maddox Lane)	☑	0	0	2.8	-	-	-
46	On	19	6	2016	High	Lidsdale (Maddox Lane)	☑	8	17.8	17.8	-	-	-
47	On	26	7	2016	High	Lidsdale (Maddox Lane)	☑	0	1.8	46	-	-	-
48	On	8	11	2016	High	Lidsdale (Maddox Lane)	☑	0	0	0	-	-	-
49	On	30	3	2017	High	Lidsdale (Maddox Lane)	☑	0	0	11.6	-	-	-
50	On	4	6	2017	High	Lidsdale (Maddox Lane)	☑	0	0	0.6	-	-	-
51	On	20	10	2017	High	Lidsdale (Maddox Lane)	☑	11.2	11.2	11.2	-	-	-
52	Prior	-	11	2017	Very Low	-	-	-	-	-	-	-	-
53	Circa	-	-	2018	Very Low	-	-	-	-	-	-	-	-
54	On	19	4	2018	High	Lidsdale (Maddox Lane)	☑	0	0	4.2	-	-	-
55	On	28	6	2018	High	Lidsdale (Maddox Lane)	☑	7	7	7	-	-	-
56	On	17	12	2018	High	Lidsdale (Maddox Lane)	☑	0	0.6	42.6	-	-	-
57	On	24	1	2019	High	Lidsdale (Maddox Lane)	☑	5.6	5.6	54	-	-	-
58	On	20	2	2019	High	Lidsdale (Maddox Lane)	☑	0	1	0	-	-	-
59	On	10	8	2020	High	Lidsdale (Maddox Lane)	☑	23.6	23.6	50.2	-	-	-

Appendix D

Community survey and feedback

Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Survey 1	Respondent 1
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Since 1975
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	No
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes the events I recall were associated with significant rainfall events
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	
For large Landslips, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of landslips	Yes, In 1986 I walked into Wolgan as significant sections of the Wolgan Gap had active slips. In one section of the road I actually walked through a moving mud slide running down the centre of the road
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Yes, it was some time before the road was reopened for traffic. We could only gain access by walking into the valley
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes, in 1986 it was a massive rainfall event
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 2
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	25 years as landowner and part time resident
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	I don't think I have ever seen a rockfall with rocks over 3m in diameter.
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Never seen
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	In the couple of years prior to the closure of the road it occasionally happened that small amounts of debris would wash down the slope onto the road which would sit on the road and/or block the drains. The largest rocks I can recall would be the size of basketballs but there also could be quite a bit more debris of a smaller size.
For large Landslips, how often would you estimate that these have occurred in the past?	I would say once every few years we could get a landslip the size shown in the photo
Can you recall any specific details of time and circumstances of landslips	
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Can't recall exactly but I also can't recall them ever closing the road.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No.

Survey 1	Respondent 3
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	60 years as visitor; 25 years as land owner
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	no
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	once every 5 years for smaller landslips that may have closed a lanne until cleared but not the whole road.
Can you recall any specific details of time and circumstances of landslips	No, although usially associated with prolonged heavy rain.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	No full closure of the road. Very occassionally major rockfall wuld clsoe the road. The land slips would require some clearing and often battering of adjacent slope.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 4
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	20 years. Visitor, worker and recent land holder.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	No
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	Every few years
Can you recall any specific details of time and circumstances of landslips	After heavy rainfall and in particular rain after bushfire.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Clearing of debris off the road
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	After rainfall
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Survey 1	Respondent 5
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	25 years as visitor and 7 as landowner. Regular user last 7 years
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	Never
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	No
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	Never

Survey 1	Respondent 6
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Landholder, purchased property in 1989 and have been a regular user of Wolgan Road for 36 years.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	Early 2000's large rockfall closed road. 2016 large rock slipped onto road.
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	? date. Large slip onto road on corner north of where the road has collapsed and is covered with black plastic
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Slip onto road north of 'black plastic corner' required extensive repair work
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 7
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Visiting family from early 1960's. Landholder since 1976. Resident from 1997.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	2016 large rockfall towards the top of the Gap
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of landslips	Around 10 years ago there was a large landslip just before the sharp left hand bend going up the gap. It slipped below the coal seam.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	It was a significant slip but we were able to get round it after some clearing. The repair work was quite extensive as they built the outside of the road up using the square blocks filled with stones.. it is now a good place to pull over if required.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Independent of rainfall
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 8
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	15 years. Landowner
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	Prior to 2019 I recall 2 in my time...
Can you recall any specific details of time and circumstances of large rockfalls?	20 June 2016. Numerous and constant post 2019 fires.
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I don't recall the 20/06/16 fall being associated with heavy rainfall, but it was a long time ago...
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	20/06/16
For large Landslips, how often would you estimate that these have occurred in the past?	prior to 2019 a few in 10 years. Post 2019 fires numerous often.
Can you recall any specific details of time and circumstances of landslips	
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	sometimes closure. Often delay. Contant discomfort driving the road as significant sections showed subsidance.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Usually with rain. I believe unrelenting heavy vehicle traffic - particular from Emirates Resort played a much more significant factor in destabilising everything.
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	

Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Survey 1	Respondent 9
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	15 years. Visitor, landholder and Business operator.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	No
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	Once. Approximately 2018. A rock approximately 300mm in diameter rolled past the front of our vehicle about 75 meters down from the top of the Gap.
For large Landslips, how often would you estimate that these have occurred in the past?	Our obsersevations were not consistent as our attendance and usage of the road was infrequent. We would have seen larger landslips a few times in the last 15 years
Can you recall any specific details of time and circumstances of landslips	Mostly between 2020 and 2022 following heavy rain events.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	From memory, just work requiring obstuction/s to be cleared, but mostly passable.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Mostly associated with significant rainfall events.
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 10
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Approx 14 years landholder
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	In 10 years, 2-3 times
Can you recall any specific details of time and circumstances of large rockfalls?	No I cannot recall however Council would have records of the events.
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No, not personally
For large Landslips, how often would you estimate that these have occurred in the past?	Every few years
Can you recall any specific details of time and circumstances of landslips	I recall the first was in 2011 and 2nd and 3rd in 2022 again I believe council would have records
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	the landslides needed repairs, the last one closed the road.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I believe they were associated with rainfall.
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No. I have had no personal experience with landslides, only the after effects.

Survey 1	Respondent 11
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	About 25 years as a landholder.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	
Can you recall any specific details of time and circumstances of large rockfalls?	Haven't really seen a rock fall of over 3m in diameter in the 25 years that we have been going back and forth to the Valley. However, I have heard of trees (twice) across the Gap road, which have either been moved by residents or the Council.
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	
For large Landslips, how often would you estimate that these have occurred in the past?	
Can you recall any specific details of time and circumstances of landslips	I don't recall a landslip in the 25 years that we have been going back and forth to the Valley. There have at times been rocks on the road, but I don't recall a landslip as such.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	

Survey 1	Respondent 12
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Over 60 yrs I grew up in Wolgan & iam still a land owner ,regular Rd by myself from 1978 through to mid 2000s, & I still try to get down every week or so ,
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	Yes 1 large rock bl9cked 3/4 of the Rd in 1990 ,council workers had to blow the rock up ,1990 was the wettest yr I remember
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes the events I recall were associated with significant rainfall events
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	About 25 yrs ago I remember the gap was blocked
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Survey 1	Respondent 13
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	We were landowners from 1990 to 2022, regularly visiting our 'weekender' property.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	No - we never encountered any.
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	N/A
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	We cannot recall any specific landslips but have recollections of there being one or two very minor landslips onto the road not big enough to block a lane. We also recall council barriers blocking part of the road for many months.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Very minor, no blockage and no repair required.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	We cannot recall.
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 14
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Since 1999. A visitor 1999 - 2001 Landholder since 2001.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	Never
Can you recall any specific details of time and circumstances of large rockfalls?	No
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I have not seen large rockfalls
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	Post the heavy rain of 2020 after the 2019 fires
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Did not close the road but did require repair.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	After heavy rain
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 15
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	40 years
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	Marathon weekend about 10 years ago
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes the events I recall were associated with significant rainfall events
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	Around twelve years ago on the corner near the ferns
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Rocks and dirt down to road , Gracey cleared over night
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Rainfall
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 16
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Resident since December 1999
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	Never seen rocks >3m diameter
Can you recall any specific details of time and circumstances of large rockfalls?	I have seen 3 large rockfalls in the period from 2008 to 2021. Details have been provided to the WVA.
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes the events I recall were associated with significant rainfall events
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	Rachel had one rock fall on the road about 100m in front of her once in 25 years.
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	The largest slip prior to 2022 was on the top side about 100m down hill from where the big slip on the lower side of the road currently is.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Closed the road for one day. Required several weeks of stabilisation work.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Only occurred with extended rainfall periods.
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	I drove around the slip I described. It was moving very slowly.

Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Survey 1	Respondent 17
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Land owner since 1984. In the valley most weekends and school holidays ever since.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	Once in 1986 no road damage just rick and debris blocking access
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes the events I recall were associated with significant rainfall events
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No close calls
For large Landslips, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of landslips	None other than 1986
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Residents cleared road and road was blocked for a couple of days
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Event occurred after significant rainfall not common
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	Not in my time

Survey 1	Respondent 18
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	resident since April 2000
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	even less frequently than 1 in 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	no
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	no
For large Landslips, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of landslips	2022 and once before 2010 (??)
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	LCC cleared the landslips quickly
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	?
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	no

Survey 1	Respondent 19
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	20 years + visitor / landholder
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	
Can you recall any specific details of time and circumstances of large rockfalls?	No just frequent episodes of small rock fall
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	no
For large Landslips, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of landslips	no
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	had to drive around
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	yes
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	yes , had to stop and remove debris

Survey 1	Respondent 20
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	From the time emirates opened until we bought our property there and continuing to this day.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	Only in the aftermath of the black summer bushfires and La Niña
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes the events I recall were associated with significant rainfall events
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of landslips	After the combination of the fires (then geniuses removing trees and their roots on the slopes) in the LaNina event of 2022
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	I only remember one
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Survey 1	Respondent 21
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	9 years as a landholder and resident. Have been a regular user of the Wolgan Rd that whole period.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	No
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of large rockfalls?	No
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	I dont recall.
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	Every few years
Can you recall any specific details of time and circumstances of landslips	No
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	The ones I recall were passable but restricted the road width to a single lane. None in my recollection required a road closure
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Usually related to rainfall events n
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Survey 1	Respondent 22
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Visitor/camper since 1978 at Newnes, landholder/resident since 2002.
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	Never
Can you recall any specific details of time and circumstances of large rockfalls?	No
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Never
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	No
For large Landslips, how often would you estimate that these have occurred in the past?	once every 10 years
Can you recall any specific details of time and circumstances of landslips	Approximately 10 years ago on the gap road. Kevin Gracey Earthmoving repaired it at 2am to allow Emirates guests to travel out of valley & workers to travel into valley. Road was not closed.
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	See above answer.
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Unknown.
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No.

Survey 1	Respondent 23
How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.	Landholder over 25 years
Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.	Yes
For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?	Every few years
Can you recall any specific details of time and circumstances of large rockfalls?	No
Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Yes the events I recall were associated with significant rainfall events
Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?	I haven't no
For large Landslips, how often would you estimate that these have occurred in the past?	Every few years
Can you recall any specific details of time and circumstances of landslips	No
How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.	Repair and at times closure
Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?	Mainly rainfall
Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?	No

Wolgan Gap - 2025 survey results (Individual responses)



We asked the residents of Wolgan Valley for their recollections of land slips or rockfalls prior to the road closure in November 2022. There were 25 respondents to the survey. You will see from the answers in question 1 that most respondents have been associated with the valley for decades.



Wolgan Gap Survey

This survey has been built to canvas the Wolgan Valley community in order to gather the residents and landholders recollections of past events on the Gap road involving landslips and rockfalls. This information will be coalated and used to inform discussion.

The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Since 1975

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: _____

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

Yes, In 1986 I walked into Wolgan as significant sections of the Wolgan Gap had active slips. In one section of the road I actually walked through a moving mud slide running down the centre of the road

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Yes, it was some time before the road was reopened for traffic. We could only gain access by walking into the valley

Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Yes, in 1986 it was a massive rainfall event

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

This form was created inside G Coates & Sons P/L.

Google Forms

Wolgan Gap Survey

This survey has been built to canvas the Wolgan Valley community in order to gather the residents and landholders recollections of past events on the Gap road involving landslips and rockfalls. This information will be coalated and used to inform discussion.

The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

25 years as landowner and part time resident

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

I don't think I have ever seen a rockfall with rocks over 3m in diameter.

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: Never seen

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

In the couple of years prior to the closure of the road it occasionally happened that small amounts of debris would wash down the slope onto the road which would sit on the road and/or block the drains. The largest rocks I can recall would be the size of basketballs but there also could be quite a bit more debris of a smaller size.

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other: I would say once every few years we could get a landslide the size shown in the photo

Can you recall any specific details of time and circumstances of landslips

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Can't recall exactly but I also can't recall them ever closing the road.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No.

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Wolgan Gap Survey

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

60 years as visitor; 25 years as land owner

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

no

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:
once every 5 years for smaller landslips that may have closed a lane until cleared but not the whole road.

Can you recall any specific details of time and circumstances of landslips

No, although usually associated with prolonged heavy rain.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

No full closure of the road. Very occasionally major rockfall would close the road. The landslips would require some clearing and often battering of adjacent slope.

Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Yes

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

20 years. Visitor, worker and recent land holder.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other: Every few years

Can you recall any specific details of time and circumstances of landslips

After heavy rainfall and in particular rain after bushfire.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Clearing of debris off the road

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

After rainfall

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

25 years as visitor and 7 as landowner. Regular user last 7 years

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

.....

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

Never

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

No

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

Never

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Landholder, purchased property in 1989 and have been a regular user of Wolgan Road for 36 years.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

Early 2000's large rockfall closed road. 2016 large rock slipped onto road.

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

? date. Large slip onto road on corner north of where the road has collapsed and is covered with black plastic

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Slip onto road north of 'black plastic corner' required extensive repair work

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Yes

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Visiting family from early 1960's. Landholder since 1976. Resident from 1997.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

2016 large rockfall towards the top of the Gap

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: _____

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

Around 10 years ago there was a large landslide just before the sharp left hand bend going up the gap. It slipped below the coal seam.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

It was a significant slip but we were able to get round it after some clearing. The repair work was quite extensive as they built the outside of the road up using the square blocks filled with stones.. it is now a good place to pull over if required.

Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Independent of rainfall

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

15 years. Landowner

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

20 June 2016. Numerous and constant post 2019 fires.

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall

Other:

I don't recall the 20/06/16 fall being associated with heavy rainfall, but it was a long time ago...

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

20/06/16

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other: prior to 2019 a few in 10 years. Post 2019 fires numerous often.

Can you recall any specific details of time and circumstances of landslips

.....

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

sometimes closure. Often delay. Contant discomfort driving the road as significant sections showed subsidance.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Usually with rain. I believe unrelenting heavy vehicle traffic - particular from Emirates Resort played a much more significant factor in destabilising everything.

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

.....

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

15 years. Visitor, landholder and Business operator.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

Once. Approximately 2018. A rock approximately 300mm in diameter rolled past the front of our vehicle about 75 meters down from the top of the Gap.

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years

Other:

Our observations were not consistent as our attendance and usage of the road was infrequent. We would have seen larger landslips a few times in the last 15 years.

Can you recall any specific details of time and circumstances of landslips

Mostly between 2020 and 2022 following heavy rain events.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

From memory, just work requiring obstruction/s to be cleared, but mostly passable.

Were these landslips associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Mostly associated with significant rainfall events.

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Approx 14 years landholder

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No I cannot recall however Council would have records of the events.

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: _____

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No, not personally

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other: In the 14 years we have owned the property it has happened maybe 3 times

Can you recall any specific details of time and circumstances of landslips

I recall the first was in 2011 and 2nd and 3rd in 2022 again I believe council would have records

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

the landslides needed repairs, the last one closed the road.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

I believe they were associated with rainfall.

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No. I have had no personal experience with landslides, only the after effects.

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

About 25 years as a landholder.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

Haven't really seen a rock fall of over 3m in diameter in the 25 years that we have been going back and forth to the Valley. However, I have heard of trees (twice) across the Gap road, which have either been moved by residents or the Council.

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

I don't recall a landslide in the 25 years that we have been going back and forth to the Valley. There have at times been rocks on the road, but I don't recall a landslide as such.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Over 60 yrs I grew up in Wolgan & iam still a land owner ,regular Rd by myself from 1978 through to mid 2000s, & I still try to get down every week or so ,

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

Yes 1 large rock blocked 3/4 of the Rd in 1990 ,council workers had to blow the rock up ,1990 was the wettest yr I remember

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

About 25 yrs ago I remember the gap was blocked

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Wolgan Gap Survey

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Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

We were landowners from 1990 to 2022, regularly visiting our 'weekender' property.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No - we never encountered any.

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: N/A

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

We cannot recall any specific landslips but have recollections of there being one or two very minor landslips onto the road not big enough to block a lane. We also recall council barriers blocking part of the road for many months.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Very minor, no blockage and no repair required.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

We cannot recall.

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Since 1999.

A visitor 1999 - 2001

Landholder since 2001.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: I have not seen large rockfalls

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

Post the heavy rain of 2020 after the 2019 fires

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Did not close the road but did require repair.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

After heavy rain

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

40 years

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

Marathon weekend about 10 years ago

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

Around twelve years ago on the corner near the ferns

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Rocks and dirt down to road , Gracey cleared over night

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Rainfall

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Wolgan Gap Survey

This survey has been built to canvas the Wolgan Valley community in order to gather the residents and landholders recollections of past events on the Gap road involving landslips and rockfalls. This information will be coalated and used to inform discussion.

The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Resident since December 1999

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

I have seen 3 large rockfalls in the period from 2008 to 2021. Details have been provided to the WVA.

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

██████ had one rock fall on the road about 100m in front of her once in 25 years.

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

The largest slip prior to 2022 was on the top side about 100m down hill from where the big slip on the lower side of the road currently is.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Closed the road for one day. Required several weeks of stabilisation work.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Only occurred with extended rainfall periods.

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

I drove around the slip I described. It was moving very slowly.

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Land owner since 1984. In the valley most weekends and school holidays ever since.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

Once in 1986 no road damage just rick and debris blocking access

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No close calls

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

None other than 1986

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Residents cleared road and road was blocked for a couple of days

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Event occurred after significant rainfall not common

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

Not in my time

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

resident since April 2000

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

no

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

no

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

2022 and once before 2010 (??)

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

LCC cleared the landslips quickly

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

?

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

no

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Wolgan Gap Survey

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

.....

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

20 years + visitor / landholder

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No just frequent episodes of small rock fall

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: _____

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

no

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

no

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

had to drive around

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

yes

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

yes , had to stop and remove debris

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The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

From the time emirates opened until we bought our property there and continuing to this day.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

Only in the aftermath of the black summer bushfires and La Niña

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

After the combination of the fires (then geniuses removing trees and their roots on the slopes) in the LaNina event of 2022

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

I only remember one

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Yes

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Wolgan Gap Survey

This survey has been built to canvas the Wolgan Valley community in order to gather the residents and landholders recollections of past events on the Gap road involving landslips and rockfalls. This information will be coalated and used to inform discussion.

The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

9 years as a landholder and resident. Have been a regular user of the Wolgan Rd that whole period.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other: Every 2 - 3 years

Can you recall any specific details of time and circumstances of landslips

No

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

The ones I recall were passable but restricted the road width to a single lane. None in my recollection required a road closure

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Usually related to rainfall events n

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Wolgan Gap Survey

This survey has been built to canvas the Wolgan Valley community in order to gather the residents and landholders recollections of past events on the Gap road involving landslips and rockfalls. This information will be coalated and used to inform discussion.

The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Visitor/camper since 1978 at Newnes, landholder/resident since 2002.

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other: Never

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

No

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other:

Can you recall any specific details of time and circumstances of landslips

Approximately 10 years ago on the gap road. Kevin Gracey Earthmoving repaired it at 2am to allow Emirates guests to travel out of valley & workers to travel into valley. Road was not closed.

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

See above answer.

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Unknown.

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No.

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Wolgan Gap Survey

This survey has been built to canvas the Wolgan Valley community in order to gather the residents and landholders recollections of past events on the Gap road involving landslips and rockfalls. This information will be coalated and used to inform discussion.

The respondent's email [REDACTED] was recorded on submission of this form.

Email *

[REDACTED]

Name and Property Address (optional)

[REDACTED]

How long have you been connected with the Wolgan Valley and in what capacity; ie resident, landholder, visitor. Can you identify the period(s) in which you have been a regular user of Wolgan Road.

Landholder over 25 years

Are you aware of previous occurrences of rockfalls and landslides on Wolgan Road prior to the closure in 2022.

Yes

No

Rockfalls



For large rockfalls, being rocks over 3m in diameter, how often would you estimate that these have occurred in the past?

- once a year
- once every 10 years
- even less frequently than 1 in 10 years

Can you recall any specific details of time and circumstances of large rockfalls?

No

Were these large rockfalls (ie greater than 3m) associated with significant rainfall events or did they occur at any time (independent of rainfall)?

- I dont recall.
- Yes the events I recall were associated with significant rainfall events
- they occur at any time independent of rainfall
- Other:

Have you had any close calls with rockfalls when you have been on the road? If so, can you remember the circumstances and year it happened?

I haven't no

Landslips



For large Landslips, how often would you estimate that these have occurred in the past?

- once a year
- Every few years
- once every 10 years
- even less frequently than 1 in 10 years
- Other: Every few years

Can you recall any specific details of time and circumstances of landslips

No

How big were the landslips; eg did they force the closure of the road, require extensive repair work to the road etc.

Repair and at times closure

Were these landslipes associated with significant rainfall events or did they occur at any time (independent of rainfall)?

Mainly rainfall

Have you had any close calls with landslips when you have been on the road? If so, can you remember the circumstances and the year it happened?

No

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Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Survey 2	Respondent 1
Do you have a story or anecdotal feedback of geological movements (including rock falls, slips and movement above and below the road) along Wolgan Road? Please provide an approximate date, location, size/volume of debris of the road (e.g. small rocks (shoebox size), 0.5m to 1m across, >1m across, soil and rock debris covering / blocking the entire road).	Not really. I have used the road for many decades and have distant recollections of slips and 1 major rockfall near 2200 on the photo below about 12 years ago but rocks greater than 50cm sitting on the road are actually pretty rare. In driving the road the blind corners induce a caution but this was always directed at anticipating oncoming vehicles or fauna rather than rock obstacles, which perhaps gives an idea of the rarity.
If you drove the road regularly (before it was closed), how often would you see rocks on the road? If so, what would the typical size of the rocks be?	Once or twice a year you might see a rock around 50cm on the road.
Have you ever seen sections of the road that have slipped / collapsed (below the road). If so, could you estimate how frequently this occurs?	Since they redveloped the road at the time the resort was constructed, it has held up very well until the post fires rains. Keeping the gutters and drains clear of mud and debris became an issue from about 2015. They widened the road when it was sealed and the concrete guttering and armco was installed. Prior to that I wasn't conscious of any down slope slips.
Do you have sense of how high on the slope rockfalls are coming from? E.g. cuttings next to the road, treed slopes, escarpments (cliffs) high above the road.	Most of the rocks are from the upside embankments. Occassionally they are from higher, and the major rockfall about 12 years ago was from on or near the escarpment
Do rocks always land on the road or do they travel beyond and below the road?	I have not seen rocks travel beyond the road, other than the one 12 years ago although very occassionally you see damage to the armco which was presumably caused by a rock travelling across the road.
How many times would you travel the road -every day, a few times, on weekends etc.	Prior to the road closure, I was driving the road about 4 times a week. I have been travelling in and out of the Valley less since the closure.
Do you think any section of the road is more hazardous than any other?	The section shown on the plan above is the where the rockfall hazards are. The narrow section at the top is also a hazard for oncoming vehicles. The other major hazard is the blind corners for oncoming vehicles.
Do falls occur immediately after rain or is there a delay?	Rain is the main instigator of rockfalls but they can occur at othe rtimes.
How many times/ how often have rocks been cleared off the road since closure? Can you comment on the size of the rocks since the closure?	Paul Bower and Mike Coates would need to answer this as they ae the only two who have direct knowledge.

Survey 2	Respondent 2
Do you have a story or anecdotal feedback of geological movements (including rock falls, slips and movement above and below the road) along Wolgan Road? Please provide an approximate date, location, size/volume of debris of the road (e.g. small rocks (shoebox size), 0.5m to 1m across, >1m across, soil and rock debris covering / blocking the entire road).	I forgot to mention in my submission that I have hunderds of photos and videos of the gap before and after closure. Im happy to share them as needed. I have also attached another video to this
If you drove the road regularly (before it was closed), how often would you see rocks on the road? If so, what would the typical size of the rocks be?	
Have you ever seen sections of the road that have slipped / collapsed (below the road). If so, could you estimate how frequently this occurs?	
Do you have sense of how high on the slope rockfalls are coming from? E.g. cuttings next to the road, treed slopes, escarpments (cliffs) high above the road.	
Do rocks always land on the road or do they travel beyond and below the road?	Australia
How many times would you travel the road -every day, a few times, on weekends etc.	
Do you think any section of the road is more hazardous than any other?	
Do falls occur immediately after rain or is there a delay?	
How many times/ how often have rocks been cleared off the road since closure? Can you comment on the size of the rocks since the closure?	

Survey 2	Respondent 3
Do you have a story or anecdotal feedback of geological movements (including rock falls, slips and movement above and below the road) along Wolgan Road? Please provide an approximate date, location, size/volume of debris of the road (e.g. small rocks (shoebox size), 0.5m to 1m across, >1m across, soil and rock debris covering / blocking the entire road).	Small rocks on the road are almost a daily occurence. The usually break up under vehicle tyres. I have been helping to maintain the road since it was closed by council in November 2022. Since that time there has been 3 rocks that I had to move with the tractor. The largest was around 500kgs
If you drove the road regularly (before it was closed), how often would you see rocks on the road? If so, what would the typical size of the rocks be?	You see rocks on the road most weeks but they are small and can be driven over. Very occsionally you get something that you need to roll off.
Have you ever seen sections of the road that have slipped / collapsed (below the road). If so, could you estimate how frequently this occurs?	I witnessed a mud slide in 1986 that flowed down the road.
Do you have sense of how high on the slope rockfalls are coming from? E.g. cuttings next to the road, treed slopes, escarpments (cliffs) high above the road.	They mostly come from down low in the mud stone layers. You get these little pressure pops that throw a few rocks onto the road. I have photos of these. Its usually only after a rainfall event.
Do rocks always land on the road or do they travel beyond and below the road?	Only ever seen them fall on the road
How many times would you travel the road -every day, a few times, on weekends etc.	Most days
Do you think any section of the road is more hazardous than any other?	Only the top 150 metres. I dont spend more time on that section than I have to.
Do falls occur immediately after rain or is there a delay?	Usually next day or so
How many times/ how often have rocks been cleared off the road since closure? Can you comment on the size of the rocks since the closure?	I have kept a close watch on the gap since closure. After a large rain event (20mm or more) I go up with the tractor and make sure the gutter drains are clear and also scrape any rocks off. Mostly I clean up the areas lower on the gap that were damaged by council when they ripped up the road. Those areas tend to wash after rain and I tidy them up. I have moved 3 rocks too large to drive over since the road was closed. I have photos of them and have attached them below

Survey 2	Respondent 4
Do you have a story or anecdotal feedback of geological movements (including rock falls, slips and movement above and below the road) along Wolgan Road? Please provide an approximate date, location, size/volume of debris of the road (e.g. small rocks (shoebox size), 0.5m to 1m across, >1m across, soil and rock debris covering / blocking the entire road).	The main one that sticks in my mind was in about 2010 when there was a bad slip at 1300 below the line of the coal seam. The road is now a bit wider at that point as it had to be built up from underneath.
If you drove the road regularly (before it was closed), how often would you see rocks on the road? If so, what would the typical size of the rocks be?	Hard to say. usually small rocks that you could drive around or some 12 to 18 inches that I could move myself
Have you ever seen sections of the road that have slipped / collapsed (below the road). If so, could you estimate how frequently this occurs?	No
Do you have sense of how high on the slope rockfalls are coming from? E.g. cuttings next to the road, treed slopes, escarpments (cliffs) high above the road.	No
Do rocks always land on the road or do they travel beyond and below the road?	Usually on the road I haven't seen any go over the side
How many times would you travel the road -every day, a few times, on weekends etc.	At least 3 times a week since 1997 less in the years prior
Do you think any section of the road is more hazardous than any other?	Probably the steep section at the top where the road is fairly narrow better since it was rock bolted
Do falls occur immediately after rain or is there a delay?	Doesn't necessarily have to rain
How many times/ how often have rocks been cleared off the road since closure? Can you comment on the size of the rocks since the closure?	Unsure but it is kept clear one way for emergeny exit

Appendix D - Community Surveys

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



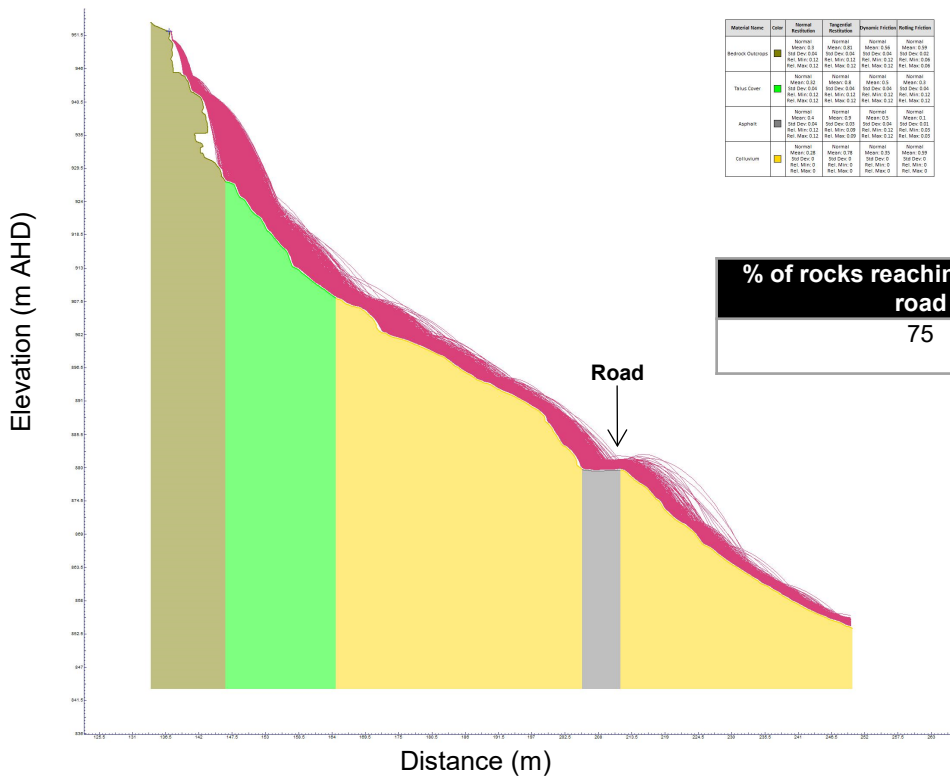
Survey 2	Respondent 5
Do you have a story or anecdotal feedback of geological movements (including rock falls, slips and movement above and below the road) along Wolgan Road? Please provide an approximate date, location, size/volume of debris of the road (e.g. small rocks (shoebox size), 0.5m to 1m across, >1m across, soil and rock debris covering / blocking the entire road).	We definitely think the LCC landslide / rockfall inventory is crucial to understanding the best account of the history of rock falls, especially in recent years following the 2019 bushfires (would expect this will cover the multiple events that occurred between 500 and 1500). This is because the road would be closed for clearing and repair every time there was a rock fall. As residents, you didn't always get to see the rock fall in situ.
If you drove the road regularly (before it was closed), how often would you see rocks on the road? If so, what would the typical size of the rocks be?	Since the 2019 bushfires, there were definitely increasing bits falling or washed onto the road, bits falling away from the road edge, water and drainage issues. Quite often on the top section of road, usually football size or smaller. One of the Wolgan Valley old timers, who's now passed, would always carry a crowbar on trips to town, so he could move any rocks that could be moved out of the way. Again, the LCC landslide/rockfall inventory would be the best account of the size of the bigger rock falls. As the road would be closed for clearing and repair every time there was a bigger rock fall, and residents didn't always get to see the rock fall in situ.
Have you ever seen sections of the road that have slipped / collapsed (below the road). If so, could you estimate how frequently this occurs?	Yes, especially after the 2019 bushfires, in at least four locations. Ranging from very bad to minor. LCC should have records of previous road failures in the 90s and 80s.
Do you have sense of how high on the slope rockfalls are coming from? E.g. cuttings next to the road, treed slopes, escarpments (cliffs) high above the road.	From all the areas mentioned. Again, the LCC inventory should detail this.
Do rocks always land on the road or do they travel beyond and below the road?	Of the rocks seen, they land on the road. Wouldn't really expect to see rocks that make it over the road and down the hill.
How many times would you travel the road -every day, a few times, on weekends etc.	Driver & 2 Children: Every day, all year round, including Christmas day. A minimum of 4 movements, maximum of 6 movements. School, sports, social and shopping runs.
Do you think any section of the road is more hazardous than any other?	The whole extent. Cliff escarpment sits above the entire extent of the road. Unconsolidated rock extends down from below the cliff escarpment into steep slopes. From the top to bottom of the road, the slopes get longer, with presumably more material to move and fall. It may be worth noting that the coal or shale seam located above the road (at 1000, ephemeral waterfall) appeared to be smouldering for quite some time following the 2019 bushfire. Presumably it was extinguished with the subsequent high rainfall, but thought it worth mentioning. It is also worth noting that there is an increased need to stop for opposite traffic to pass between 400 and 1500. The duration of the stopping time depends on the type of opposite traffic e.g. delivery trucks, tourists with caravans, 4WDs, heavy and wide vehicles and loads, luxury cars. Of most recent concern is definitely the section that closed the road in Nov-22, that was activated, but still hasn't fully realised the movement of the
Do falls occur immediately after rain or is there a delay?	Both.
How many times/ how often have rocks been cleared off the road since closure? Can you comment on the size of the rocks since the closure?	The road is closed / condemned, therefore we don't use the road. However, according to the Wolgan Telegraph WhatsApp record, there have been plenty of working bees to clear and remove obstructions to allow passage of those choosing to use the road.

Survey 2	Respondent 6
Do you have a story or anecdotal feedback of geological movements (including rock falls, slips and movement above and below the road) along Wolgan Road? Please provide an approximate date, location, size/volume of debris of the road (e.g. small rocks (shoebox size), 0.5m to 1m across, >1m across, soil and rock debris covering / blocking the entire road).	As a land holder making regular trips in and out of the valley I have seen regular rock falls when driving up and down Wolgan Road. Most common are small to medium sized rocks between diameter 15 cm and 50 cm in diameter. These mainly seemed to occur between 400 and 1100. The road has clearly become more and more unstable over time. Significant heavy vehicle traffic loads servicing larger businesses in the valley in particular have undoubtedly contributed to these problems. On many occasions I have seen rocks fall with up to 1meter in size. I believe these were mostly between location 400 and 1100 and 1500 and 1900. I have one recorded reference 20 June 2016 of a very significant slide I encountered on the way to work that morning. I have seen numerous others but I did not keep an accurate log or diary of these events and thus don't recall specifics. Suffice to say they unquestionably increased in severity and frequency during my time. I have attached all the photos I have of events along the road. These contain positional meta data for your reference. The folders are labelled as Year-month-date.
If you drove the road regularly (before it was closed), how often would you see rocks on the road? If so, what would the typical size of the rocks be?	regular rocks 15-20cm at any time. Larger rocks more randomly in particular after a little rain.
Have you ever seen sections of the road that have slipped / collapsed (below the road). If so, could you estimate how frequently this occurs?	Yes. mainly during the 3 or 4 years prior to its closure.
Do you have sense of how high on the slope rockfalls are coming from? E.g. cuttings next to the road, treed slopes, escarpments (cliffs) high above the road.	no
Do rocks always land on the road or do they travel beyond and below the road?	they can travel beyond and below the road
How many times would you travel the road -every day, a few times, on weekends etc.	usually weekends
Do you think any section of the road is more hazardous than any other?	top section and centre section
Do falls occur immediately after rain or is there a delay?	both
How many times/ how often have rocks been cleared off the road since closure? Can you comment on the size of the rocks since the closure?	I seek to avoid driving this road as I feel unsafe on it.

Survey 2	Respondent 7
Do you have a story or anecdotal feedback of geological movements (including rock falls, slips and movement above and below the road) along Wolgan Road? Please provide an approximate date, location, size/volume of debris of the road (e.g. small rocks (shoebox size), 0.5m to 1m across, >1m across, soil and rock debris covering / blocking the entire road).	9th December 2021 rockfall at 1000 (?). 6th October 2022 Wolgan Gap was closed after a landslip on 3rd October 2022 at 1400 (?) 9th November 2022 Wolgan Road closed.
If you drove the road regularly (before it was closed), how often would you see rocks on the road? If so, what would the typical size of the rocks be?	rarely, after rain some rocks at top 500-700
Have you ever seen sections of the road that have slipped / collapsed (below the road). If so, could you estimate how frequently this occurs?	only once at 1100 after rain and long period of blocked drain at 1000, 9th Nov 2022
Do you have sense of how high on the slope rockfalls are coming from? E.g. cuttings next to the road, treed slopes, escarpments (cliffs) high above the road.	no
Do rocks always land on the road or do they travel beyond and below the road?	on road as far as I have seen except for landslip on 3rd Oct '22
How many times would you travel the road -every day, a few times, on weekends etc.	3 times (return) per week myself using donkey steps + 10 return trips for my guests - 100 times on long weekends
Do you think any section of the road is more hazardous than any other?	500-1500, the road is officially closed. The landslip stretches are more hazardous. (yes, really)
Do falls occur immediately after rain or is there a delay?	straight during and after rain
How many times/ how often have rocks been cleared off the road since closure? Can you comment on the size of the rocks since the closure?	5 times (?) - fist size or smaller

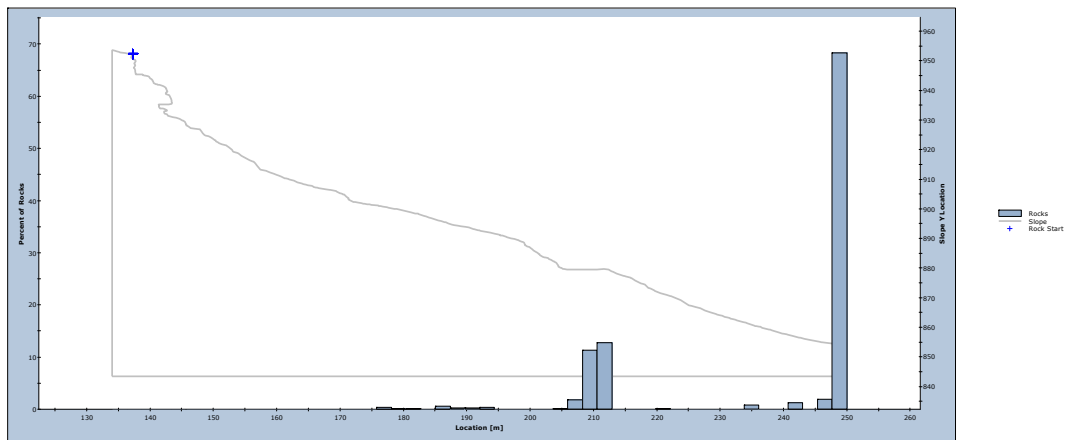
Appendix E

2D Rockfall modelling results



Material Name	Color	Normal Reaction	Tangential Resistance	Dynamic Friction	Rolling Friction
Bedrock Outcrop	Green	Normal	Normal	Normal	Normal
		Min: 0.1	Min: 0.15	Min: 0.18	Min: 0.01
		Max: 0.15	Max: 0.2	Max: 0.25	Max: 0.02
Tuff Clay	Yellow	Normal	Normal	Normal	Normal
		Min: 0.1	Min: 0.15	Min: 0.18	Min: 0.01
		Max: 0.15	Max: 0.2	Max: 0.25	Max: 0.02
Asphalt	Grey	Normal	Normal	Normal	Normal
		Min: 0.1	Min: 0.15	Min: 0.18	Min: 0.01
		Max: 0.15	Max: 0.2	Max: 0.25	Max: 0.02
Cementum	Yellow	Normal	Normal	Normal	Normal
		Min: 0.1	Min: 0.15	Min: 0.18	Min: 0.01
		Max: 0.15	Max: 0.2	Max: 0.25	Max: 0.02

Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

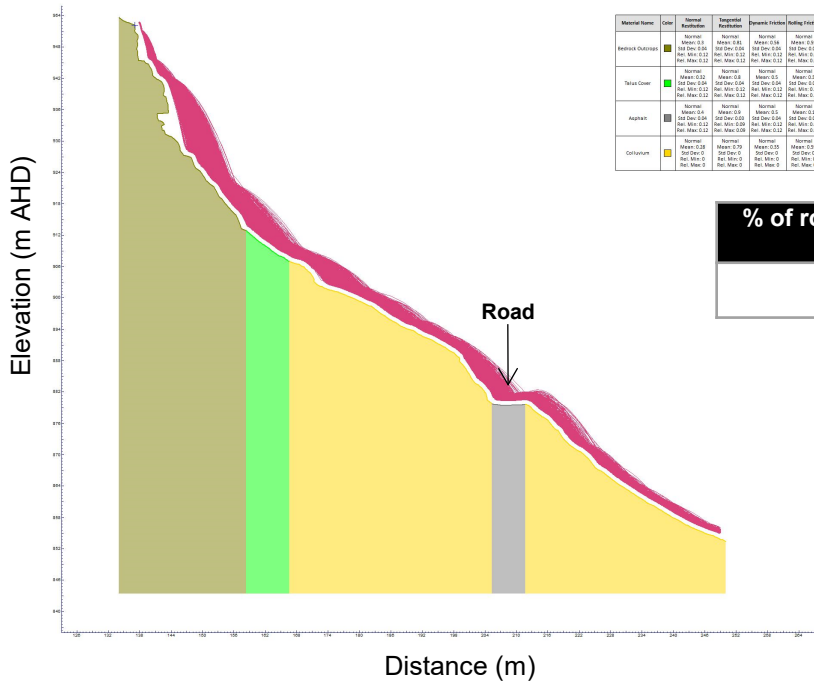
Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m ³)	Mass (kg)	Initial Horizontal velocity (m/s)
Very Small	1000	Super Ellipse (5:6)	0.6 x 0.4 x 0.4	2,500	236	0.5



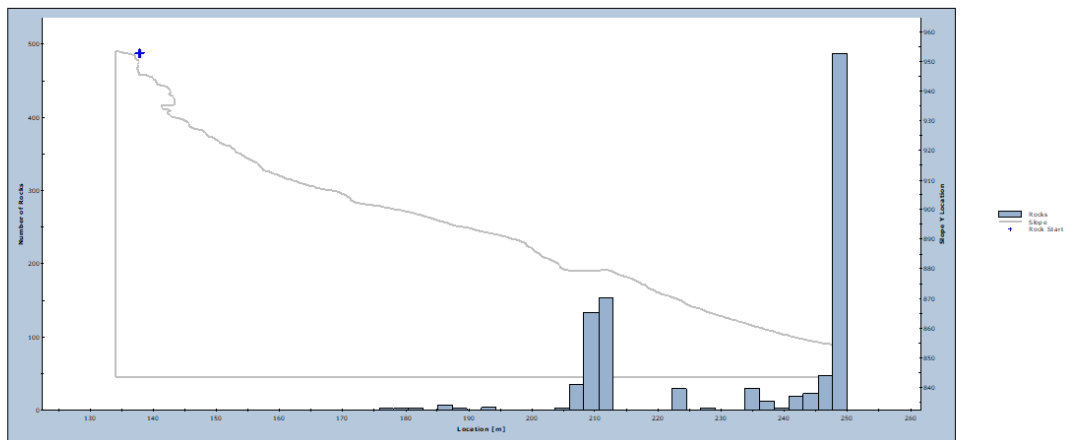
Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E1

Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field





Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

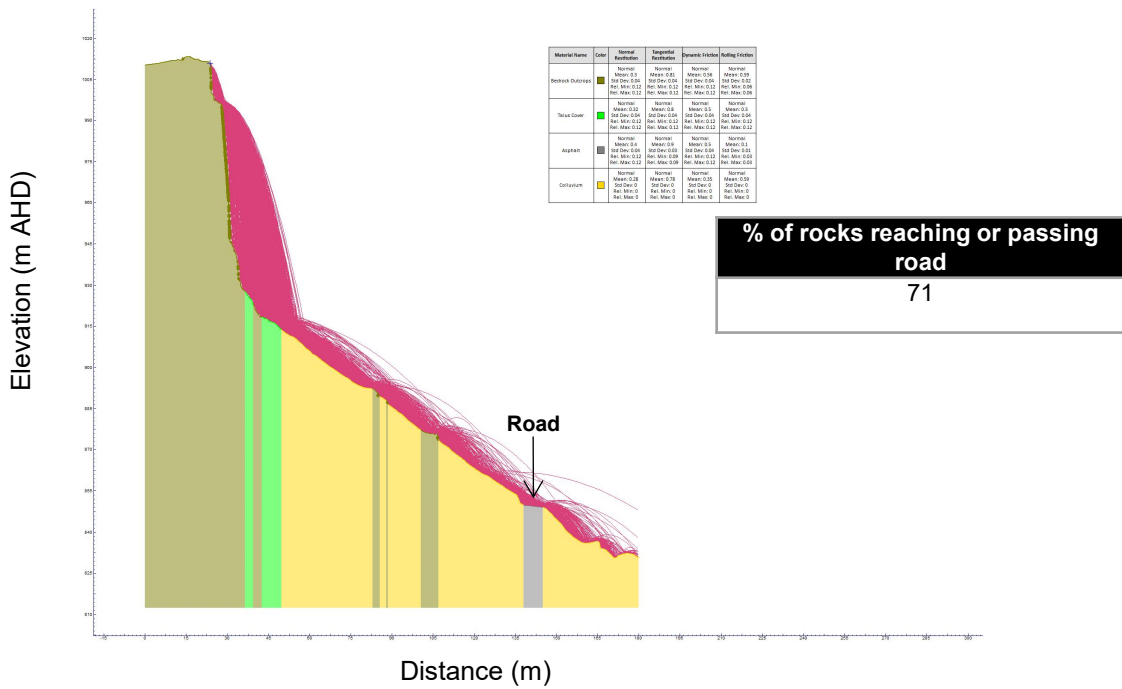
Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m ³)	Mass (kg)	Initial Horizontal velocity (m/s)
Large	1000	Super Ellipse (5:6)	2.5 x 1.5 x 1.5	2,500	13,854	0.5



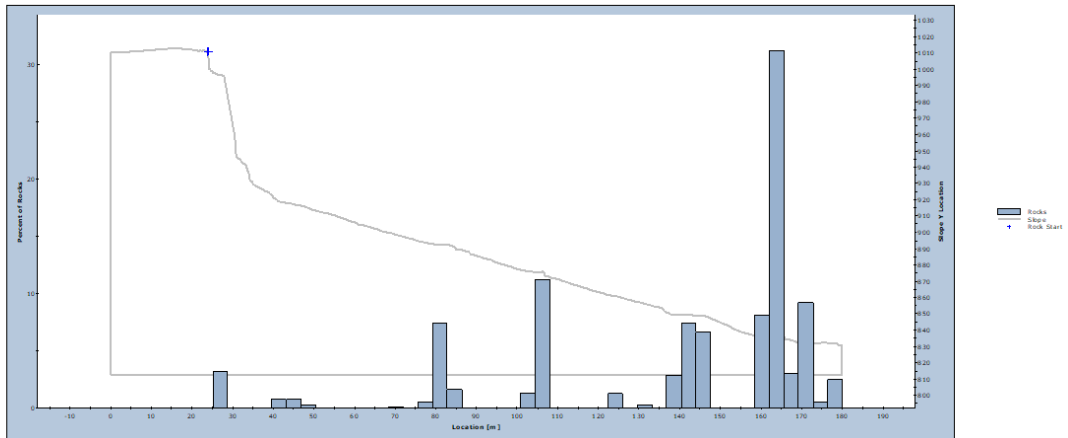
Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E2

Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field





Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

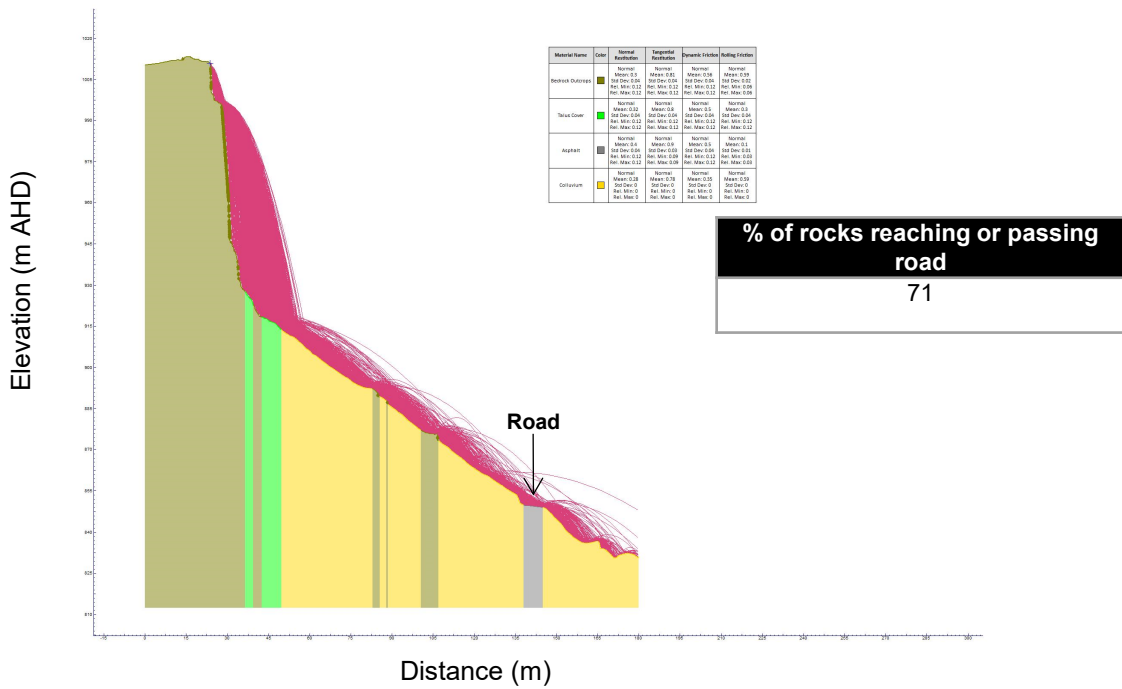
Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m³)	Mass (kg)	Initial Horizontal velocity (m/s)
Very Small	1000	Super Ellipse (5:6)	0.6 x 0.4 x 0.4	2,500	236	0.5



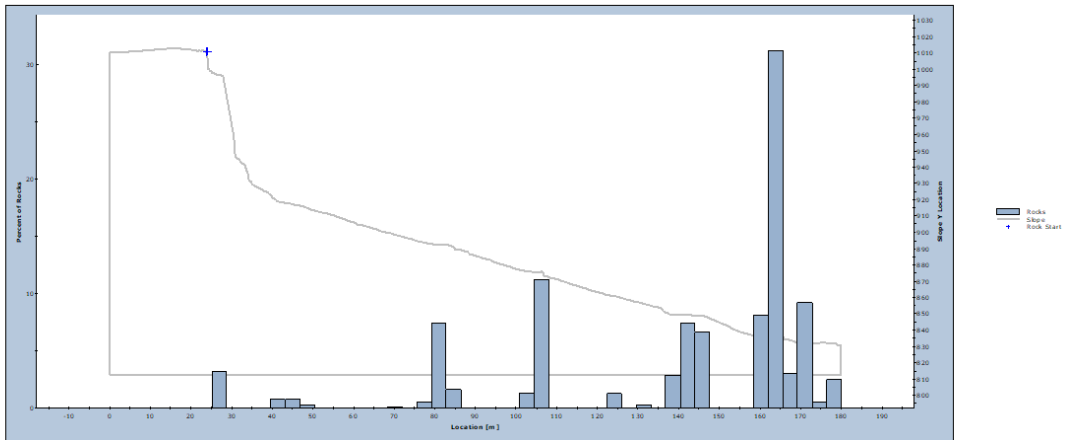
Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E3

Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field





Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m³)	Mass (kg)	Initial Horizontal velocity (m/s)
Large	1000	Super Ellipse (5:6)	2.5 x 1.5 x 1.5	2,500	13,854	0.5

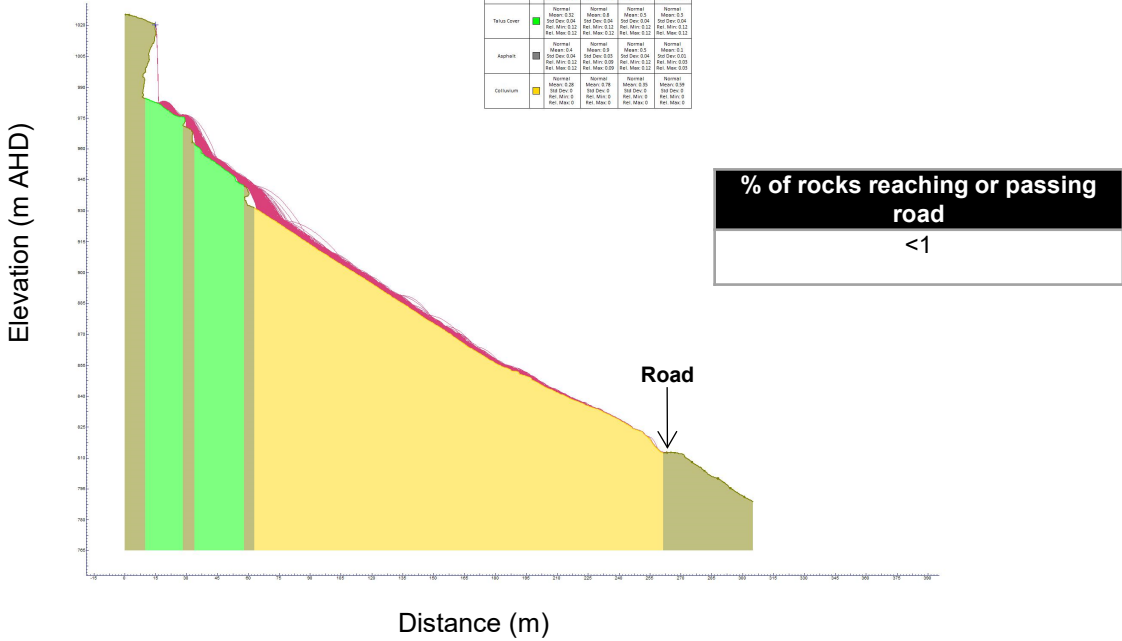


Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E4

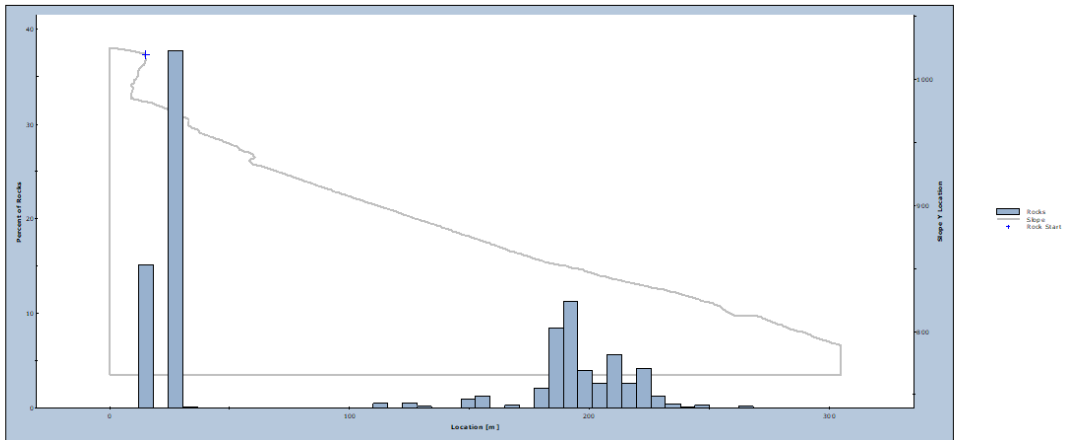
Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field



Material Name	Color	Normal Acceleration	Typical Friction	Dynamic Friction	Rolling Friction
Reddish Chertrock	[Red]	Normal	Normal	Normal	Normal
		Min Dec 0.1	Min Dec 0.1	Min Dec 0.1	Min Dec 0.1
		Max Dec 0.1	Max Dec 0.1	Max Dec 0.1	Max Dec 0.1
		Min Max 0.1	Min Max 0.1	Min Max 0.1	Min Max 0.1
Tuffa Cover	[Green]	Normal	Normal	Normal	Normal
		Min Dec 0.1	Min Dec 0.1	Min Dec 0.1	Min Dec 0.1
		Max Dec 0.1	Max Dec 0.1	Max Dec 0.1	Max Dec 0.1
		Min Max 0.1	Min Max 0.1	Min Max 0.1	Min Max 0.1
Asphalt	[Grey]	Normal	Normal	Normal	Normal
		Min Dec 0.1	Min Dec 0.1	Min Dec 0.1	Min Dec 0.1
		Max Dec 0.1	Max Dec 0.1	Max Dec 0.1	Max Dec 0.1
		Min Max 0.1	Min Max 0.1	Min Max 0.1	Min Max 0.1
Cottontail	[Yellow]	Normal	Normal	Normal	Normal
		Min Dec 0.1	Min Dec 0.1	Min Dec 0.1	Min Dec 0.1
		Max Dec 0.1	Max Dec 0.1	Max Dec 0.1	Max Dec 0.1
		Min Max 0.1	Min Max 0.1	Min Max 0.1	Min Max 0.1



Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m ³)	Mass (kg)	Initial Horizontal velocity (m/s)
Very Small	1000	Super Ellipse (5:6)	0.6 x 0.4 x 0.4	2,500	236	0.5

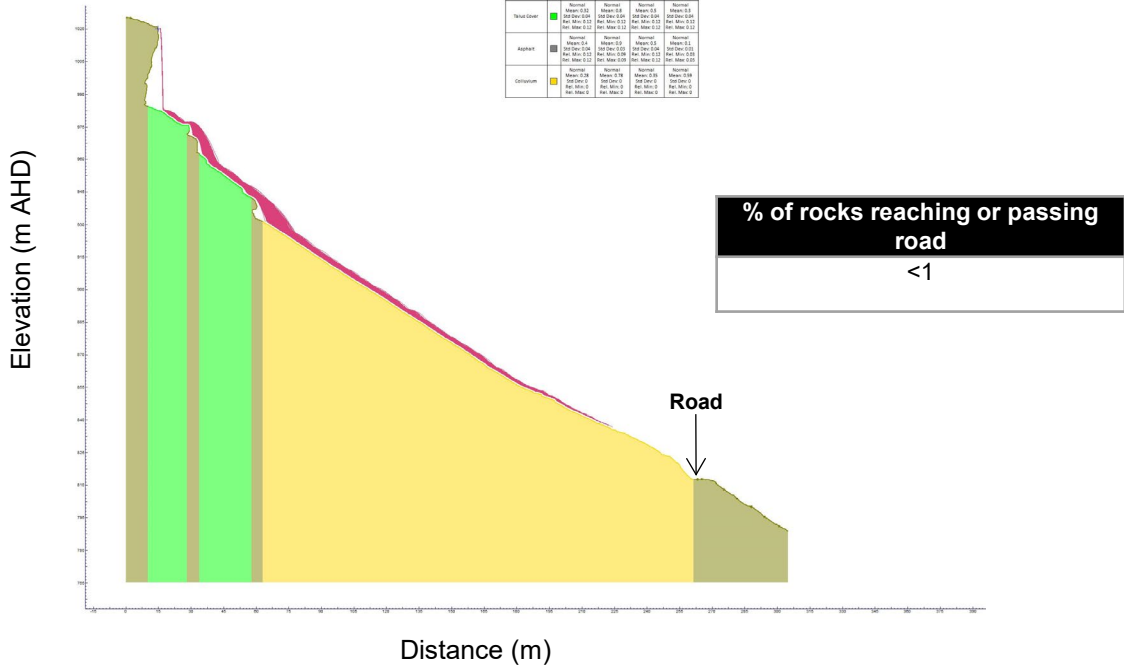


Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E5

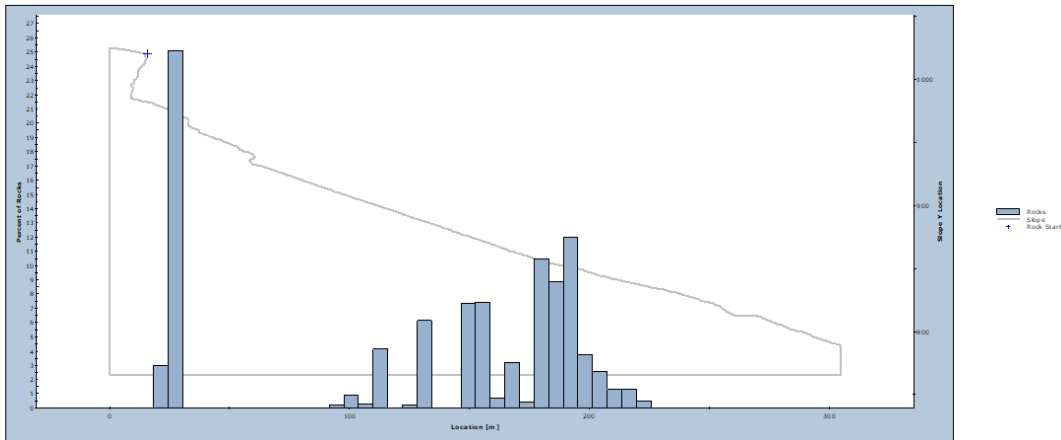
Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field



Material Name	Color	Normal Acceleration	Resilient Modulus	Dynamic Friction	Rolling Friction
Rockfall Protection	Green	0.05	1000000000	0.5	0.05
Wet Clay	Red	0.05	1000000000	0.5	0.05
Asphalt	Grey	0.05	1000000000	0.5	0.05
Granular	Yellow	0.05	1000000000	0.5	0.05



Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m ³)	Mass (kg)	Initial Horizontal velocity (m/s)
Large	1000	Super Ellipse (5:6)	2.5 x 1.5 x 1.5	2,500	13,854	0.5

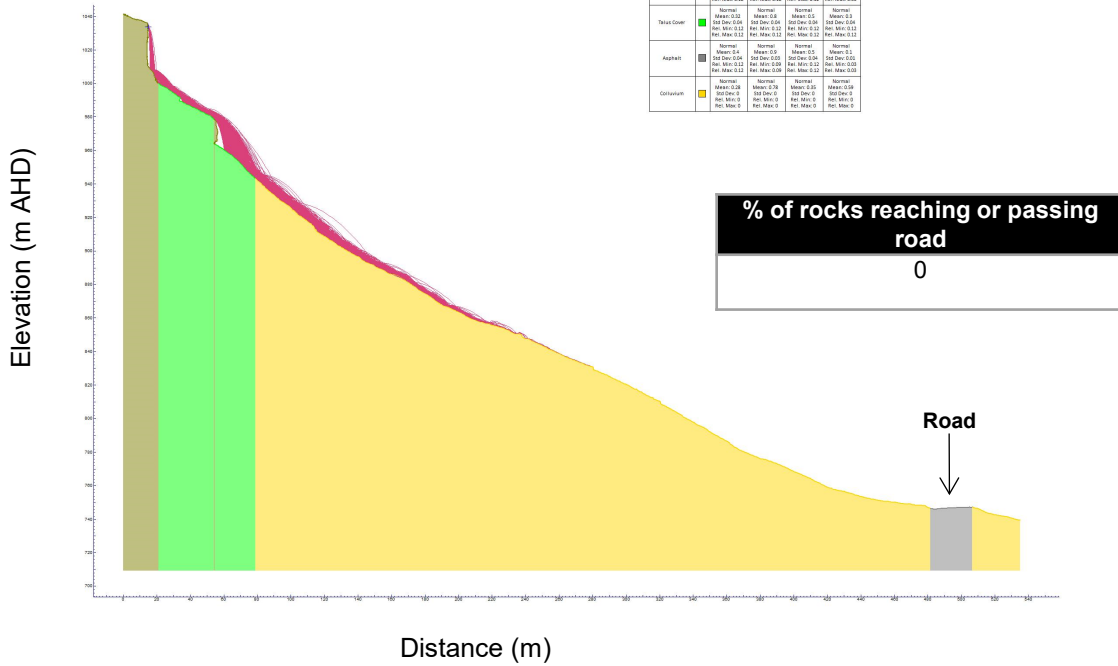


Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E6

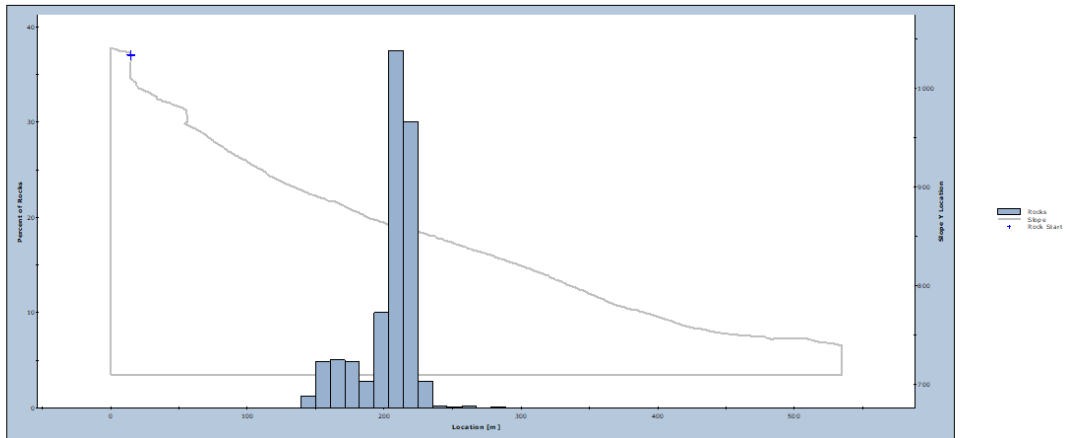
Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field



Material Name	Color	Normal Distribution	Triangular Distribution	Dynamic Friction	Rolling Friction
Bedrock Outcrop	Brown	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
Talus Cover	Green	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
Asphalt	Grey	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
Gravel/soil	Yellow	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12
		Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12	Normal: Mean: 0.15 Std Dev: 0.04 Pct. Max: 0.12



Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m ³)	Mass (kg)	Initial Horizontal velocity (m/s)
Very Small	1000	Super Ellipse (5:6)	0.6 x 0.4 x 0.4	2,500	236	0.5

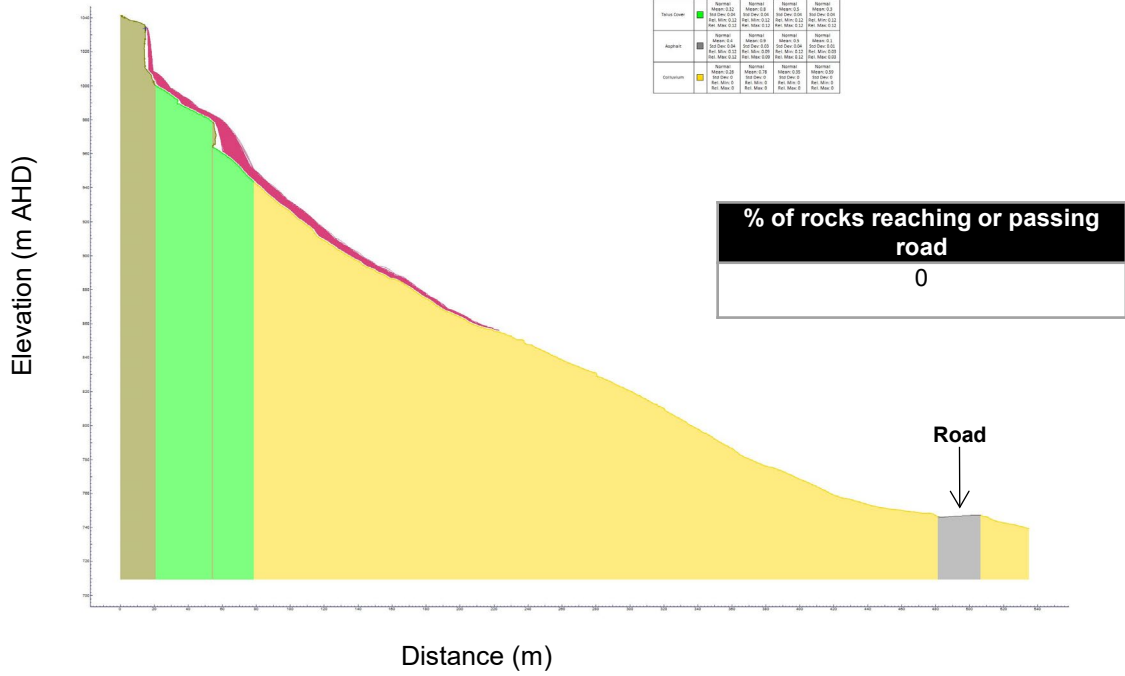


Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E7

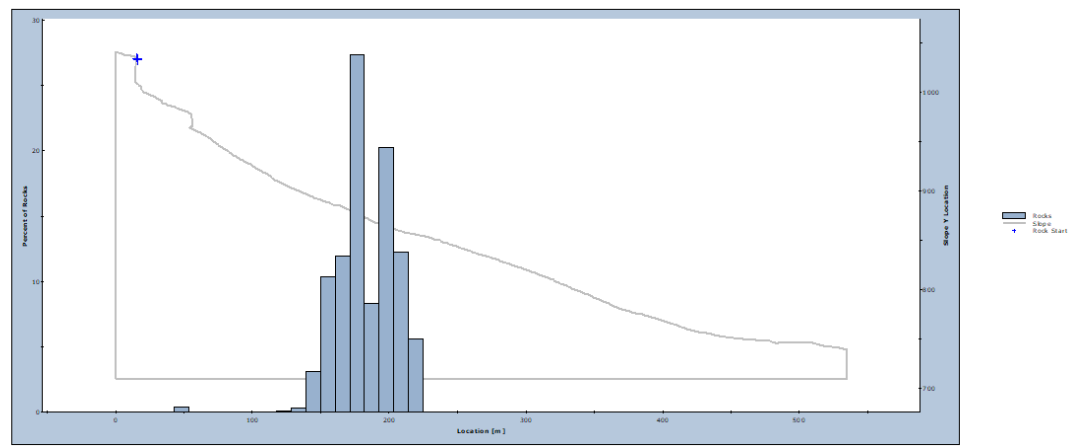
Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field



Material Name	Color	General Properties	Specific Properties	Density (kg/m³)	Scaling Factor
Bedrock (Gneiss)	Green	Mass: 2.5 Friction: 0.6 cohesion: 0 Tensile: 0 Rel. Max. S: 0	Strength: 0 Modulus: 0 Rel. Max. S: 0	2500	1.0
Topsoil (Clay)	Red	Mass: 1.8 Friction: 0.3 cohesion: 0 Tensile: 0 Rel. Max. S: 0	Strength: 0 Modulus: 0 Rel. Max. S: 0	1800	1.0
Gravel	Grey	Mass: 2.0 Friction: 0.4 cohesion: 0 Tensile: 0 Rel. Max. S: 0	Strength: 0 Modulus: 0 Rel. Max. S: 0	2000	1.0
Concrete	Yellow	Mass: 2.4 Friction: 0.6 cohesion: 0 Tensile: 0 Rel. Max. S: 0	Strength: 0 Modulus: 0 Rel. Max. S: 0	2400	1.0



Modelled rockfall trajectories



Distribution of rock path end locations (rockfall reach)

Modelled rockfall block properties.

Volume Category	Number of blocks modelled	Block Shape	Approximate dimensions (m)	Density (kg/m³)	Mass (kg)	Initial Horizontal velocity (m/s)
Large	1000	Super Ellipse (5:6)	2.5 x 1.5 x 1.5	2,500	13,854	0.5



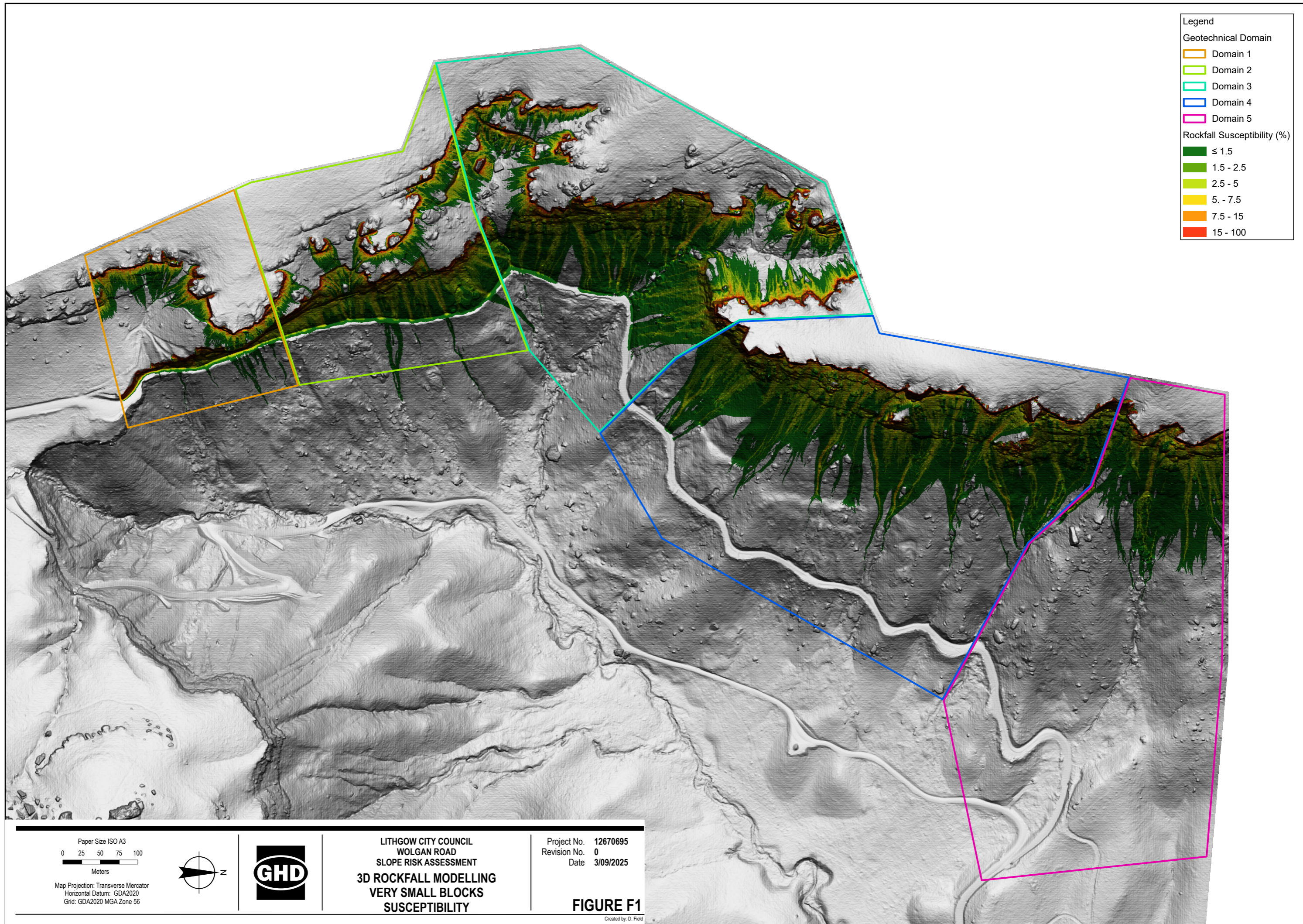
Client: Lithgow City Council
 Project: Wolgan Road Slope Risk Assessment
 Figure: E8

Project no: 12670695
 Author: Andrew Hunter
 Reviewer: David Field

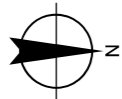


Appendix F

3D Rockfall modelling outputs



Paper Size ISO A3
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 Meters



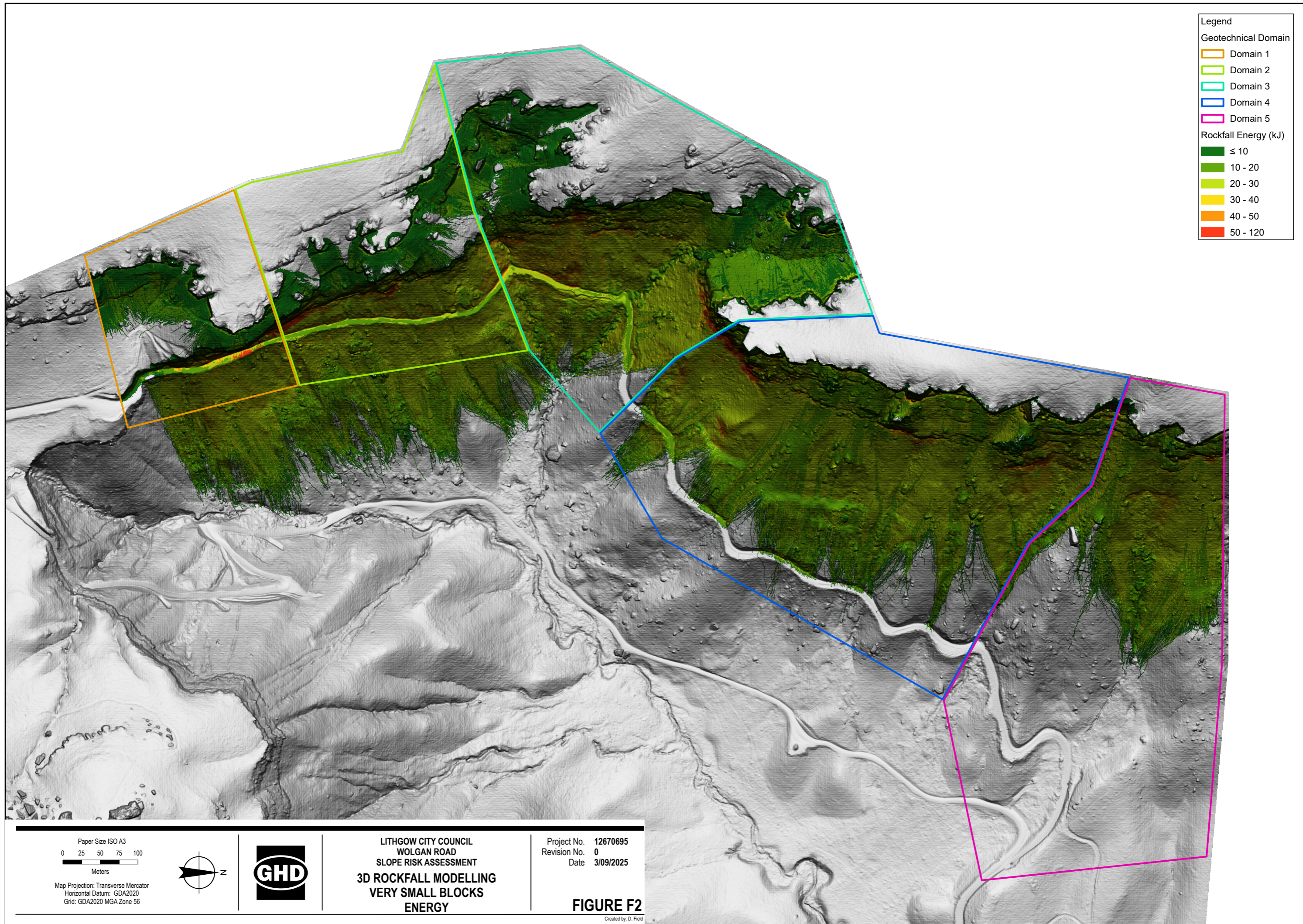
Map Projection: Transverse Mercator
 Horizontal Datum: GDA2020
 Grid: GDA2020 MGA Zone 56

LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
**3D ROCKFALL MODELLING
 VERY SMALL BLOCKS
 SUSCEPTIBILITY**

Project No. 12670695
 Revision No. 0
 Date 3/09/2025

FIGURE F1

Created by: D. Field



Legend

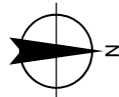
Geotechnical Domain

- Domain 1
- Domain 2
- Domain 3
- Domain 4
- Domain 5

Rockfall Energy (kJ)

- ≤ 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 120

Paper Size ISO A3
 0 25 50 75 100
 Meters



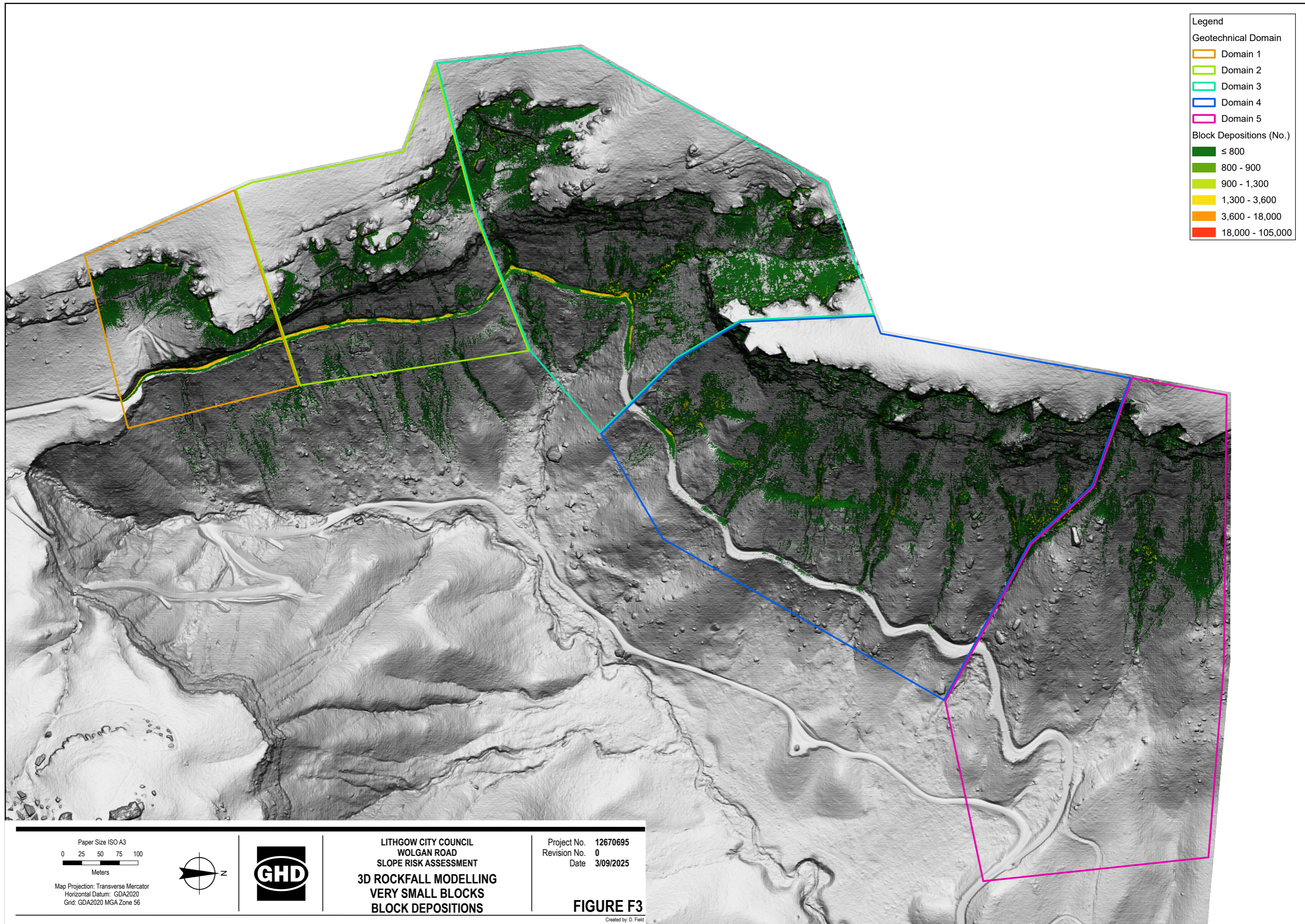
LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
3D ROCKFALL MODELLING
VERY SMALL BLOCKS
ENERGY

Project No. 12670695
 Revision No. 0
 Date 3/09/2025

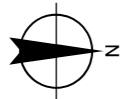
FIGURE F2

Created by: D. Field

Map Projection: Transverse Mercator
 Horizontal Datum: GDA2020
 Grid: GDA2020 MGA Zone 56



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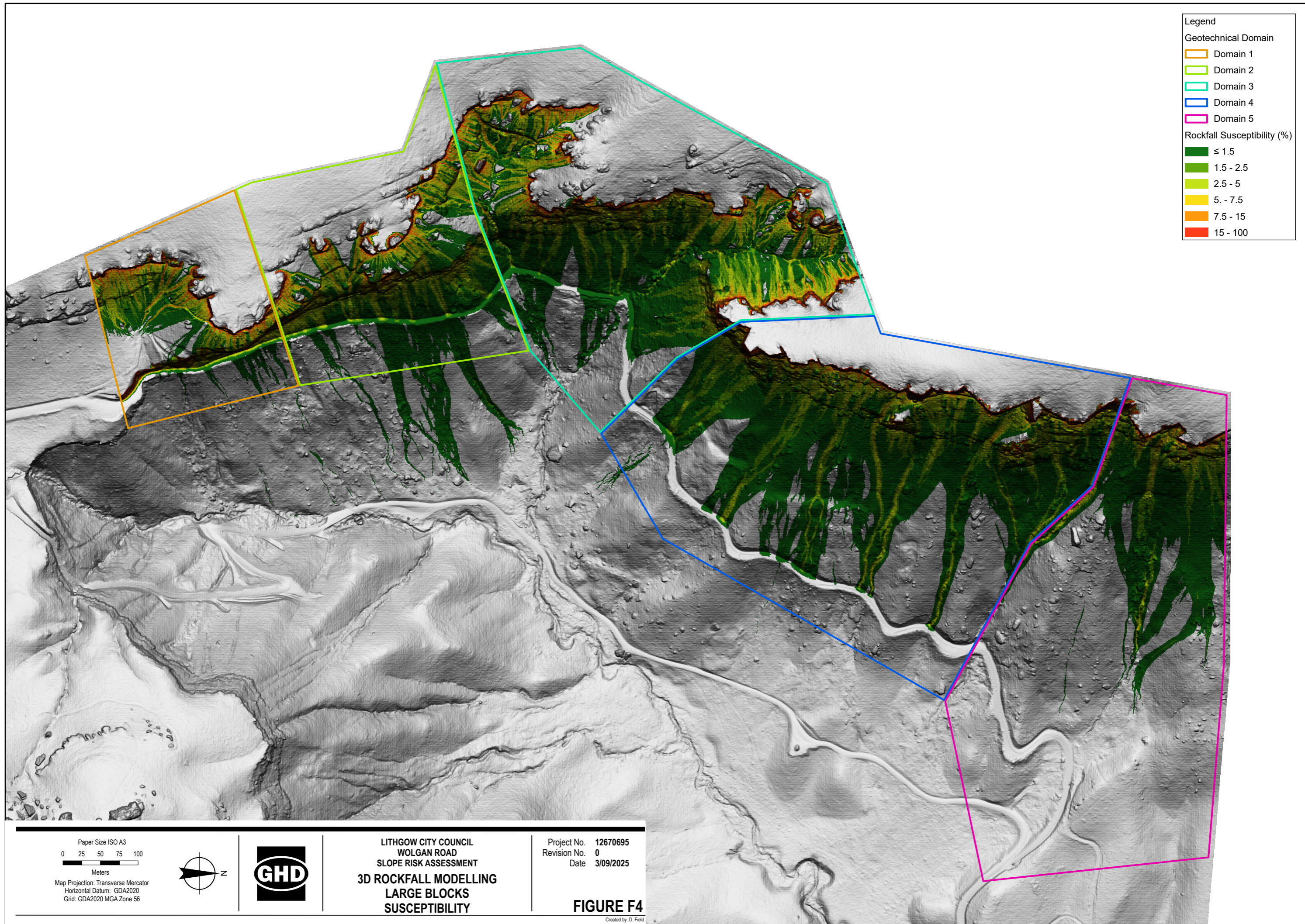
Map Projection: Transverse Mercator
 Horizontal Datum: GDA2020
 Grid: GDA2020 MGA Zone 56

LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
3D ROCKFALL MODELLING
VERY SMALL BLOCKS
BLOCK DEPOSITIONS

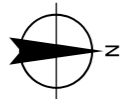
Project No. 12670695
 Revision No. 0
 Date 3/09/2025

FIGURE F3

Created by: D. Field



Paper Size ISO A3
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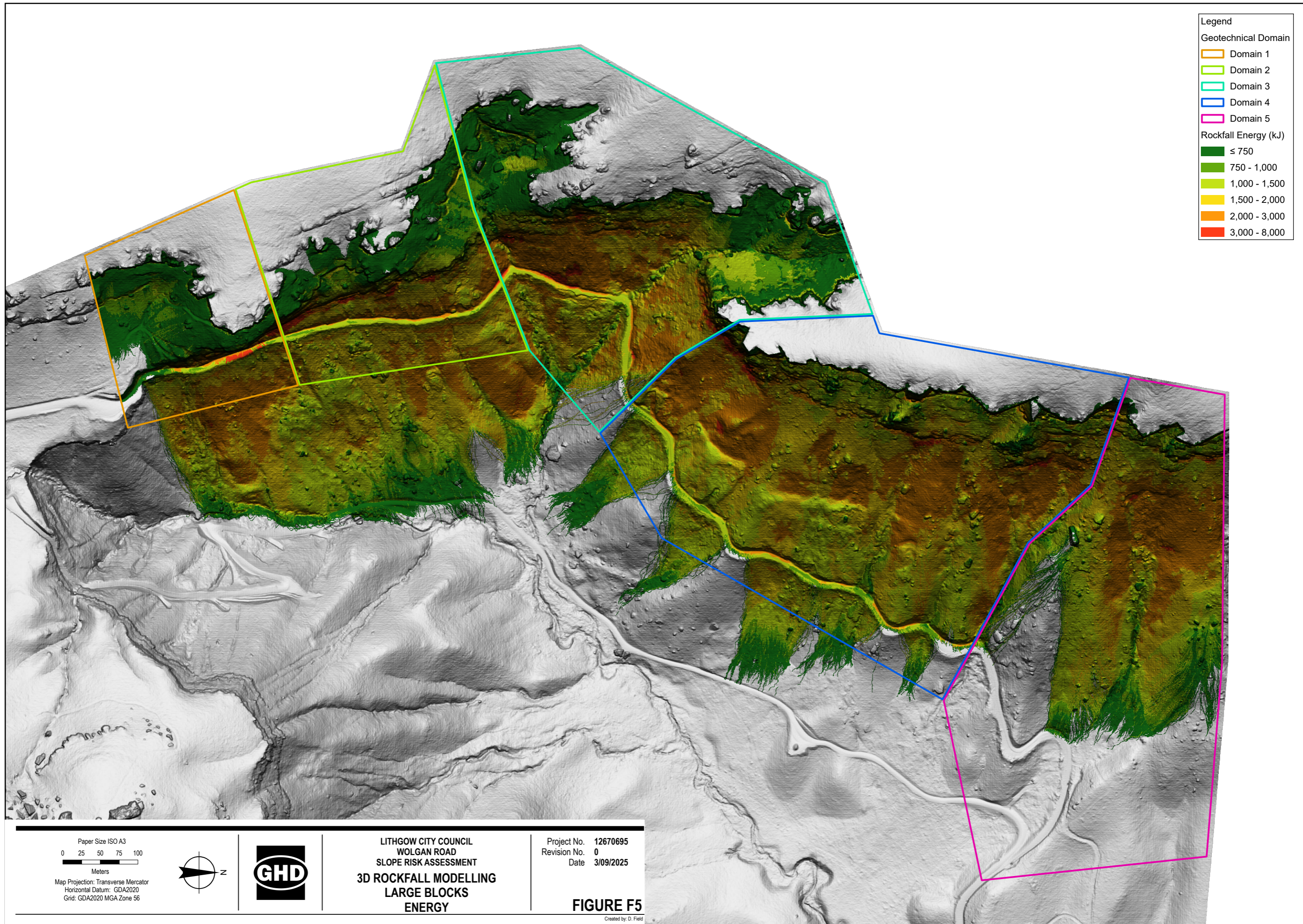
Map Projection: Transverse Mercator
 Horizontal Datum: GDA2020
 Grid: GDA2020 MGA Zone 56

LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
**3D ROCKFALL MODELLING
 LARGE BLOCKS
 SUSCEPTIBILITY**

Project No. 12670695
 Revision No. 0
 Date 3/09/2025

FIGURE F4

Created by: D. Field



Legend

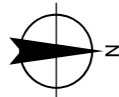
Geotechnical Domain

- Domain 1
- Domain 2
- Domain 3
- Domain 4
- Domain 5

Rockfall Energy (kJ)

- ≤ 750
- 750 - 1,000
- 1,000 - 1,500
- 1,500 - 2,000
- 2,000 - 3,000
- 3,000 - 8,000

Paper Size ISO A3
 0 25 50 75 100
 Meters



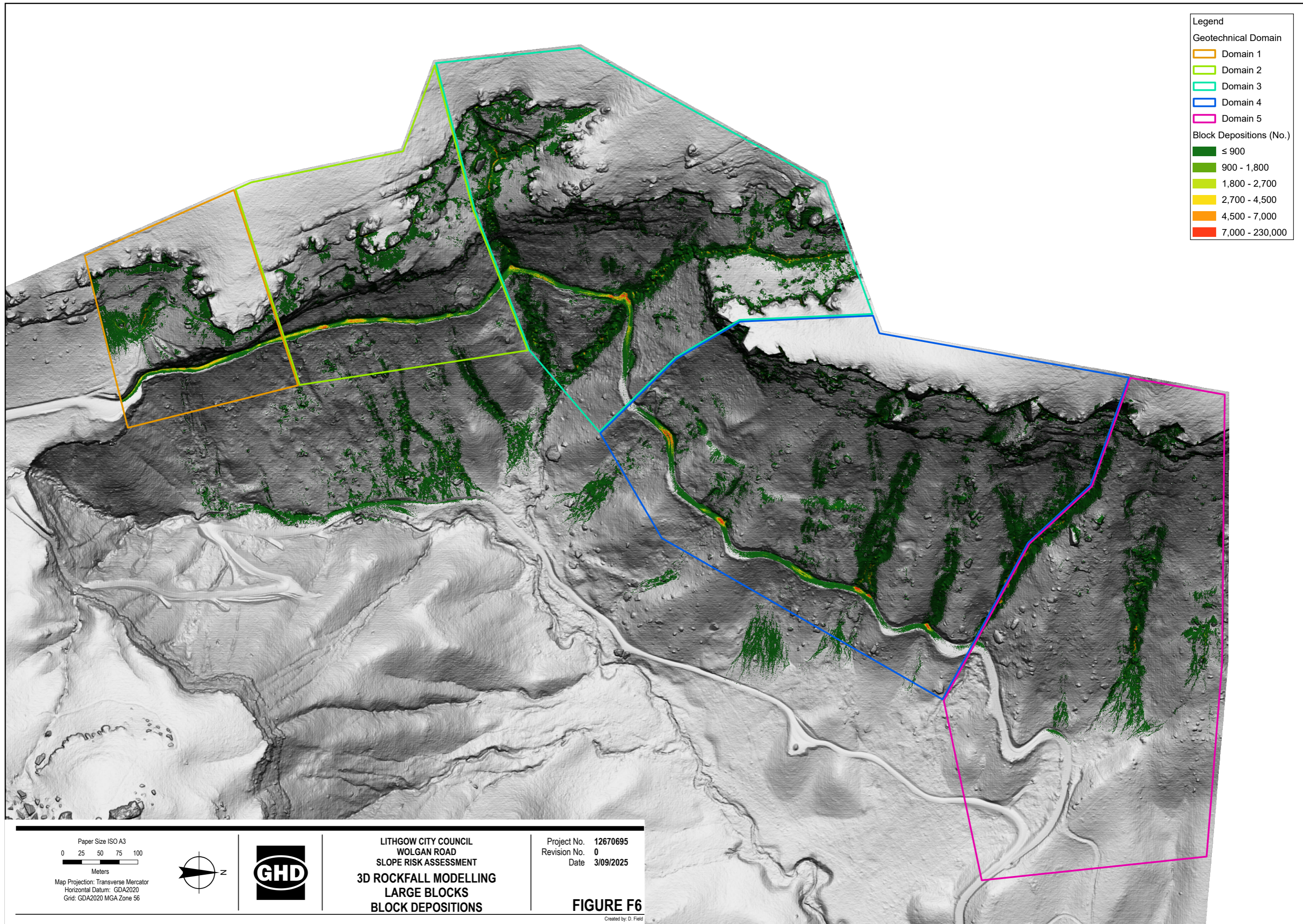
Map Projection: Transverse Mercator
 Horizontal Datum: GDA2020
 Grid: GDA2020 MGA Zone 56

LITHGOW CITY COUNCIL
 WOLGAN ROAD
 SLOPE RISK ASSESSMENT
**3D ROCKFALL MODELLING
 LARGE BLOCKS
 ENERGY**

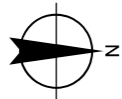
Project No. 12670695
 Revision No. 0
 Date 3/09/2025

FIGURE F5

Created by: D. Field



Paper Size ISO A3
0 25 50 75 100
Meters



Map Projection: Transverse Mercator
Horizontal Datum: GDA2020
Grid: GDA2020 MGA Zone 56

LITHGOW CITY COUNCIL
WOLGAN ROAD
SLOPE RISK ASSESSMENT
**3D ROCKFALL MODELLING
LARGE BLOCKS
BLOCK DEPOSITIONS**

Project No. 12670695
Revision No. 0
Date 3/09/2025

Appendix G

Risk assessment calculations

Appendix G - Risk Assessment Calculations

CLIENT: Lithgow City Council
PROJECT: Wolgan Road Slope Risk Assessment
PROJECT NO: 12670695

LOCATION: Wolgan Rd, NSW
DATE: 3/09/2025



Domain 1

	Hazard 1a	Hazard 1b	Hazard 2a	Hazard 2b	Hazard 3	Hazard 4	Hazard 5	Hazard 6	Hazard 7	Hazard 8	Hazard 9	Hazard 10	Hazard 11						
P(H)	1	N/A	1	N/A	0.3	0.06	0.03	N/A	N/A	N/A	N/A	0.05	0.02						
P(t)	1		1		1	1	1					1	1	1	1	1	1	1	1
V(D:T)	0.1		0.3		0.5	1	1					1	1	1	1	1	1	0.001	0.05
ni	1440		1440		1440	1440	1440					1440	1440	1440	1440	1440	1440	1440	1440
w	1		1		1	1	1					1	1	1	1	1	1	0.5	0.5
f	1		1		1	1	1					1	1	1	1	1	1	1	1
d (m)	0.4		0.6		3	5	10					10	10	10	10	10	10	10	20
si (km/h)	40		40		40	40	40					40	40	40	40	40	40	40	40
R(LOL)	1.58E-07		7.13E-07		1.78E-06	1.19E-06	1.19E-06					1.19E-06	1.19E-06	1.19E-06	1.19E-06	1.19E-06	1.19E-06	9.90E-10	3.96E-08
AvR(LOL)	1.10E-10		4.95E-10		1.24E-09	8.25E-10	8.25E-10					8.25E-10	8.25E-10	8.25E-10	8.25E-10	8.25E-10	8.25E-10	6.88E-13	2.75E-11
F	3.81E-06		1.72E-05		4.29E-05	2.86E-05	2.86E-05					2.86E-05	2.86E-05	2.86E-05	2.86E-05	2.86E-05	2.86E-05	2.38E-08	9.54E-07
R(LOLC)	5.07E-06																		
Fc	1.22E-04																		

Domain 2

	Hazard 1a	Hazard 1b	Hazard 2a	Hazard 2b	Hazard 3	Hazard 4	Hazard 5	Hazard 6	Hazard 7	Hazard 8	Hazard 9	Hazard 10	Hazard 11	
P(H)	1	1	1	0.1	0.3	0.06	0.03	0.5	0.1	0.05	N/A	0.05	0.02	
P(t)	1	1	1	1	1	1	1	1	1	1		1	1	1
V(D:T)	0.05	0.05	0.1	0.1	0.3	0.8	1	0.001	0.01	0.1		0.001	0.05	0.05
ni	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440		1440	1440	1440
w	1	1	1	1	1	1	1	0.5	1	1		0.5	0.5	0.5
f	1	1	1	1	1	1	1	1	1	1		1	1	1
d (m)	0.4	0.4	0.6	0.6	3	5	10	5	15	25		10	20	20
si (km/h)	40	40	40	40	40	40	40	40	40	40		40	40	40
R(LOL)	7.92E-08	7.92E-08	2.38E-07	2.38E-08	1.07E-06	9.50E-07	1.19E-06	4.95E-09	5.94E-08	4.95E-07		9.90E-10	3.96E-08	3.96E-08
AvR(LOL)	5.50E-11	5.50E-11	1.65E-10	1.65E-11	7.43E-10	6.60E-10	8.25E-10	3.44E-12	4.13E-11	3.44E-10		6.88E-13	2.75E-11	2.75E-11
F	1.91E-06	1.91E-06	5.72E-06	5.72E-07	2.57E-05	2.29E-05	2.86E-05	1.19E-07	1.43E-06	1.19E-05		2.38E-08	9.54E-07	9.54E-07
R(LOLC)	4.23E-06													
Fc	1.02E-04													

Domain 3

	Hazard 1a	Hazard 1b	Hazard 2a	Hazard 2b	Hazard 3	Hazard 4	Hazard 5	Hazard 6	Hazard 7	Hazard 8	Hazard 9	Hazard 10	Hazard 11
P(H)	1	1	1	0.1	0.3	0.06	0.03	0.5	0.1	0.05	0.02	0.05	0.02
P(t)	0.05	1	0.05	1	0.05	0.05	0.075	1	1	1	1	1	1
V(D:T)	0.05	0.05	0.1	0.1	0.3	0.8	1	0.001	0.01	0.1	0.05	0.001	0.05
ni	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440
w	0.5	0.5	0.5	0.5	0.5	1	1	0.5	1	1	1	0.5	0.5
f	1	1	1	1	1	1	1	1	1	1	1	1	1
d (m)	0.4	0.4	0.6	0.6	3	5	10	5	15	25	15	10	20
si (km/h)	40	40	40	40	40	40	40	40	40	40	40	40	40
R(LOL)	1.98E-09	3.96E-08	5.94E-09	1.19E-08	2.67E-08	4.75E-08	8.91E-08	4.95E-09	5.94E-08	4.95E-07	5.94E-08	9.90E-10	3.96E-08
AvR(LOL)	1.38E-12	2.75E-11	4.13E-12	8.25E-12	1.86E-11	3.30E-11	6.19E-11	3.44E-12	4.13E-11	3.44E-10	4.13E-11	6.88E-13	2.75E-11
F	4.77E-08	9.54E-07	1.43E-07	2.86E-07	6.44E-07	1.14E-06	2.15E-06	1.19E-07	1.43E-06	1.19E-05	1.43E-06	2.38E-08	9.54E-07
R(LOLC)	8.82E-07												
Fc	2.12E-05												

Domain 4

	Hazard 1a	Hazard 1b	Hazard 2a	Hazard 2b	Hazard 3	Hazard 4	Hazard 5	Hazard 6	Hazard 7	Hazard 8	Hazard 9	Hazard 10	Hazard 11	
P(H)	1	1	1	0.1	0.3	0.06	0.03	0.5	0.1	0.05	N/A	0.05	0.02	
P(t)	0.025	1	0.025	1	0.05	0.075	0.1	1	1	1		1	1	1
V(D:T)	0.05	0.05	0.1	0.1	0.3	0.8	1	0.001	0.01	0.1		0.001	0.05	0.05
ni	1440	1440	1440	1440	1440	1440	1440	1440	1440	1440		1440	1440	1440
w	0.5	0.5	0.5	0.5	0.5	1	1	0.5	1	1		0.5	0.5	0.5
f	1	1	1	1	1	1	1	1	1	1		1	1	1
d (m)	0.4	0.4	0.6	0.6	3	5	10	5	15	25		10	20	20
si (km/h)	40	40	40	40	40	40	40	40	40	40		40	40	40
R(LOL)	9.90E-10	3.96E-08	2.97E-09	1.19E-08	2.67E-08	7.13E-08	1.19E-07	4.95E-09	5.94E-08	4.95E-07		9.90E-10	3.96E-08	3.96E-08
AvR(LOL)	6.88E-13	2.75E-11	2.06E-12	8.25E-12	1.86E-11	4.95E-11	8.25E-11	3.44E-12	4.13E-11	3.44E-10		6.88E-13	2.75E-11	2.75E-11
F	2.38E-08	9.54E-07	7.15E-08	2.86E-07	6.44E-07	1.72E-06	2.86E-06	1.19E-07	1.43E-06	1.19E-05		2.38E-08	9.54E-07	9.54E-07
R(LOLC)	8.72E-07													
Fc	2.10E-05													

Domain 5

	Hazard 1a	Hazard 1b	Hazard 2a	Hazard 2b	Hazard 3	Hazard 4	Hazard 5	Hazard 6	Hazard 7	Hazard 8	Hazard 9	Hazard 10	Hazard 11					
P(H)	1	1	1	N/A	0.3	0.06	0.03	N/A	N/A	N/A	N/A	0.05	0.02					
P(t)	0	1	0		0.005	0.01	0.02					0.02	1	1	1	1	1	1
V(D:T)	0.001	0.001	0.005		0.3	0.8	1					1	0.001	0.01	0.1	0.001	0.05	0.05
ni	1440	1440	1440		1440	1440	1440					1440	1440	1440	1440	1440	1440	1440
w	0.5	0.5	0.5		0.5	0.5	1					1	0.5	1	1	0.5	0.5	0.5
f	1	1	1		1	1	1					1	1	1	1	1	1	1
d (m)	0.4	0.4	0.6		3	5	10					10	5	15	25	10	20	20
si (km/h)	40	40	40		40	40	40					40	40	40	40	40	40	40
R(LOL)	0.00E+00	7.92E-10	0.00E+00		2.67E-09	9.50E-09	2.38E-08					2.38E-08	4.95E-09	5.94E-08	4.95E-07	9.90E-10	3.96E-08	3.96E-08
AvR(LOL)	0.00E+00	5.50E-13	0.00E+00		1.86E-12	6.60E-12	1.65E-11					1.65E-11	3.44E-12	4.13E-11	3.44E-10	6.88E-13	2.75E-11	2.75E-11
F	0.00E+00	1.91E-08	0.00E+00		6.44E-08	2.29E-07	5.72E-07					5.72E-07	1.19E-07	1.43E-06	1.19E-05	2.38E-08	9.54E-07	9.54E-07
R(LOLC)	7.73E-08																	
Fc	1.86E-06																	

All Domains

R(LOLC)	1.11E-05
Fc	2.68E-04

Appendix H

**GHD standard sheets – landslide risk
assessment and risk management**

LANDSLIDE RISK ASSESSMENT AND RISK MANAGEMENT



GHD GEOTECHNICS

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INTRODUCTION

Fundamental to Landslide Risk Assessment and Landslide Risk Management is an understanding of the slope-forming processes together with an appreciation of mechanisms of instability, be they soil or rock slopes, cuttings or embankments and fills. Accordingly, the assessment will be particular to a project wherein specific property or individuals most-at-risk are identified.

GHD encourages you to read the Australian Geomechanics Society guidelines on Landslide Risk Management (LRM) and slope management and maintenance. The guidelines are a series of benchmark papers that are collectively known as AGS (2007).

Please see the references (below) and the website link from which the guidelines can be downloaded.

BASIS OF ASSESSMENT

Landslide risk assessment is initiated by observations of features on a site and its surrounds, and could include appraisal of historical data, or discovery by sub-surface investigation, which together with an interpretation of sub-surface conditions, and with an understanding of slope-forming processes, identifies natural and man-made features that may be geohazards. The assessment is conducted for a specific project and elements-at-risk.

Risk assessments are conventionally conducted to appraise the risk-to-property and risk-to-life. Risk-to-property may be conducted employing both qualitative and quantitative methods. Risk-to-life should be conducted with a quantitative component since reference to risk levels is based upon international experience with numeric values of risk included within the evaluation methodology.

The Risk Assessment process involves a series of tasks from risk analysis, to risk assessment and risk management. The process can be envisaged diagrammatically through such as Figure 1 in AGS (2007a) or AGS (2007c) – a copy of the flowchart is attached. Importantly, the process involves a feedback loop to verify the initial assumptions, the validity of the assessed risk outcome, the appropriateness of management methods, and performance of the site and intervention works (if and as may be required).

Note that a risk assessment does not preclude geohazards occurring, no matter their likelihood.

The risk assessment is based on certain expectations in terms of quality of: subsequent geotechnical investigation; geotechnical, civil & structural design; and construction of the development. These expectations are fundamental to the appraisal and assessment that has been conducted. Should these issues not be addressed nor occur, or be of lesser quality than reasonably expected, then risk conditions could well be more adverse, meaning that the assessment would need to be revised accordingly to more severe risk levels.

Note that local variations or anomalies in the generalised ground conditions do occur in the natural environment, which means that on-site verification of the nature and form of the geohazards prudently should be conducted during site development and construction. Furthermore, it should be appreciated that natural features in all likelihood will change and may deteriorate over time, which could change existing geohazards or create new ones. Should the nature of the geohazard change, the landslide risk assessment should be re-appraised and/or its validity be confirmed.

GHD's reports will outline our observations of geotechnical site features and assessment of landslide and rock fall hazards observable at the time of the fieldwork. The report will also explain the risk level appraisal.

RISK LEVELS

In our society, we do not live in a risk-free environment. There is risk, to varying degrees, in everything that we do throughout our existence – for example, the risk of fatality in driving a vehicle in NSW (2021) is approximately 1 in 30,000 per annum (3E-5pa).

The issue with risk assessment is to determine risk levels; and, in terms of landslide risk levels, to determine the likelihood of geohazards being realised and the consequences should that occur; and to appraise whether the risk levels are acceptable or are tolerable within our society.

This means that risk assessment is undertaken to compare the analysed risk levels with acceptable or tolerable levels. Should risk assessed risk levels not meet societal criteria, the aim of risk management is to reduce the assessed risk levels through their management and by implementation of remedial actions or intervention, as appropriate. Overall, the aim is to manage risk levels not only in the context of "forewarned is forearmed", but also to provide guidance to achieve risk levels acceptable to the Australian community – if not that, then to achieve tolerable risk levels.

In some situations, the management protocol may be to achieve a risk level that is 'As Low As Reasonably Practical' (ALARP). This approach can be considered in the context that risk reduction measures be carried out to the extent that the cost involved in reducing the risk further would be disproportionate to the benefit gained. It often applies to societal risk levels - being where more lives are at risk than a single individual-most-at-risk. An ALARP approach is not usually appropriate in a residential setting, principally due to the issue of transfer of risk in the event of sale of the property.

Risk levels may be determined as Acceptable or Tolerable. The appropriateness of these risk levels includes appreciation of the period of existence of the geohazard, together with the expected duration of exposure of the elements-at-risk. This is an issue that a community deems, through such as the council for a Local Government Area, to be a risk level appropriate for the overall cost to the community it represents. Whilst parties such as the property owner, the property occupier, parties around the property, developer, lender, services providers, and regulators could be involved in determination of acceptable or tolerable risk levels, pragmatically the regulator is the authority responsible for setting the tolerance criteria for risk levels, and doing so on behalf of its constituents.

There are many ways to manage adverse risk levels. The nature and extent of possible mitigation methods and techniques will be identified in our report to you. Risk avoidance is also a valid risk management approach; for example, such as wherein geohazards are removed or the elements-at-risk are re-located.

Note that whatever the assessed risk, and the appraised risk level, the event can still occur, no matter the assessed likelihood of occurrence.

PERSONS WHO SHOULD CONDUCT LANDSLIDE RISK ASSESSMENT

AGS (2007) recommends that LRM must be the responsibility of geotechnical practitioners who will be a Geotechnical Engineer or Engineering Geologist who is a specialist with core competencies in landslide risk management. These practitioners will be a professional engineer or registered professional engineering geologist, in both instances with chartered professional status (being either CPEng or CPGeo or RPGeo) with Landslide Risk Management as a core competency.

THIS REPORT

This report outlines our observations of geotechnical site features and our assessment of landslide hazards observable at the time that the observations were made. Note that natural features will change and may deteriorate over time, which could change existing hazards or create new ones. In that situation, additional investigations may be required to further assess landslide hazards, risk mitigation measures, on-going monitoring and maintenance requirements, all in the context of landslide risk management.

In regard to Landslide Risk Assessment and Landslide Risk Management, GHD follows the recommendations contained within AGS (2007).

REFERENCES

The cited references below provide detailed guidance on landslide risk management. The reader is encouraged to download copies for their own familiarisation of the concepts involved.

AGS (2007) – a generic term that covers the suite of 5 papers of which AGS (2007c, 2007d and 2007e) form part.

AGS (2007a) "Guideline for landslide susceptibility, hazard and risk zoning for land use planning", *Australian Geomechanics*, V42 N1, March 2007.

AGS (2007b) "Commentary on guideline for landslide susceptibility, hazard and risk zoning for land use planning", *Australian Geomechanics*, V42 N1, March 2007.

AGS (2007c) "Practice Note Guidelines for Landslide Risk Management 2007", Australian Geomechanics Society, Landslide Taskforce, Practice Note Working Group, *Australian Geomechanics*, V42 N1, March 2007.

AGS (2007d) "Commentary on Practice Note Guidelines for Landslide Risk Management 2007", Australian Geomechanics Society, Landslide Taskforce, Practice Note Working Group, *Australian Geomechanics*, V42 N1, March 2007.

AGS (2007e) "Australian GeoGuides for slope management and maintenance". Australian Geomechanics Society, *Australian Geomechanics*, V42 N1, March 2007.

The cited AGS (2007) Guideline papers can be downloaded from: www.australiangeomechanics.org

DEFINITIONS OF TERMS

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

Annual Exceedance Probability (AEP) – The estimated probability that an event of specified magnitude will be exceeded in any year.

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.

Danger – The natural phenomenon that could lead to damage, described in terms of its geometry, mechanical and other characteristics. The danger can be an existing one (such as a creeping slope) or a potential one (such as a rock fall). The characterisation of a danger does not include any forecasting.

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

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

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

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

Landslide inventory – An inventory of the location, classification, volume, activity and date of occurrence of landsliding

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 surfaces of rupture. Reactivation may be occasional (eg: seasonal) or continuous (in which case the slide is “active”)

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

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. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.

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

Probability – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity or the likelihood of the occurrence of the uncertain future event.

There are two main interpretations:

- (i) Statistical – frequency or fraction – The outcome of a repetitive experiment of some kind like flipping coins. It includes also the idea of population variability. Such a number is called an “objective” or relative frequentist probability because it exists in the real world and is in principle measurable by doing the experiment.
- (ii) Subjective probability (degree of belief) – Quantified measure of belief, judgement, or confidence in the likelihood of an outcome, obtained by considering all available information honestly, fairly and with a minimum of bias. Subjective probability is affected by the state of understanding of a process, judgement regarding an evaluation or the quality and quantity of information. It may change over time as the state of knowledge changes.

Qualitative Risk Analysis – An analysis which uses word form, descriptive or numeric rating scales to describe the magnitude of potential consequences and the likelihood that those consequences will occur.

Quantitative Risk Analysis – 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 affect to health, property or the environment. Risk is often estimated by the product of probability x consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

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

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

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

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

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

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

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

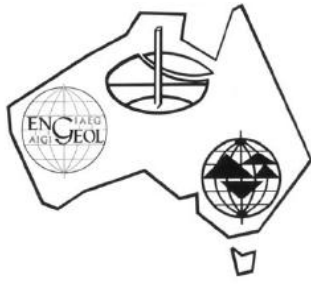
Susceptibility – see **Landslide Susceptibility**

Temporal-Spatial Probability – The probability that the element at risk is in the affected area at the time of the landslide.

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.

Zoning – The division of land into homogeneous areas or domains and their ranking according to degrees of actual or potential landslide susceptibility, hazard or risk.



**Australian
Geomechanics
Society**

Extract from

Australian Geomechanics

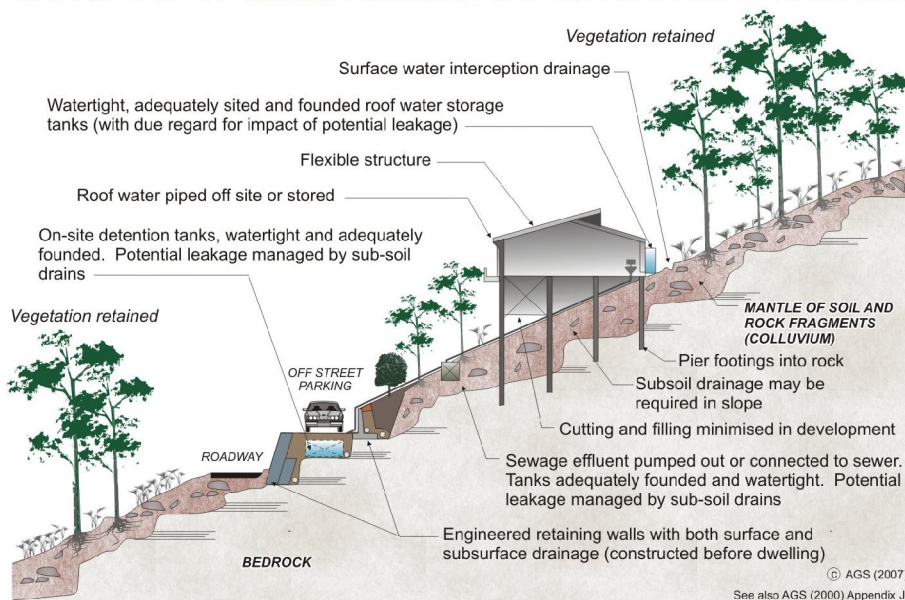
Journal and News of the Australian Geomechanics Society
Volume 42 No 1 March 2007

Extract containing:

“Practice Note Guidelines for Landslide Risk Management 2007”

Ref: AGS (2007c)

EXAMPLES OF **GOOD** HILLSIDE CONSTRUCTION PRACTICE



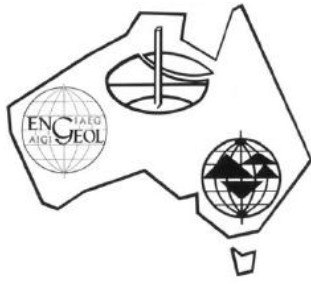
Landslide Risk Management



**ENGINEERS
AUSTRALIA**



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“The Australian GeoGuides for Slope Management and Maintenance”

Ref: AGS (2007e)



Landslide Risk Management



ISSN 0818-9110

THE AUSTRALIAN GEOGUIDES FOR SLOPE MANAGEMENT AND MAINTENANCE

AGS Landslide Taskforce, Slope Management and Maintenance Working Group

The Australian Geomechanics Society (AGS) presents on the following pages a guideline on slope management and maintenance, as part of the landslide risk management guidelines developed under the National Disaster Funding Program (NDMP). This Guideline is aimed at home owners, developers and local councils, but also has applicability to a larger audience which includes builders and contractors, consultants, insurers, lawyers, government departments and in fact any person, or organisation, with a responsibility for the management or maintenance of a slope. The objective is to inform those with little or no knowledge of geotechnical engineering about landslides.

Each GeoGuide is a stand-alone document, which is formatted so that it can be printed on two sides of a single A4 sheet. It is expected that the set of GeoGuides will increase with time to cover a range of topics. As things stand:

- **GeoGuide LR1** is an introductory sheet that should be read by all users, since it explains what the LR (landslide risk) series is about and defines terms.
- **GeoGuides LR2, 3 and 4** explain why landslides occur and provide information on different types of landslide.
- **GeoGuide LR5** discusses the critical part that water often plays in relation to landslide occurrence and discusses measures that can be adopted to limit its effect.
- **GeoGuide LR6** refers to retaining walls and their maintenance.
- **GeoGuide LR7** puts the concept of landslide risk into an everyday context, so users can relate a particular landslide risk to other risks that they know they are prepared to take, sometimes on a daily basis.
- **GeoGuide LR8** retains the ideas of good and poor hillside construction practice originally provided by an AGS sub-committee in 1985.
- **GeoGuide LR9** concentrates specifically on effluent and surface water disposal, which is an important topic in some development areas.
- **GeoGuide LR10** is specifically aimed at those who have property on the coast and could be susceptible to coastal erosion processes.
- **GeoGuide LR11** provides information about the benefits of keeping records on inspection and maintenance activities and provides a proforma record sheet for users.

It is recognised that the GeoGuides are likely to be upgraded from time to time. Feedback on use and suggested changes should be sent to the National Chair of the Australian Geomechanics Society. The latest versions of the GeoGuides will be downloadable from the AGS website www.australiangeomechanics.org

Through the NDMP, Australian governments (at Commonwealth, State and Local Government levels) are also funding the development of a Landslide Zoning Guideline (AGS 2007a), and a Practice Note Guideline (AGS 2007c) to which interested readers seeking in-depth information should refer.

ACKNOWLEDGEMENTS

These guidelines have been prepared by The Australian Geomechanics Society with funding from the National Disaster Mitigation Program, the Sydney Coastal Councils Group, and The Australian Geomechanics Society.

The Australian Geomechanics Society established a Working Group within a Landslide Taskforce to develop the guidelines. The development of the guidelines was managed by a Steering Committee. Membership of the Working Group, Taskforce and Steering Committee is listed in the Appendix.

Drafts of these GeoGuides have been subject to review by members of the AGS Landslide Taskforce, members of the geotechnical profession and local government.

REFERENCES

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management. Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1.
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1,
- AGS (2007e). The Australian GeoGuides for slope management and maintenance –. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No 1, - this paper.

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

INTRODUCTION TO LANDSLIDE RISK

Photographs courtesy of Greg Kotze and Tony Phillips



AUSTRALIAN GEOGUIDES

The **Australian GeoGuides (LR series)** are a set of information sheets on the subject of landslide risk management and maintenance, published by the Australian Geomechanics Society (AGS). They provide background information intended to help people without specialist technical knowledge understand the basic issues involved. Topics covered include:

LR1 - Introduction	LR2 - Landslides	LR3 - Landslides in Soil
LR4 - Landslides in Rock	LR5 - Water & Drainage	LR6 - Retaining Walls
LR7 - Landslide Risk	LR8 - Hillside Construction	LR9 - Effluent & Surface Water Disposal
LR10 - Coastal Landslides	LR11 - Record Keeping	

The GeoGuides explain why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local authority approval (if required) to remove, or reduce, the risk they represent.

Preparation of the GeoGuides has been funded by Australian governments through the National Disaster Mitigation Program (NDMP). This is a national program aimed at identifying and addressing natural disaster risk priorities across Australia. Technical input has been provided by experienced geotechnical engineers, engineering geologists and local government and government agency representatives from around Australia.

BACKGROUND

A number of landslides and cliff collapses occurred in Australia in the 1980's and 1990's in which lives were lost. Of these the Thredbo landslide probably received the most publicity, but there were several others. During this period the AGS issued a number of advisory notes to practitioners in relation to the assessment of landslide risk and its reduction. Building on these notes, and responding to changes in technology, a technical paper known as AGS2000 was prepared. It was followed in 2002 by an intensive nation-wide educational campaign attended by a large number of interested professionals from government departments and private industry. This resulted in an increased awareness of the risks associated with unstable slopes and a changed approach in many government departments responsible for regional planning, domestic development, roads, railways and the maintenance of natural features such as cliffs.

STATUS OF THE GEOGUIDES

The GeoGuides reflect the essence of good practice as perceived by a large number of geotechnical engineers, engineering geologists and other practitioners such as local government planners. **The GeoGuides are generic and do not, and cannot, constitute advice in relation to a specific situation. This must be sought from a geotechnical practitioner with first hand knowledge of the site.** It is expected that some local councils will refer to the GeoGuides and their companion publications in planning and building legislation. Check with your local council to see how it regards these documents. Companion publications to the GeoGuides are:

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1 and its associated commentary (AGS 2007b).
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1 2007, and its associated "Commentary" (AGS 2007d).

Copies of the above documents are available on the AGS website www.australiangeomechanics.org

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

TERMINOLOGY

Terminology tends to change with time and place and with the context in which it is used. The terms listed below have the following meanings in the GeoGuides:

Consequence	the outcome, or potential outcome, arising from the occurrence of a landslide expressed quantitatively, or qualitatively, in terms of loss, disadvantage, damage, injury, or loss of life.
Discontinuity	in relation to the ground is a crack, a bedding plane (a boundary between strata) or fault (a plane along which the ground has sheared) which forms a plane of weakness and reduces the overall strength of the ground.
Equilibrium	the condition when the forces on a mass of soil or rock in the ground, or on a retaining structure, are equal and opposite.
Factor of safety (FOS)	theoretically the forces available to prevent a part of the ground, or a retaining structure, from moving divided by those trying to move it. A FOS of one or less indicates that failure is likely to occur, but not how likely it is. To allow for unknowns and to limit movements engineers always aim to achieve a FOS significantly larger than one.
Failure	when part of the ground experiences movement as a result of the out of balance forces on it. Failure of a retaining structure means it is no longer able to fulfil its intended function.
Geotechnical practitioner	when referred to in the Australian GeoGuides (LR series), is a professional geotechnical engineer, or engineering geologist, with chartered status in a recognised national professional institution and relevant training, experience and core competencies in landslide risk assessment and management. In some government departments, technical officers are specifically trained to undertake some of the functions of a geotechnical practitioner.
Hazard	a condition with the potential for causing an undesirable consequence. In relation to landslides this includes the location, size, speed, distance of travel and the likelihood of its occurrence within a given period of time.
Landslide	the movement, or the potential movement, of a mass of rock, debris, or earth down a slope.
Likelihood	a qualitative description of probability, or frequency, of occurrence.
Partial saturation	the condition in the ground above the water table where both air and water are present as well as soil, or rock.
Perched water table	a water table above the true water table supported by a low permeability stratum.
Permeability	a measure of the ability of the ground to allow water to flow through it.
Risk	a measure of the probability and severity of an adverse effect to life, health, property or the environment.
Slip failure	landslide.
Stable	the condition when failure will not occur. Over geological time no part of the ground can be considered stable. Over short periods (eg the life of a structure) stability implies a very low likelihood of failure.
Retaining structure	anything built by humans which is intended to support the ground and inhibit failure.
Structure	in relation to rock, or soil, means the spacing, extent, orientation and type of discontinuities found in the ground at a particular location.
Tension crack	a distinct open crack that normally develops in the ground around a landslide and indicates actual, or imminent, failure.
Water table	the level in the ground below which it is saturated and the voids are filled with water.

Photograph courtesy of Phil Flentje



AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

LANDSLIDES

What is a Landslide?

Any movement of a mass of rock, debris, or earth, down a slope, constitutes a "landslide". Landslides take many forms, some of which are illustrated. More information can be obtained from Geoscience Australia, or by visiting its Australian Landslide Database at www.ga.gov.au/urban/factsheets/landslide.jsp. Aspects of the impact of landslides on buildings are dealt with in the book "Guideline Document Landslide Hazards" published by the Australian Building Codes Board and referenced in the Building Code of Australia. This document can be purchased over the internet at the Australian Building Codes Board's website www.abcb.gov.au.

Landslides vary in size. They can be small and localised or very large, sometimes extending for kilometres and involving millions of tonnes of soil or rock. It is important to realise that even a 1 cubic metre boulder of soil, or rock, weighs at least 2 tonnes. If it falls, or slides, it is large enough to kill a person, crush a car, or cause serious structural damage to a house. The material in a landslide may travel downhill well beyond the point where the failure first occurred, leaving destruction in its wake. It may also leave an unstable slope in the ground behind it, which has the potential to fail again, causing the landslide to extend (regress) uphill, or expand sideways. For all these reasons, both "potential" and "actual" landslides must be taken very seriously. They present a real threat to life and property and require proper management.

Identification of landslide risk is a complex task and must be undertaken by a geotechnical practitioner (GeoGuide LR1) with specialist experience in slope stability assessment and slope stabilisation.

What Causes a Landslide?

Landslides occur as a result of local geological and groundwater conditions, but can be exacerbated by inappropriate development (GeoGuide LR8), exceptional weather, earthquakes and other factors. Some slopes and cliffs never seem to change, but are actually on the verge of failing. Others, often moderate slopes (Table 1), move continuously, but so slowly that it is not apparent to a casual observer. In both cases, small changes in conditions can trigger a landslide with serious consequences. Wetting up of the ground (which may involve a rise in ground water table) is the single most important cause of landslides (GeoGuide LR5). This is why they often occur during, or soon after, heavy rain. Inappropriate development often results in small scale landslides which are very expensive in human terms because of the proximity of housing and people.

Does a Landslide Affect You?

Any slope, cliff, cutting, or fill embankment may be a hazard which has the potential to impact on people, property, roads and services. Some tell-tale signs that might indicate that a landslide is occurring are listed below:

- open cracks, or steps, along contours
- ground water seepage, or springs
- bulging in the lower part of the slope
- hummocky ground
- trees leaning down slope, or with exposed roots
- debris/fallen rocks at the foot of a cliff
- tilted power poles, or fences
- cracked or distorted structures

These indications of instability may be seen on almost any slope and are not necessarily confined to the steeper ones (Table 1). Advice should be sought from a geotechnical practitioner if any of them are observed. Landslides do not respect property boundaries. As mentioned above they can "run-out" from above, "regress" from below, or expand sideways, so a landslide hazard affecting your property may actually exist on someone else's land.

Local councils are usually aware of slope instability problems within their jurisdiction and often have specific development and maintenance requirements. **Your local council is the first place to make enquiries if you are responsible for any sort of development or own or occupy property on or near sloping land or a cliff.**

TABLE 1 - Slope Descriptions

Appearance	Slope Angle	Maximum Gradient	Slope Characteristics
Gentle	0° - 10°	1 on 6	Easy walking.
Moderate	10° - 18°	1 on 3	Walkable. Can drive and manoeuvre a car on driveway
Steep	18° - 27°	1 on 2	Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car.
Very Steep	27° - 45°	1 on 1	Can only climb slope by clutching at vegetation, rocks etc.
Extreme	45° - 64°	1 on 0.5	Need rope access to climb slope
Cliff	64° - 84°	1 on 0.1	Appears vertical. Can abseil down.
Vertical or Overhang	84° - 90±°	Infinite	Appears to overhang. Abseiler likely to lose contact with the face.

Some typical landslides which could affect residential housing are illustrated below:

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

Rotational or circular slip failures (Figure 1) - can occur on moderate to very steep soil and weathered rock slopes (Table 1). The sliding surface of the moving mass tends to be deep seated. Tension cracks may open at the top of the slope and bulging may occur at the toe. The ground may move in discrete "steps" separated by long periods without movement. More rapid movement may occur after heavy rain.

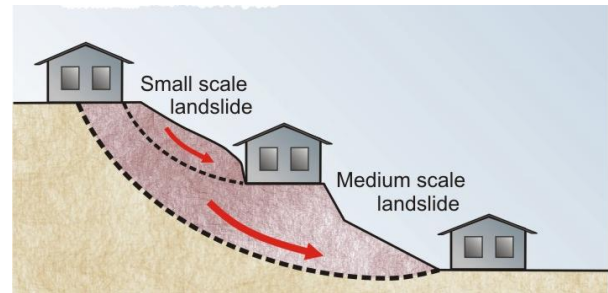


Figure 1

Translational slip failures (Figure 2) - tend to occur on moderate to very steep slopes (Table 1) where soil, or weak rock, overlies stronger strata. The sliding mass is often relatively shallow. It can move, or deform slowly (creep) over long periods of time. Extensive linear cracks and hummocks sometimes form along the contours. The sliding mass may accelerate after heavy rain.

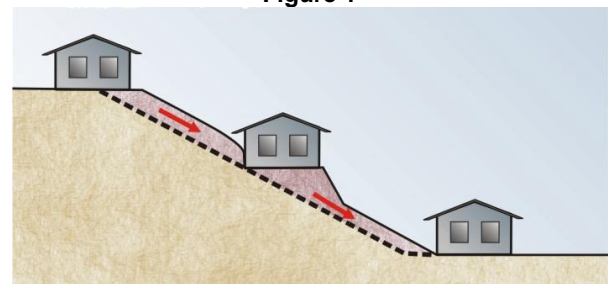


Figure 2

Wedge failures (Figure 3) - normally only occur on extreme slopes, or cliffs (Table 1), where discontinuities in the rock are inclined steeply downwards out of the face.

Rock falls (Figure 3) - tend to occur from cliffs and overhangs (Table 1).

Cliffs may remain apparently unchanged for hundreds of years. Collections of boulders at the foot of a cliff may indicate that rock falls are ongoing. Wedge failures and rock falls do not "creep". Familiarity with a particular local situation can instil a false sense of security since failure, when it occurs, is usually sudden and catastrophic.

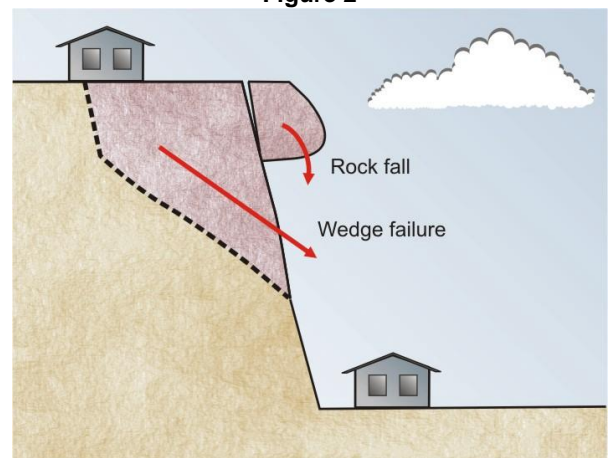


Figure 3

Debris flows and mud slides (Figure 4) - may occur in the foothills of ranges, where erosion has formed valleys which slope down to the plains below. The valley bottoms are often lined with loose eroded material (debris) which can "flow" if it becomes saturated during and after heavy rain. Debris flows are likely to occur with little warning; they travel a long way and often involve large volumes of soil. The consequences can be devastating.

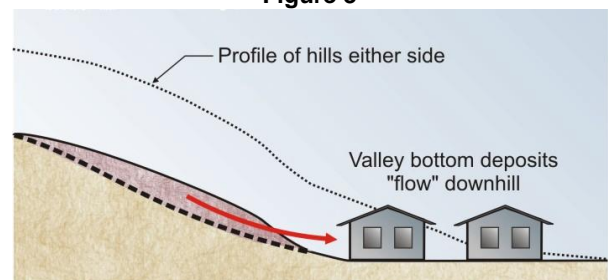


Figure 4

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR3 - Soil Slopes
- GeoGuide LR4 - Rock Slopes
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- 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.

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
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Appendix I

Comments register

Comments Register

Project: Wolgan Road
Client: Lithgow City Council
Job No: 12670698

Document: Wolgan Road Slope Risk Assessment Report
Revision: 1
File Name: 12670698-GHD-XX-XX-RPT-GT-00001-0_Wolgan Road Slope Risk Assessment.docx



Comment No.	Date Raised	Raised By	Reference/ Report Section	Review Comment	GHD Response	Response Date	Comment closed? (Yes / No)
1	19/09/2025	Wassabi Group	Executive Summary, Section 13	Delete the follow Anecdotal statement. This is a general observation about policy/practice, not a result of the Wolgan Road analysis. It speculates on how TfNSW might respond given budget constraints – an unrelated point outside the strict factual findings of the slope risk assessment. Refer to pages ii in the Executive Summary and 57: <i>"TfNSW does not publicly publish their risk tolerability criteria. Anecdotally we understand managing authorities such as TfNSW and councils typically tolerate risk levels that are ARL3 or lower risk (i.e. ARL4 and ARL5). However, we also understand that depending on funding availability and other factors TfNSW and other road authorities may tolerate ARL1 and ARL2 sites for decades or even indefinitely."</i>	GHD has removed any reference to anecdotal TfNSW risk tolerability criteria and confirm that TfNSW do not publicly publish their risk tolerability criteria.	23/09/2025	
2	19/09/2025	Wassabi Group	11.10 Risk Evaluation	In Section 11.10 Risk Evaluation on pages 51 to 52 there are a number of graphs with Domain's siting in "ALARP-Tolerable". The text within 11.10 Risk Evaluation doesn't mention ALARP, which is a significant omission.	Further discussion on the ALARP Principle has been added to Section 11.10	23/09/2025	
3	19/09/2025	Wassabi Group	11.10 Risk Evaluation	ALARP = As Low As Reasonably Practicable. A risk in the "Tolerable if ALARP" band means: The risk is not Acceptable outright (i.e. it is above the level society usually accepts without action). But it can be tolerated temporarily provided: a.The risk has been reduced as much as reasonably practicable, balancing cost, effort, technical feasibility, and the benefits of further risk reduction. b.The decision-maker (Council in this case) is satisfied that all reasonable measures to lower the risk have been considered or implemented. 3.In other words, the risk is "tolerable" only if Council can demonstrate that it has done everything practicable to reduce the risk further. GHD do not explain this point in the report. "Tolerable" (noting the omission of ALARP) is made to sound the similar or close to "Acceptable" which is clearly is not. Tolerable is not a permanent or resilient fix.	Further discussion on the ALARP Principle has been added to Section 11.10 Further discussion on tolerable and acceptable risks has been added to Section 11.10.	23/09/2025	



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