FORTIFY
GEOTECH

Proposed Demolition of Sonnblick Lodge

CLIENT

Kosciuszko
Thredbo Pty Ltd

ADDRESS

10 Bobuck Lane,
Thredbo, NSW

DATE

August 2024

Department of Planning
Housing and Infrastructure

Issued under the Environmental Planning and Assessment Act 1979

Approved Application No DA 24/448

Granted on the 3 July 2025

Signed E Murphy

Sheet No 2 of 8

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19 December 2024
Our ref: OB/C14191v3

Kosciuszko Thredbo Pty Ltd

Via email: Andrew_Harrigan@evt.com

Attention: Mr Andrew Harrigan

Proposed Demolition of Sonnblick Lodge
10 Bobuck Lane, Thredbo, NSW
Geotechnical Investigation & Landslide Risk Assessment

We are pleased to forward our geotechnical investigation and landslide risk assessment for the proposed demolition of the existing Sonnblick Lodge, located at 10 Bobuck Lane in Thredbo, NSW.

The report outlines the methods and results of field investigations, describes site subsurface conditions, and provides geotechnical recommendations for site earthworks, structure footings and a qualitative and quantitative landslide risk assessment of the existing slope and of the slope after the demolition and earthworks.

The landslide risk assessment is based on the landslide risk management concepts and guidelines issued by the Australian Geomechanics Journal Vol 35 March 2007 “Practice Note Guidelines for Landslide Risk Management 2007”. By these criteria, it was established that the level of initial or current risk for the Sonnblick Lodge and neighbouring dwelling ranges from “Very Low” to “Very High”. Provided all control measures are implemented, the residual risk for the new proposed slope and neighbouring dwellings is “Very Low” and “Low”, and within the tolerability/acceptability range for people, which is usually considered to be tolerable/acceptable for new slopes.

Should you require any further information regarding this report, please do not hesitate to contact our office.

Yours faithfully
Fortify Geotech

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About us

We work with our clients to provide practical advice and solutions tailored to each project. Our professional services are reliable, responsive and efficient.

Our highly capable Geotechnical Engineers and Geologists have a comprehensive understanding of the industry. We provide the best engineering solution for complicated geotechnical engineering issues. This has earned us a solid reputation with our Construction Industry, Municipal and Government clients.

INDUSTRIES WE WORK IN

- Residential
- Commercial
- Transport Infrastructure
- Industrial Developments of all sizes.

SERVICES

- Geotechnical Site Investigations and Reporting;
- Engineering Geology;
- Mining/Rock Geotechnics;
- Foundation Engineering;
- Dam Engineering; Embankment Design and Specification;
- Geotechnical Design Recommendations;
- Pavement Engineering and Design;
- Pavement Condition Surveys;
- Slope Stability and Risk Assessments;
- Geotechnical and Hydrological Instrumentation and Monitoring;
- Footing and Excavation Supervision and Certifications;
- Excavated soil/rock assessments and VENM assessments;
- Supervision and Certification of Earthworks and Controlled Fill, including Level 1 supervision;
- Geotechnical Construction Specifications;
- Deep Excavation Support; and
- Slope/Retaining Structure Analysis and Design

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FORTIFY
GEOTECH

Geotechnical Investigation & Landslide Risk Assessment

Proposed Demolition of Sonnblick Lodge

10 Bobuck Lane, Thredbo, NSW

QUALITY INFORMATION

Revision history

Reference/ Revision	Description	Date	Author	Reviewer
OB/C14191 Rev0	For issue – Geotechnical Investigation & Slope Stability Risk Assessment	26/04/2023	OB	JM
OB/C14191 v2 Rev0	For issue - Geotechnical Investigation & Landslide Risk Assessment	20/08/2024	OB	JM
OB/C14191 v3 Rev0	For issue - Geotechnical Investigation & Landslide Risk Assessment	18/12/2024	OB	JM/HR

Kosciuszko Thredbo Pty Ltd

Proposed Demolition of Sonnblick Lodge - 10 Bobuck Lane, Thredbo, NSW

Geotechnical Investigation & Landslide Risk Assessment

1 INTRODUCTION

1.1 PROJECT DESCRIPTION

At the client's request, Fortify Geotech Pty Ltd carried out a geotechnical investigation and a quantitative and semi-quantitative landslide risk assessment for the proposed demolition of Sonnblick Lodge, located at 10 Bobuck Lane in Thredbo, NSW.

It is understood the project involves partially demolishing the existing unoccupied lodge in preparation for selling the vacant land for future redevelopment. Following demolition, the site could potentially be vacant for 12 to 24 months. The works will include demolishing and removing all parts of the building to the ground surface; the existing retaining walls, driveway, and footings will remain on site. This geotechnical report only addresses the demolition of the lodge and not any future development.

The site is within “Zone G” of the Kosciusko National Parks Alpine Resorts, so under the NSW Department of Planning Geotechnical policy, a geotechnical investigation and landslide risk assessment is required.

1.2 SCOPE OF INVESTIGATION

The aim of the investigation was to:

- Identify subsurface conditions including extent and nature of any fill materials, soil strata, bedrock type and depth, and groundwater presence.
- Provide soil and bedrock geotechnical parameters.
- Landslide Risk Assessment to AGS (2007c)
- Advise on slope stabilisation.
- Advise on excavation conditions and suitability of excavated materials for use as fill.
- Advise on site drainage, and other relevant geotechnical issues.
- Advise on site management after the demolition.

The landslide risk assessment utilised a semi-quantitative risk assessment to property, and quantitative risk estimation for loss of life (people) and in accordance with the guidelines of “Landslide Risk Management Concepts and Guidelines”, Australian Geomechanics Journal, 2007. In this instance, the residents of the neighbouring housed, road users and construction workers are considered as “people” and the existing structure, the neighbouring residences, as well as the adjacent infrastructure were considered as “property”.

1.3 GEOTECHNICAL POLICY – KOSCIUSZKO ALPINE RESORTS

Section 4 of “Geotechnical Policy – Kosciuszko Alpine Resorts” by the NSW Department of Infrastructure, Planning and National Resources details the requirements that must be included in a geotechnical report for developments within the designated “G” areas of the Kosciuszko Alpine Resorts. Table 1-1 summarises the requirements and the sections within this report that covers those requirements.

Table 1-1: Summary of "Geotechnical Policy – Kosciuszko Alpine Resorts" Requirements

Policy Section	Policy Requirement for Inclusion in Geotechnical Report	Section in This Report Covering the Requirement
4.1 (a)	An assessment of the risk posed by all reasonably identifiable geotechnical hazards which have the potential to either individually or cumulatively impact upon people or property upon the site or related land to the proposed development in accordance with the guidelines set out in 'Landslide Risk Management Concepts and Guidelines" published in the Australian Geomechanics Journal, Volume 35 No. 1 of March 2000.	See Section 5
4.1 (b)	Plans and sections of the site and related landform from survey and field measurements with contours and key features identified, including the locations of the proposed development, buildings/structures on both the subject site and adjoining site, stormwater drainage, sub-surface drainage, water supply and sewerage pipelines, trees, and other identifiable geotechnical hazards.	See Figures 1-4, Appendices B & F
4.1 (c)	Details of all site inspections and site investigations and any other information used in preparation of the geotechnical report. A site inspection is required in all cases. Site investigation may require sub-surface investigation; appropriate investigation may involve boreholes and/or test pit excavations or other methods to adequately assess the geotechnical/geological model for the site.	See Sections 3 and 4
4.1 (d)	Photographs and/or drawings of the site and related land adequately illustrating all geotechnical features referred to in the geotechnical report, as well as the locations of the proposed development.	See Table 4-4, Appendices B & F
4.1 (e)	Presentation of the geological model of the site and related land showing the proposed development, including an analysis of sub-surface conditions, taking into account thickness of the topsoil, colluvium and residual soil layers, depth to underlying bedrock, and the location and depth of groundwater.	See Section 4, Appendices A & B
4.1 (f)	A conclusion as to whether the site is suitable for the development proposed to be carried out either conditionally or unconditionally. This must be in the form of a specific statement that the site is suitable for the development to be carried out, subject to the following conditions.	See Section 5.6
4.1 (g)	A copy of Form 1 bearing the original signature of the geotechnical engineer as defined by this policy, who has either prepared or technically verified the geotechnical report.	See Appendix E

2 SITE DESCRIPTION

2.1 GENERAL INFORMATION

The 340m^2 site is located on Lot 802 DP1119757, at 10 Bobuck Lane, in Thredbo, NSW. The lodge is partially cut into the steeply sloping site on the lower side of Bobuck Lane. The Sonnblick Lodge is a three-storey structure located on the southern two-thirds of the lot. The rear area on the northern third is grassed and mainly formed a batter slope. It is understood that the existing lodge has been unoccupied for several years due to its structural defects.

The site is bounded by Bobuck Lane to the north, and residential three-storey buildings to the east (Lot 801 'Elevation Apartments) and west (Lot 803 'The Peak at Thredbo'), and two-storey building of Talara Ski Club Lodge to the south (Lot 812).

Figure 1 shows the site locality, while Figure 2 is a recent aerial photograph showing the present site layout and the location of the proposed development.

2.2 GEOLOGY

The Thredbo area is documented on the NSW Department of Mineral Resources Monaro 1: 500,000 Geological Map (Ref. 1), as underlain by the Mowanbah Granite Formation of Silurian age. This was formed as a large batholith that cooled deep in the Earth's crust. Processes in the earth caused this to be forced to the surface, and the overlying rock was subsequently eroded. During this process, major faults and fractures developed in the granitic rock, which became areas of weakness that were more easily eroded than the stronger, unaltered rock. The faulted zones have often become drainage pathways, one of which is the Thredbo River course. The elevated topography in the area, combined with high water flows during the snow melt, has caused the Thredbo River to cut its way down into the valley, with consequent steep slopes on either side in the vicinity of Thredbo Village. The local geomorphology resulted from the relatively rapid erosion of the Thredbo River valley along the NE-trending Crackenback Fault. The Crackenback Fault is a steeply dipping strike-slip fault. The site geology is shown in Figure 3.

The bedrock is mainly a granodiorite but is locally called "granite" or "decomposed granite" if more weathered. As is typical for this formation, numerous less-weathered corestones or "floaters" and surface boulders are surrounded by decomposed granite. These boulders have often become more concentrated in watercourses where soil and finer gravel have been washed away. The massive bedrock often contains water joints, resulting in localised deep weathering and springs on the slopes.

The upper subsurface profile typically comprises loose black topsoil, ~0.1m to 1m thick, often containing granitic cobbles and boulders, then loose to medium dense colluvial soil, and then medium dense to dense residual soils typically between 1m to 2m depth. Very Low Strength, extremely weathered (XW) massive granite underlies the soil and may contain corestones of less-weathered rock to large boulder size. Wet zones can be present in the colluvium in particular, and there are often aquifers or seepage zones associated with rock jointing or sheet flows over less-weathered bedrock, especially after rain.

2.3 GEOMORPHOLOGY

The Sonnblick Lodge is located on the north-facing footslope on the southern side of the Thredbo River valley. The total elevation of the ridge ranges from the highest point around ~RL 1680 m Australian Height Datum (AHD) to RL 1360m AHD at the level of the Thredbo River. The average natural slope is around 25°-30°. However, the slope above has been cut to allow construction of the Alpine Way, located at ~RL 1410m AHD (~75m south to the site), and Bobuck Lane, immediately adjacent to the site.

The existing slope profile has a slightly convex shape from east to west, located between two shallow creek gullies ending into the stormwater inlets along Alpine Way. The creek gullies strike NW and are aligned with two larger lineaments of similar striking that can be traced to 500m/800m on aerial photographs (Figure 4). These lineaments may express underlying geological structures such as second or third-order faults or fractures related to the Crackenback Fault.

The Lot 802 dips north at the angle of ~35° to 45° from ~1392m (the level of Bobuck Lane) to ~1380m it's at the southern boundary with Talara Lodge. The existing batters on back of the site were formed at the angle of ~35° to 45°. The split levels of Sonnblick Lodge are also supported by four retaining walls with heights from 1.5 to 2.8m, designated on drawings as RW1 to RW4. There are several smaller timber retaining walls to the west and east from the lodge. One concrete block retaining wall of 0.8m high is located along the southern boundary.

2.4 CLIMATE

The Thredbo climate is a sub-alpine, montane grassland climate characterised by cold, snowy winters and cool summers. Temperatures have ranged from −3°C (mean daily minimum) to 22°C (mean daily maximum). Annual precipitation is ~1700mm, ranging from ~87mm (in February) to 205mm (in September) monthly. The village receives an average of 34.9 snowy days annually (Reference 2). The rainfall exceeded the nominated alarm over the 10 years of precipitation monitoring, from 2013 to 2023, provided by Transport for NSW (TfNSW). It triggered a level of 50mm (over 24 hours) and 100mm per 48 hours 12 times (Reference 11). However, no landslides during that period were recorded above the site along Alpine Way. Figure 8 shows the rainfall data.

3 INVESTIGATION METHODS

3.1 DESK STUDY

The desk study included a review of available geotechnical reports and publications, as part of the risk assessment. The available information included:

(i) Previous geotechnical reports for the Sonnblick Lodge and surrounding areas. The reports` summaries are provided in Section 3.2. The site has been investigated separately and as part of the larger studies and monitoring programs within Thredbo Village (References 2, 3, 7, and 8).

(ii) Geological Maps (References 5 and 10).

(iii) Site Survey (SS0279, Appendix F).

(iv) Geotechnical monitoring data (Reference 11).

(v) The client provided geospatial information, including recent aerial photographs and Class 2 (10cm resolution) Lidar data, which were used for base map contours and a cross-section elevation profile for the area's upslope. Recent survey data for Lot 802 were also used for drafting the interpretive cross-section.

(vi) Meteorological data (Reference 4 and 11).

(vii) Simulation modelling of slope instability in Geo5 software. Results are provided in Section 4.4.

(viii) Other publications on history of the landslide in the area (Reference 6 and 13).

(ix) Other publication about Alpine Way stabilisation and monitoring works (References 9 and 15).

3.1.1 Historical Landslides

The Thredbo Alpine Resort is in an area where landslides and subsidence have occurred, or land instability has previously occurred. The Thredbo Valley has a history of severe embankment stability, rock falls, debris slides, and debris flow problems.

The available publications contain information on at least eight (8) landslides that occurred ~3km from the site. Table 3-1 summarizes the available information on historical landslides in the vicinity of Sonnblick Lodge.

Table 3-1: Summaries of the available landslide Information

Location	Type	Date reported/occurred	Size & Landslide material
Upslope, Alpine Way, 11 Bobuck Lane Thredbo Alpine (~70m from the site)	Complex Deep Seated Translational Landslide	30 July 1997	The total volume ~3800m^3,· material included fill from the embankment, colluvial soils, XW bedrock, and other anthropogenic materials
Alpine Way about two kilometres east of Thredbo Village	Combination of Initial Slide and Subsequent Debris Flow	March 1989	The total volume ~2000m^3, ~20m wide, and extended from the Alpine Way Road shoulder ~200 metres downhill to the Thredbo River.
3 kilometres to the east of Thredbo	Deep Seated Translational Landslide & Debris flow	October 1978	50m long x 200m long, debris flow reached into Thredbo River
Above Alpine Way	Alpine Way Embankment Failure	1974	Details are not available
Alpine Way	Embankment Failure	1973	Details are not available
slipping of the Alpine Way towards the Village observed by the DMR	Slide, Embankment Failure	May 1968	Details are not available
Winterhaus Slide (~105m SW from the Sonnbink Lodge)	Alpine Way Embankment Failure and Mudflow	2 October 1964	50 feet long x 2 feet vertical slumping Water-saturated, essentially uncompacted and differentially settling fill of XW granite
Alpine Way in Winterhaus Corner (~105m SW from the Sonnbink Lodge)	Cut batter collapse	1958-9	Details are not available

Most of the landslides that occurred during last century were related to either cut above Alpine Way or its fill embankment. A catastrophic landslide occurred just ~70m away from the site in July 1997, which resulted in complete destruction of two lodges and 18 fatalities and one injured person. Originally, Alpine Way was constructed in the early 1950s, as a temporary connecting road for a 25 year live. The Alpine Way was upgraded in 1958-1959; however, the deterioration occurred later, and a number of landslides been reported between 1964 and 1997. Major remediation works have been completed along the Alpine Way to reduce the risk of a major landslide subsequently to the 1997 landslide. The Alpine Way embankment has been reconstructed, including compacted fill embankment, and cut supported by gabion walls with subsurface horizontal drainage (Reference 15). The geotechnical monitoring instruments (including inclinometers and piezometers) are now installed along the Alpine Way and are currently monitored by TfNSW Roads (Reference 11). Table 3-2 summarizes the data from the inclinometers monitoring instruments located along Alpine Way upslope to Lot 802. The field rainfall and monitoring inclinometer data are shown on Figures 6-8.

Table 3-2: Summaries of the available inclinometer data

Number of Instrument	Type of Instrument	Date of installation	Location	Total Depth	Observation / Movements Detected
LM762/ Ti	Inclinometer 12-montly	24/04/1999	Alpine Way downslope (embankment)	10m	Insignificant movement since previous reading. Maximum displacement observed was 0.21mm on 25/10/2022 at 2m depth.
LM210/ ULI	Inclinometer 6-montly	6/08/1998	Alpine Way (Upslope/Cut)	28m	Insignificant movement since previous reading. Maximum displacement observed on 28/9/2020 was 9.35mm at 1m depth.
LM209/ UHI	Inclinometer 6-montly	14/07/1998	Alpine Way (Upslope/Natural Slope)	40m	Insignificant movement since previous reading. Maximum displacement observed on 14/3/2001 was 0.99mm at 22.5m depth.
URS02	Inclinometer 12-montly	19/12/2003	Bobuck Lane Embankment	23.67m	No Data Available. Geotechnical information was used in this report. Borehole log was included in Appendix A.

3.2 PREVIOUS GEOTECHNICAL INVESTIGATIONS

Previous geotechnical reports for the site are summarised in the Table 3-3. Geotechnical data of previous report has been incorporated in the present report and all the previous boreholes logs are included in Appendix A.

Table 3-3: Summary of previous geotechnical investigations on Lot 802 and surrounding.

Report	Location	Scope of Work	Findings & Conclusions
Arup Geotechnics, (10664/04), 1998 (Reference 2)	Sonnblick Lodge and Lot 802	Geotechnical landslide risk management assessment, Site Mapping.	No signs of distress of the Sonnblick Lodge structure and any slumping or degradation on site. The hazards identified: •Deep seated landslide with scarp located upslope in the Lot 720. The rupture surface of that landslide was assumed running beneath existing retaining walls and Bobuck Lane embankment. •Failure of the unsupported cut at the rear of the site. Risk assessed as “Significant” to “Medium’
Coffey Partners 1997-1998 (References 7 and 9)	Thredbo Village	Gross Thredbo landslide risk assessment by	According to three issued reports the ‘assessed risk of instability’ was Medium.
Coffey Partners 1998-1999 (Reference 8)	Sonnblick Lodge & Lot 802	Geotechnical investigation and landslide risk assessment. The fieldwork included: • One borehole (KTB29), drilled from trailed-mounted rig, through the driveway on the upslope side of Sonnblick Lodge to 4.6m depth. SPT testing. • Two boreholes, designated SOBH1 and SOBH2, drilled with hand auger to 2.3m depth, • Two test pits, designated SOTP1 and AOTP2, excavated next to the rear wall of the Sonnblick Lodge, to 1.5m/1.7m depth.	The risk to the property is ‘Medium’. Hazards assessed included: 1. A large-scale failure affecting the upslope, 2. A failure involving the unsupported cut beneath the lodge, 3. A failure through the colluvial soils on the downslope side of the lodge.
Coffey Geosciences (C7763/1-AC), 2004 (Reference 16)	Lot 803 (Leitelinna Lodge – east of Sonnblick Lodge)	Geotechnical investigation and landslide risk assessment in accordance with AGS (2000). The fieldwork included: three augered boreholes to 6.7m depths, information on two augered and cored boreholes.	The risk to the property is ‘Medium’. Hazards assessed included: 4. Failure of retaining walls above and adjacent to the site (Medium Risk), 5. Failure of natural slope above the site (Low Risk)
Assetgeoenviro (5917-G1) 2020 (Reference 3)	Lot 720 (Upslope to)	Geotechnical Assessment (LRM) of existing Retaining Wall Bogong Lodge, above (upslope) Bobuck Lane, in accordance with AGS (2007c).	Hazard assessed included: • Slump in slope above retaining walls (Low Risk), • Failure of existing masonry wall (Low Risk) • Deep seated failure below Bobuck Lane (Low Risk) Risk to the property assessed as ‘Low’ and Risk Loss of Life as “Acceptable”

3.3 CURRENT INVESTIGATION

3.3.1 Phase 1 – April 2023

The initial field investigation was carried out on 12 April 2023. It comprised one (1) borehole, designated BH1, using 50mm push-tube equipment. The borehole location is shown in Figure 2, and the borehole log is presented in Appendix A.

The push tube borehole was excavated to 1.5m depth, terminating at refusal in granitic gravel/cobbles. The soil profiles were visually logged in accordance with the Unified Soil Classification System (USCS). The term 'landslide' in this report is used to cover a wide range of failure mechanisms in soil, rock and engineered structures. The terminology used in this report adopted from AGS (2007c) guidelines is provided in Appendix C. Definitions of terms used on the logs and in this report, including a copy of the USCS chart, are also provided in Appendix G.

3.3.2 Phase 2 – June 2024

The phase two included further desktop studies, fieldwork, and slope stability modelling. A second site walkover was carried out on 13 June 2024 and included re-examination of previously identified features, DCP testing, geomorphological mapping and hazard identification of the neighbouring properties upslope up to the Alpine Way and down slope the site. The site's limited access, steep slope and weather conditions prevented auger or core drilling on-site.

The landslide risk assessment was carried out in line with the requirements of the NSW DIPNR and is based on the guidelines on the AGS "Landslide Risk Management Concepts and Guidelines 2007". (Reference 2).

4 INVESTIGATION RESULTS

4.1 GEOLOGICAL MODEL (SUBSURFACE CONDITIONS)

The site's underlying geology comprises three major units: topsoil and uncontrolled fill to 0.3/1.4m depths, over loose to medium dense colluvial and residual soils up to 2.4m depth, underlain by weathered granodiorite bedrock. Weathered granodiorite bedrock was encountered in boreholes KTB29 and BH02 (URS) at 1.8m/2.4m depth. The bedrock comprised extremely (XW), extremely to highly (XW/HW), and highly (HW) weathered granodiorite with very low to medium strength. The granodiorite bedrock has a variable weathering profile, and XW bedrock extends to 10.5m depth. An MW granodiorite corestone ('floater') was encountered in borehole BH02 (URS) at 4.45m-5.6m depth but was underlain by more-weathered, XW and XW/HW granodiorite. Borehole BH02 (URS) is located on Bobuck Lane outside of Lot 802, but similar corestones may be encountered within the lot. Appendix B provides an interpretive cross-section of the site as found by the investigation boreholes and test pits. The location of the cross-section is shown on the site plan.

The subsurface profile as found in the investigation boreholes, as well as in the excavations reported by others on Lot 802 and in immediately adjacent areas is summarised in Table 4-1. The engineering logs are included in Appendix A and can be referred to for more detail.

Table 4-1: Subsurface Profile Summary

Subsurface / Geological Profile	Depth Interval	Description
CONCRETE	0.0m to 0.125m	**CONCRETE SLAB.** Encountered in KTB29 only.
UNCONTROLLED FILL	0.0m to 0.95m	**Silty SAND**; fine to medium grained, some coarse grained, brown to dark brown, some gravel to 150mm, plastic sheeting noted at 0.45m, dry, loose, loose to medium dense.
TOPSOIL	0m/0.95m to 0.3m/1.4m	**Silty SAND;** fine to coarse sand, low plasticity fines, some angular granitic gravels to 30mm, dark brown, black, some tree and grass roots, dry to moist, moist, loose & loose/medium dense.
COLLUVIAL / RESIDUAL SOIL	0.3m/1.4m to 1.5m/2.4m	**Clayey SAND, Silty SAND, Clayey Silty SAND and Clayey GRAVEL**: fine to coarse sand, low plasticity fines, angular granite gravels and cobbles to 300mm size, pale grey, pale brown, moist, moist to wet, loose to medium dense.
BEDROCK	1m/1.95m to below 23m	**XW GRANODIORITE**: extremely weathered (XW), low strength to medium strength rock. Based on other investigation boreholes excavations located near the site, we expect XW and XW/HW bedrock to extend to ~6m depth, underlain by medium strong, HW/MW and MW bedrock, possibly with corestones of MW to fresh rock within the weaker rock matrix.

To assess the soil condition on-site, three (3) Dynamic Cone Penetrometer (DCP) tests were conducted on 13 June 2024, in accordance with AS1289.6.3.2 “determination of the penetration resistance of soil – 9kg dynamic cone penetrometer test”. Table 4-2 shows the DCP results. DCP test locations are shown in Figure 2. Table 4-3 summarises the depths of each borehole's various soil and rock layers.

Table 4-2: DCP Test Results

Depth Below Base of Footing Excavation	DCP 1	DCP 2	DCP3
0mm – 100mm	2	0	0
100mm – 200mm	0	0	0
200mm – 300mm	0	0	0
300mm – 400mm	0	0	0
400mm – 500mm	0	>20 (refusal on concrete)	1
500mm – 600mm	0		2
600mm – 700mm	0		2
700mm – 800mm	1		2
800mm – 900mm	2		1
900mm – 1000mm	6		1
1000mm – 1100mm	2		1
1100mm – 1200mm	2		2
1200mm – 1300mm	2		3
1300mm – 1400mm	2		2
1400mm – 1500mm	6		1
1500mm – 1600mm	6		2
1600mm – 1700mm	>20 (refusal)		1
1700mm – 1800mm			1
1800mm – 1900mm			2
1900mm – 2000mm			2
2000mm – 2100mm			3
2100mm – 2200mm			4
2200mm – 2300mm			5
2300mm – 2400mm			5
2400mm – 2500mm			4
2500mm – 2600mm			4
2600mm – 2700mm			4
2700mm – 2800mm			4

DCP tests indicate that the soils have a very loose relative density to 0.4m/0.8m depth, a loose to medium dense relative density to 0.9m/2.0m, and a medium dense relative density below this depth. DCP 1 refusal is likely on cobbles/boulders, while DCP2 refusal on concrete is a refusal on retaining wall (RW3) footings. DCP3 did not reach refusal at a maximum of 2.8m depth, suggesting deeper bedrock depths for this location.

Table 4-3: Boreholes & DCP test summaries

Borehole Number	Date & Investigation	RL (AHD)	Total Depth (m)	Depth of Unsuitable Material – Fill & Topsoil	Depth of Colluvium/ Residual Soil	Depth of XW Bedrock	Depth to HW or Better Bedrock
BH1	12.04.2023 ACT Geotechnical Engineers	1388	1.5m	0.5m	0.5m- >1.5m	NE	NE
DCP1	13.06.2024 Fortify Geotech	1382	1.7m	N/A	N/A	N/A	N/A
DCP2	13.06.2024 Fortify Geotech	1382	0.5m	N/A	N/A	N/A	N/A
DCP3	13.06.2024 Fortify Geotech	1388	2.8m	N/A	N/A	>2.8m	N/A
KTB29	16.12.1998 Coffey	1390	4.6m	0.0m - 0.45m	0.45m – 2.4m	2.4m - >4.6m	NE
SOBH1	16.12.1998 Coffey	1383	1.6m	0.0m-1.4m	1.4m->1.6m	NE	NE
SOBH2	16.12.1998 Coffey	1383	2.3m	0.0m -1.2m	1.2m->2.3m	NE	NE
SOTP1	16.12.1998 Coffey	1383	1.6m	0.0m - ~0.8	~0.8 - >1.6m	NE	NE
SOTP2	16.12.1998 Coffey	1383	1.6m	0.0m - ~0.9	~0.8 - >1.6m	NE	NE
BH02 (URS)	19.12.2003 URS/NPWS/ Coffey Geosciences	1392	23.67m	0.0m – 0.9m	0.9m-1.8m	1.8m	10.5
BH2 (Lot 803)	09.2004 Coffey	1379	6.7m	0.0m-0.3m	0.3m – 0.6m	0.6m	>6.7m
BH3 (Lot 803)	09.2004 Coffey	1385	0.95m	0.0 - >0.95m	NE	NE	NE

NE – not encountered
N/A – not applied

4.2 GROUNDWATER AND SITE DRAINAGE

During the drilling in March 1999, borehole KTB29 encountered groundwater at 4.5 m depth. The monitoring well was measured on 13 June 2024 by Fortify Geotech, and found the groundwater level at 4.3m depth. Therefore, permanent groundwater is expected around the level of 4.3m/4.5m at the front of the site (driveway). However, groundwater levels will fluctuate due to climate conditions, and temporary subsurface seepages will occur at shallower depths following rainfall.

The rest of the boreholes and test pits within Lot 802 were excavated to the shallower levels and did not encounter groundwater; however, the colluvial/residual soils were moist to wet, which can indicate temporal seepages and insufficient surface drainage.

The general surface and subsurface drainage of the Thredbo Village hillside have been upgraded since the 1997 Thredbo Landslide. Major drainage was installed along the Alpine, including the locations above the site. Noted drainage includes a subsoil drain ~2m deep, with slotted agricultural pipe and gravel backfill.

4.3 SURFACE CONDITIONS

Fortify Geotech Engineering Geologists undertook two site inspections - on 12 April 2023 and 13 June 2024. The aim of the inspections was to assess the slope conditions across the site, understand the geotechnical ground conditions, observe any existing or potential landslide features, and develop a conceptual ground model. The site walkover included observation on Lot 802 and areas upslope (Bobuck Lane, slope up to Alpine Way), neighbouring properties to the east and west (Lots 801 and 803), and Below (Lot 812). The initial site inspection in April 2023 revealed signs of possible distress of retaining walls and soil movements underneath Bobuck Lane and the rear batter. During the second visit, the features were reinspected, and no major changes were noted. Table 4-4 provides site photographs and observation comments taken during two site inspections, allowing us to see changes between the inspections.

4.3.1 Lot 802 Sonnblick Lodge

Lot 802 is 338.4m^2 in area and ~20m long from north to south. The pre-construction natural slope can be estimated from the elevation drop of ~12m, which makes around 26°.

Sonnblick Lodge occupies at least two-thirds of the lot on a relatively steep slope. The site has been formed into level platforms, with the upper portion of the slope supported by four concrete/masonry stone retaining walls, (designated RW1 to RW4) from 1m to 2.8m height, as follows:

- RW1 is located at the rear of the property, supporting the ground level of Sonnblick Lodge. Previous investigation (Reference 2) found that the footings of that wall were found on colluvial soils. RW1 has cracks through the mortar, and is partially undermined due to soil erosion.

- RW2 supports the upper level of the lodge and has not been inspected due to the limited access.

- RW3 supports the driveway and southern wall of Sonnblick Lodge, around 2.8m in height; the easter part of RW3 was inspected. The walls have some cracks in the mortar. Weepholes at the toe were wet, indicating the draining of the backfill material. However, no drains diverted the waters further into the stormwater system, and the soils below the wall were wet with erosion. No tilting or bulging of the wall was noted. BH1 and DCP3 located at the toe of that retaining wall indicated that its footings were found on loose fill/residual soil. Very loose and loose soils extended to ~1.8m beneath that wall. The western portion of the wall beneath the driveway was not inspected due to the limited access.

- RW4 supports Bobuck Lane on the downslope site. RW4 is up to 2m high and shows cracking through mortar and loose boulders.

The rear of the lot is grass-covered unsupported batter formed at 25° to 45°, with an average angle of ~35°—the existing ground surface exposed small-scale soil heaving and rupturing. The soil horizontal movements were estimated to be 0.05m to 0.1m and assessed by exposed soil. Soil erosion in places exposed underground services. The concrete block retaining wall was in good condition with no cracks and well drained (connected to the stormwater network).

4.3.2 Bobuck Lane

Bobuck Lane is a two-line sealed local road with a shale swale drain on the inner line and no pedestrian path. It has relatively heavy traffic, including vehicles and pedestrians, but it is slow (40km/h limit). Small tourist buses operate regularly during the skiing season (June to August).

The cut above Bobuck Lane is up to ~10m high and partially supported by the masonry retaining walls. The retaining walls are in good condition, with some cracking and loose blocks in the lower section. The retaining wall has three levels, with some mature trees remaining. The trunks of the trees are inclined towards Bobuck Lane. A possible vertical back scarp was noted on the unsupported portion of the batter to the east of the retaining walls. A ~0.5m/1m high scarp exposed dry to moist colluvial soils.

The downslope lane of the road pavement has tension cracks several meters long and 10mm to 30mm wide. The tension crack in front of the driveway is 2.5m long. No major changes were noted in the cracks during the site reinspection after 1.5 years. The road embankment is supported by retaining wall RW4 on Lot 802.

4.3.3 Slope above Bobuck Lane

Lot 720 (Aneeki Ski Lodge) and Lot 707 (Schuss Alpine Club) are at the upslope of the Sonnblick Lodge and Bobuck Lane. The lodges are located on a partially supported, relatively steep 25 to 35° slope with drystone retaining walls. Some boulders of 0.2m/1m size were noted, and soil creep and cracking were present, and tiled backfill pavement and retaining walls were damaged.

4.3.4 Alpine Way Embankment and Cut

Alpine Way is the major road connecting Thredbo. It is located ~70m uphill from the site. The Alpine Way embankment was reconstructed after the 1997 landslide. Generally, the existing embankment is in good condition, and caged gabion walls with subsurface horizontal drainage support batters and cuts above Lot 802. No tension cracking was found on the Alpine Way section above the site. Pipes and shallow surface drainage are located at the base of the Alpine Way embankment. The drains divert stormwater to the creek gully located to the west. Caged gabion walls with drainage support the cut above the Alpine Way in that location and show no signs of instability.

4.3.1 Neighboring Lots (West) and (East)

The lots to the west (Lot 801) and east (Lot 803) are occupied by relatively new residential/commercial developments founded on a similar natural slope as Lot 802.

Table 4-4: Photographs of the Site and Neighbouring Areas

Aspect & Location	Observations	
	2023	2024
Sonnblick Lodge Overview		
	 Looking north from Bobuck Lane cut	 Looking south from Bobuck Lane cut

Aspect & Location	Observations	
	2023	**2024**
Bobuck Lane		
Multiple tension cracks – Pavement of lower Bobuck Lane	The cracks are to 10mm wide and running to 6m long. One tension crack in front of the driveway to 2.5m long.  	  Three tension cracks on the lower (outer) lane adjacent to the Sonnblick Lodge. The cracks are 10mm to 30mm wide and 1-3m long. The tension crack in front of the driveway remained ~2.5m long.

Aspect & Location	Observations 2023	Observations 2024
Cracking in the Retaining Walls – RW 4 (Driveway Retaining Wall) Beneath Bobuck Lane	Generally, good condition cracks through mortar to 20mm, some detached stones: no bulging or tilting. 	  The cracks run through mortar to 20mm, some detached stones: no bulging or tilting.
RW3 (Beneath/ supporting driveway) Most to wet soils, soil erosion/	The weep holes existed at the base of the retaining wall. However, the soils (fill) below RW3 were moist to wet, in loose density. 	The weep holes were wet soils below RW3 that were moist to wet. Some water was dripping from the roof. There is no surface drainage catching water from the roof.   DCP 2 & 3 were done at the toe of the RW3 retaining wall.

Aspect & Location	Observations 2023	Observations 2024
RW 1 supporting the Rear side of the lodge	Undermined to 5-10mm. Some soil erosion. Cracking through mortar. 	Undermined to 5-10mm. Some soil erosion. No major changes noted 

Aspect & Location	Observations 2023	Observations 2024
Batter on the rear of Sonnblick Lodge	Batter formed at the angles of 35° to 40°. The batter is planar with some soil ruptures and minor irregular ground. Underground services included gas and electricity.  	Batter formed at the angles of 35° to 40°. Some service cables became exposed over the year due to ongoing soil erosion. Minor bulging of the batters at the lower faces above the concrete retaining wall.   Erosion of fill material and exposed services.  The concrete retaining wall on the lot boundary with Talara Lodge is free-flowing and in good condition.

Aspect & Location	Observations	
	2023	2024
Batters on the western side of the block (boundary with Lot 801)	No photographs are available.	The access stairs to level 1 are located on the western side of the block. Loose, moist, and wet soils (fill) were observed on the batters beneath the stairs. The subsurface drain inlet adjacent to the lodge was partially blocked with leaves and debris. Timber retaining walls on the block boundary were in good condition with only minor tilting.     View on timber retaining walls from above

Aspect & Location	Observations 2023	Observations 2024
Batters on the eastern side of the block (boundary with Lot 803)	No photographs are available.	The access stairs to the Sonnblick are located on the eastern side of the block. The batters are partially buttressed with boulders. Shallow swale drains and underground drainage dispose of stormwater from a neighbouring lodge. Some loose, moist, and wet soils (fill) were observed on the batters beneath the stairs and adjacent to the Sonnblick Lodge. The timber retaining wall was in good condition with only minor tilting.  

Aspect & Location	Observations 2023	Observations 2024
Adjacent Areas – June 2024		
Lot 720 Retaining Walls and Scar above Bobuck Lane		  The cut above Bobuck Lane is up to ~10m high and partially supported by the masonry retaining walls. The retaining walls are in good condition, with some cracking and loose blocks in the lower section. To the east of the retaining walls, a 0.5m/1m high scarp exposed dry to moist colluvial soils. Some mature trees were recently cut, and the remaining trees, Snow Gums, tilted towards and opposite the cut face. 

Aspect & Location	Observations 2023	Observations 2024
Lodges between Bobuck Lane and Alpine Way (Lots 720 & 707)	 	 The lodges above Bobuck Lane are located on a relatively steep slope of 25 to 35°. Some boulders 0.2m/1m were noted, soil creep and cracking were present, and tile backfill pavement and retaining walls were damaged.

Aspect & Location		Observations	
		2023	2024
Alpine Way Cut		The Alpine Way has been reconstructed, including gabion retaining walls with subsurface horizontal drainage above and below the road.	
		 Reconstructed Alpine Way embankment at location of 1997 Landslide	 Reconstructed Alpine Way cut (~70m upslope Lot 802)

4.4 SLOPE STABILITY SIMULATION

4.4.1 Simulation Geotechnical Parameters

The computer slope stability simulation was done for the existing slope in its current conditions with existing retaining walls. It was done using Geo5 software, using the Bishop method and an acceptable Factor of Safety (FOS) of 1.5. Table 4-5 show the estimated geotechnical parameters of the soil/rock units encountered on the site (visual assessment, DCP testing, and review data only) used for the slope instability modelling.

Table 4-5: Estimated Geotechnical Parameters

Unit	Typical Interval Depth	Bulk Density γ_b (kN/m^3)	Cu (kPa)	C' (kPa)	Ø' (degrees)	Young's Modulus (MPa)	K_a	K_o	K_p
Existing Uncontrolled Fill	0.4 – 1.0	19	0	0	25	10	0.41	0.58	2.46
Topsoil	0m to ~0.5m	18	0	0	20	10	0.49	0.66	2.04
Colluvial & Residual Soil	0.4– 1.0	20	5	2	28	25	0.436	0.53	2.77
XW Granodiorite	0.4 – 1.0	22	50	25	30	100	0.33	0.50	3.0
HW/MW & MW Granodiorite	>6.7m /10.5m	24	100	50	35	200	0.27	0.43	3.7
SW or better Granodiorite	>19m	25	200	100	45	500	0.27	0.43	3.7

Where,

γ_b	=	in-situ, dry unit weight, in kN/m^3
Cu	=	undrained cohesion, in kPa
C'	=	effective drained cohesion, in kPa
Ø'	=	effective internal friction angle, in degrees
K_a	=	active pressure coefficient
K_0	=	at rest coefficient
K_p	=	passive pressure coefficient

4.4.2 Existing Slope Conditions

Plates 1 to 3 show the simulation results for the existing conditions. The factor of safety (FOS) of the existing slope is 1.55 for the circular rupture surface beneath Bobuck Lane and 0.59 (unacceptable) for the smaller failure through the fill batter at the rear of the site. The slope instability was identified in the unsupported upper batter of Bobuck Lane embankment. The location of the failure on the slope analysis results correlates with the existing tension cracks on the outer line Bobuck Lane. The FOS for this shallow failure is 0.34 <1.50, and is unacceptable.

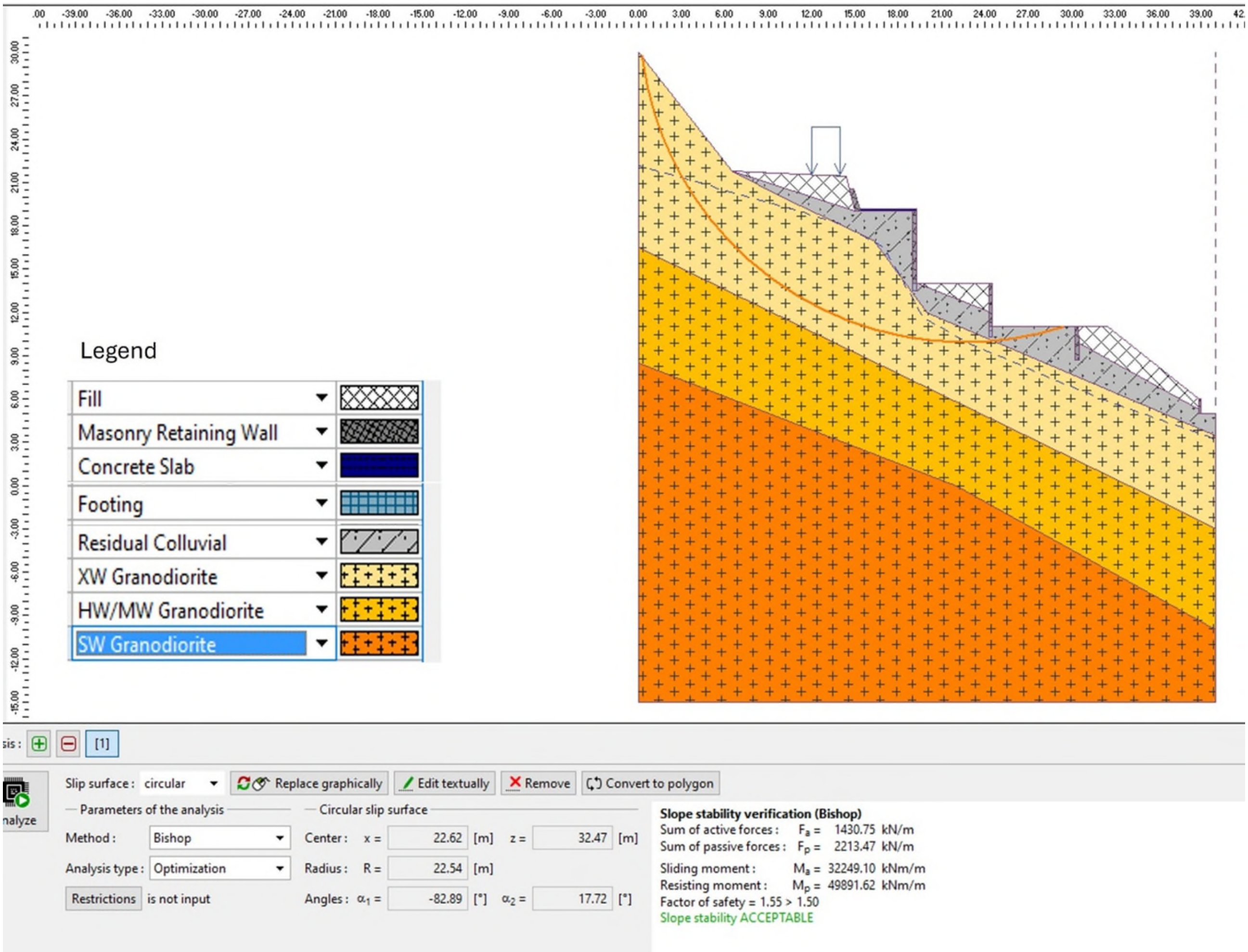

Plate 1: Results of Geo5 modelling for large deep-seated circular rupture surface.

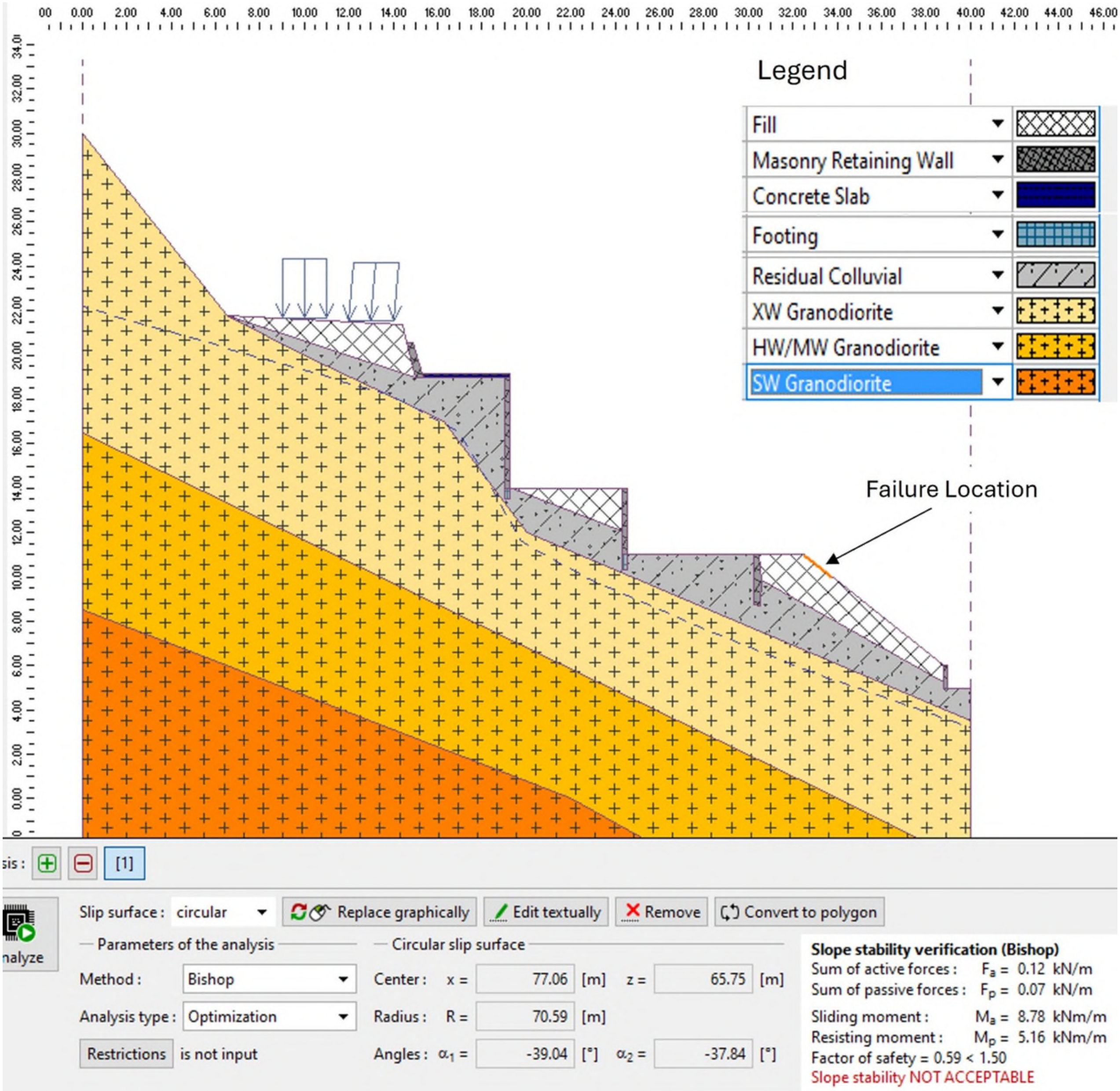

Plate 2: Results of Geo5 modelling for the smaller failure of the batter at the rear of the site.

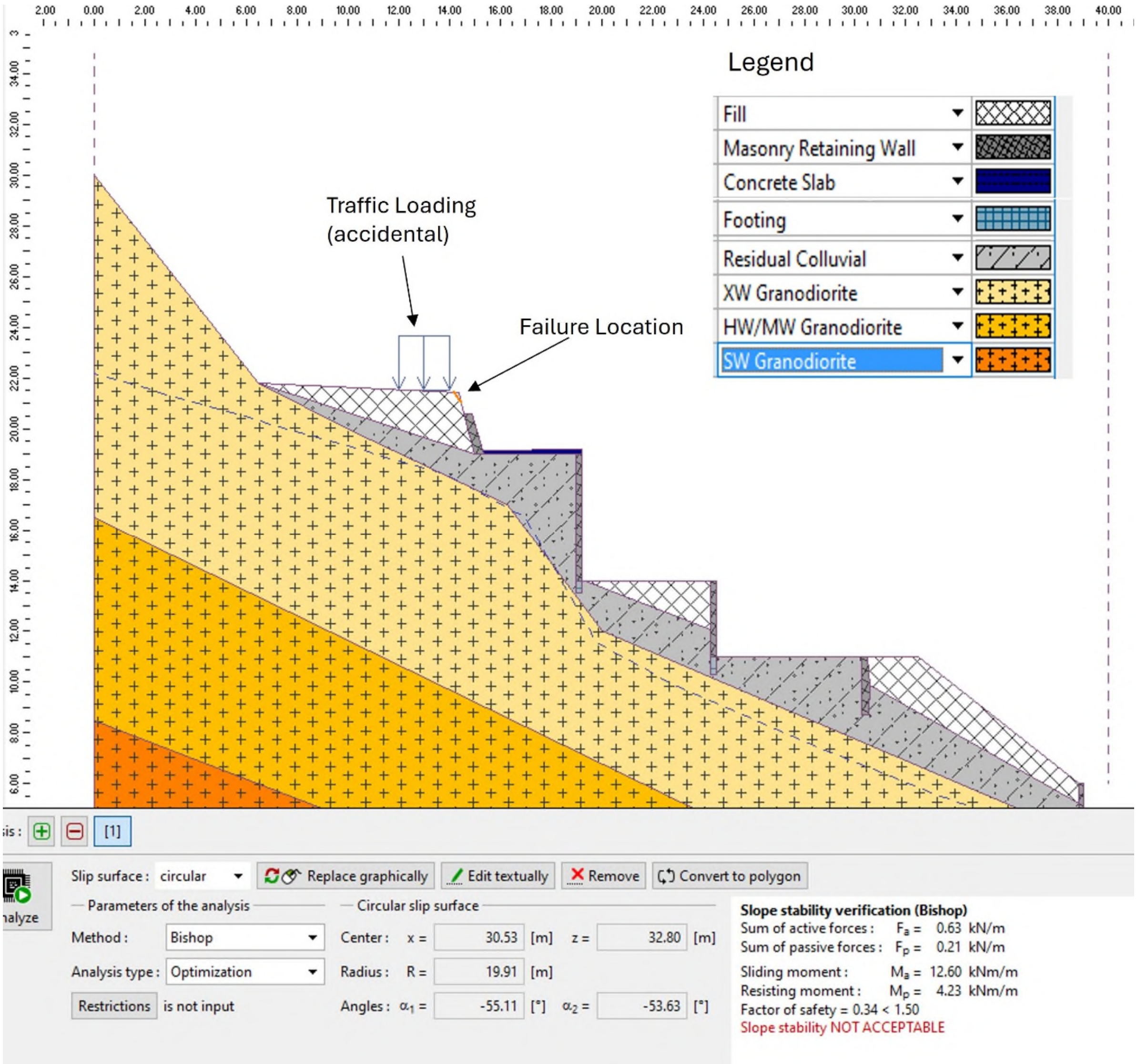

Plate 3: Results of Geo5 modelling for the smaller failure of the batter at the rear of the site.

4.4.3 Proposed Slope Conditions

Plate 4 shows the results of analysis that include additional permanent surcharge of 75kN/m^2 for the proposed buttressing of the retaining walls (Section 6.3). The gabion wall buttress was assumed for the surcharge calculation. The slope stability analysis results indicate a FOS of 1.54, which is acceptable.

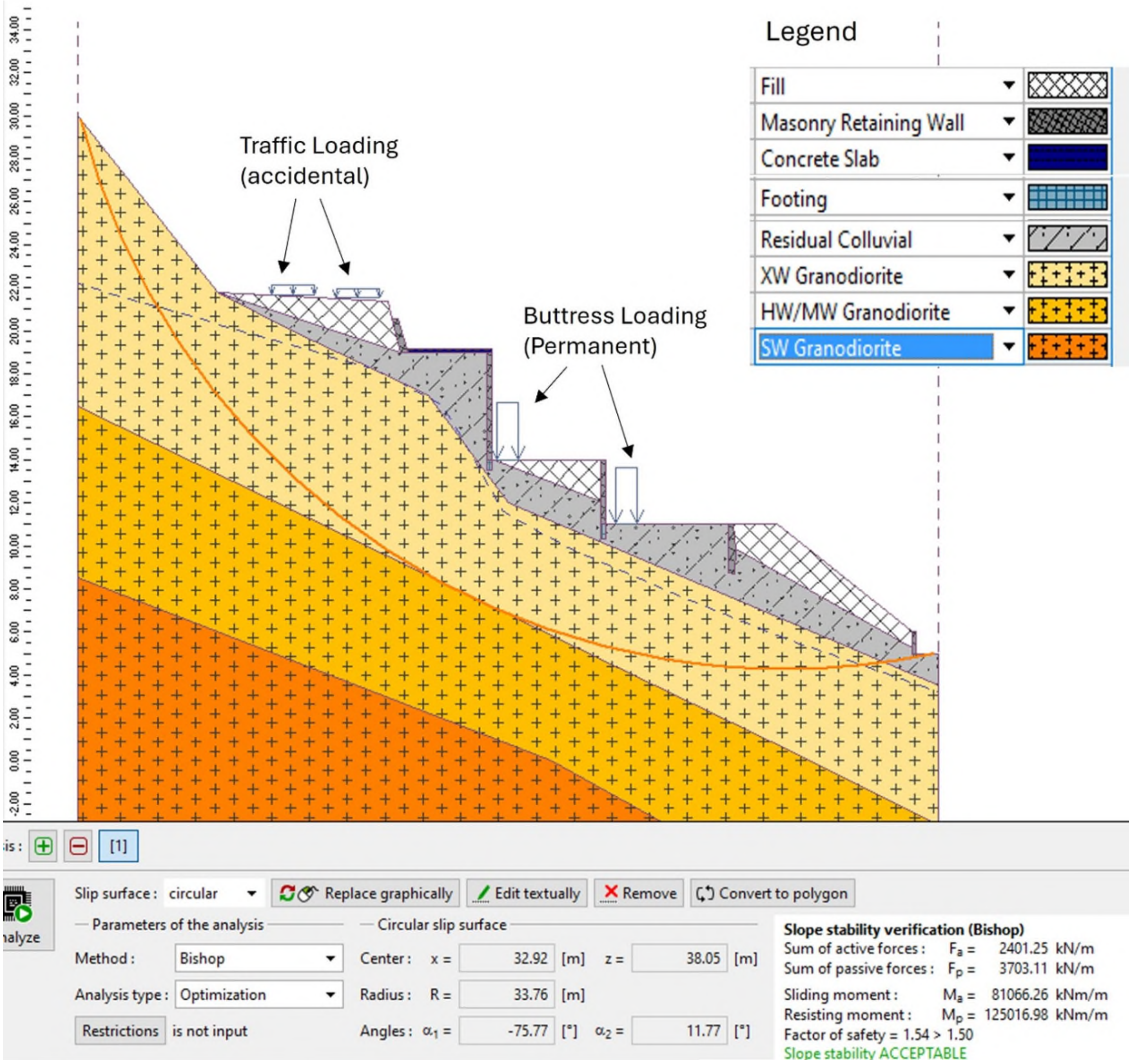

Plate 4: Results of Geo5 modelling for large deep-seated circular rupture surface including traffic and buttress loading.

5 LANDSLIDE RISK ASSESSMENT

5.1 METHOD OF RISK ASSESSMENT

The landslide risk assessment required the development of a semi-quantitative risk assessment of property and quantitative risk estimation for loss of life (people) by the guidelines of "Landslide Risk Management Concepts and Guidelines", Australian Geomechanics Journal, 2007. In this instance, the residents of the neighbouring houses, road users and construction workers are considered "people", and the existing structure, the neighbouring residences, as well as the adjacent infrastructure are considered "property".

The semi-quantitative risk assessment approach was carried out for the property, while the results were summarised in qualitative terminology. Risk assessment involves the following components:

(i) ***Risk Analysis*** involves hazard analysis, frequency (or likelihood) analysis, consequence analysis and risk estimation.

(ii) ***Risk Assessment*** includes estimating a risk via a semi-quantitative and quantitative approach and evaluating the risk against a tolerability threshold. Consistent with the AGS guidelines, this report uses NPWS quantitative thresholds to assess whether a risk is acceptable, tolerable or unacceptable (Reference 12).

(iii) ***Risk Management*** involves selecting one or more risk mitigation options, including accepting the risk and monitoring the hazard on an ongoing basis, avoiding the risk, reducing the likelihood of the risk, reducing the consequences of the risk, and transferring the risk.

5.1.1 Qualitative Risk Assessment – Loss to Property

The qualitative risk assessment has been completed to assess the risk to existing and proposed property and infrastructure only. It is qualitative, based on the guidelines provided in the Australian Geomechanics Journal, Vol 42, March 2007, and has been adopted by the NSW Department of Infrastructure, Planning, and Natural Resources. This uses a matrix approach to determine the risk level of each hazard based on the likelihood and consequences of each hazard occurring. Appendix C presents AGS Guidelines for qualitative terminology.

5.1.2 Quantitative Risk Assessment – Loss of Life

The quantitative risk assessment for loss of life (individual risk) was calculated using the below equation.

$$R(LoL) = P(H) * P(S{:}H) * P(T{:}S) * V(D{:}T)$$

Where,

R(LoL)	is the risk (annual probability of loss of life(death) of an individual),
P(H)	is the annual probability of a hazardous event (Landslide),
P(S: H)	is the probability of the spatial impact of the landslide impacting a building (location), taking into account the travel distance and travel direction given the event,
P(T:S)	is the temporal-spatial probability
V(D: T)	is the vulnerability of the individual (probability of loss of life of the individual given the impact)

Following the risk assessment, options for treating the risk are provided as a guide to the owner, administrator, and regulatory authorities, who will need to decide whether to avoid or accept the risk or treat the site to reduce the likelihood and/or consequences of the hazards.

A flowchart, included in the Australian Geomechanics Journal, Vol 42, March 2007, paper on "Landslide Risk Management Concept & Guidelines" 2007 (Reference 3), which shows the processes of risk assessment/risk management is copied here in Appendix C. Appendix D provides guidelines for hillside construction.

5.2 HAZARD ANALYSIS

The slope above the Sonnblick Lodge can be divided into at least four sections with different characteristics – (1) the natural slope above Alpine Way, (2) the cut and embankment of Alpine Way, (3) the slope between Alpine Way and Bobuck Lane, and (4) Bobuck Lane cut and embankment. The natural slope above the Alpine Way ranges from 20° to 25°. In addition, the geological setting of granodiorite bedrock with shallow weathering depths and dense vegetation above the Alpine Way and the recent retaining structures would decrease the likelihood of the landslide from upslope to barely credible and therefore, this hazard was not considered. Other hazards, like rockfall from the upslope and failure of the batters on the development's upslope, were considered; however, they were not included in the final analysis due to very low spatial factors.

The identified potential landslide hazards (in the present condition, during demolition, and post-demolition) to Sonnblick Lodge were considered as follows:

1. Alpine Way Cut or Embankment Failure
2. Debris Flow from Upslope
3. Deep-seated Failure below Bobuck Lane
4. Bobuck Lane Fill Embankment Shallow Failure
5. Failure of Retaining Walls (On-site)
6. Failure of the Batter at the rear of Sonnblick Lodge
7. Shallow Soil Translational Slide (post-demolition)

5.2.1 Alpine Way Embankment or Cut Failure

The larger-scale landslides that have previously occurred in the Thredbo area have generally been triggered by changes in the slope (cut or fill) or changes in the drainage, combined with heavy rainfall. Previous landslides indicate that the cut and embankment of Alpine Way would be the most prone structure above the site. The failure occurred as a deep-seated translational landslide triggered by excessive rainfall or water leakage. The landslides were mostly fast-moving and displaced material, including fill, colluvial and residual soils and XW granite bedrock. In addition, the translational landslide generated mud or debris flow that extended lower down the slope and was considered a separate hazard (Section 5.2.2)/ The width of the Alpine Way embankment failures ranged from several meters to sections 50m long. The known volume of that failure ranges between 2000m^3 and 3800m^3.

Figure 4 shows the landslides that we were able to locate. The figure illustrates that the most destructive and repeated failures (1964/ Winterhaus and 1997/Carynia) occurred in the intersection of the Alpine Way with two distinctive in the relief creek gullies. The gullies serve as intermittent watercourses or drainage lines. The position of the Sonnblick Lodge is between these two gullies, which would decrease the likelihood of that failure.

The Alpine Way upslope to Sonnblick Lodge is currently under geotechnical monitoring by TfNSW (Reference 11). Two inclinometers (LM762/Ti and LM210/UME) and two piezometers (URS 216/A&B) were installed directly upslope Sonnblick Lodge along Alpine Way and monitored on 6 month and 12-month basis. The last readings didn't show significant ground movements (Figures 6-8). No geological data were available from these boreholes.

Sonnblick Lodge is located ~70 m below the Alpine Way. The previous 1997 landslide transported distance was estimated to be around 50m below the back scarp. The high number of historically reported landslides and a relatively short distance to the recent failure suggested that the initial likelihood estimation should be 10^{-2} or 10^{-3}. However, the latest major remediation and reconstruction of Alpine Way significantly improved the stability of the fill and embankment and, therefore, reduced the likelihood of the failure to 'Rare' (10^{-5}).

5.2.2 Debris Flow from Upslope

The records of historic landslides show that at least two larger landslides in Thredbo and its vicinity caused debris flow that reached Snowy River or the toe of the slope. In the case of a landslide upslope, the moisture-saturated soil may trigger debris flows. Some previous landslides along Alpine Way evolved into debris flows that reach the Thredbo River flood valley. The velocity of such debris flow may range from moderate to rapid, depending on the volume. The travel distance can be estimated to be 200-300m. The closest Landslide occurred in 1997 and generated a mudflow of ~90m travel distance from the Alpine Way. Therefore, the Sonnblick Lodge can be affected by debris flow from the upslope.

However, the convex profile along the site slope may reduce the channelling of the potential debris flow. The likelihood of that event is "Rare" (10^{-5}) due to the Alpine Way reconstruction and the existing drainage/stormwater system in a well-working condition. If the debris flow reaches the existing lodge, it may cause major damage to the structure.

5.2.3 Deep-Seated Failure below Bobuck Lane

The Sonnblick Lodge is located on the northern side (down lope) of Bobuck Lane. The road cut above is 10m high, relatively steep (around 50-60° degrees), and partially supported by updated masonry retaining walls. The upper (unsupported) faces of the cut have some mature native trees that are slightly tilted towards the cut. The existing retaining walls are in good condition with weep holes; only the lower wall shows some cracking.

The Arup Geotechnics report states the presence of a scarp located above Bobuck Lane. The report map shows a ~2m high and ~30m long concave scarp approximately 25m south of the Sonnblick Lodge. During the site walkover, a portion of the potential scarp was mapped due to the recent retaining wall updates. The mapped scarp is located to the east of the retained wall. The scarp can indicate a translational landslide with unknown state of activity. The possible slip surface is beneath the existing road fill dam, the driveway and a retaining wall of Sonnblick Lodge. The assumed landslide can be reactivated in rare events such as severe rainfall or earthworks along Bobuck Lane.

Tension cracks and some fracturing of retaining walls below Bobuck Lane may indicate movement along that landslide. No further progress of the existing cracking was noted over the 1.5 years. Considering the recently reconstructed retaining wall supporting cut improved its stability and affected subsurface drainage, the likelihood of that failure was reduced to Unlikely (10^{-4}).

Two inclinometers (with a 12-month monitoring period) were installed on Bobuck Lane, including URS02 (~15m SW) and KTB25 (~32m SW), which were monitored by TfNSW. The authors did not have access to the monitoring data on the inclinometers.

If the scarp continues as a surface of rupture under Bobuck Lane, the groundwater level (4.3m) in KTB29 can be assumed to be a possible level of a rupture surface. Then, at least the part of Sonnblick Lodge is located within the possible slip. The landslide materials above include the embankment fill and colluvial /residual soils. The lodge could be partially damaged or destroyed if that failure occurred, considering the construction age and footing foundation on colluvial soils. The landslide velocity can vary from slow to very rapid.

Since the rupture surface can be located upslope on Lot 720 and below Bobuck Lane, demolishing the Sonnblick Lodge structure (considering retaining walls remaining) would not affect the hazard likelihood provided the slope stabilisation measures are carried out. Removing the lodge and proposed control and stabilisation measures would minimise possible consequences for the lodges' downslope.

5.2.4 Bobuck Lane Fill Embankment Shallow Failure

The tension cracks on the outer lane of Bobuck Lane and slope stability analysis point out the possible shallow failure of the unsupported road embankment. The road embankment is ~2m high and upper ~0.5m/0.8m are grass-covered and were formed at moderate angles. The lower faces (~1.2m/1.5m) are supported by masonry retaining wall (RW4). A low steel road barrier is installed at the edge of the batter (See Table 4-4).

Considering the existing tension cracks and results of the analysis, the likelihood of that event is “Likely” (10^{-2}). The rates for this movement have been assessed as very slow, however, rates can be increase in the adverse conditions to ‘Rapid’. If the failure occurs, the failed material can travel to the lodge and cause minor damage to the structure. Bobuck Lane carriageway will also be impacted and will require remediation works.

5.2.5 Failure of Retaining Wall (On-site)

Five retaining walls support the existing slope. One retaining wall on the site's rear was not considered because it was in good condition and well-drained. The other four walls are old masonry retaining walls that have not been properly engineered, including the following factors:

- The footings are founded on fill or colluvial soils,
- RW4 (supporting Bobuck Lane) does not have weep holes, so the drainage degree is unclear, and
- Existing cracks through masonry and loose rock blocks.

In addition, RW2 was not inspected due to the limited access. The failure can potentially occur via overturning, sliding or foundation failure mechanisms. Currently, no evidence of a particular mechanism is noted. The current signs of the walls deterioration and distress can be estimated as minor, evident but not sufficiently advanced to imply any failure. The walls are vertical, no lateral deformations, tilting of bulging were noted. As no failures were observed on similar retaining walls on the adjacent blocks, the likelihood of the retaining walls failure is judged to be “Unlikely” (10^{-4}) in the current state. If a retaining wall fails, damage may result in the lodge and Bobuck Lane damage.

5.2.6 Failure of the Fill Batters on Lot 802

The slope at the rear and along the sides of Sonnblick Lodge are mostly formed batters with angles from 25 to 45 degrees. The signs of instability include soil creep, erosion and moisture-affected soil. The landslide hazard would be a shallow translational soil slide with a relatively slow movement rate. In the present conditions, the likelihood of this failure of the formed batter in its current conditions is judged to be “Possible” (10^{-3}). If this occurs, the failure of the cut can result in the collapse of the rear of Sonnblick Lodge or adjacent retaining walls. Some materials can travel to the lodge located downslope.

5.2.7 Shallow Soil Translational Slide (proposed slope)

After the Sonnblick Lodge demolition, a new slope will be formed at ~2H:1V, with the remaining retaining walls being rock-fill buttressed. The newly placed compacted fill material may fail because shallow, slow-moving, active translational soil is sliding through the fill. Some signs of soil creep and frost heaving on site facilitate surface erosion by exposing soils and moving 'rupturing' grass-covered areas. The surface erosion was probably enhanced after the site was partially cleared of the mature trees in the past. In addition, the upper soils are quite silty, and surface water flow paths are allowed to develop, which can facilitate this type of failure. The initial likelihood was assessed as "Possible" (10^{-3}). However, if all control and stabilisation measures are implemented, this likelihood will be reduced.

5.3 RISK ASSESSMENT

5.3.1 Risk to Property

A semi-qualitative assessment has been undertaken for the proposed new slope that will be constructed after the lodge demolition. The neighbouring residences were also considered in the assessment. A semi-quantitative approach was chosen because the vulnerability of the properties was uncertain for the existing neighbouring residences. The assessment included some quantitative parameters where it was possible, and based on this, the qualitative terms "Likelihood" and "Consequence" were adopted, using descriptions provided in the Australian Geomechanics Society (AGS) Guidelines for Landslide Risk Management (2007) (Appendix D). The resulting risk level was derived using the AGS risk analysis matrix presented in Appendix C.

A summary of estimated risk to property and life for each of the potential hazards identified in the previous sections is provided in Table 5-1. This risk assessment in Table 5-1 is based on the present conditions prior to any mitigation measures being implemented.

Table 5-1: Risk Estimation for Property Summary

Potential Hazard	Element at Risk	Initial Risk Level			Control Measures	Residual Risk Level		
		Likelihood	Consequences	Risk Rating		Likelihood	Consequences	Risk Rating
1 - Alpine Way Embankment or Cut Failure	Existing Sonnblick Lodge	**Rare (10^{-5})** Occurred in a rare combination of events such as extreme rainfalls, earthquakes, etc. The high number of reported landslides suggested that the initial likelihood estimation would be 10^{-2}. However, the latest remediation works and reconstruction of Alpine Way significantly improved the stability of the fill and embankment, reducing the likelihood of failure. In addition, Sonnblick Lodge's distant location decreases the likelihood since previous landslides along Alpine Way did not reach similar topographic levels.	**Catastrophic**: The Sonnblick Lodge has footings and retaining walls founded on colluvial soils and existing structural cracks. Therefore, if the soil moves, the property would be dislocated and severely damaged. The remediation works would require more funds than normal demolition procedures.	**Moderate**	Monitoring along Alpine Way by TfNSW: Two inclinometers (LM762/Ti and LM210/UME) and two piezometers (URS 216/A&B) were installed directly upslope Sonnblick Lodge along Alpine Way and monitored on 6 month and 12-month basis. The last reading didn't show significant movements. Continue geotechnical monitoring with the existing inclinometers installed directly upslope Lot 768 along Alpine Way (TfNSW).	**Rare (10^{-5})**	**Catastrophic**	**Moderate**
	Proposed Slope		**Major:** No property will remain after the demolition. However, some services, retaining walls, and batters may require stabilisation.	**Low**	Regular maintenance of the existing drainage system of the embankment. Ensure the permanent open drains are not blocked. Complete construction during drying summer months (November – March) Do not undertake construction work during or immediately after a heavy rainfall event.		**Major**	**Low**
2 - Debris Flow from Upslope	Existing Sonnblick Lodge	**Rare (10^{-5})** It has occurred in the past; however, the likelihood was decreased due to the updated drainage system upslope and gabion retaining walls along Alpine Way and upslope buildings that would retain some debris material and potentially dissipate the energy of a flow.	**Major to Medium:** The footings will likely be founded on colluvial soils. Signs of distress are abundant in the existing structure. The damage to the structure would depend on the velocity and volume of the transported material.	**Low**	Continue monitoring the existing water wells and piezometers. The current alarm system for the upslope applied a trigger level of 100mm in 48 hours. Ensure surface water diversion from the site, avoiding erosion and ponding.	**Rare (10^{-5})**	**Major to Medium**	**Low**
	Proposed Slope		**Medium:** No property will remain after the demolition. The new slope would have shallower angles. Some services, retaining walls, and batters may require stabilisation.	**Low**	If a failure occurs during construction, halt works and seek geotechnical advice before recommencing. We are minimising the extent of vegetation cleared during construction and reinstatement of vegetation post-construction, where possible. Construction will be completed over the summer period (November – March). Do not undertake construction work during or immediately after a heavy rainfall event.		**Medium**	**Low**
3 - Deep-seated failure below Bobuck Lane	Existing Sonnblick Lodge	**Unlikely** (10^{-4}). The existing scarp and the tension cracks on the pavement can indicate landslide and soil movements below Bobuck Lane. The retaining walls supporting the cut are in good condition. Slope stability modelling for existing slope indicated FOS>1.5.	**Catastrophic:** The Sonnblick Lodge is adjacent to the potential landslide; however, whether the rupture surface is located beneath the Bobuck Lane and potentially beneath RW3 &4 is unclear. The landslide will likely damage or destroy the existing structure.	Very High	Demolition should be carried out in several phases, and further investigation of this hazard should be included during the construction. The geotechnical engineer should inspect the site and retaining walls after removing the second and first levels. RW2	**Rare (10^{-5})**	**Minor:** (considering no structure remains after a demolition)	**Very Low**

Potential Hazard	Element at Risk	Initial Risk Level			Control Measures	Residual Risk Level		
		Likelihood	Consequences	Risk Rating		Likelihood	Consequences	Risk Rating
	Property downslope of the site (Lot 812)		**Major:** The building is older and located ~20m away from Bobuck Lane, so it would likely be partially damaged.	**Moderate**	Control measures compensating for the change in loading and increase in surface water should include buttressing the retaining walls, placing engineered fill, forming batter at a stable angle, and installing sufficient drainage. Retaining walls and foundations are to be preserved on the slope. Adequate subsurface drainage should be installed and maintained on the upper section of the site. Horizontal drainage pipes should be installed to RW4 that supports Bobuck Lane, and drains should be free-flowing. The waters should be diverted to the Thredbo stormwater system. Further instructions on on-site drainage are provided in Section 6.5. The existing retaining walls will be buttressed. Follow the proposed buttressing design provided in Section 6.3. ***During construction, ensure all stockpiles are kept within the designated area, shape stockpiles, and control runoff. Surface water must be controlled during construction and not pond*** on the slope or upslope. Ensure surface water diversion from the site, avoiding erosion and ponding. If a failure occurs, seek geotechnical advice.		**Medium**	**Low**
	Properties to the west and east (Lot 801 & 803)		**Medium:** The buildings are relatively new and were constructed after the 1997 landslide. The footing is likely found in bedrock. However, the building might be partially undermined.	**Low**			**Minor**	**Very Low**
	Infrastructure - Bobuck Lane Embankment & Services		**Major:** The landslide would destroy road pavement, fill embankments, and underground services.	**High**			**Major**	**Low**
	Proposed Slope		**Medium to Minor:** No property will remain after the demolition. However, some services, retaining walls, and batters may require stabilisation.	**Low**			**Medium to Minor**	**Low**
4 - Bobuck Lane Fill Embankment Shallow Failure	Existing Sonnblick Lodge	**Likely (10^{-2}):** Consideration included existing tension cracks on the outer lane and slope stability analysis results.	**Minor:** Some failed material can reach the Sonnblick Lodge building and driveway downslope.	**Moderate**	Stabilise the unsupported upper faces of the road embankment with: • Shotcrete • New gabion wall installed in front of the existing retaining wall to the level of the Bobuck Lane.	**Rare (10^{-5})**	**Minor**	**Very Low**
	Infrastructure - Bobuck Lane Embankment & Services		**Medium:** The outer lane may demand some reconstruction and pavement resealing. The impact and subsequent works would require at least one lane closure.	**High**			**Medium**	**Low**
5 - Retaining Walls Failure	Existing Sonnblick Lodge	**Unlikely** (10^{-4}) The inspected retaining walls are in acceptable condition, vertical, no deformation or other signs of failure. Some signs of deterioration such as cracking via mortar and loose blocks were considered.	**Major:** The retaining wall failure would result in damage to the structure.	**Moderate**	Adequate subsurface drainage should be installed and maintained on the upper section of the site. The horizontal drainage pipes should be installed to RW4, which supports Bobuck Lane, and the drains should be free-flowing. The waters should be diverted to the Thredbo stormwater system. Section 6.5 provides further instructions on on-site drainage. The existing retaining walls will be buttressed (See Figure 5 for the conceptual sketch). Follow the proposed recommendations provided in Section 6.3. A new slope should be monitored for stability and movement regularly (before and after the snow season). If any signs of movement or instability are observed, a geotechnical engineer should be consulted immediately.	**Rare (10^{-5})**	**Major**	**Low**
	Property downslope of the site (Lot 812)		**Minor:** Some failed material can reach the building downslope if the rear retaining walls fail.	**Low**			**Minor**	**Very Low**
	Properties to the west and east (Lot 801 & 803)		**Insignificant:** The failed retaining walls can expose the neighbouring services or structures, and some material may be transported to the neighbouring properties.	**Very Low**			**Insignificant**	**Very Low**

Potential Hazard	Element at Risk	Initial Risk Level			Control Measures	Residual Risk Level		
		Likelihood	Consequences	Risk Rating		Likelihood	Consequences	Risk Rating
6 - Failure of the Unsupported Batter at the rear of Sonnblick Lodge	Existing Sonnblick Lodge	**Possible (10^{-3}):** Consideration included very loose moist to wet material (possibly uncontrolled fill and colluvial soils) to 0.7m/1.8m depth, presence of the backfilled service trenches, existing soil erosion, and existing insufficient drainage of the site.	**Major to Medium:** May expose or undermine footings of the rear side of the Sonnblick Lodge. The low rates of velocity would allow the remediation.	**High**	The newly engineered slope will be supported by existing retaining wall and the unsupported slope will be battered back at an angle of ~26° (2H:1V). If required, the slope should be formed in accordance with the controlled fill placement procedure (Section 6.2). The original slope can be estimated from ~20m length and ~12m elevation drop, around 26° (or 2H:1V). This allows for the formation of stable slope angles on the site after the lodge demolition. Install sufficient drainage connected to the stormwater system (See Section 6.5). ***During demolition and new slope construction***: Limit excavation depths to 1.5m at a single run in soils and XW bedrock and 2m in XW/HW bedrock. Any temporary excavations greater than 1.0m vertical height must be supported with a temporary ground retention system or appropriate benching, as per the requirements of the Worksafe Compliance Code of Excavation (2019). Excavation batter angles must be at or shallower than recommended (Section 6.3) for both temporary and permanent batters. Position excavated material in a stable manner. A spoon drain or bund should be constructed along the top edges of the batter to prevent rainfall run-off from flowing over the face and causing erosion. Leaking pipes, tanks, or storage are to be repaired immediately. Control drainage to prevent rainfall from ponding in excavated areas. Suppose water ponds or seeps into the excavation; a conventional sump and pump dewatering system may be required. A geotechnical engineer would be required to inspect the batters regularly. As a guide, these inspections must be conducted every week. At the same time, a competent person representing the contractor should check the batters daily, preferably in the mornings, for any signs of movement. Trucks, heavy construction plant/equipment (especially with the motor idling), and large soil stockpiles must not be located close to the top edge of the batters (they must be at least 4m back from the top edge). No work must be conducted close to the toe of the cut during rain and 24 hours after. A geotechnical engineer must re-inspect the site cut following rainfall (about 10mm of rain or enough rain that the faces become wet).	**Rare (10^{-5})**	**Medium**	**Low**
	Property downslope of the site (Lot 812)		**Medium:** The failed fill material can damage the walls and windows of the rear side of the Talara Ski Lodge.	**Moderate**			**Medium**	**Low**
	Properties to the west and east (Lot 801 & 803)		**Insignificant:** The failed batter can expose the neighbouring services or structures, and some material may be transported to the neighbouring properties.	**Very Low**			**Insignificant**	**Very Low**
	Services at the rear of the site - Bobuck Lane		**Medium:** Buried gas pipes and electric cables would become exposed or ripped/damaged.	**Moderate**			**Medium**	**Low**
7 - Shallow Soil Translational Slide (post-demolition)	Proposed Slope	**Possible (10^{-3}):** Consideration included existing silty sand material on site, the site angle, the presence of the backfilled service trenches, and existing soil erosion.	**Medium:** No property will remain after the demolition. The new slope would have shallower angles. Some services, retaining walls, and batters may require stabilisation.	**Moderate**	The new slope should be monitored for stability and movement regularly (before and after the snow season). Follow the Trigger Action Response Plan (TARP) (Section 5.4.1), which outlines the monitoring of the site (visual and instrumentation), trigger levels, and actions to ensure the risk levels at the site remain at tolerable levels throughout the period prior to redevelopment of the site. If any signs of movement or instability are observed, a geotechnical engineer should be consulted immediately.	**Rare (10^{-5})**	**Medium**	**Low**
	Property downslope of the site (Lot		**Medium:** The failed fill material can damage the walls and windows of the rear side of the Talara Ski Lodge.	**Moderate**			**Medium**	**Low**

Potential Hazard	Element at Risk	Initial Risk Level			Control Measures	Residual Risk Level		
		Likelihood	Consequences	Risk Rating		Likelihood	Consequences	Risk Rating
	812)				New slope/ soil batter should be formed with controlled fill, following the procedure in Section 6.2. Adequate subsurface drainage should be installed and maintained on the site. Ensure a permanent drainage system is installed to divert surface water from the slope face and prevent water from ponding at the slope's toe. The horizontal drainage pipes should be installed to RW4 that supports Bobuck Lane, and drains should be free-flowing. The waters should be diverted to the Thredbo stormwater system. Further instructions on on-site drainage are provided in Section 6.5. Erosion protection measures prevent or halt erosion. These measures include minimising the extent of vegetation cleared during construction and reinstating vegetation post-construction, where possible. The existing retaining walls will be buttressed by caged gabion walls/ mass concrete or rock /recycled concrete buttress. The stabilisation advice for retaining walls and batters are provided in Section 6.3			
	Properties to the west and east (Lot 801 & 803)		**Minor:** The buildings are relatively new and were constructed after the 1997 landslide. The footings are likely found in bedrock.	**Moderate**			**Minor**	**Very Low**
	Services at the rear of the site - Bobuck Lane		**Medium:** Buried gas pipes and electric cables would become exposed or ripped/damaged.	**Moderate**			**Medium**	**Low**

5.3.1 Risk Loss of Life

Risk to life has been assessed for each hazard for the person most at risk, as per the equation in Section 5.1.2.

The proposed slope will not be occupied during the assessment period. For the construction period, the number of workers was considered nominally 10 people. People were assumed to spend 8 hours on the block during the day.

For Lot 812 (Talara Ski Club), located downslope, we assumed 24 people, 20 people for Lot 803 ('Elevation Apartments', east of the site), 25 people for Lot 720 ('Aneeki Ski Lodge', south from the site), and 38 people for Lot 801 ('The Peak'), west from the site. The number of people for each lodge was taken from their websites as advertised capacities. The assumption was that people spent 10 hours per day in the lodges.

The following parameters were used in the calculations:

- **P(H)** - Likelihood or Annual Probability for the event was the same as for the risk to property estimation, and the argumentation for each hazard in the existing state can be found in Sections 5.2.1 to 5.2.8 and Table 5-1. The risk at the existing slope condition was calculated using the existing likelihood values. The residual risk loss of life has been calculated using the value of likelihood after all the control measures are implemented, which was estimated to be Rare (10^{-5}) for all hazards. The control measures are summarized in Table 5-1, and Sections 5.4 and 6 provide further recommendations.

- **P(S:H)** - The Spatial Impact probability was considered depending on the element's distance at risk from the possible individual location, velocity, and obstacles or channelization factors.

- **P(T:S)** - Temporal Probability. People were assumed to spend 10 hours on the property during the day. For the Bobuck Lane users, we assumed one vehicle with two passengers driving past Lot 768 every 10 minutes during the day (12 hours), assuming passing the road section for 10 seconds. Regular Thredbo shuttle buses operating during ski season (June-September), we assumed to carry 10 people (including the driver) every 30 minutes, passing the section for 10 seconds. The assumption for pedestrians was two pedestrians every 20 minutes, assuming passing the road section for 40 seconds. The 8-hour working day for construction workers was used.

- **V(D: T)** - The individual's vulnerability was assessed based on the examples and recommended values provided in Appendix E of AGS 2007c. The value depended on people's location and possibility of being buried. The possible locations included buildings, vehicle or open space. For example, construction workers and pedestrians were considered as located in open space. The possibility of being trapped or buried in the landslide would significantly decrease the chances of surviving. It should be noted that in the past large-scale landslides, 18 of 19 people died, being trapped within building and landslide material indicating a high vulnerability of ~0.9 in case of the large-scale landslide event (Hazard 1&2). Considering only a construction phase was calculated for people working during the daytime (past landslide occurred during the night with some delays in the rescue operation), and during good weather condition, the vulnerability was decreased to 0.8, which still lies withing the recommended data range. There is no known death in Thredbo related to the smaller scale events, such as Hazards 3-6. In addition, modern construction would allow the people inside the building to decrease their vulnerability, which would be applicable to neighboring properties on Lots 801 & 803.

Table 5-2 & 5-3 provide further details on the risk assessment for the site and neighboring areas regarding risk to life. Table 5-2 provides details on calculation for the existing slope conditions with current likelihood values (Table 5-1). The risk calculation in Table 5-3 is based on the assumed future conditions, assuming that all recommended mitigation measures are implemented, and residual likelihood values (Table 5-1) were used. For this risk assessment to be valid, a suitably qualified geotechnical engineer must sign Form 2 and Form 3 to check that these mitigation measures have been incorporated into the design and constructed correctly.

Table 5-2: Risk to Loss of Life – Calculation Summary – Existing Slope Conditions.

Possible Hazard	Affected Location/ Structure	Number of People at Risk at One Time	Likelihood / Annual Probability P(H)	Probability of the Spatial Impact P(S: H)	Temporal Probability P(T:S)	Vulnerability of the Individual V (D: T)	Risk for Person Most at Risk R(LoL) Risk Evaluation (F) / Annual Probability	Annual probability of N or more fatalities (F)	Number of Fatalities (N)	Risk Outcome*
1 - Alpine Way Embankment or Cut Failure	Lot 802 Construction Phase	10	10^{-5}	0.8	0.33	0.8	$2.1 * 10^{-6}$	$8 * 10^{-6}$	8	**Acceptable**
2 - Debris Flow from Upslope	Lot 802 Construction Phase	10	10^{-5}	0.6	0.33	0.8	$1.6 * 10^{-6}$	$6 * 10^{-6}$	8	**Acceptable**
3 - Deep-seated failure below Bobuck Lane	Lot 802 Construction Phase	10	10^{-4}	1	0.33	0.8	$2.6 * 10^{-5}$	$1 * 10^{-4}$	8	**Tolerable**
	Lot 812 - Talara Ski Club	24	10^{-4}	0.8	0.42	0.8	$2.7 * 10^{-5}$	$8 * 10^{-5}$	19.2	**Tolerable**
	Lot 803 - Elevation Apartments	20	10^{-4}	0.3	0.42	0.5	$6.3 * 10^{-6}$	$3 * 10^{-5}$	16	**Acceptable**
	Lot 801 - The Peak	38	10^{-4}	0.3	0.42	0.5	$6.3 * 10^{-6}$	$3 * 10^{-5}$	30.4	**Acceptable**
	Lot 720 - Aneeki Ski Lodge	25	10^{-4}	0.05	0.42	0.7	$1.5 * 10^{-6}$	$5 * 10^{-6}$	20	**Acceptable**
	Bobuck Lane (Vehicles)	2	10^{-4}	1	0.0083	0.6	$5 * 10^{-7}$	$1 * 10^{-4}$	1.2	**Acceptable**
	Bobuck Lane (Pedestrians)	2	10^{-4}	1	0.017	0.8	$1.4 * 10^{-6}$	$1 * 10^{-4}$	1.6	**Acceptable**
	Bobuck Lane (Buses)	10	10^{-4}	1	0.0028	0.6	$1.7 * 10^{-7}$	$1 * 10^{-4}$	6	**Acceptable**
4 - Bobuck Lane Fill Embankment Shallow Failure	Lot 802 Construction Phase	10	10^{-2}	1	0.33	0.1	$3.3 * 10^{-4}$	$3 * 10^{-3}$	0.01	**Unacceptable**
	Bobuck Lane (Vehicles)	2	10^{-2}	1	0.0083	0.1	$8.3 * 10^{-6}$	$5 * 10^{-3}$	0.002	**Acceptable**
	Bobuck Lane (Pedestrians)	2	10^{-2}	1	0.017	0.1	$1.7 * 10^{-5}$	$5 * 10^{-3}$	0.002	**Acceptable**
	Bobuck Lane (Buses)	10	10^{-2}	1	0.0028	0.1	$2.8 * 10^{-6}$	$5 * 10^{-3}$	0.01	**Acceptable**

Possible Hazard	**Affected Location/ Structure**	**Number of People at Risk at One Time**	**Likelihood / Annual Probability P(H)**	**Probability of the Spatial Impact P(S: H)**	**Temporal Probability P(T:S)**	**Vulnerability of the Individual V (D: T)**	**Risk for Person Most at Risk R(LoL) Risk Evaluation (F) / Annual Probability**	**Annual probability of N or more fatalities (F)**	**Number of Fatalities (N)**	**Risk Outcome***
5 - Retaining Walls Failure	Lot 802 Construction Phase	10	10^{-4}	1	0.33	0.01	$3.3 * 10^{-7}$	$5 * 10^{-4}$	1	**Acceptable**
	Lot 812 - Talara Ski Club	24	10^{-4}	0.8	0.42	0.01	$3.4 * 10^{-7}$	$8 * 10^{-5}$	0.24	**Acceptable**
	Lot 803 - Elevation Apartments	20	10^{-4}	0.1	0.42	0.01	$4.2*10^{-8}$	$1 * 10^{-5}$	0.2	**Acceptable**
	Lot 801 - The Peak	38	10^{-4}	0.1	0.42	0.01	$4.2*10^{-8}$	$1 * 10^{-5}$	0.38	**Acceptable**
	Bobuck Lane (Vehicles)	2	10^{-4}	0.5	0.0083	0.01	$4.2*10^{-9}$	$5 * 10^{-5}$	0.02	**Acceptable**
	Bobuck Lane (Pedestrians)	2	10^{-4}	0.5	0.017	0.01	$8.5 *10^{-9}$	$5 * 10^{-5}$	0.01	**Acceptable**
	Bobuck Lane (Buses)	10	10^{-4}	0.5	0.0028	0.01	$1.4 *10^{-9}$	$5 * 10^{-5}$	0.02	**Acceptable**
6- Failure of the Unsupported Batter at the rear of Sonnblick Lodge	Lot 802 Construction Phase	10	10^{-3}	1	0.33	0.1	$3.3 * 10^{-5}$	$1 * 10^{-3}$	1	**Tolerable**
	Lot 812 - Talara Ski Club	24	10^{-3}	1	0.42	0.05	$2.1 * 10^{-5}$	$1 * 10^{-3}$	1.2	**Acceptable**

Table 5-3: Individual Risk to Loss of Life for the Person most at Risk – Existing Slope.

Locations	**Lot 802 - Construction Phase**	**Lot 812 - Talara Ski Club**	**Lot 803 - Elevation Apartments**	**Lot 801 - The Peak**	**Lot 720 – Aneeki Ski Lodge**	**Bobuck Lane Road Users**		
						Pedestrians	**Vehicles**	**Buses**
Annual Individual Risk for the person most at risk for the separate location across the site and neighboring properties – Existing Slope	**$6.7 * 10^{-5}$**	**$4.82 * 10^{-5}$**	**$1 * 10^{-6}$**	**$1 * 10^{-6}$**	**$1.7 * 10^{-6}$**	**$5.4*10^{-7}$**	**$1.4 * 10^{-6}$**	**$1.8 * 10^{-8}$**
Risk Outcome	Tolerable	Tolerable	Acceptable	Acceptable	Acceptable	Acceptable	Tolerable	Acceptable

Table 5-4: Risk to Loss of Life – Calculation Summary after control measures are implemented – New Slope.

Possible Hazard	Affected Location/ Structure	Number of People at Risk at One Time	Likelihood / Annual Probability P(H) (after control measures implementation)	Probability of the Spatial Impact P(S: H)	Temporal Probability V(T:S)	Vulnerability of the Individual V (D: T)	Risk for Person Most at Risk R (LoL)	Annual Probability of N or more Fatalities (F)	Number of Fatalities (N)	Risk Outcome*
3 - Deep-seated failure below Bobuck Lane	Lot 812 - Talara Ski Club	24	10^{-5}	0.8	0.42	0.8	$2.7 * 10^{-6}$	$8 * 10^{-6}$	19.2	**Tolerable**
	Lot 803 - Elevation Apartments	20	10^{-5}	0.3	0.42	0.5	$6.3 * 10^{-7}$	$3 * 10^{-6}$	16	**Acceptable**
	Lot 801 - The Peak	38	10^{-5}	0.3	0.42	0.5	$6.3 * 10^{-7}$	$3 * 10^{-6}$	30	**Acceptable**
	Lot 720 - Aneeki Ski Lodge	25	10^{-5}	0.05	0.42	0.7	$1.5 * 10^{-7}$	$5 * 10^{-7}$	20	**Acceptable**
	Bobuck Lane (Vehicles)	2	10^{-5}	1	0.0083	0.6	$5 * 10^{-8}$	$1 * 10^{-5}$	1.2	**Acceptable**
	Bobuck Lane (Pedestrians)	2	10^{-5}	1	0.017	0.8	$1.4 * 10^{-7}$	$1 * 10^{-5}$	1.6	**Acceptable**
	Bobuck Lane (Buses)	10	10^{-5}	1	0.0028	0.6	$1.7 *10^{-8}$	$1 * 10^{-5}$	6	**Acceptable**
4 - Bobuck Lane Fill Embankment Shallow Failure	Bobuck Lane (Vehicles)	2	10^{-5}	0.5	0.0083	0.001	$4.2 *10^{-11}$	$5 * 10^{-6}$	0.002	**Acceptable**
	Bobuck Lane (Pedestrians)	2	10^{-5}	0.5	0.017	0.001	$8.5 *10^{-11}$	$5 * 10^{-6}$	0.002	**Acceptable**
	Bobuck Lane (Buses)	10	10^{-5}	0.5	0.0028	0.001	$1.4 *10^{-11}$	$5 * 10^{-6}$	0.01	**Acceptable**
5- Retaining Walls Failure	Lot 812 - Talara Ski Club	24	10^{-5}	0.8	0.42	0.01	$3.4 *10^{-8}$	$8 * 10^{-6}$	0.24	**Acceptable**
	Lot 803 - Elevation Apartments	20	10^{-5}	0.1	0.42	0.01	$4.2*10^{-9}$	$1 * 10^{-6}$	0.2	**Acceptable**
	Lot 801 - The Peak	38	10^{-5}	0.1	0.42	0.01	$4.2*10^{-9}$	$1 * 10^{-6}$	0.38	**Acceptable**

Possible Hazard	Affected Location/ Structure	Number of People at Risk at One Time	Likelihood / Annual Probability P(H) (after control measures implementation)	Probability of the Spatial Impact P(S: H)	Temporal Probability V(T:S)	Vulnerability of the Individual V (D: T)	Risk for Person Most at Risk R (LoL)	Annual Probability of N or more Fatalities (F)	Number of Fatalities (N)	Risk Outcome*
	Bobuck Lane (Vehicles)	2	10^{-5}	0.5	0.0083	0.01	$4.2*10^{-10}$	$5 * 10^{-6}$	0.02	**Acceptable**
	Bobuck Lane (Pedestrians)	2	10^{-5}	0.5	0.017	0.01	$8.5 *10^{-10}$	$5 * 10^{-6}$	0.02	**Acceptable**
	Bobuck Lane (Buses)	10	10^{-5}	0.5	0.0028	0.01	$1.4*10^{-10}$	$5 * 10^{-6}$	0.1	**Acceptable**
6 - Failure of the Unsupported Batter at the rear of Sonnblick Lodge	Lot 812 - Talara Ski Club	24	10^{-5}	1	0.42	0.05	$2.1* 10^{-7}$	$1 * 10^{-5}$	1.2	**Acceptable**
7 - Shallow Soil Translational Slide (post-demolition)	Lot 812 - Talara Ski Club	24	10^{-5}	0.8	0.42	0.05	$1.7 * 10^{-7}$	$8 * 10^{-6}$	0.12	**Acceptable**
	Lot 803 - Elevation Apartments	20	10^{-5}	0.1	0.42	0.01	$4.2 * 10^{-9}$	$1 * 10^{-6}$	0.02	**Acceptable**
	Lot 801 - The Peak	38	10^{-5}	0.1	0.42	0.01	$4.2 * 10^{-9}$	$1 * 10^{-6}$	0.38	**Acceptable**

* AGS (2007c) suggested tolerable loss of life individual risks are 10^{-4} / annum for existing slope or development and 10^{-5} for newly constructed slope, development or existing landslide; the acceptable risk is usually one order less than tolerable (Table 5-8)

Table 5-5: Individual Risk to Loss of Life for the Person most at Risk – New Slope.

Locations	Lot 812 - Talara Ski Club	Lot 803 - Elevation Apartments	Lot 801 - The Peak	Lot 720 – Aneeki Ski Lodge	Bobuck Lane Road Users		
					Pedestrians	Vehicles	Buses
Annual Individual Risk for the person most at risk for the separate location across the site and neighboring properties – New Proposed Slope	**$3.1 * 10^{-6}$**	**$1 * 10^{-6}$**	**$1 * 10^{-6}$**	**$1.7 * 10^{-7}$**	**$1.4*10^{-7}$**	**$5 * 10^{-8}$**	**$1.7 * 10^{-8}$**
Risk Outcome	Tolerable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable

5.4 RISK TREATMENT

5.4.1 Recommendations

Mitigation measures should be implemented to maintain and reduce the risk level of slope stability during the demolition and construction of the new slope and associated structures. The recommendations and design parameters for each element of the proposed slope (batters, drainage, etc) are provided in Section 6. The following is a summary of the measures that must be implemented:

- Construction is to be completed over the dryer summer period, from November to March, preferably.
- Install and maintain site monitoring, as described in Section 5.4.1 of the Trigger Action Response Plan (TARP).
- Do not undertake construction work (particularly earthworks) during or immediately after a heavy rainfall event. TfNSW's nominated alarm level is 50mm over 24 hours; however, the failure can be triggered by lower precipitation if other favourable conditions, such as channelisation, erosion, etc., exist on site.
- Install and maintain adequate site drainage and ensure drains are free-flowing. Details on the drainage are provided in Section 6.5.
- All retaining walls should be properly supported and positively drained. Section 6.3 provides details on the proposed retaining wall updates.
- The proposed new slope will cover most of the site after the demolition of Sonnblick Lodge. Following completion of the development, any exposed ground must be protected against erosion by newly established vegetation or provide suitable erosion protection (e.g., erosion control mats, etc.).
- Periodic inspection of the slope uphill for signs of erosion development and remediation as necessary.
- During the demolition, all temporary site cuts must be battered back to a stable angle (See Section 6.5). If space restrictions prevent battering back to a stable angle, then temporary excavation support systems (shoring such as soldier pile walls) must be implemented.
- Any water seepages or leaks around the development or associated infrastructure (upslope and downslope) should be investigated and repaired as soon as possible.
- If a failure occurs, seek geotechnical advice before re-opening the construction site. Bobuck Lane closure might be necessary for the failure event.
- Complete a full inspection of the site post-construction by an experienced geotechnical engineer or engineering geologist prior to opening to identify any additional hazards (preferably completed before full completion of works to allow rectification to be completed).

Some useful guidelines on hillside construction, prepared by the Australian Geomechanics Society (Reference 1), are presented in Appendix D. A summary of estimated risk to property and life for each of the potential hazards identified in the previous sections is provided in Table 5-2. This risk assessment in Table 5-2 is based on the proposed future conditions, assuming that all recommended mitigation measures are implemented. For this risk assessment to be valid, a suitably qualified geotechnical engineer must sign Form 2 and Form 3 to check that these mitigation measures have been incorporated into the design and constructed correctly. The resulting risk level was derived using Appendix C's AGS risk analysis matrix.

5.4.2 Trigger Action Response Plan (TARP)

The Trigger Action Response Plan (TARP) outlines the monitoring of the site (visual and instrumentation), trigger levels, and actions to ensure the site's risk levels remain tolerable throughout the period prior to redevelopment.

The landslide risk assessment is an iterative process, and this report summarises the initial stage. Further geotechnical investigation will need to allow the geotechnical data acquisition to refine the risk assessment and monitoring of the site. It can include the following elements:

- After the demolition of the upper levels of the lodge, allowing drill rig access to the site, two investigation boreholes should be drilled to depth, allowing a 3m core of the bedrock.
- Preferably, one borehole should be located near the Bobuck Lane frontage, and the other should be located centrally within the block.
- Inclinometer casing should be installed in at least one borehole (preferably adjacent to Bobuck Lane), and the depth of the casting should allow the intersection of the potential shear zone.
- One standpipe piezometer with water level data loggers should be installed in one of the boreholes. It can be installed in the middle of the site for groundwater monitoring.
- The site should be monitored at least bi-annually, every six months, before the snow season, in March/April, and after the snow season, in September/October. Instrumentation monitoring will need to be carried out in conjunction with visual slope inspections. If trigger levels are exceeded beyond 1, an inspection should be carried out by a competent geotechnical practitioner who should also carry out the monitoring site inspections.
- It is also recommended that monitoring of the two existing inclinometers on Bobuck Lane recommence. This may require coordination with Transport for NSW to obtain the necessary permission. Even in the absence of historical data, monitoring the inclinometers, which are likely still operational, would provide valuable information. A baseline reading should be taken prior to the commencement of demolition works.
- Survey monitoring of the retaining walls should be conducted for the duration that the site remains undeveloped. This monitoring should be performed by a registered surveyor at a minimum interval of every six months. Movement triggers were included in the TARP.

The indicative site inspection checklist is provided below:

1) Inspect the existing scarp and retaining wall above Bobuck Lane. Check for cracks, loose blocks, water seepages, and drainage outflow. Photograph this site aspect.

2) Inspect the Bobuck Lane pavement to see if there has been progress on the existing tension cracks, new cracks, subsidence, or any other signs of instability. Take photographs of this site aspect.

3) Inspect existing retaining walls and buttress any movements or cracks. Photograph this site aspect.

4) Inspect the soil slope faces on any rupture surfaces, erosion, cracks or other signs of slope instability. Take photographs of this site aspect.

5) Measurements from inclinometers and groundwater well/standpipe piezometers should be taken. Then, compare them with tolerance criteria (provided in Tables 5-6 and 5-7.

This TARP was developed to identify any slope movement and needs to be used to manage the new proposed slope on Lot 812. It is understood that the management and monitoring of the new site slope and implementing TARP is the landowner's responsibility, while TfNSW currently monitors the areas upslope (Bobuck Lane). This is the initial TARP, which considers the failure mechanisms, triggers, and threshold based on the existing geotechnical data. Once in place, TARPs can be optimised as the understanding of each failure improves and more information becomes available after the Sonnblick Lodge demolition and subsequent geotechnical investigation and installation of geotechnical monitoring instruments on-site.

The used triggers include displacement or lateral movement. Lateral movement or “displacement” is the change of position of the inclinometer casing. Displacement of the inclinometer by taking away the original reading by the most resent reading taken from the inclinometer. Once a number of readings have been attained then the movement of the structure can be shown incrementally. Cumulative displacement is the addition of all the incremental data. The displacement can be seen of a inclinometer in relation to a fixed reference point at the top of the casing, that will have to be surveyed before.

Table 5-6: Response and Slope Behaviour for different trigger Action Response Plan Levels

Trigger Action Response Plan	Slope failure progression	Typical Response
0-1	Slight or no deformation	• No response required. • Routine slope maintenance, continued slope monitoring, and continued keeping of records/reports.
2	Gradual slope deformation, no acceleration.	• Confirm monitoring results (QA check). • Additional site inspection. • Investigate the movements on site if detected, • A suitably trained and experienced person check drainage/water leaking and soil conditions • Seek geotechnical advice on slope stabilisation/remediation. Remediation may include reprofiling, revegetation, and a review of the slope design. • Increase the frequency of monitoring and drainage maintenance.
3	Accelerated slope movement (progressive phase)	• Remove personnel. • Notify the neighbouring lodges and authorities, • Urgently seek geotechnical advice (within 1 week or sooner), • Investigate the movements on site, check drainage/water leaking and soil conditions, and seek geotechnical advice on slope stabilisation. • Review the slope and/or drainage design and confirm whether changes to the design specifications are required. • Implement the stabilisation measures urgently.
4	Failure inspected	• Remove personnel • Evacuate the site, the downslope, and neighbouring lodges immediately. • Immediately seek geotechnical advice • Apply the stabilisation measures. • Bobuck Lane closure until stabilisation is implemented.
5	Unexpected failure	• Address any injuries or risks to life, including providing first aid and contacting emergency services if required. • Managers should assess the risk to workers participating in rescue operations or immediate stabilisation works. • Evacuate the site and the downslope, upslope and neighbouring lodges. • Bobuck Lane closure until stabilisation is implemented.

Table 5-7: Suitable Triggers and Thresholds for Different Trigger Action Response Plan Level

Trigger	Typical Threshold	Comments	Suitable TARP Level
Incremental displacement (mm) measured by inclinometer testing	0mm-10mm	Displacement or lateral movement is measured by the proposed inclinometer. The inclinometer should be installed in the borehole intersection potential shear zone (rupture surface for the proposed landslide below Bobuck Lane). Both cumulative and incremental displacements should be reported.	0-1
	10mm-100mm		2-3
	>100mm		3 or 4
Lateral Movement (mm) by survey monitoring of the retaining walls movements	< 2.5mm	Deformation and movement monitoring should measure and track any alterations in the shape or dimensions of a retaining wall every six months. Set out of the survey markers shall be carried out in consultation with a qualified geotechnical / structural engineer after the demolition of the lodge.	0-1
	2.5mm-10mm		2-3
	>10mm		3 or 4
Rainfall (mm)*	Alert levels of >50mm of rain in 24 hours	The rainfall information can be used from the two nearby weather stations monitored by the Bureau of Meteorology (BoM) for Thredbo Village (station number 71041) and Thredbo AWS (station number 71032) (Reference 5). The rainfall does not necessarily cause the slope movements, so the response and suitable TARP level are indicative and will be pending additional site inspection.	0-1
	>100mm in a 48-hour		0-1 or 2
	Recorded rainfall >300mm over 7-day period		2-3
Water seepages/ springs/ ponding Water on-site	Wet or swampy areas identified	The proposed drainage measures are designed to divert the stormwater into the Thredbo stormwater system. Any seeping or ponding water will indicate inefficient drainage measures and require a design review.	0-2
	Ponding/seeping water on the slope faces		2-4
Slope Erosion	No gully or tunnel erosion. No active rilling > 300mm deep.	This trigger cannot cause the landslide but should be monitored in conjunction with other triggers. Any signs of erosion need to be remediated; TARP levels define urgency.	0-1
	Minor sheet, gully or tunnel erosion present and active rilling between 300mm-600mm deep		2
	Significant gully or tunnel erosion present and active rilling > 600 mm deep.		3

Trigger	Typical Threshold	Comments	Suitable TARP Level
Tension cracking was detected on Bobuck Lane and New Slope Faces.	Cracks width between 0mm and 20mm	Cracks can be identified visually in the field during regular inspection and will be combined with other data to define the suitable TARP level.	0-1
	Cracks width between 20mm and 40mm		2 or 3
	Cracks >40mm in width, sinkholes and ruptures in the new slope faces		3 or 4

5.5 SIGNIFICANCE OF RISKS (RISK EVALUATION)

In the present conditions, the overall risk to property is assessed to be “Very Low” to “High” (See Table 5-1). Provided design and construction of the new slope is undertaken in accordance with accepted procedures for hillside construction, and treatments and mitigation measures are carried out to reduce the potential hazards (as recommended in Section 5.6 and Section 6), the risk is assessed to be “Very Low” to “Low” (See Table 5-2).

For the proposed development on Lot 802, this assessment of risk-to-life for six hazards analysed indicates an annual probability of loss of life for the individual most at risk for the development is equal to or below the AGS 2007 (Table 5-4) recommended tolerable limit of 1×10^{-5} per annum. For the neighbouring properties, the risk estimates were below and within the acceptability limit for the existing structures. This was calculated for an individual, considered the most critical person-at-risk, which was a person occupying a unit (customer) or staff.

The risks for the construction workers were calculated to be within the acceptability limit; however, with the highest values, considering the relatively higher vulnerability of the workers on site and higher chances of being trapped in a landslide, compared to people in the building. This should be addressed by WHS measures designed for the site specification, regular stability inspection and development of prompt evacuation practices. The risk for Bobuck Lane road users, including pedestrians and vehicle passengers, was calculated to be below the acceptability criteria.

Table 5-8: Recommendations for Acceptable and Tolerable risk in AGS (2007c) and AGS (2007d)

	Acceptable Risk		Tolerable Risk	
	Risk to Property	Risk to Life	Risk to Property	Risk to Life
New Slopes, new development or existing landslide	LOW to VERY LOW	$<1*10^{-6}$ per annum	MODERATE, LOW or VERY LOW	$<1*10^{-5}$ per annum
Existing slopes or existing development	LOW to VERY LOW	$<1*10^{-5}$ per annum	MODERATE, LOW, or VERY LOW	$<1*10^{-4}$ per annum

The societal risk assessment process requires the development of F-N plots for the identified hazards at a site, where N represents the number of expected fatalities from a hazard (from multiplying vulnerability and number of people at risk), and F is the annual probability of N or more fatalities (from multiplying hazard likelihood P(H) and spatial probability P(S:H)).

Societal risk was calculated for the existing conditions, showing the assessment for a site and neighboring properties in the current condition (Plate 5). Most N-F pairs for hazards listed in Table 5-3 fall within the 'Tolerable' or the As Low As Reasonably Practical (ALARP) Zone. However, the societal risk for Hazards 3 (Deep-seated failure below Bobuck Lane) for Talara Ski Lodgeis on the edge of the 'Unacceptable' Zone. Hazards 6 (Failure of the Unsupported Batter at the rear of Sonnblick Lodge) also lies on the boundary with unacceptable for the Talara Ski Lodge and during construction.

As shown on Plate 6, the proposed new slope (in case if properly engineered) will decrease the societal risks to 'Tolerable' (ALARP) and 'Broadly Acceptable' areas.

Risk evaluation is the process by which owners, administrators and relevant regulatory authorities can decide whether the potential risks (See Table 5-1 and Table 5-2) are acceptable and whether these can be feasibly eliminated or reduced by remedial treatment.

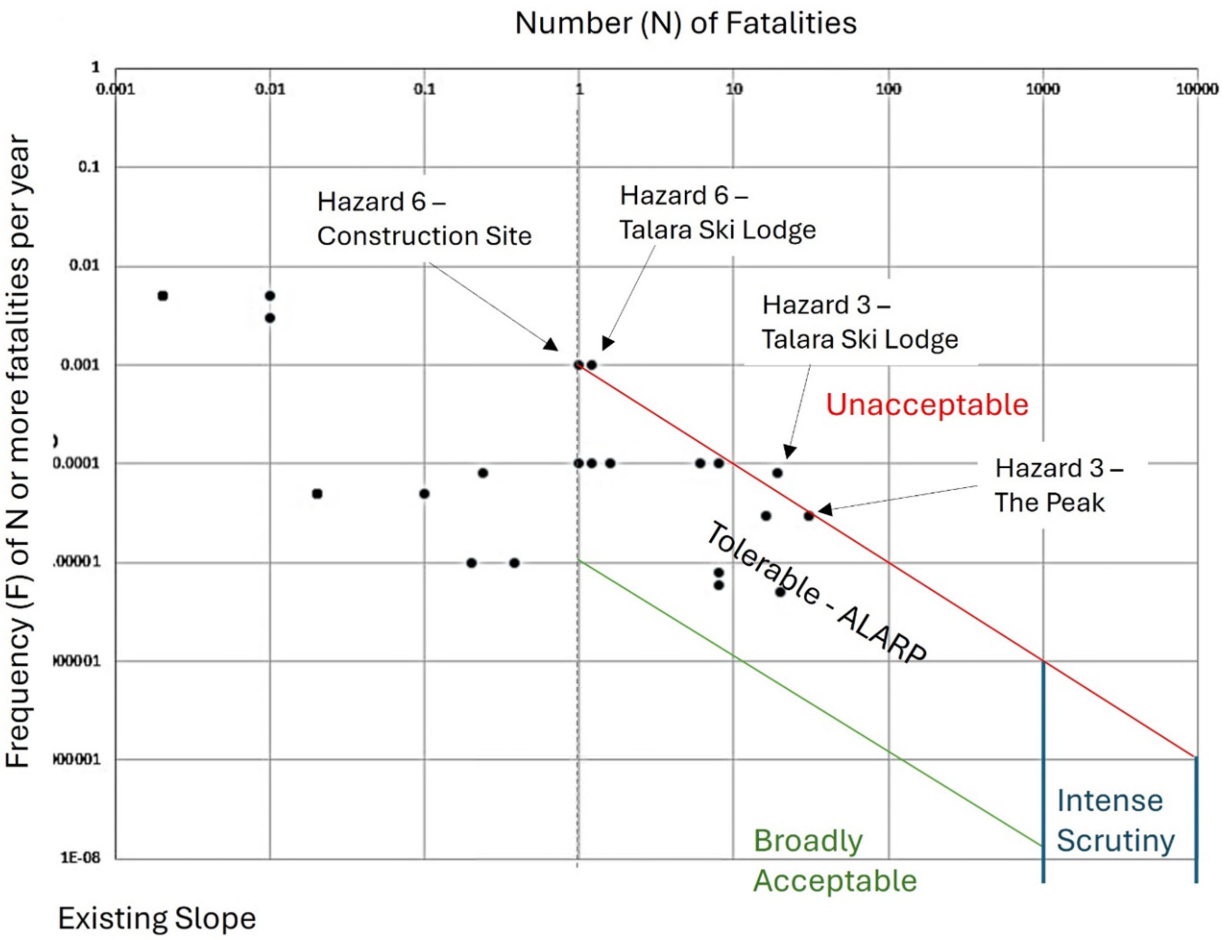

Plate 5: Societal Risk Assessment Plot (N-F) for Lot 802 and the vicinity – Existing Slope

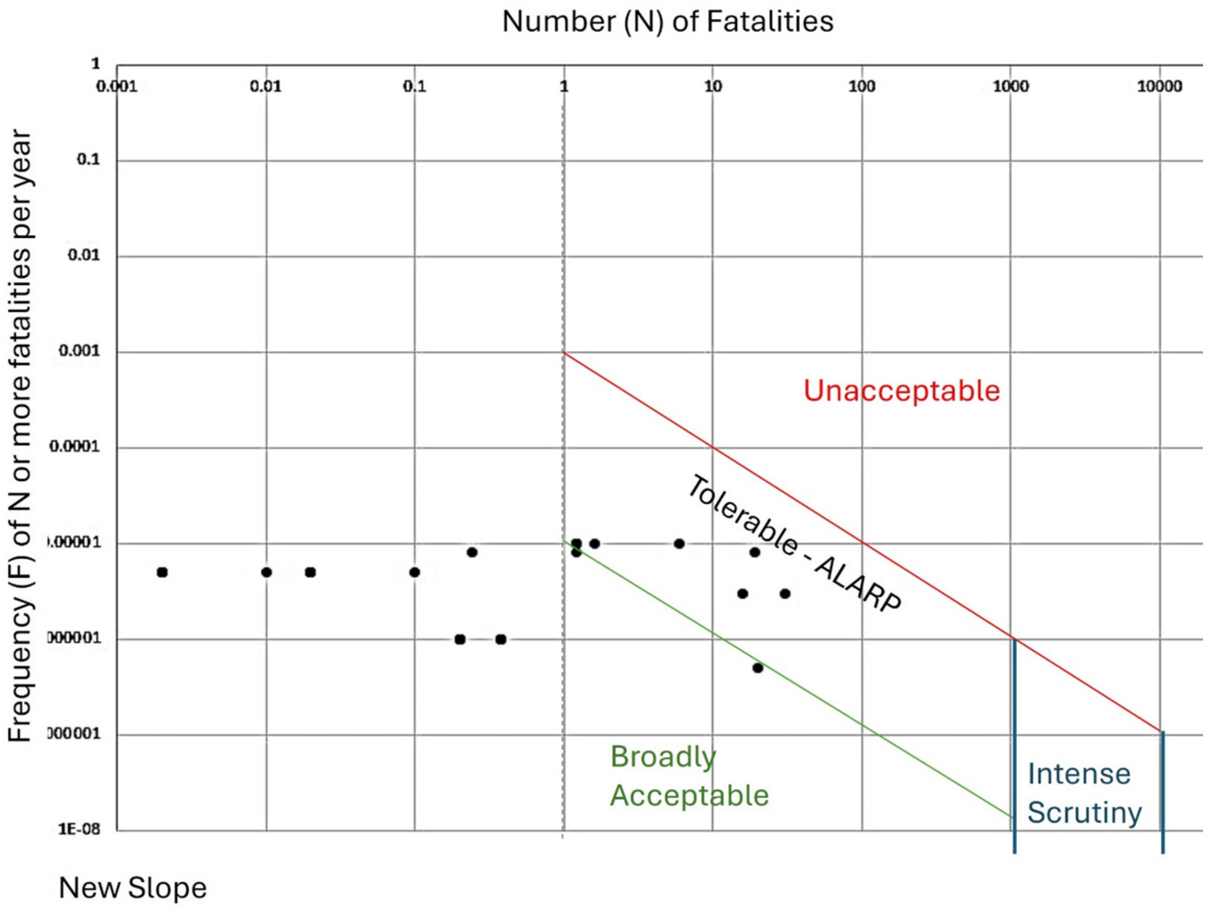

Plate 6: Societal Risk Assessment Plot (N-F) for Lot 802 and the vicinity – New Slope

5.6 SUITABILITY OF THE PROPOSED DEVELOPMENT (DEMOLITION OF EXISTING LODGE)

Provided that the design and works are undertaken in accordance with accepted procedures for hillside construction, and treatments and mitigation measures are carried out to reduce the potential hazards (as recommended in Section 5.5 and Section 6), the risk is assessed to be "Very Low" to "Low" (See Table 5-1) and the risk to life within a tolerable range for the proposed demolition of the existing lodge (Table 5-2). Therefore, it is assessed that the site is suitable conditionally for the proposed demolition and subject to the following conditions summarised in Table 5-9 (provided all the recommendations in our report are followed).

Table 5-9: Summary of the conditions

Policy Requirements	Requirements / Conditions of Site Suitability
Conditions to be provided to establish the design parameters.	
Footing levels and supporting rock quality, bearing capacities for use in the design of all structural works, including footings, retaining walls, and drainage.	Not applied - Footings and retaining walls to remain on site.
Recommendations for excavation (temporary and permanent) batters.	Only minor excavation may be required. Follow Section 6.1.
Recommendations for excavation support (stability of the batters, temporary and permanent).	See Section 6.3.
(ii) Conditions applying to the detailed design to be undertaken for the construction certificate.	Any structural design relating to the geotechnical aspects of the proposal is to be checked and certified by a suitably qualified and experienced geotechnical engineer; any other design conditions the geotechnical engineer preparing the geotechnical report believes are required in the design phase to ensure the design will achieve the "acceptable risk management" level as defined in the policy for potential loss of both property and life, signing of Form 2 as the mechanism to check that these parameters have been used and interpreted correctly.
(iii) Conditions applying to the construction phase.	
Recommendations for control fill platform constructions.	See Section 6.2.
The report must highlight and detail the inspection regime to provide the builder with adequate notification of all necessary inspections and any other construction conditions, including works methodology and temporary works that the geotechnical engineer preparing the geotechnical report believes are required in the construction phase to ensure the design will achieve "acceptable risk management" level as defined by the policy for potential loss of both property and life and signing of Form 3 as the mechanism to check that these parameters have been used and interpreted correctly.	See section 6.6.
(iv) Conditions regarding the ongoing management of the site/structure, including but not limited to any conditions that may be required for the ongoing mitigation and maintenance of the site and the proposal from a geotechnical viewpoint.	Subsequent geotechnical investigation and geotechnical monitoring are required after the demolition and slope stabilisation; see Sections 5.4.1 & 6.

6 DISCUSSION & RECOMMENDATIONS

The following sections provide geotechnical recommendations for designing and building the proposed slope. After the civil design is complete, a suitably qualified geotechnical engineer must review the design and sign Form 2 to check that these design recommendations and slope stability mitigation measures have been correctly incorporated into the design.

6.1 EXCAVATION CONDITIONS & USE OF EXCAVATED MATERIAL

At this stage, the footings and retaining walls will remain on site. Before buttress placement, minor excavation to 0.5m/1.4m is required in front of the retaining walls. The excavation would be through topsoil and uncontrolled fill. The soils and any weak rock (XW/HW) are readily diggable by a backhoe and medium-sized excavator. However, it should be noted that core stones of moderately (MW) or less-weathered granitic rock can be encountered.

The low and medium plasticity colluvial/residual soils can be used in controlled fill construction of building platforms. The weathered granite bedrock is also suitable for fill material, although rock particles should be broken down to <75mm in size. The silty topsoil and slopewash material and any high plasticity clay should not be used in controlled fill construction but could be used in non-structural applications such as landscaping.

If imported fill is required, a suitable select fill material would include a low—or medium-plasticity soil such as clayey sand or gravelly clayey sand, containing between 25% and 50% fines less than 0.075mm size (silt and clay) and no particles greater than 75mm size.

6.2 CONTROLLED FILL CONSTRUCTION

For the construction of any new fill foundation platforms and road subgrades, it is recommended that:

- Areas be fully stripped of all silty topsoil and any uncontrolled fill. A stripping depth of up to ~0.5m/1.4m may be required. Stripped foundations should be proof-rolled by a vibratory pad-foot roller of not less than 9-tonne static mass to check for any weak or wet areas requiring replacement. No fill should be placed until a geotechnical engineer has confirmed the suitability of the foundation.

- Controlled fill comprising suitable site excavated or imported materials of not greater than 75mm maximum particle size be compacted in layers not greater than 150mm to not less than 95%ModMDD at about OMC.

- Fill placement and control testing should be reviewed and certified by a geotechnical engineer with Level 1 or 2 involvement in AS3798 – 1996 “Guidelines on Earthworks for Commercial & Residential Developments” (Reference 3).

6.3 STABLE CUT/FILL BATTER SLOPES

6.3.1 Temporary Batters (During Construction)

Temporary site excavations deeper than 1.5m must be battered back at the following angles:

- Overburden soils - 1(H):1(V)

- XW, XW/HW, & HW Granite bedrock - 0.5(H):1(V)

- HW/MW & MW Granite bedrock - 0.25(H):1(V)

Where space restriction precludes battering back to a stable angle, batter stabilisation or temporary excavation support systems will be required.

A geotechnical engineer should inspect all cut batters during construction to confirm stability. Exposed temporary batters should be protected from the weather by black plastic pinned to the face with link-wire mesh or similar.

During construction, the following recommendations must be followed to maintain the stability of all temporary unsupported excavations:

- All equipment/machinery/stockpiles/site sheds and containers are located 1(H):1(V) from the toe of the batters. Trucks, heavy construction plants/equipment, and large soil stockpiles must not be located close to the top edge of the batters, especially with motor idling. Trucks and heavy construction plants/equipment must be located outside the zone of influence (1(H):1(V)) of the excavation batter.

- A bund or dish drain must be constructed along the top edge of all cuts to intercept and divert surface water away from the batters.

- To protect the downslope lodge from any accidental falling of the material, install a catch fence along the northern boundary of the lot. This should be extended for the full length of the new slope, and the catch fence should be 1/5m high.

- A geotechnical engineer would be required to inspect the batters regularly. As a guide, this inspection must be conducted weekly, while a competent person representing the contractor should do daily checks.

- No work must be conducted close to the toe of the batters during rain and 24 hours after. The batters must be re-inspected by a geotechnical engineer following rainfall (about 20mm of rain, or enough rain that the batter faces become wet).

- If deterioration or significant weathering of the batter face occurs, stabilisation/remediation of the batter must be applied. A geotechnical engineer will confirm this recommendation.

6.3.2 Permanent Batters (Post-Demolition)

New permanent unsupported cut and fill soil batters should be formed at no steeper than 2(H): 1(V). All soil cut and fill surfaces should be protected against erosion by placing topsoiling, grassing, or other suitable means. Structural retaining walls should support steeper permanent cuts. Permanent batters should be inspected during excavation by an experienced geotechnical engineer to confirm stability. It is possible that the demolition work could damage the existing retaining walls, compromising their functionality. A structural engineer should assess the condition of the walls after demolition and recommend any necessary stabilisation treatments.

To reduce the risk of future slope instability, all surface slopes around the development must be protected to prevent erosion using new vegetation or erosion control mats, and regular maintenance and inspections will be required to ensure ongoing stability.

The new slope will comprise the existing retaining walls, requiring further stabilisation. The existing retaining walls should be updated; it is recommended that:

RW1 to RW3 (currently support Sonnblick Lodge)

- During the current investigation, only a part of RW3 was inspected, while RW2 was not inspected due to the limited access. After the lodge demolition, a geotechnical engineer should also inspect the retaining walls and backfill material to estimate the sufficiency of the existing drainage. This can be done by drilling push-tube boreholes or DCP testing on the ground behind the retaining walls. A sub-surface horizontal drainage at the base of the existing retaining walls may need to be installed during this inspection.

- Areas in front of the existing retaining walls must be fully stripped of all silty topsoil and any uncontrolled fill. A stripping depth of up to ~0.5m/1.4m may be required. Stripped foundations should be proof-rolled by a vibratory pad-foot roller of not less than 9-tonne static mass to check for any weak or wet areas requiring replacement. No fill should be placed until a geotechnical engineer has confirmed the suitability of the foundation. A structural engineer should assess the condition of the walls after demolition and recommend any necessary stabilisation treatments.

- Caged gabion walls or Rock buttress should be placed before the existing walls and battered back not less than 1V:1H. Buttress fills are normally constructed of blasted quarry rock, boulders, and cobbles, as well as recycled concrete, which are relatively free draining. The rock fill should comprise 100mm to 500mm particle size. The rockfill should be placed to allow a drainage pipe to divert the water from behind retaining walls. A swale/ jute mat drain should be installed at the toe of the retaining wall to direct the stormwater away from the new slope into the Thredbo stormwater system.

- All cut and fill surfaces should be stabilised using a fabric such as Terramat or another suitable fabric approved by the geotechnical engineer. Vegetation can then be established on the slope to protect against scour and erosion.

RW4 (Supports Bobuck Lane)

- Install sub-surface horizontal drainage at the base of RW4 (which supports Bobuck Lane). The drainpipe should be ~100mm in diameter and extend to 5m long (under the Bobuck Lane embankment). During the drainage installation, the existing services along Bobuck Lane should be located and avoided. The swale drain should be installed at the toe of the retaining wall to direct the stormwater away from the new slope into the Thredbo stormwater system.

- There are two options for the stabilisation of the upper faces. Option 1 includes shortcrete the upper faces, while Option 2 may include caged gabion walls installed in front of the existing RW4 up to the level of Bobuck Lane.

Any permanent unsupported cut and fill soil batters should be formed at no steeper than 2(H): 1(V). Structural retaining walls should support steeper permanent cuts. An experienced geotechnical engineer should inspect permanent batters during excavation to confirm stability. To reduce the risk of future slope instability, all surface slopes around the development must be protected to prevent erosion using new vegetation or erosion control mats, and regular maintenance and inspections will be required to ensure ongoing stability.

6.4 EARTHQUAKE SITE FACTOR

Table 2.3 of AS1170.4 "Minimum Design Loads on Structures - Part 4: Earthquake Loads" (Reference 14) lists the earthquake acceleration coefficients for major centres to be considered in structural design. The Thredbo area has an acceleration coefficient of 0.08.

Section 4 of AS1170.4 summarises the Site Soil Class, which depends on the subsurface conditions at the site in question. A Site Soil Class of C_e is applicable for this development.

6.5 DRAINAGE

Permanent groundwater is not expected within the proposed 10m deep excavation; however, temporary, perched groundwater seepages will be encountered within the proposed excavation depths following rainfall. Therefore, suitable subsoil horizontal drains must be installed, including behind all retaining walls (if they do not already exist). Surface drainage should also ensure rainfall run-off or other surface water cannot be ponded against buildings or pavements.

Following rainfall, overland flow from uphill could also be an issue, so a swale/bund drain should be installed in front of the retaining walls and included in the civil drawings.

6.6 HOLD POINTS FOR GEOTECHNICAL INSPECTIONS

During lodge demolition, a suitably qualified geotechnical engineer must inspect retaining walls remaining on site and sign Form 3 to check that these design recommendations and slope stability mitigation measures have been correctly constructed. The following is a list of hold points that require geotechnical inspection and sign-off:

1) Review all structural and civil design drawings before the start of demolition and slope updates construction to check that our geotechnical design recommendations and slope stability mitigation measures have been interpreted correctly and incorporated into the design. A suitably qualified geotechnical engineer must sign Form 2.

2) Inspect all the foundation material to ensure it is suitable for the rock buttressing placement. A suitably qualified geotechnical engineer must sign Form 3.

3) Inspect all temporary and permanent cut and fill batters to check stability and advise on remediation/treatment measures.

4) Inspection and certification of all controlled fill construction (where it is specified to be controlled fill in accordance with AS3798).

5) Inspect all surface and subsurface drainage measures to ensure that they are adequate and advise on additional measures if necessary.

Fortify Geotech Pty Ltd

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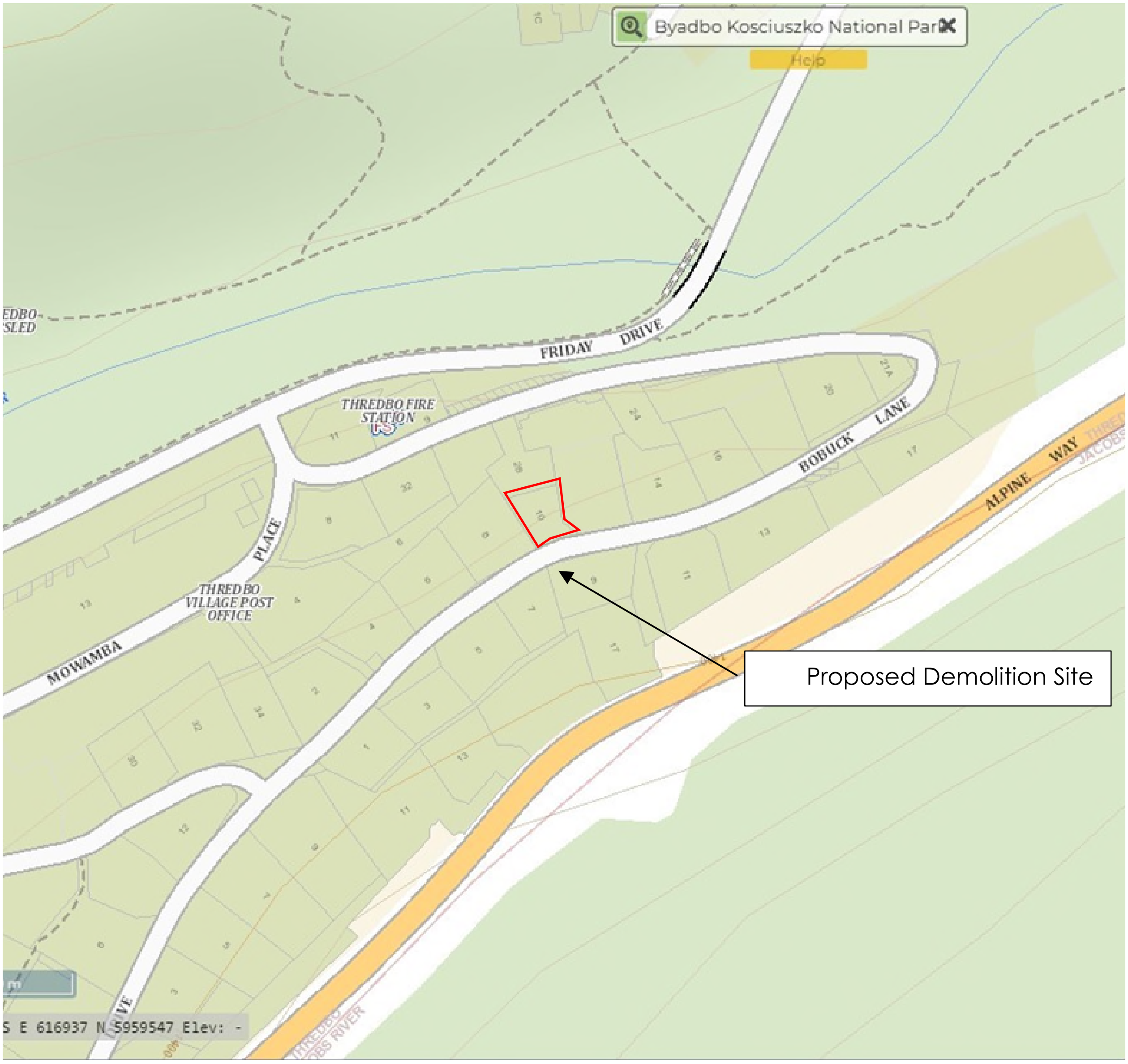


FIGURE 1: SITE LOCALITY	OB/C14191

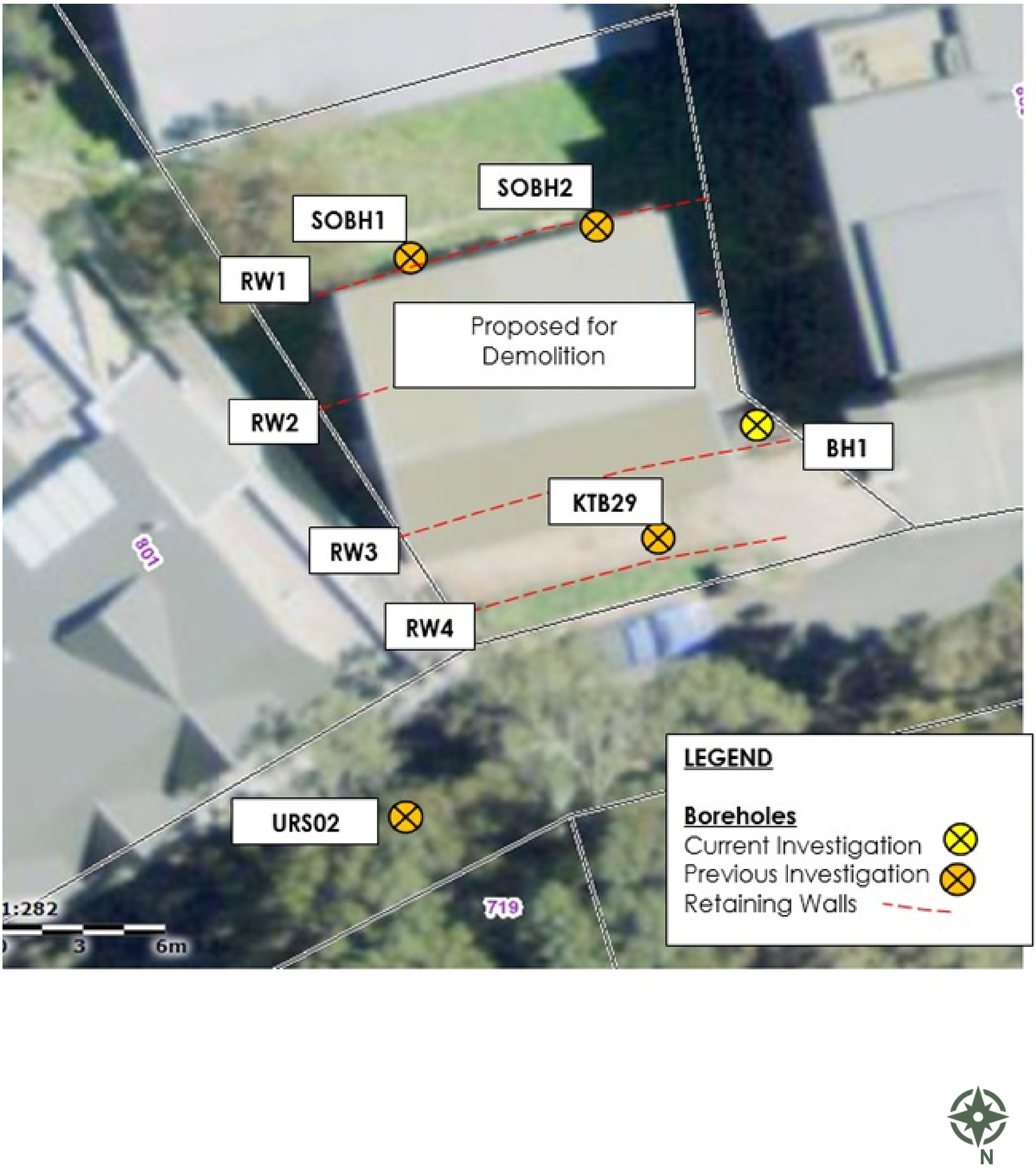


FIGURE 2: AERIAL PHOTOGRAPH & BOREHOLES LOCATIONS	OB/C14191

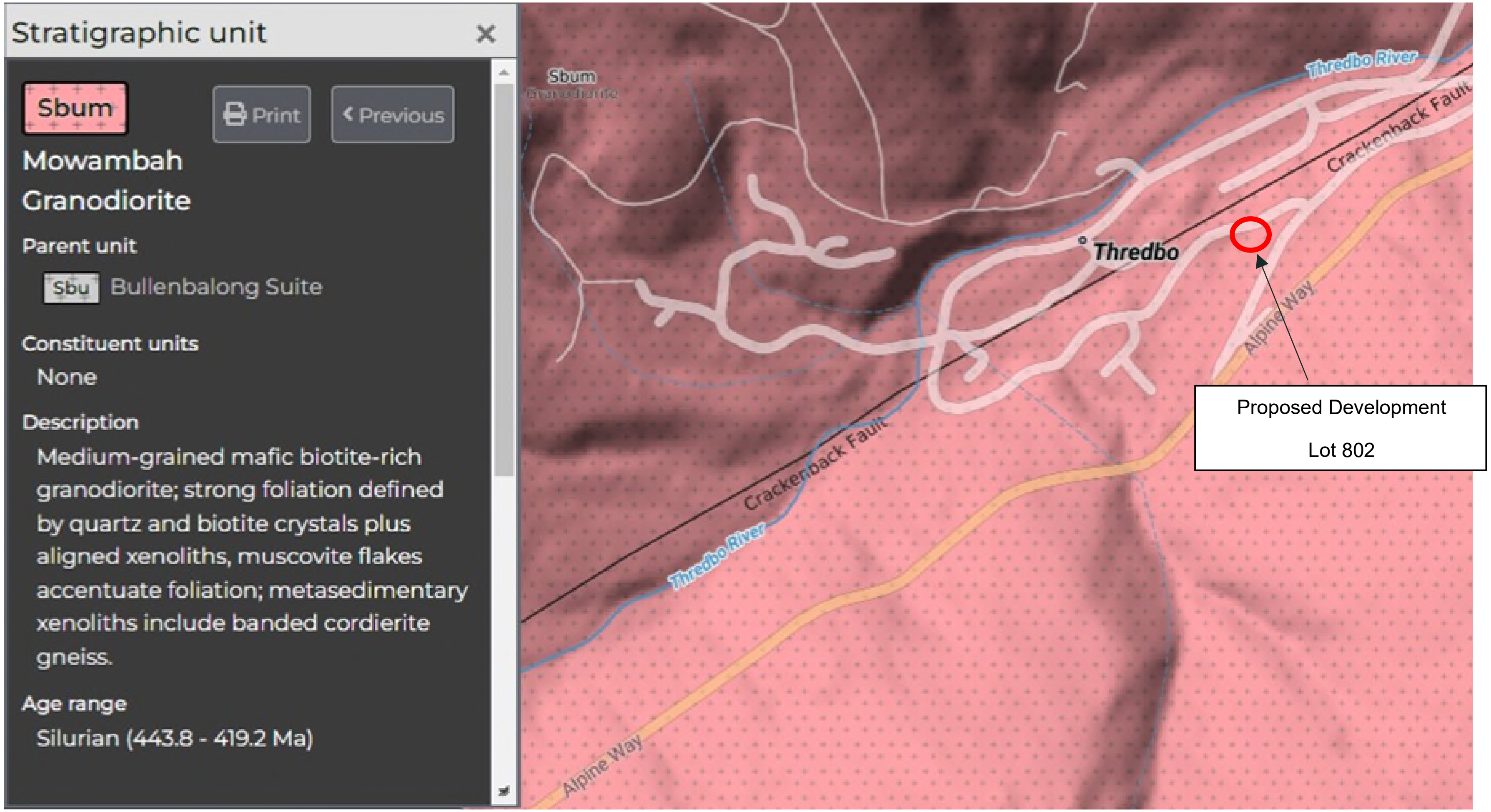


FIGURE 3: SITE GEOLOGY	OB/14191

FIGURE 4: COUNTOUR MAP WITH SITE LOCATION

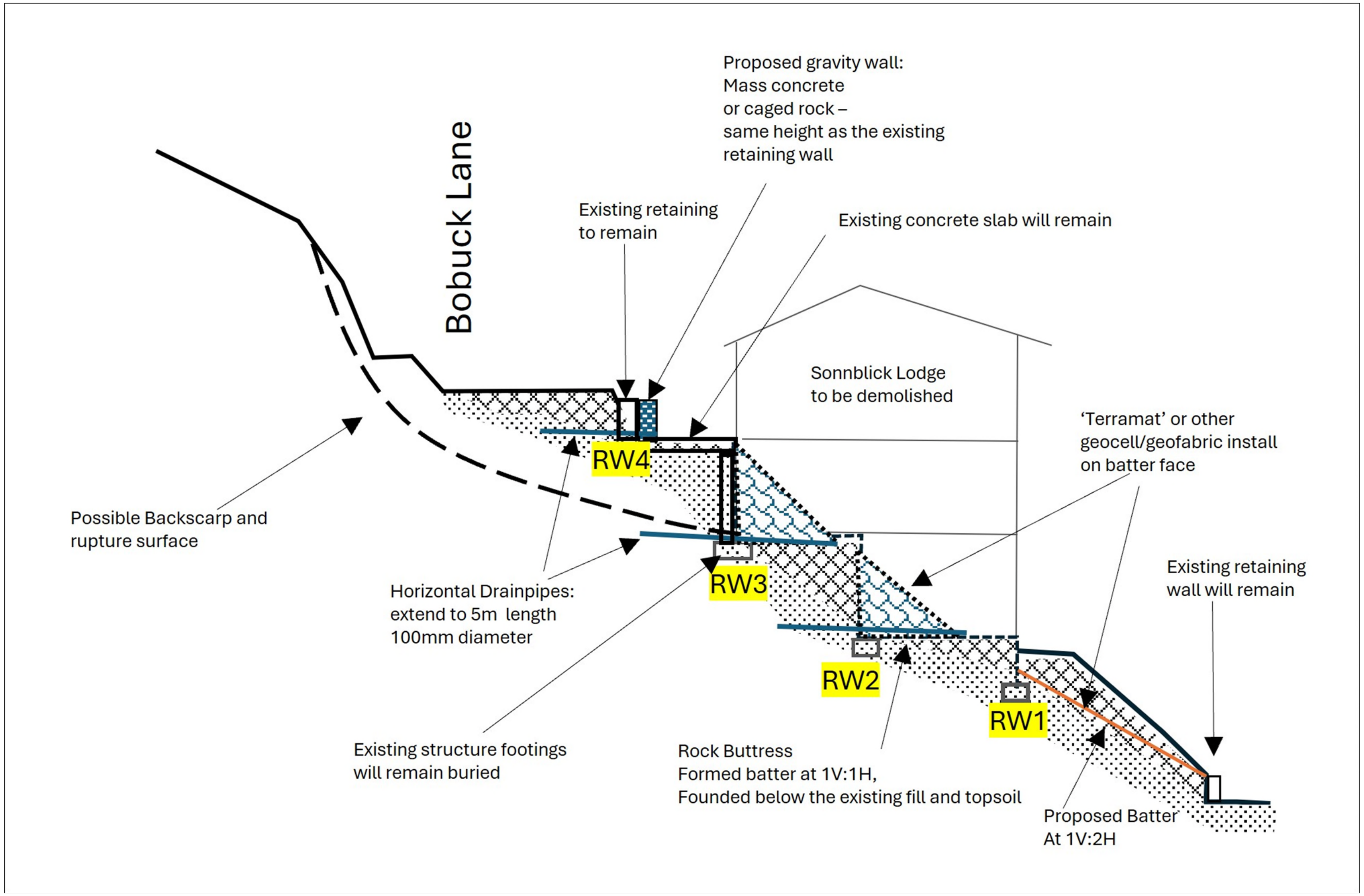


FIGURE 5: SKETCH OF THE PROPOSED STABILISATION MEASURES AFTER DEMOLITION

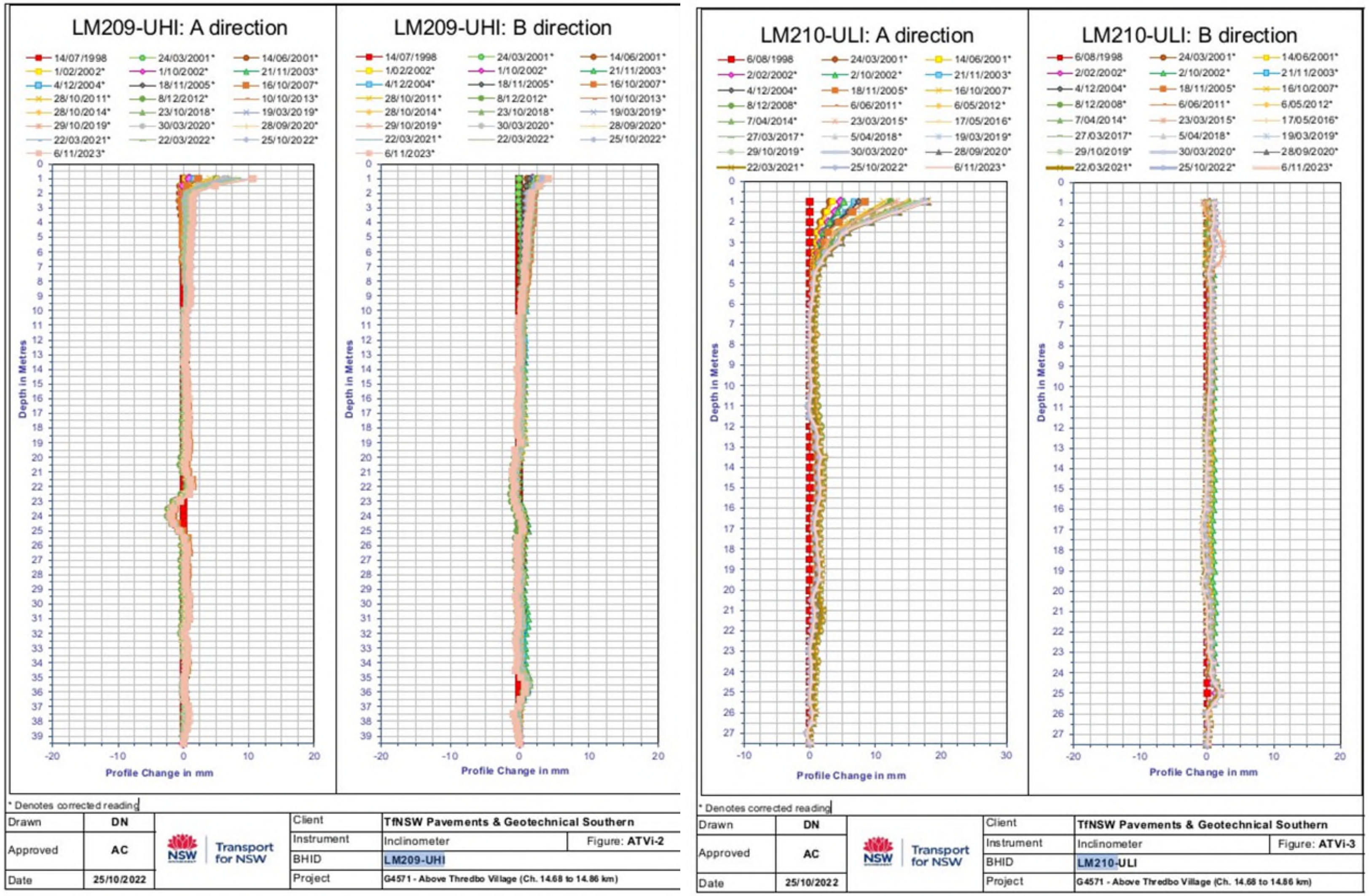
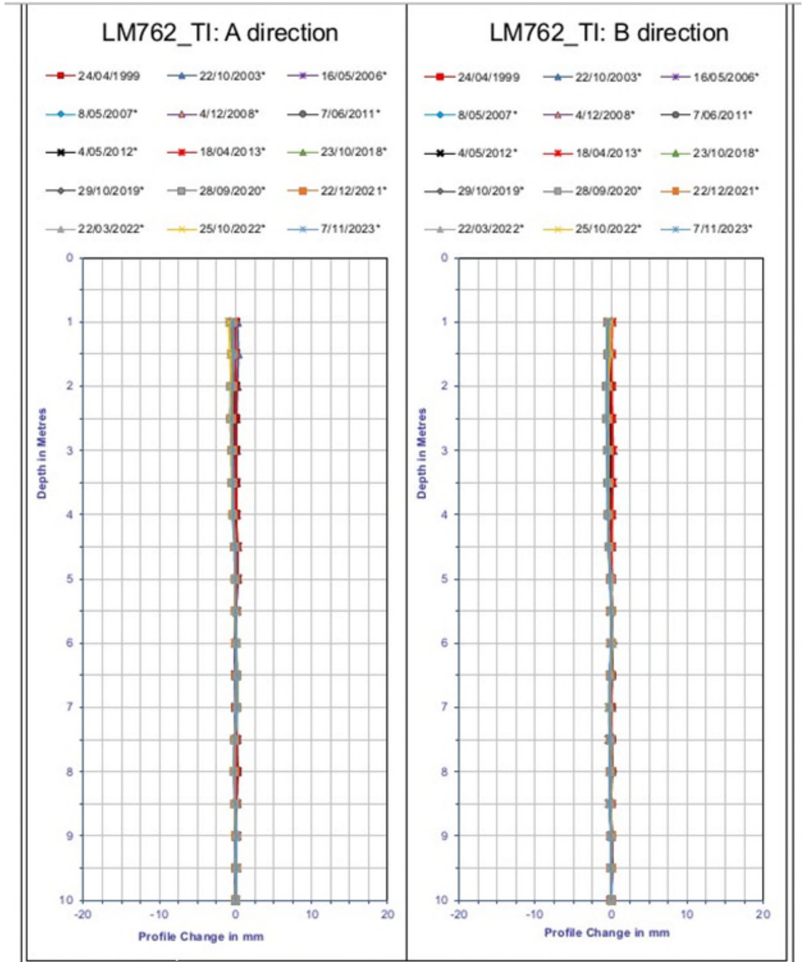


FIGURE 6: RESULTS OF GEOTECHNICAL MONITORING ALONG ALPINE WAY – LM209 AND LM210 (REFERENCE 7)

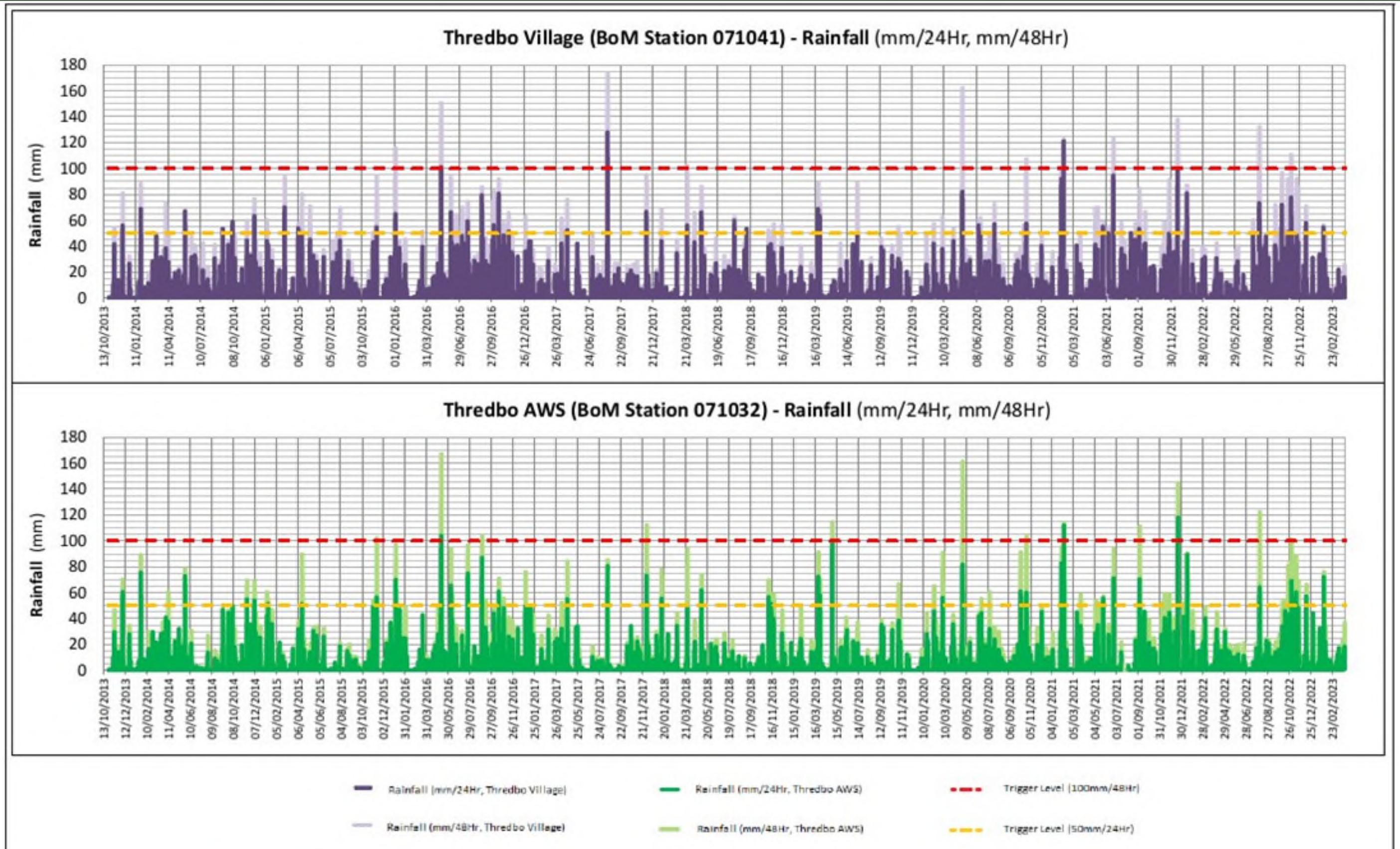
OB/12365



* Denotes corrected reading

Drawn	DN	NSW Transport for NSW	Client	TfNSW Pavements & Geotechnical Southern	
Approved	AC		Instrument	Inclinometer	Figure: AWCi-15
			BHID	LM762_TI	
Date	7/11/2023		Project	G4571 - Alpine Way Corridor (Ch. 14.52 to 15.22 km)	

FIGURE 7: RESULTS OF GEOTECHNCAL MONITORING ALONG ALPINE WAY – LM762	OB/12365



Drawn	DN	NSW GOVERNMENT Transport for NSW	Client	**TfNSW Pavements & Geotechnical Southern**
Approved	AC		Instrument	**Bureau of Meteorology (BoM) - Rainfall (mm/24hr, mm/48hr)**
Date	31/03/2023		Project	**GEO4571 Alpine Way Instrumentation and Monitoring** — **Appendix B**
				Rainfall sourced from Bureau of Meteorology: Thredbo Village (071041) and Thredbo AWS (071032) (BoM, 2023)

FIGURE 8: RAINFALL DATA FROM TWO BOM STATIONS	OB/12365

FORTIFY
GEOTECH

Appendix A

Borehole and Test Pits Logs

Borehole Log

Borehole No.	BH1
Sheet	1 of 1
Job No.	C14191

CLIENT: Kosciuszko Thredbo Pty Ltd

PROJECT PROPOSED DEMOLITION AND REDEVELOPMENT - SONNBLICK LODGE -10 BOBUCK LANE, THREDBO, NSW

Location : See Figure 1

Collar Level : Not Known
Angle From Vertical : 0°
Bearing : N.A.

Equipment Type : Pushtube
Hole Diameter : 50mm

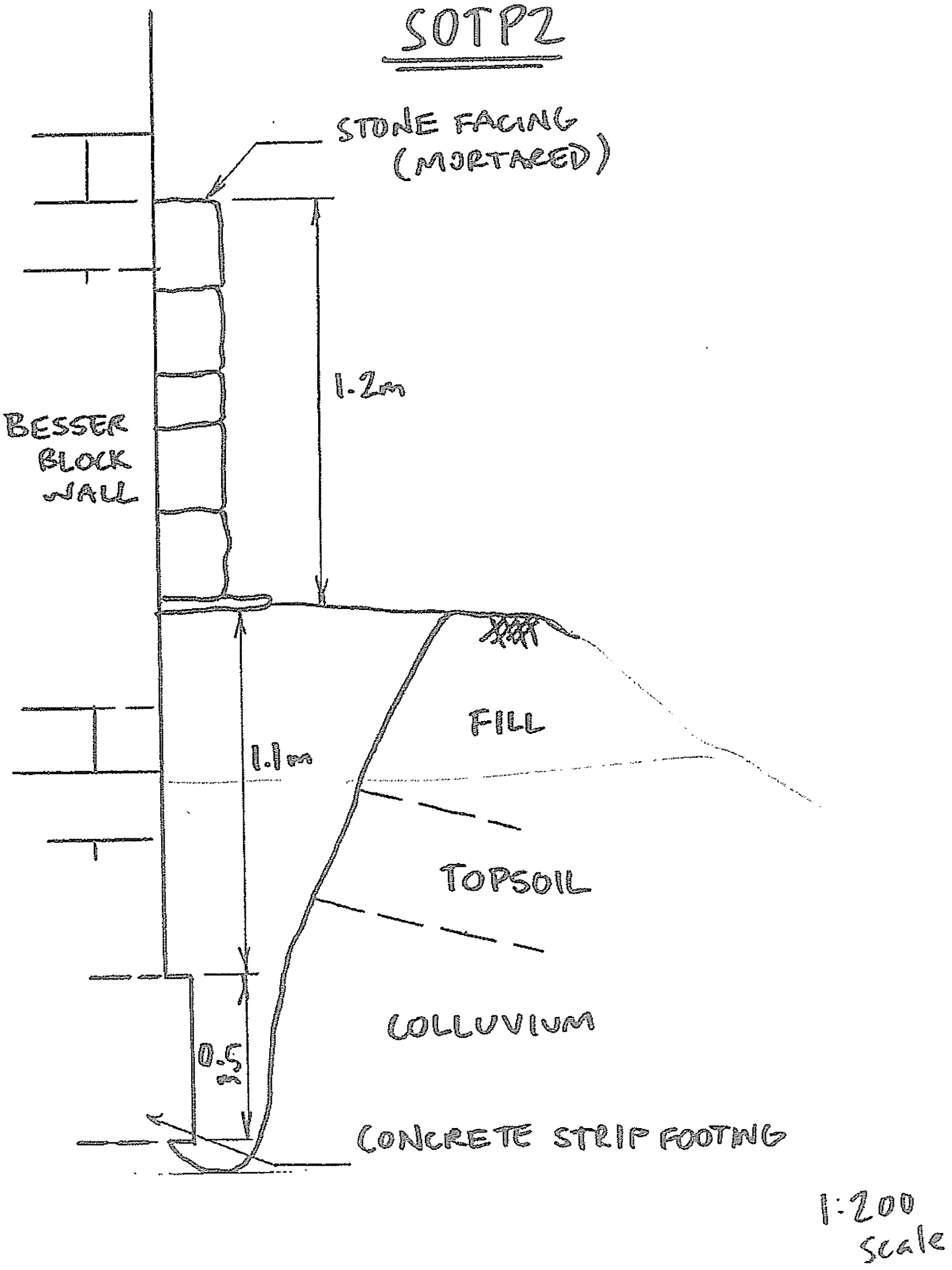
Samples		Casing	Depth Metres	Graphic Log	U.S.C.S.	Material Description, Structure Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components, Moisture, Structure	Consistency or Relative Density	Field Test Results	Geological Profile
			0.2		CL	Sandy Silty CLAY; fine to coarse sand, low plasticity, some fine angular gravel, pale brown, some brick/ceramic pipes fragments, moist.	SOFT		FILL
			0.5		SM	Silty SAND with clay; fine to coarse sand, low platicity, dark grey, black, moist.	LOOSE		TOPSOIL
			1.0 1.5		SC-SM	Silty Clayey SAND; fine to coarse sand, low plasticity, brown. grey, some fine to moderate angular granite gravel, moist.	LOOSE TO MEDIUM DENSITY		COLLUVIAL SOIL
			2.0			BOREHOLE TERMINATED AT 1.5m			

Logged By : OB Date : 6/4/22 Checked By : JM Date : 30/4/22

BOREHOLE/EXCAVATION LOG THREDBO.GPJ ACT GEO.GDT 17/4/23

ACT Geotechnical Engineers

aaaaa

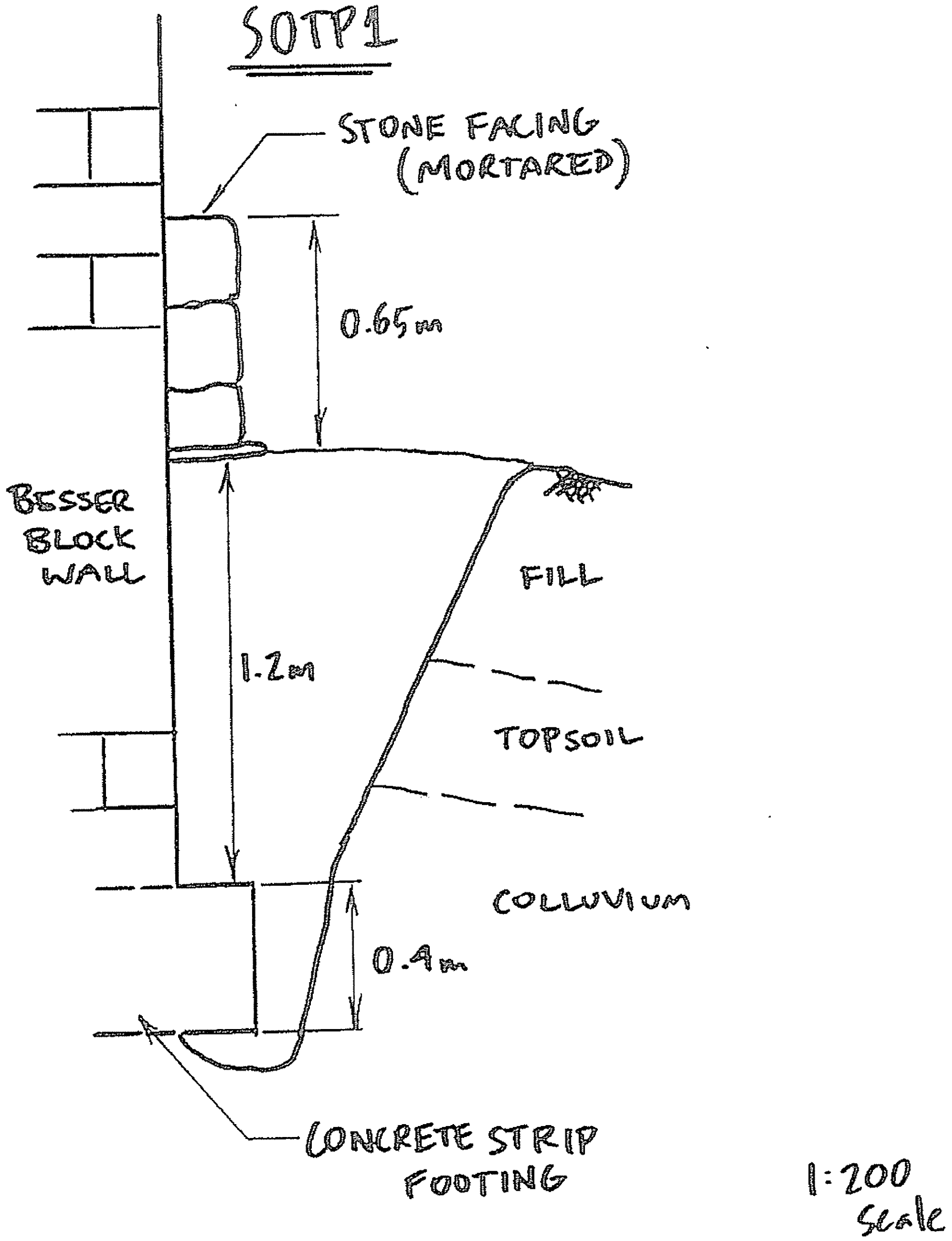


Coffey Partners International Pty Ltd

Consulting Engineers, Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

A.C.N. 003 692 019

drawn	GAH	KOSCIUSKO THREDBO PTY LTD	SOTP2
approved		SONNBLICK LODGE	
date	10/3/99	THREDBO ALPINE VILLAGE	
scale	AS SHOWN	TEST PIT SOTP2 ENGINEERING LOG	job no: S10803/1



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Consulting Engineers, Managers and Scientists
Environment · Geotechnics · Mining · Water Resources

A.C.N. 003 692 019

drawn	GAH	KOSCIUSKO THREDBO PTY LTD	SOTP1
approved		SONNBLICK LODGE	
date	10/3/99	THREDBO ALPINE VILLAGE	job no: S10803/1
scale	AS SHOWN	TEST PIT SOTP1 ENGINEERING LOG	

1382

Coffey Partners International Pty. Ltd
ACN 003 692 019

COFFEY

engineering log - borehole

borehole no	SOBH2
sheet	1 of 1
office job no:	S10803/4
hole commenced:	16/12/98
hole completed:	16/12/98
logged by:	GAH
checked by:	

client:	LANE & LANE
principal:	KOSCIUSKO THREDBO PTY LTD
project:	THREDBO ALPINE VILLAGE - SONNBLICK LODGE
borehole location:	REFER TO FIGURE 1
drill model and mounting:	HAND AUGER
hole diameter:	100mm
slope:	-90 DEG
bearing:	
R.L. Surface:	1393.0 m
datum:	AHD

method	penetration 1 2 3 4	support	water	samples, tests, etc	R.L.	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa 100 200 300 400	structure and additional observations
HA		Nil	D		1393	0		SM	FILL: Silty SAND: fine to medium grained, some coarse grained, brown to dark-brown, some gravel, fine grained, some cobbles to 150mm.	D / M	L / MD		FILL
					1392	1		SM	TOPSOIL: Clayey Silty SAND: fine to medium grained, some coarse grained, dark-brown, some gravel fine grained, trace root fibres.				TOPSOIL
						1.2		SM	SILTY SAND: fine to coarse grained, brown, trace to some clay of low plasticity, some cobbles to approx. 80mm.				COLLUVIUM
					1391	2							
									Borehole SOBH2 Terminated at 2.30 m due to limit of reach of auger.				
					1390	3							
					1389	4							
					1388	5							
					1387	6							
					1386	7							
					1385	8							

COFBORE VERSION B3 6/2/99 9:28:49

METHOD
- AS auger screwing*
- AD auger drilling*
- RR roller/tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- Nil no support
- M mud
- C casing

PENETRATION
1 2 3 4 — little resistance ranging to very slow progress

WATER
- * not measured
- D none observed
- water level
- water outflow
- water inflow

SAMPLES, TESTS, ETC
- U undisturbed sample (mm)
- D disturbed sample
- Bs bulk sample
- E environmental sample
- N standard penetration test
- N* SPT + sample recovered
- Nc SPT with solid cone
- VS vane shear
- PM pressuremeter
- DP dynamic penetrometer
- WS water sample
- PZ piezometer

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit
- Wl liquid limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

IO7-230

Coffey Partners International Pty. Ltd.
ACN 003 692 019

engineering log - borehole

COFFEY

borehole no: S0BH1
sheet 1 of 1

office job no: S10803/4

client:	LANE & LANE	hole commenced:	16/12/98
principal	KOSCIUSKO THREDBO PTY LTD	hole completed:	16/12/98
project:	THREDBO ALPINE VILLAGE - SONNBLICK LODGE	logged by:	GAH
borehole location:	REFER TO FIGURE 1	checked by:	

drill model and mounting:	HAND AUGER	slope:	-90 DEG	R.L. Surface:	1392.5 m
hole diameter	100mm	bearing:		datum:	AHD

method	penetration 1 2 3 4	support	water	samples, tests, etc	R.L.	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa 100 200 300 400	structure and additional observations
HA		NIL	0		1392			SM	FILL: Silty SAND: fine to medium grained, brown-dark brown, some gravel, fine grained, some cobbles to 80mm and some fine roots throughout, plastic sheeting noted @ 0.45m depth.	D / M	L / MD		FILL
						1 (0.55)		SM	TOPSOIL: Silty SAND: fine to coarse grained, dark brown, some gravel, fine grained, trace of fine roots.				TOPSOIL
					1391	(1.4)		SM	CLAYEY SILTY SAND: fine to coarse grained, brown, clay is of low plasticity, some gravel, fine grained, & a trace of cobbles to 100mm.				COLLUVIUM
						2			Borehole S0BH1 Terminated at 1.60 m due to refusal on cobbles.				
					1390	3							
					1389	4							
					1388	5							
					1387	6							
					1386	7							
					1385	8							

COFBORE VERSION B3 6/ 2/99 9.23.28

METHOD
- AS auger screwing*
- AD auger drilling*
- RR roller/tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- *bit shown by suffix
- B blank bit
- V V bit
- T TC bit
- e.g. ADT

SUPPORT
- Nil no support
- M mud
- C casing

PENETRATION 1 2 3 4 — little resistance ranging to very slow progress

WATER
- X not measured
- 0 none observed
- water level
- water outflow
- water inflow

SAMPLES, TESTS, ETC
- U undisturbed sample (mm)
- D disturbed sample
- Bs bulk sample
- E environmental sample
- N standard penetration test
- Nx SPT + sample recovered
- Nc SPT with solid cone
- VS vane shear
- PM pressuremeter
- DP dynamic penetrometer
- WS water sample
- PZ piezometer

CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
- D dry
- M moist
- W wet
- Wp plastic limit
- Wl liquid limit

CONSISTENCY/DENSITY INDEX
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

Coffey Partners International Pty. Ltd.
ACN 003 692 019

COFFEY

engineering log - borehole

borehole no KTB29
sheet 1 of 1

office job no: S10803/4
hole commenced: 16/12/98
hole completed: 16/12/98
logged by: GAH
checked by:

client: LANE & LANE
principal: KOSCIUSKO THREDBO PTY LTD
project: THREDBO APINE VILLAGE - SONNBLICK LODGE
borehole location: REFER TO FIGURE 1

drill model and mounting: GEMCO - TRAILER MOUNTED
hole diameter: 100mm
slope: -90 DEG
bearing:
R.L.Surface: 1398.7 m
datum: AHD

method	penetration 1 2 3 4	support	water	samples, tests, etc	R.L.	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics colour, secondary and minor components	moisture condition	consistency/density index	hand penetrometer kPa 100 200 300 400	structure and additional observations
DT		Nil	D						CONCRETE: Concrete slab, 125mm thick				CONC
								SM	FILL: Silty SAND: fine to coarse grained, brown, trace of gravel, fine grained.	M	L		FILL
					1398	1		SM	CLAYEY SILTY SAND: fine to coarse grained, brown, clay is of low plasticity, some gravel, fine to medium grained.				COLLUVIUM
				1 ,2 ,2 Nx= 4	1397								
						2		SM	SILTY SAND: fine to coarse grained, brown, some gravel, fine grained.		L / MD		RESIDUAL
					1396				GRANODIORITE: fine to coarse grained, brown, & light brown, extremely weathered, extremely low strength.		MD		EW GRANODIORITE
				2 ,4 ,5 Nx= 9	1395	3							
					1394	4			Borehole KTB29 Terminated at 4.60 m. Standpipe installed to 4.4m depth bottom 3m slotted, sealed over 0.2-4.4m.				
					1393	5							
					1392	6							
					1391	7							
						8							

METHOD
AS auger screwing*
AD auger drilling*
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
*bit shown by suffix
B blank bit
V V bit
T TC bit
e g ADT

SUPPORT
Nil no support M mud
C casing

PENETRATION
1 2 3 4
little resistance ranging to very slow progress

WATER
X not measured D none observed
water level
water outflow
water inflow

SAMPLES, TESTS, ETC
U undisturbed sample (mm)
D disturbed sample
Bs bulk sample
E environmental sample
N standard penetration test
Nx SPT + sample recovered
Nc SPT with solid cone
VS vane shear
PM pressuremeter
DP dynamic penetrometer
WS water sample
PZ piezometer

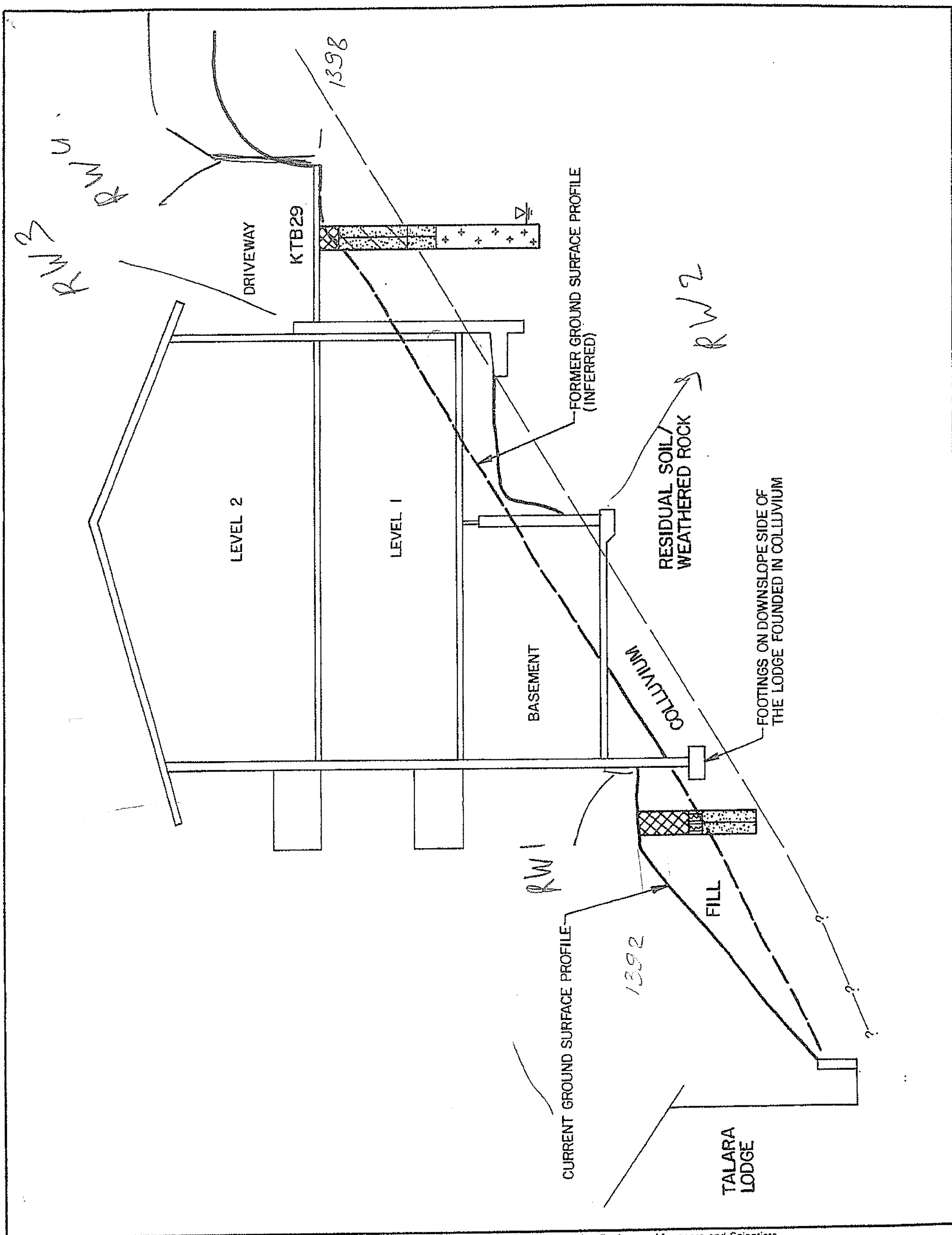
CLASSIFICATION SYMBOLS AND SOIL DESCRIPTION
based on unified classification system

MOISTURE
D dry
M moist
W wet
Wp plastic limit
Wl liquid limit

CONSISTENCY/DENSITY INDEX
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

COFBORE VERSION 83 6/ 2/99 9:32:11

IB7-230



Coffey Partners International Pty Ltd		Consulting Engineers, Managers and Scientists Environment • Geotechnics • Mining • Water Resources	ACN 003 692 019
drawn:	GAH/SW	KOSCIUSKO THREDBO PTY LTD THREDBO ALPINE VILLAGE LOT 54 – SONNBLICK LODGE SECTION A-A'	FIGURE 2
approved:			
date:	12/3/99		Job no. S10803/15-AE
scale:	1:100		

Coffey Geosciences Pty Ltd ACN 056 335 516

Engineering Log - Borehole

Borehole No. BH1
Sheet 1 of 1
Office Job No.: C7763/1

Client: ALPINE DEVELOPMENTS PTY LTD
Principal:
Project: REDEVELOPMENT OF LEITELINNA LODGE
Borehole Location: THREDBO VILLAGE, NSW

Date started: 4.8.2004
Date completed: 4.8.2004
Logged by: SF
Checked by: [signature]

Coffey

drill model and mounting: SCOUT FRAME | Easting: | slope: -90° | R.L. Surface: ESL
hole diameter: 90 mm | Northing | bearing: | datum:

drilling information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/density index	pocket penetrometer kPa (100 200 300 400)	structure and additional observations
W		C	None Observed			0.0			**FILL: CLAYEY SAND:** fine to coarse grained, grey-brown and mottled orange-brown, low plasticity clay, some fine grained gravel	M			FILL
						1		SC	**CLAYEY SAND:** fine to coarse grained, grey-brown, low plasticity clay, some fine grained gravel	D/M	L		COLLUVIUM
				SPT 1,2,3 N*=5									
						2		SC	**CLAYEY SAND:** fine to coarse grained, grey, low plasticity clay, some fine grained gravel		MD		
								SM	**SILTY SAND:** fine to coarse grained, brown and mottled grey, low liquid limit silt, some fine grained gravel		D		EXTREMELY WEATHERED GRANODIORITE
				SPT 3,4,6 N*=10		3							
						4							
				SPT 7,9,11 N*=20									
						5							
				SPT 7,7,10 N*=17		6							
									Borehole BH1 terminated at 6.15m				
						7							
						8							

BOREHOLE C7763X1.GPJ COFFEY.GDT 17.09.04

method
AS auger screwing*
AD auger drilling*
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
B blank bit
V V bit
T TC bit
*bit shown by suffix
e.g. ADT

support
M mud N nil
C casing

penetration
1 2 3 4
no resistance ranging to refusal

water
10/1/98 water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear (kPa)
P pressuremeter
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Form GEO 5.3 Issue 3 Rev.2

Coffey Geosciences Pty Ltd ACN 056 335 516

Coffey

Engineering Log - Borehole

Borehole No.	BH2
Sheet	1 of 1
Office Job No.:	C7763/1
Date started:	5.8.2004
Date completed:	5.8.2004
Logged by:	SF
Checked by:	[signature]

Client: *ALPINE DEVELOPMENTS PTY LTD*

Principal:

Project: *REDEVELOPMENT OF LEITELINNA LODGE*

Borehole Location: *THREDBO VILLAGE, NSW*

drill model and mounting:	SCOUT FRAME	Easting:		slope:	-90°	R.L. Surface:	ESL
hole diameter:	90 mm	Northing		bearing:		datum:	

drilling information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material — soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/ density index	pocket penetrometer kPa 100 200 300 400	structure and additional observations
W		C	None Observed						**FILL: SILTY SAND:** fine to coarse grained, grey-brown, low liquid limit silt, trace of fine grained gravel	D			FILL
								SC	**CLAYEY SAND:** fine to coarse grained, dark brown, low plasticity clay, trace of fine grained gravel	D/M	MD		COLLUVIUM
						1		SM	**SILTY SAND:** fine to coarse grained, brown and pale yellow-brown, low liquid limit silt, some fine grained gravel		D		EXTREMELY WEATHERED GRANODIORITE
				SPT 4,8,11 N*=19		2							
				SPT 10,R N*=R		3							SPT refusal after 4 blows per 40mm
						4							
						5							
						6							
									Borehole BH2 terminated at 6.7m				
						7							
						8							

method
- AS auger screwing*
- AD auger drilling*
- RR roller/tricone
- W washbore
- CT cable tool
- HA hand auger
- DT diatube
- B blank bit
- V V bit
- T TC bit
- *bit shown by suffix e.g. ADT

support
- M mud
- N nil
- C casing

penetration 1 2 3 4 — no resistance ranging to refusal

water
- 10/1/98 water level on date shown
- water inflow
- water outflow

notes, samples, tests
- U_{50} undisturbed sample 50mm diameter
- U_{63} undisturbed sample 63mm diameter
- D disturbed sample
- N standard penetration test (SPT)
- N* SPT - sample recovered
- Nc SPT with solid cone
- V vane shear (kPa)
- P pressuremeter
- Bs bulk sample
- E environmental sample
- R refusal

classification symbols and soil description
based on unified classification system

moisture
- D dry
- M moist
- W wet
- Wp plastic limit
- W_L liquid limit

consistency/density index
- VS very soft
- S soft
- F firm
- St stiff
- VSt very stiff
- H hard
- Fb friable
- VL very loose
- L loose
- MD medium dense
- D dense
- VD very dense

BOREHOLE C7763X1.GPJ COFFEY.GDT 17.09.04

Form GEO 5.3 Issue 3 Rev.2

Coffey Geosciences Pty Ltd ACN 056 335 516

Engineering Log - Borehole

Borehole No. BH3
Sheet 1 of 1
Office Job No.: C7763/1
Date started: 5.8.2004
Date completed: 5.8.2004
Logged by: SF
Checked by: [signature]

Client: ALPINE DEVELOPMENTS PTY LTD
Principal:
Project: REDEVELOPMENT OF LEITELINNA LODGE
Borehole Location: THREDBO VILLAGE, NSW

drill model and mounting: HAND AUGER | Easting: | slope: -90° | R.L. Surface: ESL
hole diameter: 90 mm | Northing | bearing: | datum:

drilling information / **material substance**

method	penetration 1 2 3	support	water	notes samples, tests, etc	RL	depth metres	graphic log	classification symbol	material: soil type: plasticity or particle characteristics, colour, secondary and minor components.	moisture condition	consistency/density index	pocket penetrometer kPa (100 200 300 400)	structure and additional observations
HA		N	None Observed						FILL: SILTY SAND: fine to coarse grained, dark brown-grey, low liquid limit silt, some fine to medium grained gravel	M			FILL some granodiorite cobbles
									FILL: CLAYEY SAND: fine to coarse grained, grey, low plasticity clay, some fine grained gravel				
						1			Auger refusal on granodiorite cobble/boulder. Three holes attempted within 2m diameter with simialr conditions encountered. Borehole BH3 terminated at 0.9m				
						2							
						3							
						4							
						5							
						6							
						7							
						8							

BOREHOLE C7763X1.GPJ COFFEY.GDT 17.09.04

method
AS auger screwing*
AD auger drilling*
RR roller/tricone
W washbore
CT cable tool
HA hand auger
DT diatube
B blank bit
V V bit
T TC bit
*bit shown by suffix
e.g. ADT

support
M mud N nil
C casing

penetration
1 2 3 4 — no resistance ranging to refusal

water
10/1/98 water level on date shown
water inflow
water outflow

notes, samples, tests
U_{50} undisturbed sample 50mm diameter
U_{63} undisturbed sample 63mm diameter
D disturbed sample
N standard penetration test (SPT)
N* SPT - sample recovered
Nc SPT with solid cone
V vane shear (kPa)
P pressuremeter
Bs bulk sample
E environmental sample
R refusal

classification symbols and soil description
based on unified classification system

moisture
D dry
M moist
W wet
Wp plastic limit
W_L liquid limit

consistency/density index
VS very soft
S soft
F firm
St stiff
VSt very stiff
H hard
Fb friable
VL very loose
L loose
MD medium dense
D dense
VD very dense

Form GEO 5.3 Issue 3 Rev.2

Coffey

URS Non-cored Hole — BOREHOLE BH02

URS Australia Pty Ltd
Level 3 116 Miller St Nth Sydney NSW 2060
Phone 02 8925 5500
Fax 02 8925 5555

Drilling Contractor: Mulligan Drilling	Project Reference: Hillslope Feature Geotechnical Investigations	Client: NPWS	
	Project No.: 33871-023	Location: Thredbo Village	
Logged By: AH	Bore Size: mm	Relative Level: mRL	Drill Type: Solid stem auger
Checked By: RJ	Total Depth: 4.40 m	Coordinates: 5959382.00 mN 617138.00 mE	Drill Model: GEMCO 210D
Date Started: 24-11-03	Casing Size: mm		
Date Finished: 25-11-03		Permit No:	Drill Fluid:

SAMPLE TYPE	RUN (m)	FIELD SHEAR STRENGTH (kPa)	PENETROMETER BLOWS (N)	SAMPLING AND OTHER TESTING	GROUND WATER DATA AND COMMENTS	DEPTH (m)	GRAPHIC LOG	DESCRIPTION OF STRATA	MOISTURE CONDITION	USCS	CONSISTENCY/ DENSITY	GEOLOGICAL DESCRIPTION
						0		Asphalt: 50 mm thick				
								Silty Sand with some gravel: fine to coarse grained, brown to orange/brown, with rounded river pebbles, granite gravel to 30 mm, trace wood fragments	D		L	FILL
						1		Silty Sand: fine to coarse grained, brown to orange/brown, with trace granite gravel, some mica flakes	D/M		MD	RESIDUAL
SPT			N=16	SPT @ 1.5 m (5,8,8)								
						2		Granitoid: extremely low strength, extremely weathered, brown, dark yellow/brown, white, fine to coarse grained, abundant mica flakes, poorly developed to massive fabric	D/M		D-VD	MOWAMBA GRANODIORITE
SPT			N=51	SPT @ 3.0 m (19,30,21)		3						
								As above, becoming quite hard	M		VD	
						4						
								End of Augered Borehole @ 4.4 m				

URS Cored Borehole

BOREHOLE BH02

URS Australia Pty Ltd Level 3 116 Miller St Nth Sydney NSW 2060	Phone 02 8925 5500 Fax 02 8925 5555	Project Reference: Hillslope Feature Geotechnical Investigations	Client: NPWS
Drilling Contractor: Mulligan Drilling		Project No.: 33871-023	Location: Thredbo Village
Logged By: AH Checked By: RJ Date Started: 24-11-03 Date Finished: 25-11-03	Bore Size: mm Total Depth: 23.67 m Casing Size: mm Borehole Inclination and Bearing:	Relative Level: mRL Coordinates: 5959382.00 mN 617138.00 mE Permit No:	Drill Type: NMLC Drill Model: GEMCO 210D Drill Fluid: Water

METHOD	RUN	TESTING	WEATHERING	DEPTH (m)	DEFECT DESCRIPTION	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
	4.45			4		Continues from non-cored borehole (see separate log)	
NMLC			MW		JN 55° Ir R JN 65-70° Ir R JN 70-75° Ir R JN 50-65° Ir R JN 45-50° Ir R	Granitoid: high to very high strength, moderately weathered, orange/brown, white, grey, fine to coarse grained, poorly developed fabric, abundant mica	MOWAMBA GRANODIORITE
			SW			Becoming slightly weathered, grey, blue/grey	
			MW	5	JN 40° Pl - Ir Sr - R JN 40° Pl - Cu Sr - R JN 40° Pl - Cu Sr - R		
			SW		JN 50-60° Pl - Cu Sr		
			EW	5.6	JN 70-80° Pl - Ir Sr - R	Becoming very low to extremely low strength rock, orange/brown, abundant mica	
	6					No Core 230 mm	
			EW	6		Granitoid: extremely low strength, extremely weathered, orange/brown	
	7.5			7		No Core 2.28 m	
	8.85		EW	8		Granitoid: extremely low strength, extremely weathered, becoming medium strength, highly weathered, brown, yellow/brown, white, fine to coarse grained, abundant mica flakes	

SYDNEY_CORE TVROCK.GPJ URS1.GDT 19-12-03

URS Cored Borehole — BOREHOLE BH02

URS Australia Pty Ltd
Level 3 116 Miller St Nth Sydney NSW 2060
Phone 02 8925 5500
Fax 02 8925 5555

Project No.: 33871-023

Project Reference: Hillslope Feature Geotechnical Investigations

METHOD	RUN	TESTING	WEATHERING	STRENGTH (EL VL L M H VH EH)	RQD (%) (25 50 75)	DEFECT SPACING (mm) (0-19 20-49 50-99 100-199 200-599 >600)	DEPTH (m)	DEFECT DESCRIPTION	GRAPHIC LOG	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
NMLC							9			No Core 1.03 m	MOWAMBA GRANODIORITE
	10.15		EW-HW				10		+	Granitoid: extremely low strength, becoming medium to high strength, extremely to highly weathered, orange/brown, dark yellow/brown, white, black, fine to coarse grained	
										No Core 280 mm	
			HW					JN 60° Pl - Ir Sr	+	Granitoid: very low strength rock, becoming high strength, highly weathered, dark yellow/brown, white/grey/black mottled, medium to coarse grained	
								JN 60-90° Ir Sr - R	+		
								JN 15-20° Pl - Ir Sr	+		
								JN 75-80° Pl Sr	+		
	11.05						11	JN 55° Pl - Cu Sr - S	+		
										No Core 700 mm	
	12.12		MW				12	JN 40-45° Ir R	+	Granitoid: high to very high strength, moderately weathered, orange/brown, blue/grey, white, black, coarse grained, massive	
								JN 40° Pl - Ir Sr	+		
								JN 85-90° Pl - Ir Sr	+		
								JN 40-45° Pl Sr - S	+		
	12.7		MW-HW					JN 45° Pl S	+	Becoming medium to high strength	
								JN 50° Ir R	+		
								JN 35° Ir R	+		
								JN 20° Pl - Ir Sr	+		
								JN 80-90° Ir Sr	+		
							13	JN 15° Pl Sr	+		
								JN 50° Pl - Ir Sr - R	+		
			HW						+		
			MW-SW					JN 50° Pl - Ir Sr - R	+	Becoming high to very high strength rock, moderately to slightly weathered, foliated at 40°	
	13.63							JN 30° Ir Sr - R	+		
			HW					JN 30° Ir R	+	Granitoid: very low to low strength, moderatley to highly weathered, brown, orange/brown, white, foliated at 40 to 50°	
								JN 35-40° Pl - Ir Sr	+		
			HW-MW				14	JN 45° Ir Sr - R	+		
								JN 20° Pl - Ir Sr	+	Granitoid: high strength, highly to moderately weathered, orange/brown, grey, black, medium to coarse grained, foliated at 70°	
								JN 70° Pl Sr - S	+		
								JN 15° Pl - Ir Sr	+		
			EW							No Core 240 mm	
	14.6		HW					JN 45° Pl Sr	+	Granitoid: high strength, highly weathered, brown, orange/brown, white, dark yellow/brown, fine to coarse grained, foliated at 45°	
								JN 40° Pl - Ir Sr	+		
								JN 40-60° Ir Sr	+		

URS Cored Borehole — BOREHOLE BH02

URS Australia Pty Ltd
Level 3 116 Miller St Nth Sydney NSW 2060
Phone 02 8925 5500
Fax 02 8925 5555

Project No.: 33871-023

Project Reference: Hillslope Feature Geotechnical Investigations

Columns: METHOD | RUN | TESTING | WEATHERING | STRENGTH (EL VL L M H VH EH) | RQD (%) (25 50 75) | DEFECT SPACING (mm) (0-10, 20-40, 50-99, 100-199, 200-599, >600) | DEPTH (m) | DEFECT DESCRIPTION | GRAPHIC LOG | DESCRIPTION OF STRATA | GEOLOGICAL DESCRIPTION

Method: NMLC

Geological description: MOWAMBA GRANODIORITE

Run	Weathering	Depth (m)	Defect Description	Description of Strata
		15	JN 50° Pl Sr - S	
			JN 60-65° Ir R	Becoming medium to high strength
			JN 70-80° Ir R Iron stained	
	EW			
15.6				No Core 160 mm
15.78	HW		JN 65-70° Pl Sr	As above + foliated at 55°
			JN 40° Pl Sr	
			JN 45° Pl Sr - S	
		16		
			JN 20-25° Pl - Ir Sr	
	MW-SW		JN 20° Pl - Ir Sr	
			JN 30° Pl - Cu Sr	
	MW		SH 35° Ir - Cu R RC (5mm)	
			SH 0° Pl - Ir R RC	
	EW		SH 55° Ir R RC (30-60 mm)	
	MW		JN 25° Pl Sr - S	Granitoid: high to very high strength, moderately to slightly weathered, blue/grey, trace orange/brown along defect boundaries, coarse grained, poorly developed fabric, becoming slightly weathered
	MW-SW		JN 20° Pl Sr - S thin c veneer	
	SW	17	JN 20° Pl S	
17.35			17.35-17.63 m 5 x JN 40-50° Pl Sr	
		18		
			JN 0-5° Ir R (iron stained)	
			JN 20° Pl - Ir Sr	
18.93			JN 70° Pl - Ir Sr - R	
		19	JN 30° Pl - Ir Sr - R	Granitoid: very high strength, slightly weathered, blue/grey, grey, with trace orange/brown, fine to coarse grained, poorly developed fabric, slightly fractured, trace fine grained xenoliths
			JN 60° Ir - Cu Sr - R	
			JN 25° Pl Sr - S Iron stained	
			19.73-19.83m 3 x JN 60-65° Pl - Ir Sr	
		20		
				Quartz vein (10mm thick)
20.4				As above + high to very high strength, with some quartz veins to 30 mm
			JN 75° Pl Sr - S (122 mm long)	
			JN 85-90° Ir Sr - R	

URS Cored Borehole — BOREHOLE BH02

URS Australia Pty Ltd
Level 3 116 Miller St Nth Sydney NSW 2060
Phone 02 8925 5500
Fax 02 8925 5555

Project No.: 33871-023

Project Reference: Hillslope Feature Geotechnical Investigations

METHOD	RUN	DEPTH (m)	DEFECT DESCRIPTION	GRAPHIC LOG	DESCRIPTION OF STRATA	GEOLOGICAL DESCRIPTION
NMLC	22	21	JN 75° Pl - Ir Sr	+		MOWAMBA GRANODIORITE
			SH 5° Ir R RC (10-15 mm)	+		
			21.43-21.55m 3 x JN 80-85° Ir R RC iron staining	+	Vertical quartz vein, vesicular in part, 300mm long	
			JN 60-65° Ir R	+		
			JN 45° Pl - Ir Sr	+		
		22	2 x JN 50-55° Pl - Ir Sr	+	Granitoid: high to very high strength, slightly weathered to fresh, blue/grey, white, black, poorly developed fabric (possible 90° foliation)	
			JN 20-25° Pl Sr - S	+		
			JN 70° Pl Sr	+		
			22.9-23.11m JN 80° Pl - Ir Sr	+		
		23	JN 25° Pl - Cu Sr - S	+	Fine grained xenolith (90 x 75 mm)	
			JN 45° Pl Sr - S	+		
			JN 30° Pl Sr - S	+		
					End of Cored borehole @ 23.67 m	
		24				
		25				
		26				

Column headers also include: TESTING; WEATHERING; STRENGTH (EL, VL, L, M, H, VH, EH); RQD (%) (25, 50, 75); DEFECT SPACING (mm) (0-10, 20-40, 50-90, 100-190, 200-590, >600).

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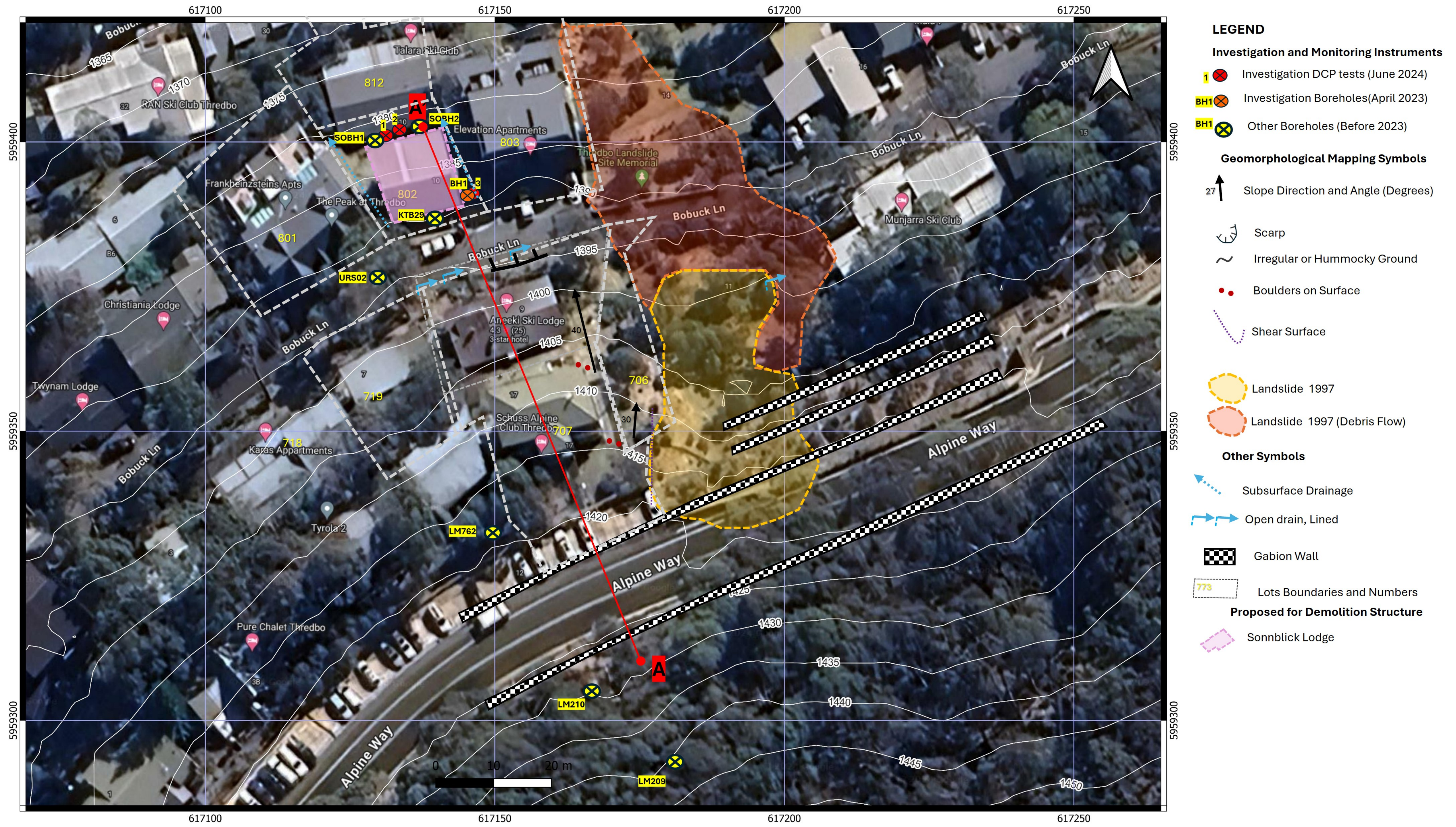
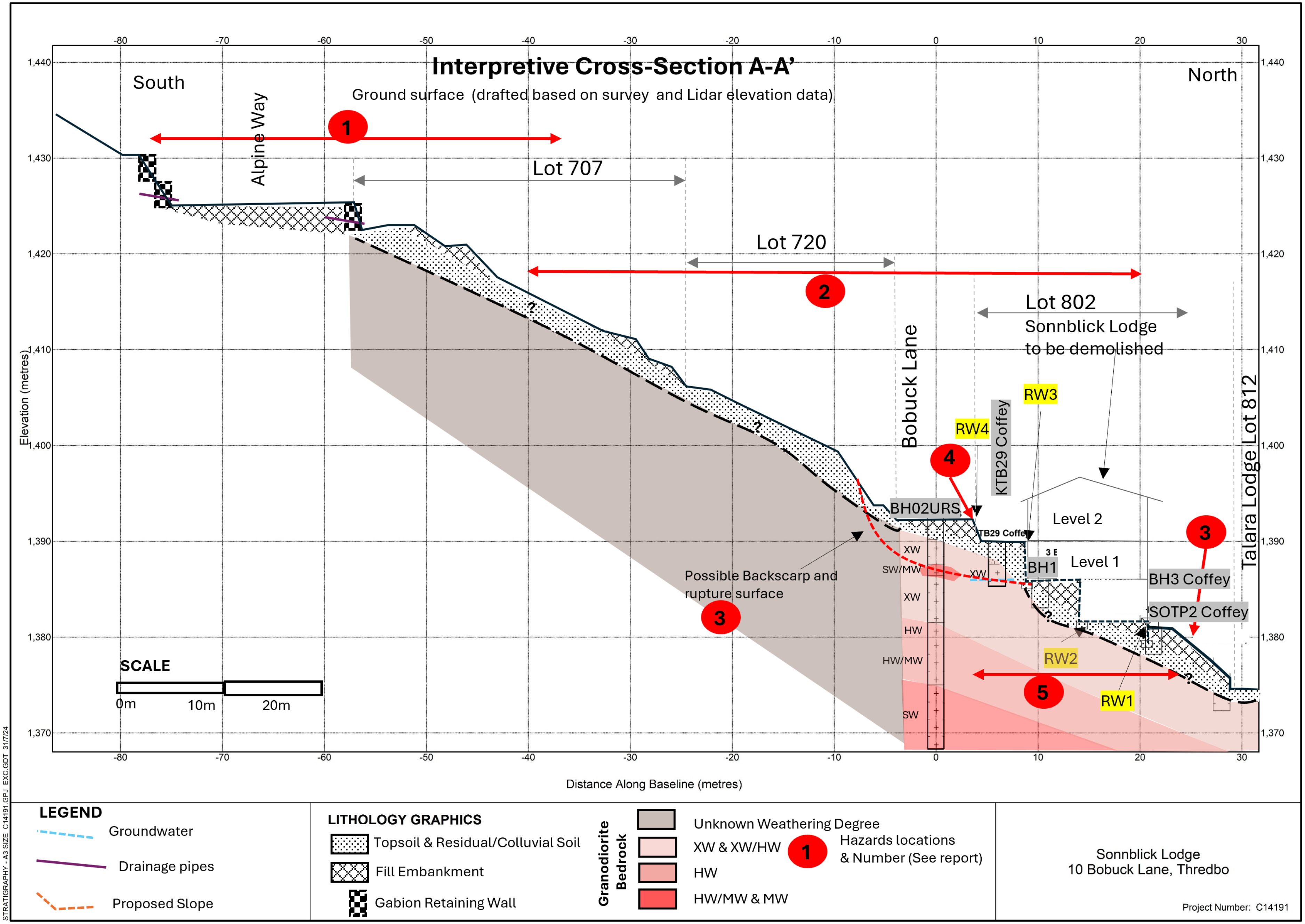
Appendix B

Site Plan & Cross-Section



617100
617150
617200
617250
5959400
5959350
5959300
LEGEND
Investigation and Monitoring Instruments
Investigation DCP tests (June 2024)
Investigation Boreholes(April 2023)
Other Boreholes (Before 2023)
Geomorphological Mapping Symbols
Slope Direction and Angle (Degrees)
Scarp
Irregular or Hummocky Ground
Boulders on Surface
Shear Surface
Landslide 1997
Landslide 1997 (Debris Flow)
Other Symbols
Subsurface Drainage
Open drain, Lined
Gabion Wall
Lots Boundaries and Numbers
Proposed for Demolition Structure
Sonnblick Lodge
Talara Ski Club
RAN Ski Club Thredbo
Elevation Apartments
Thredbo Landslide Site Memorial
Frankheinzsteins Apts
The Peak at Thredbo
Munjarra Ski Club
Christiania Lodge
Aneeki Ski Lodge
Twynam Lodge
Schuss Alpine Club Thredbo
Karas Apartments
Tyrola 2
Pure Chalet Thredbo
Bobuck Ln
Alpine Way
SOBH1
SOBH2
BH1
KTB29
URS02
LM762
LM210
LM209
A
A'
812
803
802
801
719
718
707
706
0
10
20 m



Interpretive Cross-Section A-A’
Ground surface (drafted based on survey and Lidar elevation data)
South
North
Alpine Way
Lot 707
Lot 720
Lot 802
Sonnblick Lodge
to be demolished
Bobuck Lane
Talara Lodge Lot 812
RW1
RW2
RW3
RW4
KTB29 Coffey
BH02URS
BH1
BH3 Coffey
SOTP2 Coffey
Level 2
Level 1
XW
SW/MW
HW
HW/MW
SW
Possible Backscarp and
rupture surface
1
2
3
4
5
SCALE
0m
10m
20m
Elevation (metres)
Distance Along Baseline (metres)
1,440
1,430
1,420
1,410
1,400
1,390
1,380
1,370
-80
-70
-60
-50
-40
-30
-20
-10
0
10
20
30
LEGEND
Groundwater
Drainage pipes
Proposed Slope
LITHOLOGY GRAPHICS
Topsoil & Residual/Colluvial Soil
Fill Embankment
Gabion Retaining Wall
Granodiorite Bedrock
Unknown Weathering Degree
XW & XW/HW
HW
HW/MW & MW
Hazards locations
& Number (See report)
Sonnblick Lodge
10 Bobuck Lane, Thredbo
Project Number: C14191
STRATIGRAPHY - A3 SIZE C14191.GPJ EXC.GDT 31/7/24

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Appendix C

AGS2007 Terminology and Risk Assessment Matrix

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

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

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

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

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

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

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

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

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

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

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

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

RISK LEVEL IMPLICATIONS

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

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

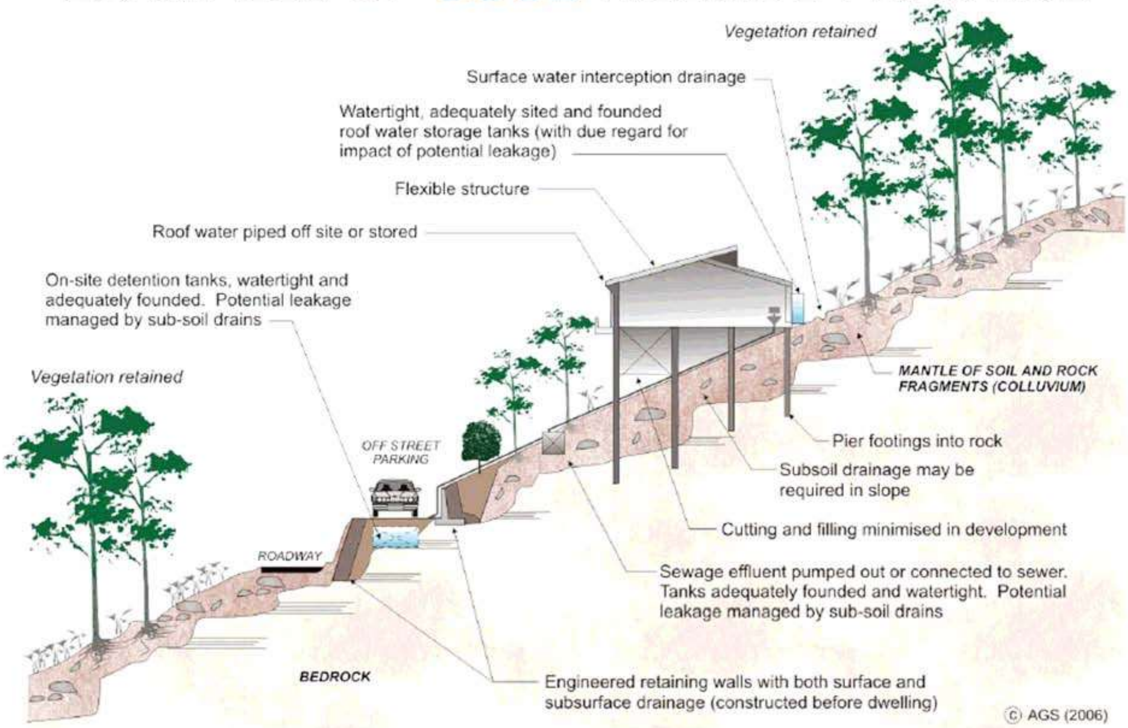
Appendix D

Guidelines for Hillside Construction

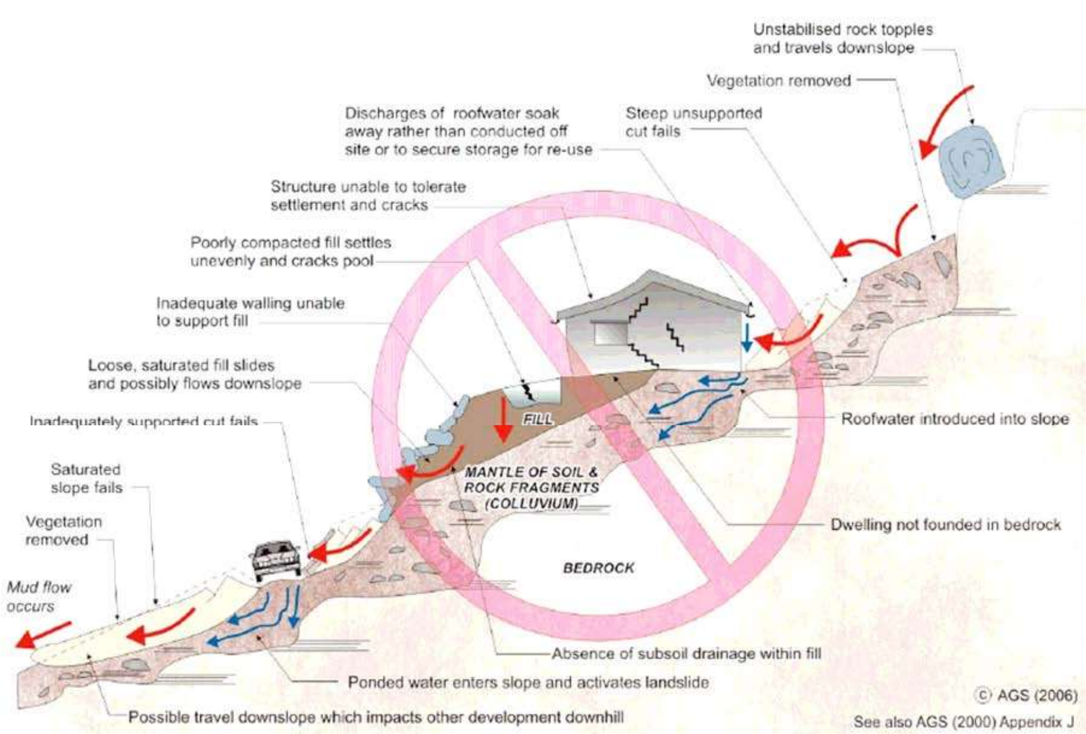
APPENDIX G - SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical practitioner at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminatory bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE		
SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



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Appendix E

Form 1

NSW GOVERNMENT | Planning & Environment

Geotechnical Policy
Kosciuszko Alpine Resorts

Form 1 – Declaration and certification made by geotechnical engineer or engineering geologist in a geotechnical report.

DA Number: ____________________

To be submitted with a development application

You can use Form 1 to verify that the author of a geotechnical report is a geotechnical engineer or engineering geologist as defined by the Department of Planning & Environment (DP&E) Geotechnical Policy. Alternatively, where a geotechnical report has been prepared by a professional person not recognised by DP&E Geotechnical Policy, then Form 1 may be used as technical verification of the geotechnical report if signed by a geotechnical engineer or engineering geologist as defined by the DP&E Geotechnical Policy.

Please contact the Alpine Resorts Team in Jindabyne for further information - phone 02 6456 1733.

To complete this form, please place a cross in the appropria[te boxe]s ☐ and complete all sections.

NSW GOVERNMENT Department of Planning Housing and Infrastructure

Issued under the Environmental Planning and Assessment Act 1979

Approved Application No DA 24/448

Granted on the 3 July 2025

Signed E Murphy

Sheet No 3 of 8

1. Declaration made by geotechnical engineer [or engineering geologist as part of a] geotechnical report

I,

Mr ☑ Ms ☐ Mrs ☐ Dr ☐ Other

First Name: JEREMY

Family Name: MURRAY

OF

Company/organisation: FORTIFY GEOTECH

on this the 21st day of August 2024

certify that I am a geotechnical engineer or engineering geologist as defined by the "Policy" and I (tick appropriate box)

☑ prepared the geotechnical report referenced below in accordance with the AGS 2000 and DP&E Geotechnical Policy – Kosciuszko Alpine Resorts.

☑ am willing to technically verify that the Geotechnical Report referenced below has been prepared in accordance the AGS 2000 and DP&E Geotechnical Policy – Kosciuszko Alpine Resorts.

2. Geotechnical Report Details

Report Title: Proposed Demolition of Sonnblick Lodge - 10 Bobuck Lane, Thredbo, NSW - Geotechnical Investigation and Landslide Risk Assessment

Author: Fortify Geotech - Jeremy Murray

Dated: 21/8/2024

DA Site Address: 10 Bobuck Lane, Thredbo

DA Applicant:

I am aware that the Geotechnical Report I have either prepared or am technically verifying, (referenced above) is to be submitted in support of a development application for the proposed development site (referenced above), and it's findings will be relied upon by the Consent Authority in determining the development application.

3. Checklist of essential requirements to be contained in a geotechnical risk assessment report to be submitted with a development application

The following checklist covers the minimum requirements to be addressed in a Geotechnical Risk Management Report. This checklist is to accompany the report.

Please tick appropriate box

- ☑ Risk assessment of all identifiable geotechnical hazards in accordance with AGS 2000, as per 6.1 (a) of the policy.
- ☑ Site plans with key hazards identified and other information as per 6.1 (b)
- ☑ Details of site investigation and inspections as per 6.1 (c)
- ☑ Photographs and/or drawings of the site as per 6.1 (d)
- ☑ Presentation of geotechnical model as per 6.1 (e)
- ☑ A specific conclusion as to whether the site is suitable for the development proposed on the above site, if applicable, subject to the following conditions;
  - ☑ Conditions to be provided to establish design parameters,
  - ☑ Conditions to be incorporated into the detailed design to be submitted for the construction certificate,
  - ☑ Conditions applying to the construction phase,
  - ☑ Conditions relating to ongoing management of the site/structure.

4. Signatures

Signature	Chartered professional status
[signature]	CPEng #2122247
Name	**Date**
Jeremy Murray	23/8/24

5. Contact details

Department of Planning & Environment
Alpine Resorts Team
Shop 5A, 19 Snowy River Avenue
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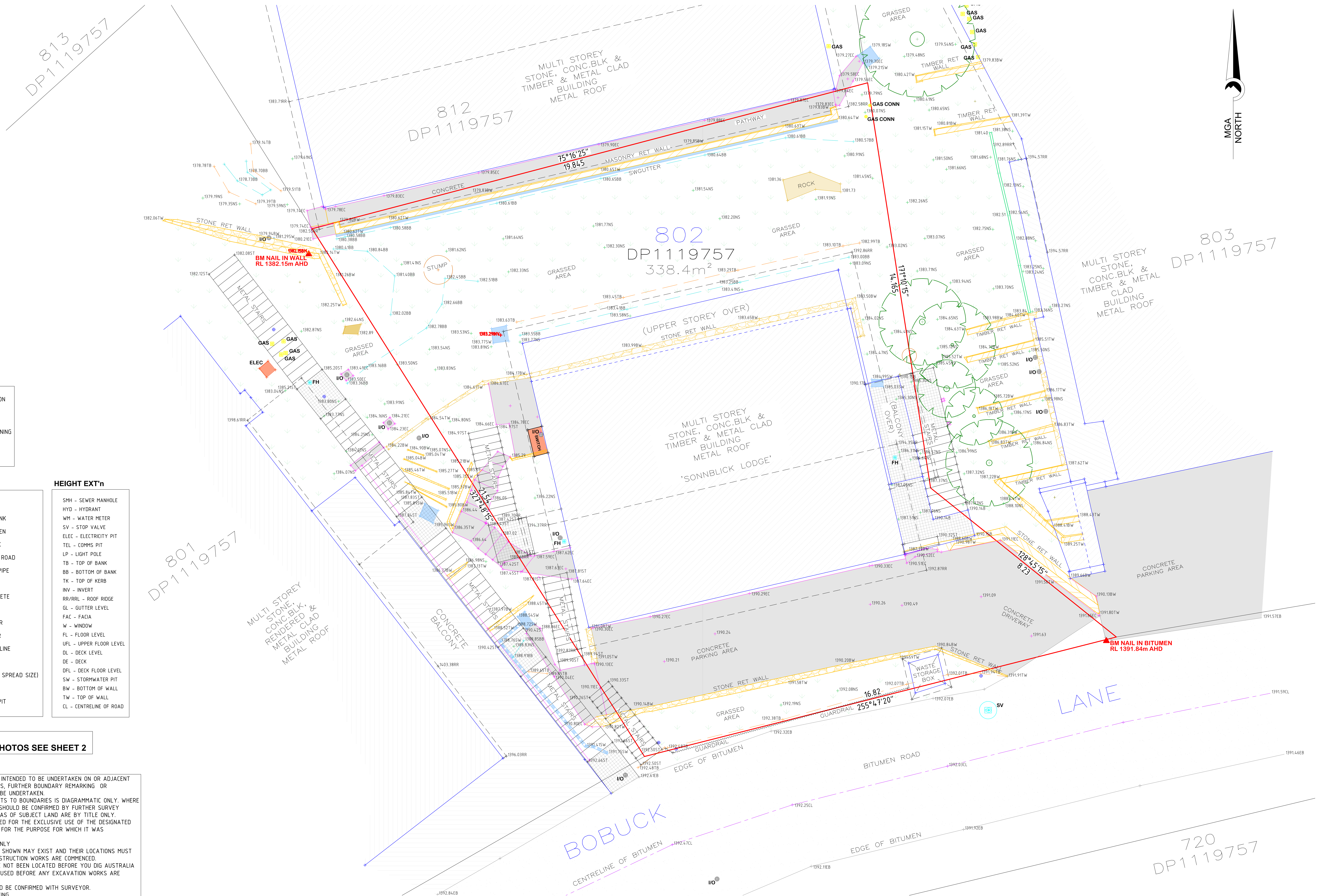
Appendix F

Site Survey Plans



SYMBOL LEGEND

- GAS - GAS CONNECTION
- GAS - GAS METER
- P - PILLAR
- I/O - INSPECTION OPENING
- FH - FIRE HYDRANT
- SV - STOP VALVE

LINE LEGEND

- TOP OF BANK
- BOTTOM OF BANK
- EDGE OF BITUMEN
- EDGE OF TRACK
- CENTERLINE OF ROAD
- STORMWATER PIPE
- FENCELINE
- EDGE OF CONCRETE
- BUILDING
- MAJOR CONTOUR
- MINOR CONTOUR
- GUTTER/RIDGE LINE
- GUARD RAIL
- TREE (APPROX. SPREAD SIZE)
- ROCKS
- STORMWATER PIT

HEIGHT EXT'n

- SMH - SEWER MANHOLE
- HYD - HYDRANT
- WM - WATER METER
- SV - STOP VALVE
- ELEC - ELECTRICITY PIT
- TEL - COMMS PIT
- LP - LIGHT POLE
- TB - TOP OF BANK
- BB - BOTTOM OF BANK
- TK - TOP OF KERB
- INV - INVERT
- RR/RRL - ROOF RIDGE
- GL - GUTTER LEVEL
- FAC - FACIA
- W - WINDOW
- FL - FLOOR LEVEL
- UFL - UPPER FLOOR LEVEL
- DL - DECK LEVEL
- DE - DECK
- DFL - DECK FLOOR LEVEL
- SW - STORMWATER PIT
- BW - BOTTOM OF WALL
- TW - TOP OF WALL
- CL - CENTRELINE OF ROAD

NOTE:
FOR AERIAL & SITE PHOTOS SEE SHEET 2

NOTES:

- IF CONSTRUCTION WORKS ARE INTENDED TO BE UNDERTAKEN ON OR ADJACENT TO THE PROPERTY BOUNDARIES, FURTHER BOUNDARY REMARKING OR CONSTRUCTION SETOUT MUST BE UNDERTAKEN.
- RELATIONSHIP OF IMPROVEMENTS TO BOUNDARIES IS DIAGRAMMATIC ONLY. WHERE OFFSETS ARE CRITICAL THEY SHOULD BE CONFIRMED BY FURTHER SURVEY
- BOUNDARY DIMENSIONS & AREAS OF SUBJECT LAND ARE BY TITLE ONLY.
- THIS PLAN HAS BEEN PREPARED FOR THE EXCLUSIVE USE OF THE DESIGNATED CLIENT & MAY ONLY BE USED FOR THE PURPOSE FOR WHICH IT WAS COMMISSIONED.
- TREE SIZES ARE ESTIMATES ONLY
- SERVICES OTHER THAN THOSE SHOWN MAY EXIST AND THEIR LOCATIONS MUST BE VERIFIED BEFORE ANY CONSTRUCTION WORKS ARE COMMENCED.
- UNDERGROUND SERVICES HAVE NOT BEEN LOCATED BEFORE YOU DIG AUSTRALIA (www.bdya.com.au) SHOULD BE USED BEFORE ANY EXCAVATION WORKS ARE UNDERTAKEN.
- CRITICAL SPOT LEVELS SHOULD BE CONFIRMED WITH SURVEYOR.
- COPYRIGHT © SNOWY SURVEYING
- THIS DOCUMENT SHOULD NOT BE REPRODUCED OR ALTERED IN ANY WAY WITHOUT THE WRITTEN PERMISSION OF SNOWY SURVEYING.
- AERIAL UNDERLAY PHOTO SUPPLIED BY KOSCIUSZKO THREDBO PTY LTD

No.	DESCRIPTION	DATE
A	CLIENT ISSUE	19/07/24

AMENDMENTS

SNOWY SURVEYING
LAND AND ENGINEERING SURVEYING SERVICES

Ph: 0403297791
Email: max@snowysurveying.com.au
ABN: 75270142975
4 Lakeview Tce East Jindabyne NSW 2627

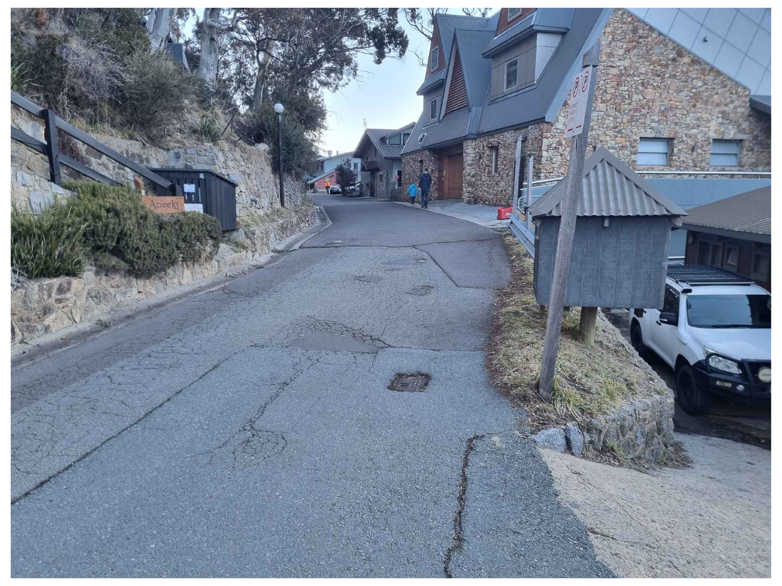
MAX WINDSHUTTLE
REGISTERED SURVEYOR
BOSSI NUMBER 8973

AZIMUTH:	MGA
COORDINATE SYSTEM:	MGA 2020
MARKS ADOPTED:	DP1119757
VERTICAL DATUM:	AHD
B.M ADOPTED:	PM54397
R.L.	1361.261m
SOURCE:	SCIMS
Scale @A1:	1:60 DO NOT SCALE DRAWING
Contour Interval	N/A
Survey Date:	8/07/2024
LGA:	SNOWY MONARO REGIONAL
Parish:	KOSCIUSZKO
County:	WALLACE
Surveyed	JH
Drafted	PD
Checked	MW

Client: KOSCIUSZKO THREDBO PTY LTD

Title: PLAN SHOWING DETAIL & LEVEL SURVEY
LOT 802 IN DP1119757
SONNBLICK LODGE - 8 BOBUCK LANE, THREBO

Sheet No.	Paper Size	Drawing No.	Job No.	Revision
01/02	A1	SS0279_CD_A	SS0279	A



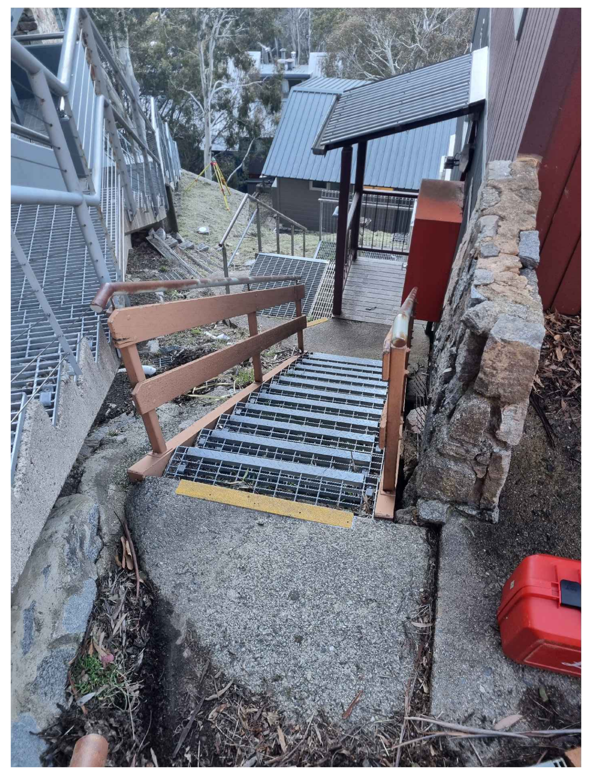
P1

P2

P3

P4

P5



P6

P7

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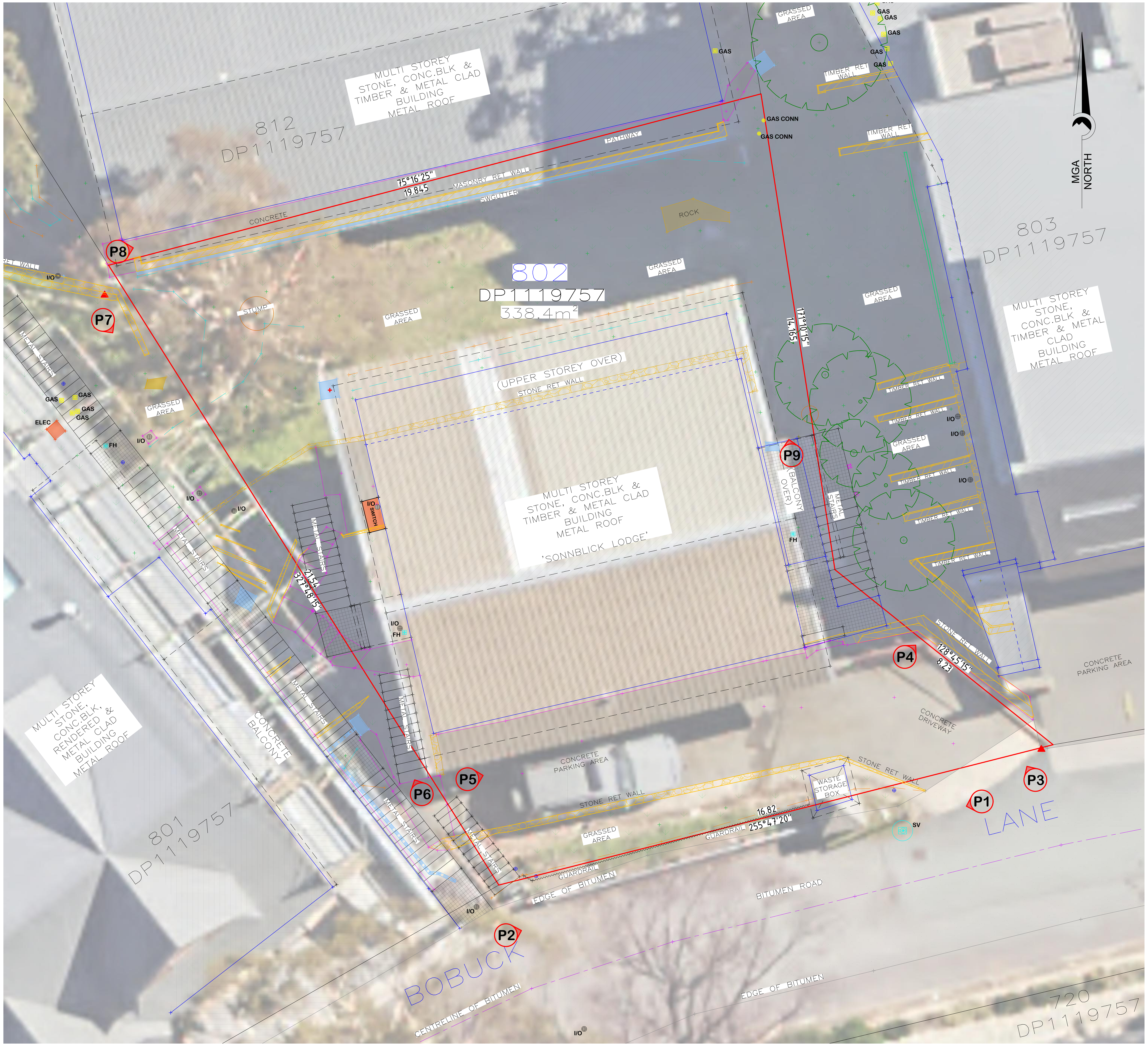

No.	DESCRIPTION	DATE
A	CLIENT ISSUE	19/07/24

AMENDMENTS

SNOWY SURVEYING

LAND AND ENGINEERING SURVEYING SERVICES

Ph: 0403297791
Email: info@snowysurveying.com.au
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12 Thredbo Tce Jindabyne NSW 2627

MAX WINDSHUTTLE
REGISTERED SURVEYOR
BOSSI NUMBER 8973

AZIMUTH:	MGA
VERTICAL DATUM:	AHD
COORDINATE SYSTEM:	MGA 2020
B.M ADOPTED:	PM54397
R.L.	1361.261m
MARKS ADOPTED:	DP1119757
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Contour Interval	N/A
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LGA:	SNOWY MONARO REGIONAL
Parish:	KOSCIUSZKO
County:	WALLACE
Surveyed	JH
Drafted	PD
Checked	MW
Client	KOSCIUSZKO THREDBO PTY LTD
Title	PLAN SHOWING DETAIL & LEVEL SURVEY LOT 802 IN DP1119757 SONNBLICK LODGE - 8 BOBUCK LANE, THREBO
Sheet No.	02/02
Paper Size	A1
Drawing No.	SS0279_CD_A
Job No.	SS0279
Revision	A

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Appendix G

Definitions of Geotechnical Engineering Terms

Limitations in the Use and Interpretation of this Geotechnical Report

Our Professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross- sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observes in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and the recommendations considering the changed conditions and time lapse.

The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The boring logs and related information depict subsurface conditions only at the specific locations and at the particular time designated on the logs. Soil conditions at the other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, borings or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report: nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.

DESCRIPTION AND CLASSIFICATION OF SOIL

The methods of description and classification of soils used in this report are based on the Australian Standard 1726 – 2017, Geotechnical site investigations. In general, soils are described along the following characteristics: soil name, plasticity or behavioural or particle characteristics of the primary soil component, colour, secondary soil components' plasticity or behavioural or particle characteristics, condition, structure, inclusions, strength or density and origin.

GENERAL DEFINITION - SOIL

SOIL In engineering usage, soil is a natural aggregate of mineral grains which can be separated by such gentle mechanical means as agitation in water, can be remoulded and can be classified according to the Unified Soil Classification System.

SOIL ORIGIN

Soil origins fall into the following categories:

Residual soil: Soils which have been formed in-situ by the chemical weathering of parent rock. These soils no longer retain any visible structure or fabric of the parent soil or rock material.

Extremely weathered material: Formed directly from in situ weathering of geological formations. Although this material of soil strength it retains the structure and/or fabric of the parent rock material.

Alluvial soil: Deposited by streams and rivers.

Estuarine soil: Deposited in coastal estuaries, and including sediments carried by inflowing rivers and streams, and tidal currents.

Marine soil: Deposited in a marine environment.

Lacustrine soil: Deposited in freshwater lakes.

Aeolian soil: Carried and deposited by wind.

Colluvial soil: Soil and rock debris transported down slopes by gravity, with or without the assistance of flowing water.

Topsoil: Mantle of surface and/or near-surface soil often but not always defined by high levels of organic material, both dead and living.

Fill: Any material which has been placed by anthropogenic processes.

SOIL CLASSIFICATION

PARTICLE SIZE DEFINITIONS

Soil components are described according to the predominating particle size, qualified by the grading of other particles present (e.g. sandy clay) on the following basis:

Classification	Components	Subdivision	Particle Size (mm)
Oversize	Boulders		>200
	Cobbles		63 to 200
Coarse grained soil	Gravel	Coarse	19 to 63
		Medium	6.7 to 19
		Fine	2.36 to 6.7
	Sand	Coarse	0.6 to 2.36
		Medium	0.21 to 0.6
		Fine	0.075 to 0.21
Fine grained soil	Silt		0.002 to 0.075
	Clay		<0.002

MOISTURE CONDITION

Coarse Grained Soil		Fine Grained Soil	
Dry (D)	Non-cohesive and free-running.	Moist, dry of plastic limit (w<W_P)	Hard and friable or powdery.
Moist (M)	Soil feels cool, darkened in colour. Soil tends to stick together.	Moist, near plastic limit (w≈W_P)	Soils can be moulded at a moisture content approximately equal to the plastic limit.
Wet (W)	As for moist, with free water forming when handled.	Moist, wet of plastic limit (w>W_P)	Soils usually weakened and free water forms on hands when handling.
		Wet, near liquid limit (w≈W_L)	Near liquid limit.
		Wet, wet of liquid limit (w>W_L)	Wet of liquid limit.

CONSISTENCY/RELATIVE DENSITY

Cohesive soils are classified on the ease by which the soil can be remoulded and can be either assessed in the field by tactile means, by laboratory testing or through mechanical determination methods. Non-cohesive soils are classified on the basis of relative density, generally from the results of in-situ penetration tests and terms for both are defined as below:

Cohesive Soils			Non-cohesive Soils	
Consistency	**Indicative Undrained Shear Strength s_u(kPa)**	**Field Guide to Consistency**	**Term**	**Relative Density (%)**
Very soft (VS)	≤12	Exudes between the fingers when squeezed in hand.	Very Loose (VL)	≤15
Soft (S)	>12 - ≤25	Can be moulded by light finger pressure.	Loose (L)	>15 - ≤35
Firm (F)	>25 - ≤50	Can be moulded by strong finger pressure.	Medium Dense (MD)	>35 - ≤65
Stiff (St)	>50 - ≤100	Cannot be moulded by fingers.	Dense (D)	>65 - ≤85
Very Stiff (VSt)	>100 - ≤200	Can be indented by thumb nail.	Very Dense (VD)	>85
Hard (H)	>200	Can be indented with difficulty by thumb nail.		
Friable (Fr)	-	Can be easily crumbled or broken into small pieces by hand.		

MINOR COMPONENTS

Descriptive Term	Assessment Guide	Proportion of minor component in:
With	Easily detectable by visual or tactile means and little difference between general properties and properties of primary component.	Coarse grained soils: Fines – 5 to 12% Accessory coarse component – 15 to 30% Fine grained soils: Coarse component - 15 to 30%
Trace	Detectable by visual or tactile means but little or no difference between general properties and properties of primary component.	Coarse grained soils: Fines – <5% Accessory coarse component – <15% Fine grained soils: Coarse component - <15%

CEMENTATION

Where cementation is present in soils, they can be either weakly cemented where they are easily disaggregated by hand in air or water or moderately cemented where effort is required to disaggregate the soil by hand in air or water.

SAMPLING

Sampling is carried out during drilling to allow engineering examination (and laboratory testing where required) of soil or rock.

Disturbed samples taken during drilling provide information on colour, type, inclusions and depending upon the degree of disturbance, some information on strength and structure.

Undisturbed samples are generally taken by one of two methods:

1. Driving or pushing a thin walled sample tube into the soil and withdrawing with a sample of soil in a relatively undisturbed state.
2. Core drilling using a retractable inner tube (R.I.T.) core barrel.

Such samples yield information on structure and strength in additions to that obtained from disturbed samples and are necessary for laboratory determination of shear strength and compressibility. Undisturbed sampling is generally effective only in cohesive soils.

Details of the type and method of sampling are given in the report.

PENETRATION TESTING

The relative density of non-cohesive soils is generally assessed by in-situ penetration tests, the most common of which is the standard penetration test. The test procedure is described in Australian Standard 1289 "Testing Soils for Engineering Purposes" – Test No. F3.1.

The standard penetration test is carried out by driving a 50mm diameter split tube penetrometer of standard dimensions under the impact of a 63kg hammer having a free fall of 750mm.

The "N" value is determined as the number of blows to achieve 300mm of penetration (generally after disregarding the first 150mm penetration through possibly disturbed material). The results of these tests can be related empirically to the engineering properties of the soil.

The test is also used to provide useful information in cohesive soils under certain conditions, a good quality disturbed sample being recovered with each test. Other forms of in situ testing are used under certain conditions and where this occurs, details are given in the report.

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Unified Soil Classification System (Metricated)
Data for Description Identification and Classification of Soils

COARSE GRAINED SOILS – More than 65% by dry mass, less than 63mm is greater than 0.075mm. (Field identification: More than 65% of material less than 63mm is greater than 0.075mm. A 0.075mm particle is about the smallest particle visible to the naked eye.) (Laboratory classification: Use the gradation curve of material passing 63mm for classification of fractions according to criteria for major component.)

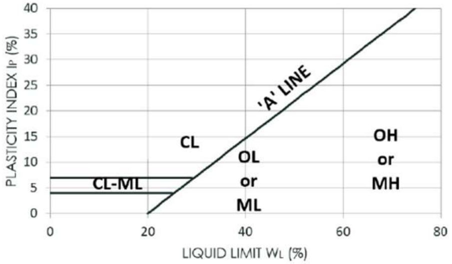
MAJOR DIVISIONS	Group Symbol	Graphic Symbol	TYPICAL NAME	DESCRIPTIVE DATA	GRADATIONS (GRAVELS AND SANDS)		NATURE OF FINES	DRY STRENGTH	Group Symbol	% < 0.075 mm	PLASTICITY OF FINE FRACTION	Coefficient of Uniformity C_u	Coefficient of Curvature C_c	Notes
GRAVELS – More than 50% of coarse grains are greater than 2.36mm.	GW		Well graded gravels and gravel-sand mixtures, little or no fines	Give soil name, indicate approximate percentages of sand and gravel, particle characteristics including particle size subdivision, particle shape, colour, secondary component characteristics and other pertinent descriptive information, symbols in parenthesis. For undisturbed soil add information on structure including zoning, defects and cementing, moisture condition, and relative density. Example: (SP) SAND, trace silt, grey, medium grained, medium dense; dry; Tomago Sand Beds.	GOOD	Wide range in grain size	"Clean" materials (not enough fines to bond coarse grains)	None	GW	0-5	-	>4	Between 1 and 3	1. Identify fines by the method given for fine grained soils. 2. For fines contents between 5% and 12%, the soil shall be given a dual classification comprising the two group symbols separated by a dash, e.g. for a gravel with between 5% and 12% silt fines, the classification is GP-GM. 3. Soils that are dominated by boulders, cobbles or peat (Pt) are described separately and are not classified.
GRAVELS	GP		Poorly graded gravels and gravel-sand mixtures, little or no fines		POOR	Predominantly one size or range of sizes			GP	0-5	-	Fails to comply with above		
GRAVELLY SOILS	GM		Silty gravels, gravel-sand-silt mixtures		GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are silty (1)	None to medium	GM	12-50	Below 'A' line and I_P >7	-	-	
GRAVELLY SOILS	GC		Clayey gravels gravel-sand-clay mixtures				Fines are clayey (1)	Medium to high	GC	12-50	Above 'A' line and I_P >7	-	-	
SANDS – More than 50% of coarse grains are less than 2.36mm.	SW		Well graded sands and gravelly sands, little or no fines		GOOD	Wide range in grain size	"Clean" materials (not enough fines to bond coarse grains)	None	SW	0-5	-	>6	Between 1 and 3	
SANDS	SP		Poorly graded sands, little or no fines		POOR	Predominantly one size or range of sizes			SP	0-5	-	Fails to comply with above		
SANDY SOILS	SM		Silty sand, sand-silt mixtures		GOOD TO FAIR	"Dirty" materials (Excess of fines)	Fines are silty (1)	None to medium	SM	12-50	Below 'A' line or I_P <4	-	-	
SANDY SOILS	SC		Clayey sands, sand-clay mixtures				Fines are clayey (1)	Medium to high	SC	12-50	Above 'A' line and I_P >7	-	-	

FINE GRAINED SOILS – More than 35% by dry mass, less than 63mm is less than 0.075mm. (Field identification: More than 35% of material less than 63mm is smaller than 0.075mm.) (Laboratory classification: More than 35% of material is less than 63mm passing 0.075mm.)

SILT AND CLAY FRACTION – Fraction smaller than 0.2 mm AS sieve size

MAJOR DIVISIONS	Group Symbol	Graphic Symbol	TYPICAL NAME	DESCRIPTIVE DATA	DRY STRENGTH	DILANTANCY	TOUGHNESS	Group Symbol	PLASTICITY OF FINE FRACTION
Liquid Limit less than 50%.	ML		Inorganic silts, very fine sands, rock flour, silty or clayey fine sands.	Give soil name, indicate degree and character of plasticity, colour, secondary component characteristics other pertinent descriptive information, symbols in parenthesis. For undisturbed soil add information on structure including zoning, defects and cementing, moisture condition, and consistency. Example: (CI) CLAY, with gravel, red-brown, medium plasticity, very stiff; gravel 20%, fine to medium, sub-rounded; moist, with desiccation cracks; residual.	None to low	Slow to rapid	Low	ML	Below 'A' line
Liquid Limit less than 50%.	CL		Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		Medium to high	None to slow	Medium	CL, CI	Above 'A' line
Liquid Limit less than 50%.	OL		Organic silts and organic silty clays of low plasticity		Low to medium	Slow	Low	OL	Below 'A' line
Liquid Limit more than 50%.	MH		Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		Low to medium	None to slow	Low to medium	MH	Below 'A' line
Liquid Limit more than 50%.	CH		Inorganic clays of high plasticity, fat clays		High to very high	None	High	CH	Above 'A' line
Liquid Limit more than 50%.	OH		Organic clays of medium to high plasticity		High to high	None to very slow	Low to medium	OH	Below 'A' line

Group Symbol	Graphic Symbol	TYPICAL NAME	FIELD IDENTIFICATION	Group Symbol	LABORATORY CLASSIFICATION
Pt		Peat muck and other highly organic soils	Readily identified by colour, odour, spongy feel and generally fibrous texture	PT	* Effervescence with H_2O_2



PLASTICITY CHART
FOR CLASSIFICATION
OF FINE GRAINED SOILS

DESCRIPTION AND CLASSIFICATION OF ROCK

The methods of description and classification of rock used in this report are based on the Australian Standard 1726 – 2017, Geotechnical site investigations. In general, descriptions cover the following properties for rock – rock name, grain size, colour, fabric and texture, inclusions or minor components, moisture content, durability, rock material condition including strength and weathering and/or alteration, defects and geological description.

GENERAL DEFINITIONS – ROCK

ROCK In engineering usage, rock is a natural aggregate of minerals connected by strong and permanent cohesive forces. Since "strong" and "permanent" are subject to different interpretations, the boundary between rock and soil is necessarily an arbitrary one. Rock material is intact rock that is bounded by defects.

DEFECT Discontinuity, fracture, break or void in the material or materials across which there is little or no tensile strength.

STRUCTURE The nature and configuration of the different defects within the rock mass and their relationship to each other.

ROCK MASS The entirety of the system formed by all of the rock material and all the defects that are present.

DESCRIPTIVE TERMS

ROCK NAME Simple rock names are used rather than precise geological classification. Rock names fall into category types of sedimentary rocks, igneous rocks, metamorphic rocks and duricrust rocks.

PARTICLE SIZE

Grain size terms for sedimentary rocks with predominantly sand sized grains are:

Coarse grained – mainly 0.6mm to 2mm.

Medium grained – mainly 0.2mm to 0.6mm.

Fine grained – mainly 0.06mm (just visible) to 0.2mm.

In igneous and metamorphic rock types, where significant, the following terms are used to describe the dominant or average grain size and/or the grain size may be recorded in millimetres:

Coarse grained – mainly greater than 2mm.

Medium grained – mainly 0.06mm to 2mm.

Fine grained – mainly less than 0.06mm (just visible).

If readily identifiable, the minerals should be described.

FABRIC

When the arrangement of grains shows an alignment, a preferred orientation or a layering that is visible, descriptive terms for sedimentary rocks are bedding and lamination. Bedding is layering produced by changes in sedimentation. Lamination is similar to bedding but developed in layer thicknesses of less than 20mm. Fabric descriptive terms for metamorphic rocks are foliation, which is the parallel arrangement of minerals due to metamorphic processes and cleavage, which is a type of foliation developed in fine grained metamorphic rocks such as slates. For igneous rocks, flow banding is a layering produced during flow of a partially solidified igneous rock that causes crystals to become oriented.

INDISTINCT FABRIC

Where layering or fabric is just visible. There is little effect on strength properties.

DISTINCT FABRIC

Where layering or fabric is easily visible. The rock may break more easily parallel to the fabric.

ROCK WEATHERING DEFINITIONS

Extremely Weathered (XW)	Rock substance affected by weathering to the extent that the rock exhibits soil properties, i.e. it can be remoulded and can be classified according to the Unified Soil Classification System, but the texture of the original rock is still evident.
Highly Weathered (HW)	Rock substance affected by weathering to the extent that limonite staining or bleaching affects the whole of the rock substance and other signs of the chemical or physical decomposition are evident. Porosity and strength may be increased or decreased compared to the fresh rock usually as a result of iron leaching or deposition. The colour and strength of the original fresh rock substance is no longer recognisable.
Moderately Weathered (MW)	Rock substance affected by weathering to the extent that staining extends throughout the whole of the rock substance and the original colour of the fresh rock is no longer recognisable.
Slightly Weathered (SW)	Rock substance affected by weathering to the extent that partial staining or discolouration of the rock substance, usually limonite, has taken place. The colour and texture of fresh rock is recognisable.
Fresh (FR)	Rock substance unaffected by weathering.

The degrees of rock weathering may be gradational. Intermediate stages are described by dual symbols with the prominent degree of weathering first (e.g. EW-HW).

The various degrees of weathering do not necessarily define strength parameters as some rocks are of low strength, even when fresh, to the extent that they can be broken by hand across the fabric, and some rocks may increase in strength during the weathering process.

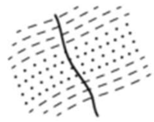
ROCK STRENGTH

Rock strength is defined by the Point Load Strength Index (Is 50) and refers to the strength of the rock substance in the direction normal to the bedding. The test procedure is described by the International Society of Rock Mechanics.

Term	**Point Load Strength Index $I_{s(50)}$ MPa**	**Field Guide**	**Approx Unconfined Compressive Strength MPa***
Very Low Strength (VL)	0.03 to 0.1	Material crumbles under firm blows with sharp end of pick; can be peeled with knife; too hard to cut a triaxial sample by hand. Pieces up to 30mm thick can be broken by finger pressure.	0.6 to 2
Low Strength (L)	0.1 to 0.3	Easily scored with a knife; indentations 1mm to 3mm show in the specimen with firm blows of the pick point; has dull sound under hammer. A piece of core 150 mm long by 50 mm diameter may be broken by hand. Sharp edges of core may be friable and break during handling.	2 to 6
Medium Strength (M)	0.3 to 1	Readily scored with a knife; a piece of core 150mm long x 50mm dia. can be broken by hand with difficulty.	6 to 20
High Strength (H)	1 to 3	A piece of core 150mm long x 50mm dia. cannot be broken by hand but can be broken by a pick with a single firm blow, rock rings under hammer.	20 to 60
Very High Strength (VH)	3 to 10	Hand specimen breaks with pick after more than one blow; rock rings under hammer.	60 to 200
Extremely High Strength (EH)	more than 10	Specimen requires many blows with geological pick to break through intact material; rock rings under hammer.	more than 200

ROCK DEFECT TYPES

This classification applies to the range of possible rock defect types that are types of natural fractures along which the core is discontinuous. These include bedding plane partings, joints and other rock defects, but exclude known artificial fractures such as drilling breaks.

Term		Description	Diagram
Parting		A surface or crack across which the rock has little or no tensile strength. Parallel or sub-parallel to layering (e.g. bedding) or a planar anisotropy in the rock material (e.g. cleavage). May be open or closed.	
Joint		A surface or crack with no apparent shear displacement an across which the rock has little or no tensile strength, but which is not parallel to layering or to planar anisotropy in the rock material. May be open or closed.	
Sheared Surface		A near planar, curved or undulating surface which is usually smooth, polished or slickensided and which shows evidence of shear displacement.	
Sheared Zone		Zone of rock material with roughly parallel near planar, curved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.	
Seams	Sheared Seam	Seam of soil material with roughly parallel almost planar boundaries, composed of soil materials with roughly parallel near planar, cuved or undulating boundaries cut by closely spaced joints, sheared surfaces or other defects. Some of the defects are usually curved and intersect to divide the mass into lenticular or wedge-shaped blocks.	
	Crushed Seam	Seam of soil material with roughly parallel almost planar boundaries, composed of disoriented, usually angular fragments of the host rock material which may be more weathered than the host rock. The seam has soil properties.	
	Infilled Seam	Seam of soil material usually with distinct roughly parallel boundaries formed by the migration of soil into an open cavity or joint, infilled seams less than 1mm thick may be described as a veneer or coating on a joint surface.	
	Extremely Weathered Seam	Seam of soil material, often with gradational boundaries. Formed by weathering of the rock material in place.	

The spacing, length (sometimes called persistence), aperture (openness), and seam thickness should generally be described directly in millimetres or metres.

ROCK DEFECT DESCRIPTIONS

DEFECT ROUGHNESS TERMS		DEFECT SHAPE TERMS		DEFECT COATING TERMS	
Term	**Description**	**Term**	**Description**	**Term**	**Description**
Very Rough	Many large surface irregularities (amplitude generally more than 1mm). Feels like, or coarser than very coarse sand paper.	Planar	The defect does not vary in orientation.	Clean	No visible coating.
Rough	Many small surface irregularities (amplitude generally less than 1mm). Feels like fine to coarse sand paper.	Curved	The defect has a gradual change in orientation.	Stained	No visible coating but surfaces are discoloured.
Smooth	Smooth to touch. Few or no surface irregularities.	Undulating	The defect has a wavy surface.	Veneer	A visible coating or soil or mineral, too thin to measure; may be patchy.
Polished	Shiny smooth surface.	Stepped	The defect has one or more well defined steps.	Coating	A visible coating up to 1mm thick. Thicker soil material should be described using appropriate defect terms (e.g. infilled seam). Thicker rock strength material should be described as a vein.
Slickensided	Grooved or striated surface, usually polished.	Irregular	The defect has many sharp changes of orientation.		