

Remarkables Ski Area Expansion Project Natural Hazards Assessment

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Remarkables Ski Area Expansion Project - Natural Hazards Assessment

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The author of this report is Derek Chinn. I am a Senior Principal Engineer and my qualifications are BE, Chartered Professional Engineer (Civil and Structural), Chartered Member of Engineering New Zealand, Fellow of Engineering New Zealand and I am on the International Professional Engineers Register. I have 38 years' experience in a wide variety of Civil Engineering projects including alpine geotechnical risk assessment, specifically in relation to ski area infrastructure and alpine buildings. My specific areas of interest are alpine structures and ski area infrastructure. I was made a Life Member of the New Zealand Alpine Club and a Fellow of Engineering New Zealand as a result of my contribution to alpine engineering in New Zealand.

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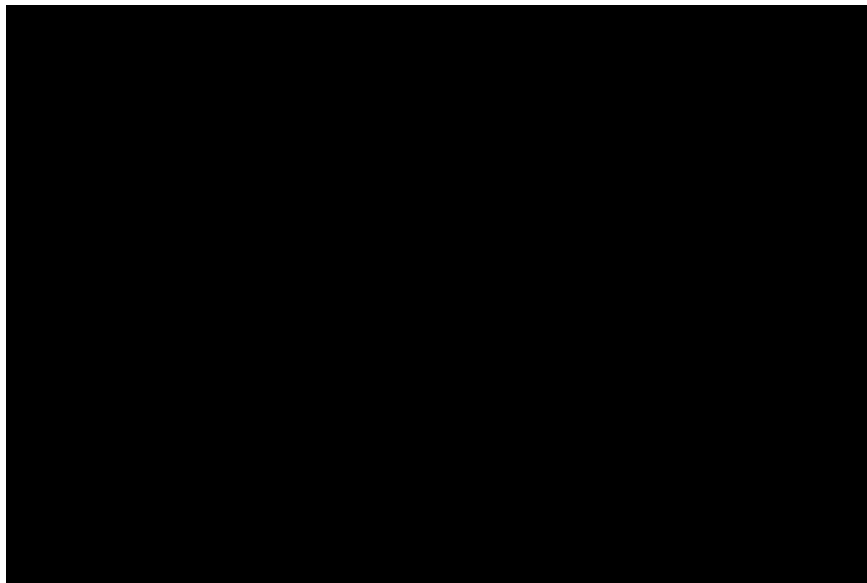


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Executive Summary

This document describes an investigation of natural hazards for the proposed Remarkables Ski Area Upgrades and Doolans Expansion Project. As the Project relates to an existing ski field, the assessment focuses on the new features being proposed, including the new Doolans Gondola and ski trails / access roads. The Risk Assessment has been carried out in accordance with the Methodology described in the National Policy Statement for Natural Hazards 2025. The Natural Hazard Risks identified for the various components of the development are as follows. These assessments are residual risk assessments and include consideration of risk mitigation measures

Table 1. Risk Matrix Summary

Element Considered	Risk Assessment
Gondola Base Area Flood Risk	Medium
Gondola Return Station Flood Risk Low	Low
Doolans Creek Right Branch Intake Flood Risk	Low/Inapplicable
Upper Doolans Creek Right Branch Solifluction Risk	Low
Upper Doolans Creek Right Branch Debris Flow Risk Low	Low
Debris Flow Risk in Rastus Burn	Low
Seismic risk	Medium
Wind risk	Medium
Global Land Stability risk in the Doolans Creek Right Branch Upper Basin	Medium
Global Land Stability risk in the Upper Rastus Burn Basin	Medium
Gondola alignment rockfall risk	Medium
Ridge above Swan Lake rockfall risk	High
Ridge above snow making reservoir rockfall risk	Medium
Snow Avalanche	Medium
Localised Land Instability	Medium

1 Introduction

The purpose of this report is to provide an assessment of the Natural Hazards associated with the proposed upgrade of existing facilities at the Remarkables Ski area plus new facilities proposed in the upper Doolans Creek Right Branch.

- Solifluction – as a risk to infrastructure
- Seismic – structures and land stability
- Land stability – natural localized
- Global landslide – existing and manmade
- Flood – water flow
- Debris flow
- Rockfall
- Snow avalanche
- Wind – structures and operation

This document excludes considerations of terrain hazards such as bluffs or Doolans Creek Right Branch. Such features may pose a terrain risk such as falls, drowning or entrapment to staff or users. Such terrain hazards would be managed by the ski area operations and ski patrol by methods including signage and fencing.

The report has been prepared in accordance with the National Policy Statement for Natural Hazards 2025 in accordance with the risk management framework in this document. Risk assessment is as per the table below.

Table 2. Risk likelihood table

Likelihood level	Annual exceedance probability (AEP)	Average recurrence interval (ARI) or 'return period'
Almost certain	10% or more	Up to and including 10 years
Very likely	10% to 5%	Over 10 and up to and including 20 years
Likely	5% to 2%	Over 20 and up to and including 50 years
Possible	2% to 1%	Over 50 and up to and including 100 years
Unlikely	1% to 0.2%	Over 100 and up to and including 500 years
Rare	0.2% to 0.02%	Over 500 and up to and including 5,000 years
Very rare	less than 0.02%	More than 5,000 years

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Risk consequences are assessed as per the National Policy Statement as shown in the table below.

Table 3. Risk consequence table

Consequence level	Damage to property	Potential for injury or fatalities
Catastrophic	Severe damage to land and building(s), potential for collapse or total destruction of structures. Building(s) need to be demolished, rebuilt or relocated.	High threat to life safety, with probable fatalities and/or critical injuries.
Major	Major damage to land and building(s), including structural damage. Loss of use and substantial repair required.	Unsafe for people, with potential for many injuries, or critical injuries and/or fatalities.
Moderate	Some damage to land and non-structural damage to building(s). Limited loss of use, repairs required.	Unsafe for people, with potential for injuries, although expected to be minor.
Minor	Minor damage to land and building(s). No loss of use, minimal repairs required.	Isolated minor injuries possible.
Negligible	No loss of use, no building repairs required.	No injuries.

The results of the risk analysis are presented in a matrix format in accordance with the National Policy Statement as below

Table 4. Risk matrix table.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

The risks identified in this report are residual risks and assume that risk mitigation measures have been implemented. The individual mitigation measures are described in each relevant section.

2 Background

NZSki is applying for approvals to construct, maintain and operate ski area infrastructure within the upper Doolans Creek Right Branch as part of an extension of the ski area operations. In addition, NZSki is applying for approval to upgrade, maintain and operate ski area infrastructure at existing Remarkables Ski area in the Rastus Burn valley to support the Doolans development and cater for predicted increases in visitor number. This development is intended to achieve the following objectives.

- Increase the capacity and area of the Remarkables Ski Area
- Provide new infrastructure, and upgrade existing infrastructure, to support the development and the increased visitor numbers resulting

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Upper Doolans Creek Right Branch is south-east of the existing ski area and is separated from the existing Remarkables Ski area by a ridge known as 'Helicopter Ridge'. The scope of the upgrades associated with the development involves the following elements.

- Construction of a new Gondola between the existing Rastus Burn Base Building and the Return Station in the Upper Doolans Creek Right Branch, via Helicopter Ridge
- Construction of vehicle access roads and ski trails between the vehicle existing roads and trails in the Rastus Burn Basin and the facilities at the Doolans Gondola Return Station
- Upgrade of power supply to accommodate the additional gondola, snow making and other facilities
- Implementation of new telecommunicators facilities in the Upper Doolans Creek Right Branch and upgrading of existing telecommunications facilities to cope with increased telecommunications traffic
- Construction of a new raw water intake within the Doolans Creek to abstract water from the creek for snow making within the Upper Doolans Creek Right Branch firefighting at the Doolans facilities and for potable water supply at the Doolans facilities
- Upgrade of the existing potable water facilities within the Rastus Burn base facilities to accommodate the increase in visitor numbers
- System to pump untreated wastewater over Helicopter Ridge to be treated at a plant in the Rastus Burn area

The location of the elements of the proposed development, including the access roads and formed ski field, within the Rastus Basin and the Upper Doolans Creek Right Branch is shown in the rendering provided by NZSki below.

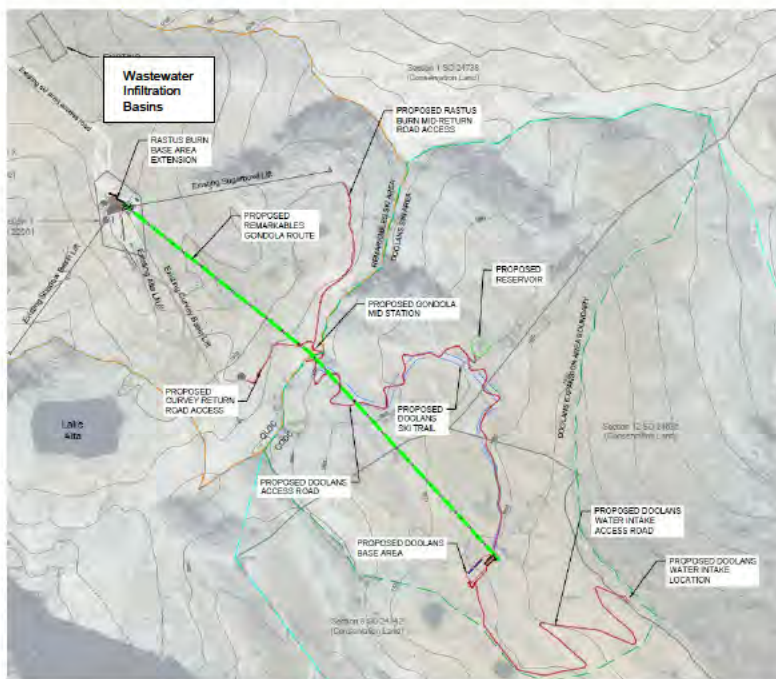


Figure 1. Overall Proposed Upgrade Layout

3 Climate Change Allowances

In regard to the assessment of Natural Hazards, climate change is predicted to increase precipitation and increase temperature. The concept developed for stormwater management accounts for Climate Change to Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 for the period 2081-2100.

The effect of climate change on snow and wind is more difficult to predict quantifiably. Increased precipitation may result in higher snow fall events, but increased temperature is likely to result in a shorter ski season.

Increased wind speed and wind run resulting from climate change is likely to increase the volume of snow stripped off ridge lines and redeposited on lee slopes and basins. Lee slope avalanche risk is a known and existing risk and is well managed by the Remarkables Ski Patrol using techniques including slope closure, ski cutting, land-based explosives and aerial dropped explosives onto slopes of known risk. The Remarkables also operate avalanche transceiver and 'RECCO' search equipment and have an avalanche search dog on site, frequently but not every day, during winter.

4 Site Investigations Undertaken

Site inspections in the Doolans Creek Right Branch to date have been visual and have involved both helicopter and walking survey. Neither excavation nor drilling has been undertaken as there is not wheeled vehicle access to site.

4.1 Winter Site Inspection Activities

The following winter site investigations have been undertaken by the report authors.

- August 29, 2022, Combined Remarkables/Coronet/Cardrona Patrol /ACR avalanche training exercise below Helicopter Ridge. Avalanche and terrain risk assessment.
- July 23, 2020, Alpine Cliff Rescue avalanche training course below Helicopter Ridge involving both terrain and avalanche risk assessment and avalanche scenario.
- August 4, 2018 – ski and avalanche inspection via Sugar Bowl ridge
- June 4, 2018, ski into Doolans via gullies from Curvey Basin. Avalanche and terrain assessment.
- July 16, 2017, Combined Remarkables Patrol/ACR avalanche training exercise below Helicopter Ridge involving avalanche and terrain risk assessment and avalanche scenario.
- March 19, 2017, walking trip to proposed reservoir site involving inspection of rockfall risk from ridge above

4.2 Summer/Spring Site Inspection Activities

The following summer and spring site investigations have been undertaken by the authors

- April 10, 2026, Combined aerial inspection geotech engineer and NZSki staff to inspect rockfall risk of ridge above between Sugar Bowl and Helicopter Ridge and above Reservoir location
- 3 December 2025, combined walkover geotech and NZSki staff of Sugar Bowl to Helicopter ridge to assess route risks.
- November 15, 2025, ski into proposed Doolans Creek Right Branch water intake site and ski out via creek bed and reservoir site
- March 26, 2025, Combined walkover of complete Gondola Route and out via Sugar Bowl ridge by two geotech engineers to assess natural hazards to Gondola Route
- October 22, 2022, ski to lower Doolans via Sugar Bowl involving both terrain and Avalanche risk assessment
- September 11, 2021, ski to lower Doolans and Avalanche and terrain risk assessment
- October 15, 2021, Ski to upper basins via Sugar Bowl Ridge and Avalanche risk assessment
- November 10, 2010, ski below Helicopter ridge. Observed large wind slab avalanches following warming conditions, assessment of avalanche risk conditions.

5 Flood Risk

In relation to the infrastructure required for the proposed Doolans Expansion, only the following areas of infrastructure are in an area of potential flood risk:

- Bottom drive station for the gondola and the expansion to the existing base building
- Doolans Creek right branch intake structure

The concept developed for stormwater management accounts for Climate Change to Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 for the period 2081-2100.

5.1 Gondola Base Station and Base Building Flood Risk

Both the proposed gondola base station and base building are located near the Rastus Burn Creek and warrant considerations of flood risk.

The proposed gondola bottom drive station and the Base Building are adjacent to the vehicle arrival and Drop Zone area. This location is immediately west of the Rastus Burn Creek and the nominal location is shown in the figure below.



Figure 2. Nominal Location of Gondola Base Drive Station (red) and the Rastus Burn Creek.

The channel of the Rastus Burn Creek (adjacent to the learners' ski area), has been relocated from its original location and the channel cross section designed for calculated flows and lined with armouring rock with a designed minimum size. The creek bed was designed to convey a 1/100 ARI (Average Recurrence Interval) with a 600mm freeboard. The creek bed through the learners' slope and past the

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Sugar Bowl Lift Base Station and the Ski Patrol Building has been armoured to protect against erosion. A photograph of the armouring during construction of the stream training is shown below.



Figure 3. Rastus Burn Creek Stream Training and Armouring

Downstream of the stream crossing beneath the Sugar Bowl lift line, the stream bed has greater depth, and the channels hydraulic capacity is significantly greater than a 1/100 event. In this area the bed is largely in situ-rock, and consequently, the risk of significant erosion of the bed in this area is considered to be low to nil. Should a 'super design' (an event with a longer recurrence interval than 100 years) the creek will overtop its banks and spill onto the level platform and flow as low velocity sheet flow. Such a super-design event could result in erosion of the platform shoulder but no significant damage to the gondola base station or base building is anticipated. Such a consequence would be considered moderate. Flooding is unlikely to occur as it has an ARI of greater than 100 years. Thus, this risk can be considered to be Medium as identified in the matrix below.

Table 5. Gondola Base Station and Base Building risk matrix table.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

5.1.1 Mitigation Measures Gondola Base Station and Base Building

The measures undertaken to mitigate the risk of flooding at the Gondola Base Station and the Base Building include the previous engineered stream training for the Rastus Burn Creek described above. Secondary mitigation measures include localised surface flow redirection on the lower learners slope to redirect sheet flow into the Rastus Burn Creek rather than allowing this to flow directly into the vehicle

arrival and Drop Zone area and Buildings. This channel is visible in Figure 2 above as a snaking white line (because the channel is partially snow filled). In addition, if a super-design event does occur water flow will spread out onto the vehicle arrival and Drop Zone area and a degree of attenuation will occur, it is expected that should this occur much of the flow will dissipate over the vehicle arrival and Drop Zone area bank.

5.2 Gondola Return Station Flood Risk

The gondola towers and mid stations are located away from watercourses and any potential flood risks. The proposed Gondola Return Station would be located adjacent to an unnamed creek on a rock knoll and there is approximately 5m height between the location of the top station and the adjacent creek bed. Consequently, the station location is not anticipated to experience flooding.



Figure 4. The Return Station Location and showing height distance to adjacent creek on the right



Figure 5. Location of the Gondola Return Station showing the freeboard to the adjacent creek. Return station location arrowed

The likelihood of flooding of the Doolans Gondola Station is assessed to be at Rare (because of the freeboard between the platform and the creek) and the consequence is assessed as Moderate. Thus, the risk of flooding to these facilities is low as identified in the matrix below. The presence of the

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Gondola Return Station facilities in the Upper Doolans Creek Right Branch will not exacerbate the risk of flooding to any detectable extent. There will be an insignificant increase in flow from the hard roof structures, but this is not significant compared to the size of the catchment, nor the large size of the channel available for flood flow.

Table 6. Gondola Return Station and Doolans Return Area Facilities Flood Risk Matrix

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

5.2.1 Mitigation Measures Gondola Return Station Facilities

The measures undertaken to mitigate the risk of flooding at the Gondola Return Station facilities include the significant height distance between the facilities and the adjacent un-named creek. In addition stormwater from both the Carrier Stacking Building/Café and the return station will be collected in a piped drainage system and conveyed to the creek in order to manage surface water around the facilities.

5.3 Doolans Creek Right Branch Intake Flood Risk

The intake structure for the raw water intake within Doolans Creek is designed to be submerged. No adverse effects other than temporary sedimentation at the intake is likely to result from flooding. The high-head pump buildings are located on the terrace approximately 10m above the creek bed. Thus, the ARI of a flood which will threaten the pump building is well over 500 years and the risk of flooding to this building is low in accordance with the Risk Matrix. Climate change may increase the magnitude of flooding at the intake structure, but this will not have a material effect on the design.

The Risk Matrix for the Doolans Creek Right Branch Intake is as below.

Table 7. Doolans Creek Right Branch Intake Flood Risk Matrix

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

5.3.1 Mitigation Measures Doolans Creek Right Branch Intake Flood Risk

The intake structure will be designed to be submerged. The risk if inundation to the pumps will be mitigated by the low head booster pumps being submersible pumps that will not be damaged by immersion. There remains a risk of either aggradation or erosion around the facilities. Rip rap scour protection will be provided to minimise the risk of erosion at the weir and flume structures and adjacent to the lid of the low head pump chamber. If significant aggradation occurs in the intake weir, on the lid of the booster pump chamber, or at the bypass pipe outlet then this will need to be cleared as part of maintenance activities.

6 Solifluction Risk

Solifluction is slow, downslope creeping of water-saturated soil and rock debris associated with cyclic freeze thaw conditions which occurs on slopes in cold alpine regions. It is caused by gravity movement of the upper layers of ground thawing and creeping downslope. This often occurs because of the upper layers becoming saturated from snow melt while resting on an impermeable, still frozen, or layers below. The Upper Doolans Creek Right Branch contains notable examples of this phenomenon. These are shown in the figure below.



Figure 6. Aerial view of solifluction lobes in the Upper Doolans Right Branch

Solifluction movement is seasonal and slow. Consequently, it is not considered to be a risk to human safety but can be potentially damaging to structures.

The effects of solifluction creep may be managed by locating gondola towers or other structures in locations where existing lobes are either non-existent or small (in the order of a 200mm or less). In addition, any structures within an area potentially prone to such movement should be founded a minimum of 2m below ground level or a level where the surface movement does not affect the founding of the structure. This is standard practice for structures such as gondola or lift towers.

Solifluction is considered possible in the upper Gondola Tower areas but is considered less likely along the proposed trail and road formations as these are within predominantly scree areas which are less susceptible to such movement as they do not hold water. The likelihood is considered Unlikely if appropriate tower site selection is made to avoid areas of ground movement. The Consequence of solifluction affecting towers is Minor as neither injuries nor fatalities are likely to result but there is the potential for minor damage to infrastructure from surficial ground movement.

Climate change is likely to reduce the severity of solifluction due to the reduced season length and potentially higher temperatures.

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Thus, the Risk is Low as per the matrix below.

Table 8. Upper Doolans Creek Right Branch Solifluction Risk Matrix .

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

6.1.1 Mitigation Measures For Solifluction Risk

Mitigation of the risk from solifluction is primarily by selection of gondola tower location and founding depth below any potentially mobile soil. This is further mitigated by this being a slow process that occurs in Spring. Thus, should surficial movement occur that may threaten a tower or surface infrastructure then it may be addressed by mobilising a tracked excavator.

7 Debris Flow Risk

7.1 Debris Flow Risk East of Helicopter Ridge

There is a significant solifluction lobe southeast of Helicopter Ridge which is sufficiently deep to be considered a minor debris flow. The flow speed of this feature has been a slow creeping movement, but the quantity of material involved is greater than typical solifluction lobes.

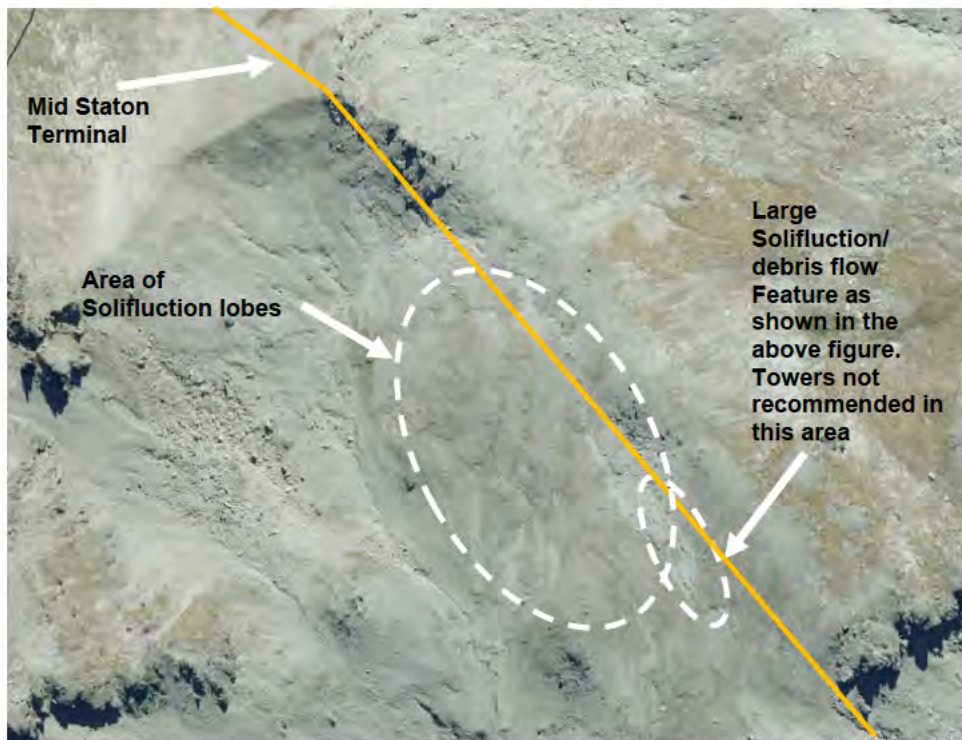


Figure 7. Debris flow & solifluction features in Upper Doolans Creek Right Branch



Figure 8. Large solifluction lobe/minor slow debris flow southeast of Helicopter Ridge with person for scale

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An expanded aerial view of this feature, plus part of the survey location drawing, is shown below.

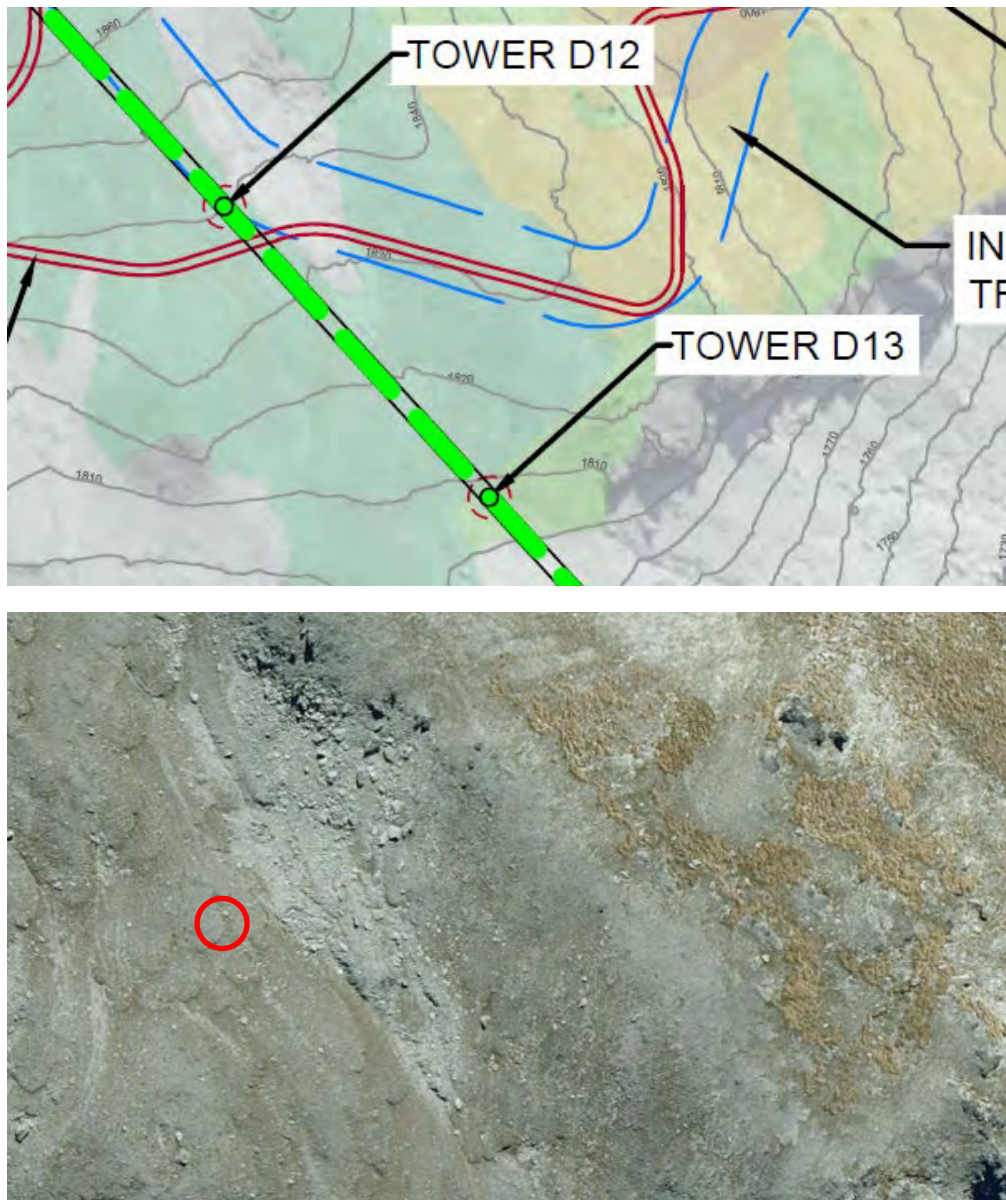


Figure 9. Expanded aerial view of solifluction/debris flow feature and approximate tower 12 location drawing

The solifluction/debris flow feature is up to approximately 2m maximum depth. This feature appears to be recent, as vegetation has not become established on the surface. This feature is likely to have been caused by water build up within the surficial material which has fluidized the debris and caused the flow. It is possible that this feature is caused by a solifluction mechanism where surficial material becomes saturated during snow melt (potentially combined with heavy rain) over top of the subsoil, which is impermeable due to either frozen ground or underlying rock. The resulting fluidized slurry has flowed down the slope.

This feature is in the vicinity of the proposed tower 12. Although we note that the Gondola supplier has not yet been selected and thus the tower details have yet to be developed.

The preliminary alignment indicates that the proposed tower 12 location is immediately west of the active lobe of the feature. Further setout and site investigation is required to confirm the location of the tower in relation to this feature. It is recommended that the tower is located in a location outside active lobes of this feature.

7.2 Debris Flow Within Doolans Creek Right Branch

Debris flow as a result of a landslide dam within Doolans Creek Right Branch is considered a possibility. Slipping of the bank, potentially as a result of erosion, saturation, or both may result in localised failures of the bank which could result in a natural dam forming. The dam may fail because of water pressure and cause a debris flow within the creek bed.

The Upper Doolans Creek Right Branch is deeply incised and thus a localised naturally occurring dam is a possibility.

The deeply incised nature of the upper Doolans Creek Right Branch is visible in the figure below.



Figure 10. Deep Vee shaped creek bed where a natural dam and resulting dam break may occur

The risk of such a dam forming and a resulting dam break is considered to be Rare. The consequences of a dam forming leading to a dam break are considered to be Minor as neither staff nor guests will be within the creek bed, and such an occurrence is more likely to be outside the winter period, when the creek is snow filled.

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The Risk Matrix for this possibility is shown below, and the risk is considered to be Low.

Table 9. Upper Doolans Creek Debris Flow Risk.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

7.2.1 Mitigation Measures For Doolans Creek Right Branch Risk

Debris flow in creeks such as this is a low, but present, risk. We have observed a number of debris flows in alpine streams, but these have generally been related to dams formed by trees combined with other debris and these have been in catchments steeper than the Doolans Creek Right Branch. These previous examples we are aware of have occurred in Fiordland where the terrain is steeper and tree covered and the potential rainfall is more intense. Thus, while this risk is considered Rare, it is possible.

Flood flows that carry a significant quantity of sediment are possible, if not likely, in the Doolans Creek Right Branch. But such high sediment events are not specifically a high density flossed granular debris flow or mudflow.

It is not anticipated that there will be people within the intake facilities during the sort of conditions likely to result in a debris flow. These conditions would be outside most ski area operating times of the year and in conditions where the stream will be too turbid for either snow making or potable water abstraction to occur. This is also a known risk during heavy rainfall and will be covered by standard operating procedures.

7.3 Debris Flow Within Rastus Burn Basin

The Remarkables Ski Area in the Rastus Basin includes numerous terrain modifications including trails, terrain parks, access roads, underground services and lift infrastructure. No areas of concern for significant debris flow have been identified in this area. There are areas of slope rilling erosion on the steeper slopes on the western side of helicopter ridge between the Curvey Basin Lift and the Sugar Bowl Lift. Intermittent avulsion of small amounts of scree debris occurs in these rills during heavy rain, but we do not believe that there is the opportunity for significant quantities of material to develop in these features which could lead to a larger debris flow. This area is shown in the google earth view below.



Figure 11. Area of localised rilling erosion where periodic avulsion occurs but there is no identified risk of build-up of sufficient material to result in a debris flow

8 Seismic Risk to Structures

The seismic risk associated with propagation of avalanches, rockfall or slips is covered in those specific sections of this report. This section addresses the seismic risks to manmade structures such as buildings, retaining structures, the gondola stations and towers and the snow making reservoir.

The structures will be designed to resist the loads imparted by earthquake calculated in accordance with the New Zealand Standard NZS 1170.5 Structural Design Actions Part 5: Earthquake Actions. This standard covers the loading on structures resulting from earthquakes. Loads derived from the methodology in this standard, plus specific design in accordance with the relevant New Zealand materials design standards (reinforced concrete, steel or timber), is the primary method of demonstrating compliance with Clause B1 (Structures) the New Zealand Building Code. All significant structures associated with the development will require specific design in accordance with this methodology.

The method for addressing seismic loads which structures are designed to resist involves a variety of factors, including the following.

- The importance level of the structure
- The location of the structure in terms of national seismic risk
- Proximity to identified major faults. If the site is within 20 km of an identified 'major fault' then an additional factor is applied (the 'near fault factor' $N(T,D)$). In the case of the Doolans Right Branch development this factor is 1.0 as the nearest major fault, the alpine fault, is greater than 20km distant from the site
- The foundation conditions and depth of underlying soil
- The seismic response of the structure and its natural period of vibration
- The structures ductility – i.e. how much will the design of the structure allow bending or plastic hinging without failure

The location of identified faults for which the Near Fault Factor $N(T,D)$ is shown in NZS 1170.5 as below, if a structure is located within 20km of an identified fault this additional factor applies.

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TABLE 3.6
MAJOR FAULTS REQUIRING NEAR-FAULT FACTORS > 1.0

Major faults requiring near-fault factors > 1.0
Alpine
Awatere
Clarence
Hope
Kakapo
Kekerengu
Kelly
Mohaka
Wairarapa
Wairau
Wellington



FIGURE 3.5 MAJOR FAULTS REQUIRING NEAR-FAULT FACTORS

Figure 12. Relevant part of NZS 1170.5 showing Major Faults for which a Near Fault Factor applies

The design of the reservoir structure is covered by the NZSOLD (New Zealand Society On Large Dams). the reservoir structure is not a large dam but will need to comply with the New Zealand Building Code and the mechanism for this is a design in accordance with the 'Dam Safety Guidelines'. The Dam Safety Regulations 2022 are not applicable as the reservoir structure is not a Classifiable Dam.

The design of buildings and gondola structures is covered by the relevant materials design standard. There are a variety of loads that buildings or the gondola structures are required to resist in addition to seismic loads. These individual load cases are covered by the relevant standard from the NZS 1170 suite of loading standards. These loads include live loads (such as crowds), dead loads of the structures themselves, wind loads, snow loads, and seismic loads.

Retaining structures will be designed in accordance with the relevant materials design standard typically using loads derived from section 6.0 of the Transit New Zealand Bridge Manual. Section 6.2 and 6.6 of this manual address seismic loading and the design of soil retaining structures.

8.1 Likelihood of a Design Level Earthquake

Using the New Zealand Standard NZS 1170.0, the ARI of design events is chosen on the basis of the importance level of the structure. The more important a structure is the longer the ARI is and the higher the resulting loads. This approach is similar for loadings including earthquake, snow and wind.

The structures associated with the development will generally be of importance level 2. The Gondola Carrier Stacking Building, which has a dual function as a Café area, will be Importance level 3 as more than 300 people can congregate in one area. The importance levels are defined in NZS1170.0 as follows:

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TABLE 3.1
CONSEQUENCES OF FAILURE FOR IMPORTANCE LEVELS

Consequences of failure	Description	Importance level	Comment
Low	Low consequence for loss of human life, or small or moderate economic, social or environmental consequences	1	Minor structures (failure not likely to endanger human life)
Ordinary	Medium consequence for loss of human life, or considerable economic, social or environmental consequences	2	Normal structures and structures not falling into other levels
High	High consequence for loss of human life, or very great economic, social or environmental consequences	3	Major structures (affecting crowds)
		4	Post-disaster structures (post disaster functions or dangerous activities)
Exceptional	Circumstances where reliability must be set on a case by case basis	5	Exceptional structures

TABLE 3.2
IMPORTANCE LEVELS FOR BUILDING TYPES—NEW ZEALAND STRUCTURES

Importance level	Comment	Examples
1	Structures presenting a low degree of hazard to life and other property	Structures with a total floor area of <30 m ² Farm buildings, isolated structures, towers in rural situations Fences, masts, walls, in-ground swimming pools
2	Normal structures and structures not in other importance levels	Buildings not included in Importance Levels 1, 3 or 4 Single family dwellings Car parking buildings
3	Structures that as a whole may contain people in crowds or contents of high value to the community or pose risks to people in crowds	Buildings and facilities as follows: (a) Where more than 300 people can congregate in one area (b) Day care facilities with a capacity greater than 150 (c) Primary school or secondary school facilities with a capacity greater than 250

Figure 13. Importance Levels as Defined in NZS 1170.0

The design seismic return period as defined in NZS 1170.0 is as below.

ANNUAL PROBABILITY OF EXCEEDANCE

Design working life	Importance level	Annual probability of exceedance for ultimate limit states			Annual probability of exceedance for serviceability limit states	
		Wind	Snow	Earthquake	SLS1	SLS2 Importance level 4 only
50 years	1	1/100	1/50	1/100	—	—
	2	1/500	1/150	1/500	1/25	—
	3	1/1000	1/250	1/1000	1/25	—
	4	1/2500	1/500	1/2500	1/25	1/500

Figure 14. Return Periods for various importance levels from NSZ 1170.0

Thus, the annual probability of seismic exceedance for importance level 2 structures is 500 years, but the annual probability of seismic exceedance for importance level 3 structures is 1,000 years. A 1/1000 ARI event is 1.3 times the load of a 1/500 ARI event. As per the table below.

RETURN PERIOD FACTOR	
Required annual probability of exceedance	R_s or R_n
1/2500	1.8
1/2000	1.7
1/1000	1.3
1/500	1.0

Figure 15. Return Period Factors for Earthquake from NZS 1170.5

Climate change is not believed to affect the earthquake risk.

8.2 Topographic Amplification

Topographic amplification is the increase in earthquake shaking resulting from the topography. This can lead to amplification of earthquake shaking on hill tops, ridge lines and steep slopes.

Currently New Zealand standards do not specifically address topographic amplification. Guidance on this subject is currently largely related to academic studies and there is little clear guidance for the application of such factors. We note that factors to increase seismic loads were applied to the Skyline Gondola towers and structure as part of the design, however this is a particularly steep ridge and is prone to this effect.

It is uncommon to apply topographic amplification factors for such structures unless there are specific features such as steep slopes, peaks or pronounced ridges. In the case of the gondola alignment, steep or pronounced features are not present. Topographic amplification factors have not been applied to the construction of any chairlifts or gondolas constructed in the Southern Lakes area other than the Skyline Gondola.

Neither the current version of Structural Design Actions NZS 1170.5 nor the draft for public consultation DZ TS 1170.5 2024 reference topographic amplification

8.3 Seismic Risk Matrix for Structures

The Risk Matrix for Seismic Risk to Structures is shown below.

Alpine fault ruptures have occurred on average at 250-year intervals over the last 4,000 years. The last significant Alpine Fault rupture was in 1717, 309 years ago. Published figures are that there is a 75% chance of a magnitude 8 alpine fault earthquake in the next 50 years. This may occur at any location along the fault. An alpine fault earthquake would have Major consequences, but may occur some distance from Queenstown and thus,

would not necessarily provide shaking at the level of an ultimate limit state event in Queenstown.

The ARI of a design level earthquake is 1/500 years for an IL2 building and 1/1000 for an IL3 Building. Thus, NZS 1170.0 identifies that the likelihood of a Design Level earthquake is 'Rare'.

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However, if we consider the published likelihood of a design level earthquake in the next 50 years, then the likelihood of a significant earthquake accruing is as per the matrix may be 'likely' to 'Possible'. This would change the risk outcome from matrix to "High" risk.

Irrespective of whether an ultimate limit state earthquake was to occur within either 50 years or 500 years, the loads to which the structure would be designed to resist would be the same in accordance with the NZS 1170.5

Table 10. Seismic Risk Matrix.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

8.3.1 Mitigation Measures For Seismic Risk

The seismic risk to structures proposed as part of the development are mitigation by compliance with the New Zealand Building Code. This is achieved by Clause B1 verification method 1, which requires that loads are calculated in accordance with the relevant New Zealand Standard, as identified below.

- NZS 1170.5:2004 Earthquake Actions Standard
- NZS 3404:1997 Steel Structures Standard
- NZS 3101:2006 Concrete structures Standard
- NZS AS 1720.1:2022 Timber Structures
- Transit New Zealand Bridge Manual (in relation to retaining structures)

9 Wind Risks

In this section we undertake the following.

- Provide an initial description of the calculation of wind speeds
- Specific calculation of the wind speeds for the Gondola Base Station, Helicopter Ridge Mid Station and the Doolans Creek Right Branch Return Station.
- Describe wind mitigation measures
- Provide the Risk Matrix for wind issues.

9.1 Wind Speed Calculation

New Zealand alpine regions are prone to wind speeds and wind run equal to any other place on earth. Wind speeds calculated in accordance with 'NZS 1170.2:2021 Structural Design Actions, Part 2: Wind Actions', will frequently predict ultimate limit state wind speeds more than 300 km/h in exposed alpine sites for an importance level 2 building. The terminal velocity for a falling human is approximately 200 km/h and thus this wind speed is more than sufficient to lift a person into the air. This speed is also more than sufficient to cause erosion of granular ground surfaces.

There is industry acceptance that NZS 1170.2 predicts unrealistically high wind speeds for exposed sites. This includes the following industry warnings and publications:

Wind Loading Handbook for Australia & New Zealand, which states that:

- Extreme wind speeds in complex terrain (including alpine ridges and escarpments) are poorly represented by observations
- The standard therefore intentionally adopts conservative topographic multipliers where data are sparse
- Users are warned that local measurements frequently do not reach the design values predicted by the Standard in mountainous terrain

Holmes (2017, 2015): "Direct commentary on alpine conservatism" and "*The Australasian Wind Actions Standard AS/NZS 1170.2 – recent & future developments*" (2017)

- Notes systematic conservatism in topographic and terrain multipliers
- States that alpine escarpment amplification is likely overestimated relative to field data
- "*Observations from mountainous regions suggest that the present topographic speed-up multipliers are often conservative, particularly for narrow ridges and alpine summits.*"

BRANZ (Building Research Association New Zealand) report that;

- Wind speeds in alpine South Island locations rarely approach AS/NZS 1170.2 design gusts
- Terrain category and topographic multipliers dominate the result more than regional climate

Standards New Zealand acknowledge the limitation. Both AS/NZS 1170.2:2011 and :2021 include non-normative caveats:

- Design wind speeds are based on regional statistical extrapolation
- No guarantee is made that local terrain effects are accurately reproduced
- Alpine sites are outside the density of calibration data

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Consequently, NIWA have developed an alternative model for the prediction of wind speeds at particularly exposed sites. This model is applicable to a variety of applications including alpine structures. The NIWA model is accepted, defensible, and can this analysis produces a wind speed of approximately 80% of the result gained using NZS 1170.2 for exposed sites.

To inform structural design, and risk mitigation, we calculated wind speeds for the three IL2 Gondola Stations and the IL 3 Gondola Carrier Stacking/Café building Using NZS 1170.2. We do not consider that the results obtained for the Gondola Mid Station on Helicopter Ridge using NZS 1170.2 are credible, and we engaged NIWA on behalf of NZSki to undertake an alternative ultimate limit state speed calculation for the Gondola Mid Station site. The results of these calculations are summarised in the table below.

Further assessment of ultimate limit state wind speed will be required prior to detailed design, but these figures demonstrate the level of wind speed at each of the sites.

9.1.1 Wind Speed Calculation Summary

The wind speeds for the Gondola Stations and the comparison between the calculation using 'Check Wind' and the NZS 1170.2 methodology vs the check calculation undertaken for the Gondola Mid Station by NIWA, is summarised in the table below.

Table 11. Summary of wind speed calculations at Gondola Station Sites using two methods.

Site (Importance level 2, ARI 500-years)	'Check Wind ' using NZS 1170.2	NIWA calculation methodology
Rastus Burn Gondola Base Station at 6m height	89.9 m/s (323 km/h)	Not calculated
Helicopter Ridge Gondola Mid Station at 7m height for (comparison)	101.6 m/s, (365.8 km/h)	Not calculated
Helicopter Ridge Gondola Mid Station at 10m height	105.15 m/s, (378 km/h)	80 m/s
Doolans Creek Right Branch Gondola Return Station 10m height	71 m/s (255.6 km/h)	Not calculated
Site (Importance level 3, ARI 1,000-years)		
Doolans Creek Right Branch Gondola Carrier Stacking Building/Café 10m height	72.6 m/s (261 km/h)	Not calculated

9.1.2 Importance Levels and Return Period

The Gondola Stations have been assumed to be Importance Level 2 structures as defined in 'NZS 1170.0:2002 Structural Design Actions Part 0:General Principals'. Importance Level 2 buildings are 'normal' structures which do not have more than 300 people congregating in one area (within the station structure) and are not designated for post disaster function.

The Gondola Carrier Stacking building, which doubles as a Café, can accommodate more than 300 people and is thus an importance level 3 building

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The ultimate limit state wind speed for a building with an importance level 2 building, with a 50-year design life, has a 1/500-year Average Return Interval (ARI). The ARI for an importance level 3 building is 1/1000. The relevant sections of this standard are shown below.

TABLE 3.3
ANNUAL PROBABILITY OF EXCEEDANCE

Design working life	Importance level	Annual probability of exceedance for ultimate limit states			Annual probability of exceedance for serviceability limit states	
		Wind	Snow	Earthquake	SLS1	SLS2 Importance level 4 only
50 years	1	1/100	1/50	1/100	—	—
	2	1/500	1/150	1/500	1/25	—
	3	1/1000	1/250	1/1000	1/25	—
	4	1/2500	1/500	1/2500	1/25	1/500

Figure 16. Return period requirements for wind snow and earthquake from NZS 1170.0

'Ultimate limit state' wind speed is the maximum load the structure is designed to resist before serious structural damage or collapse will occur. There are operational limits of the gondola which are significantly less than the ultimate limit state wind speed. At the operational limits actions taken include stopping operations and removing the carriers from the rope.

9.1.3 Gondola Base Station Ultimate Limit State Wind Speed

The Gondola Base Station terminal will be located adjacent to the existing base building in the Rastus Burn. The 500-year ARI wind speed calculated using 'Check Wind' software, using the methodology in NZS 1170.2 was 89.9 m/s (323 km/h) at 6m height.

The assumed dimensions of the Base (Drive) Station are as shown in the figure below. We understand that this structure will be partially set down into the car park level and thus a height of 6m has been used in the calculation.

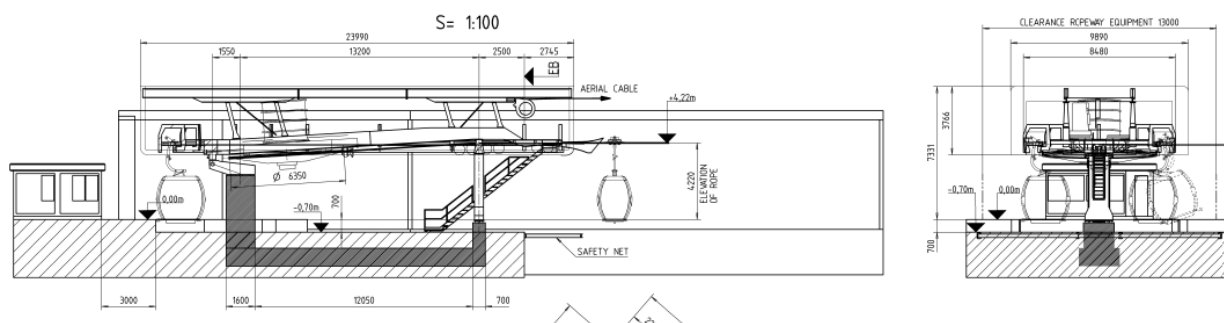


Figure 17. Assumed Gondola Base Station Dimensions From Doppelmayr (Gondola Supplier not yet selected)

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The location used for the wind speed calculation is as shown below.

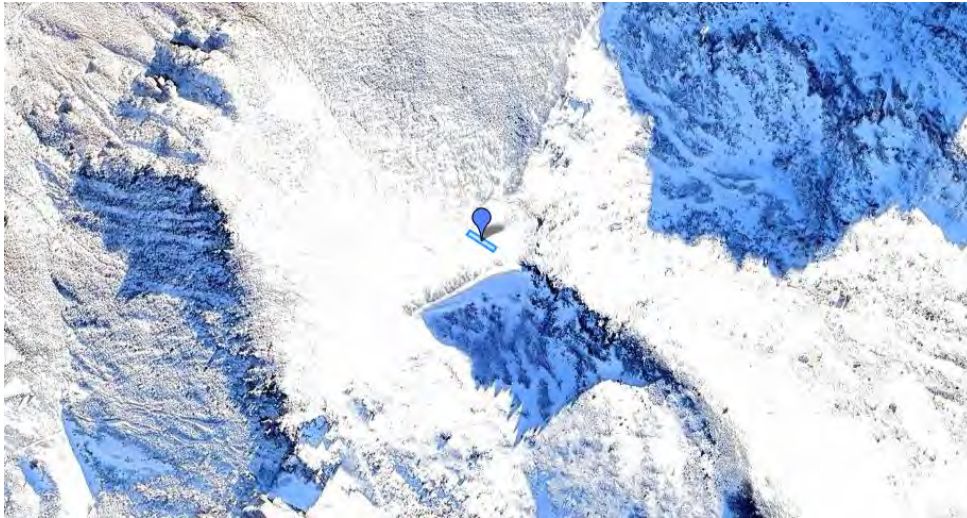


Figure 22. Site used for wind speed calculation of the gondola mid station

The windswept nature of the site is visible in the figure below. It is conceivable that the wind speed has been a contributing factor to surface erosion at the site.



Figure 23. Windswept location of the mid station terminal

9.1.5 Gondola Return Terminal Ultimate Limit State Wind Speed

The approximate dimensions of the Doolans Creek Right Brach Return Terminal are as shown in the figure below. A height of 10m has also been used for this calculation which may also be conservative and is dependent on the final layout of the structure.

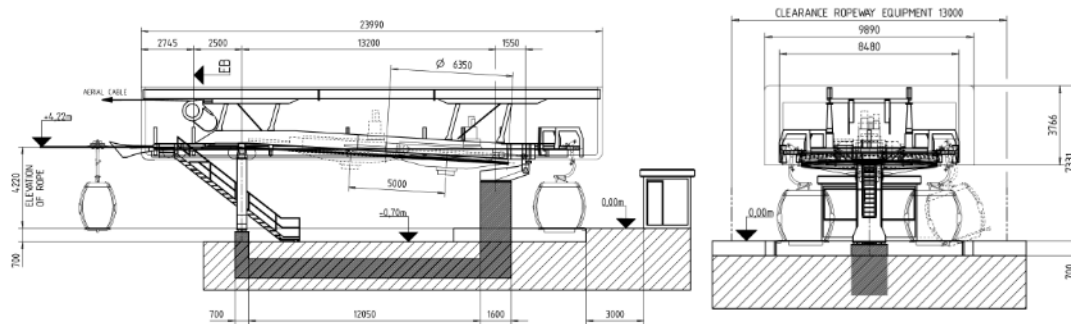


Figure 24. Approximate dimensions of the Doolans Gondola Return Terminal From Doppelmayr (Gondola Supplier not yet selected)

The maximum wind speed calculated for a 1/500-year event for the Doolans return terminal using NZS 1170.2 with the dimensions above, is approximately 71m/s or 255 km/h and is from the west. This wind speed is typical for this type of installation in the area and less than experienced in exposed locations. Chair lift top stations are typically exposed to wind speeds of up to approximately 300 km/h. The wind speed calculations for the Doolans return terminal site are shown in the figure below.

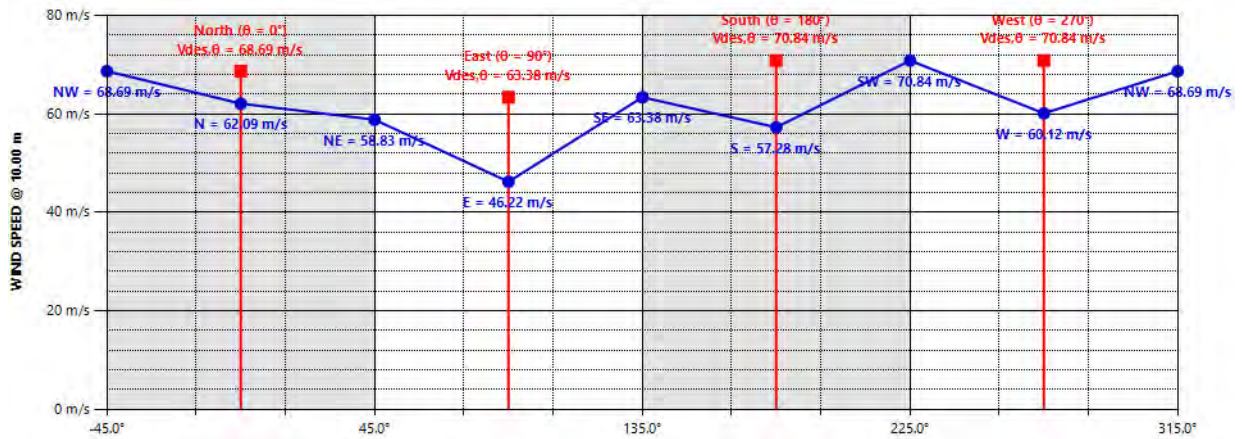


Figure 25. 70.84 m/s wind speed at 10m height for 500-year ARI at Doolans Creek Right Branch Gondola Return Terminal using the 1170.2 methodology

9.1.6 Gondola Carrier Stacking/Cafe Ultimate Limit State Wind Speed IL3 Building

The wind diagram for the importance level 3 Carrier Stacking/Café building at the Gondola Return Station in the Doolans Creek Right Branch is as shown below, the maximum wind speed is 72.6 m/s (261.4 km/h) at 10m.

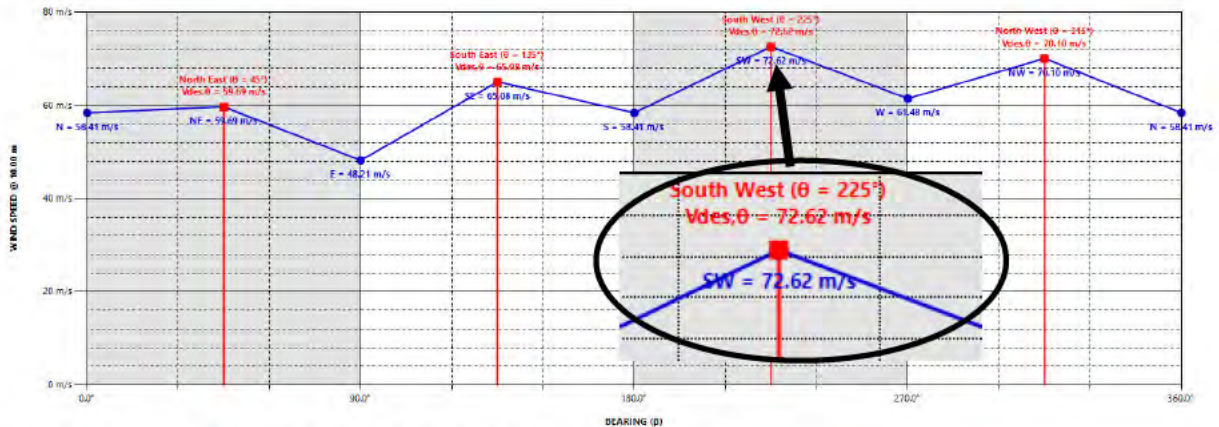


Figure 26. Wind diagram for IL3 Carrier Stacking/Cafe building

The location for the calculation is as shown below.

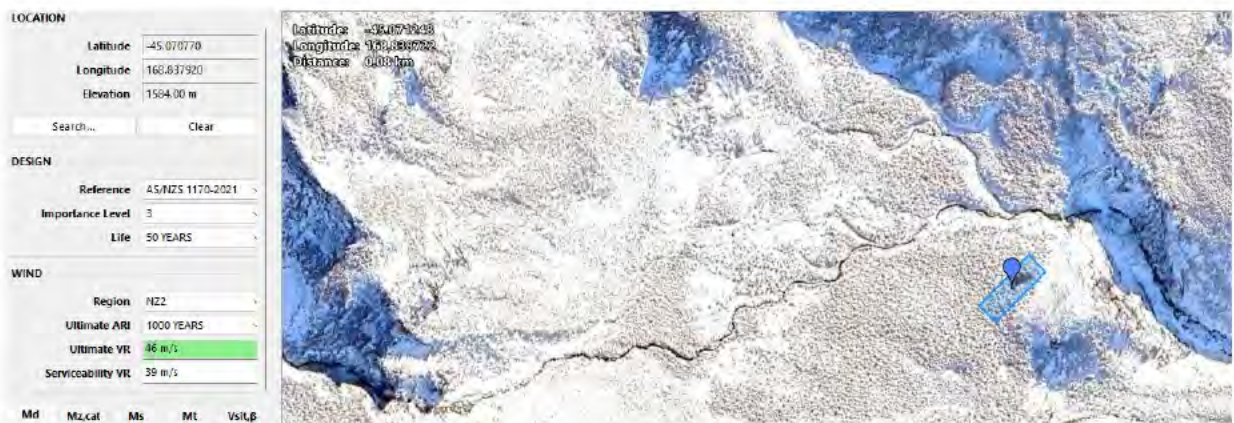


Figure 27. Location for wind speed calculation for Carrier Stacking/Cafe Building

9.2 Wind Mitigation Measures - Gondola

The potential ultimate limit state design wind speeds for the Gondola Base Station and Return Station are typical of what can be expected in an exposed alpine site. We do not consider that the result of 105.15 m/s (378.5 km/h), calculated for the Gondola Mid Station using NZS 1170.2 is credible, and we have obtained the alternative calculation from NIWA, using their proprietary wind speed prediction model, of 80 m/s km/h, 288 km/h. The ultimate limit state wind speed provided by NIWA is high but is within the limits of what is credible and achievable for structural design of both the station and the towers. Wind drag is proportional to the square of the wind speed, consequently wind drag increases dramatically with wind speed.

The rope load on the top and bottom station significantly exceeds the potential wind load as the rope tension can be in the order of 100 tonnes. Consequently, extremely robust station masts and station foundations are required. The strength required from the masts and machine deck required to resist rope loads exceeds the strength requirement to resist wind loads on the stations. Consequently, cladding and other such secondary items are more likely to be damaged before structural damage occurs to the masts or structural components required to resist rope loads.

The longitudinal and transverse wind loads on the towers (transverse loads are higher due to the rope area) are a design case for the tower stability and are generally similar to seismic loads.

There is currently insufficient data to comment on the number of days when the wind speed exceeds the operational speed for lift operation. This information is currently being collected by a fixed anemometer.

It is not uncommon for ski lifts around the world to be closed due to wind. The gondola manufacturer supplies wind speeds rules for lift operation. At an initial stated speed, the lift will be closed to passengers, at higher wind speeds the carriers are removed from the gondola or lift. The carriers are detachable to allow carrier passenger loading and unloading and to allow carrier stacking. A spring-operated jaw arrangement clamps the carrier onto the rope. An example is shown in the picture of the skyline gondola below.



Figure 28. Detachable carrier and an example of the carrier rope grip

In the case of the Doolans Gondola the carriers will be stored in the carrier stacking building at the Doolans Creek Right Branch return station. At ultimate limit state wind speed the towers and sheaves are not designed to have the carriers fixed on the rope. Nor would it be safe for the carriers to be attached at wind speeds approaching the ultimate limit state wind speed as there is a risk of damage to the carrier, failure of the carrier grips, or the added wind drag on the carriers derailing the rope or even causing collapse of a tower.

9.3 Wind Mitigation Measures - Alpine Buildings

9.3.1 Previous Wind Damage to Alpine Buildings

Wind speed and its effects on alpine structures is a known issue and requires appropriate Robust Engineering solutions. Examples of some recent wind to alpine buildings damage include:

- In 2016 approximately \$100,000 worth of damage was caused to windows on the Remarkables by wind load and wind-borne rocks from the car park. No structural damage was caused to the building.
- In 2025 a number of polycarbonate panels were damaged by wind and flying debris impacts on the conveyor lifts at the Remarkables. No damage to the chassis or foundations occurred was caused
- In 2025 a number of doors on the Remarkables base building were blown open by wind and caused damage to the cladding.
- A historic failure occurred in 1977 when 'Three Johns hut' on Barron Saddle at Aoraki Mt Cook was blown away with four fatalities.

Since the Three Johns tragedy understanding of the risk of wind plus the building code requirements have significantly improved. Structural design of buildings and alpine structures is well covered by existing Standards, specifically 'AS/NZS 1170.2:2011 Structural design actions Part 2 Wind actions'. We are not aware of any recent significant structural failures caused by wind to alpine buildings which have been designed in accordance with current loading and materials design standards. We are aware of some recent failures of buildings which have had either no, or insufficient, Engineering input. The current satisfactory performance of Engineered buildings in the alpine environment is a result of robust designs, current standards and industry understanding of the risk of wind. There are numerous architectural details appropriate for wind prone buildings and structures including door and window details and materials. Such selections are part of detailed design and require appropriately experienced designers. With appropriate structural design and detailing recent alpine buildings in New Zealand have performed satisfactorily. Plateau Hut on Aoraki Mt Cook is an example of a robust alpine building incorporating robust structural design with detailing for wind resistance. This building is 20 years old and has weathered numerous alpine storms. The detailing includes an entry vestibule structure to mitigate direct wind loading on the door leaf.



Figure 29. Plateau Hut on Aoraki Mt Cook with a combination of structural design and architectural detailing for wind such as the vestibule over the door

Ultimate limit state wind speeds would be a significant threat to life for people outside. These risks result from windblown objects, exposure to cold and wet plus the risk of being physically carried away by the wind. It is inappropriate for people to be outside during a storm approaching ultimate limit state wind, and this risk would be addressed by the ski area’s operating procedures.

9.4 Wind Risk Matrix

The ultimate limit state wind speed has a 1/500-year ARI and is consequently Rare. The potential outcome of design level winds would be Major but not Catastrophic as it is unlikely to result in death as in such a storm people would have departed the mountain or made themselves safe in the base building basement. Consequently, the wind risk can be considered medium if the buildings and structures are appropriately designed.

Table 12. Wind Risk Matrix.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

10 Global Land Stability Risk

10.1 Global Land Stability Risk in the Upper Doolans Creek Right Branch

A specific site walkover of the gondola and chair lift alignments was undertaken in March 2025. No significant land slide areas were identified along the route of the gondola either during the walk over or in a review of aerial photographs.

We note there is a large rock glacier feature within the Upper Doolans Creek Right Branch. This is an ancient feature and is no longer moving as there is no longer permanent ice in the area. The last glaciation in the area was the Ōtira Glaciation, which was at a peak approximately 16–18,000 years ago, and ended approximately 10,000 years ago.

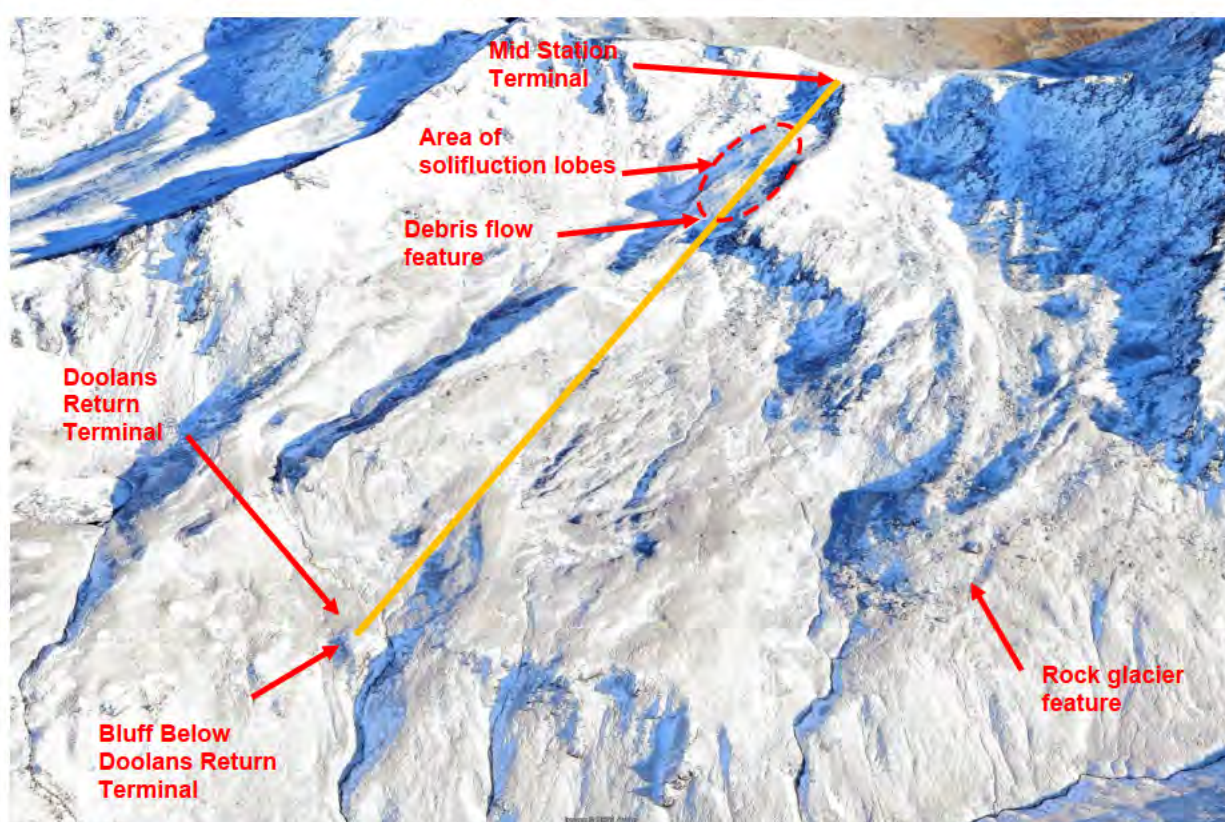


Figure 30. Large rock glacier feature (arrowed) and the approximate gondola alignment and features in Upper Doolans Creek Right Branch

The Doolans Return Terminal is located above, and near, an existing bluff. In this location the foliation of the schist is favourable and approximately horizontal and thus there is a low risk of sliding along the schist planes. No signs of settlement or land movement were detected in the area but there remains a potential risk of localised block toppling failure or failure along joints at the upper part of the feature which may compromise the station foundations. A preliminary assessment indicates that it is prudent to found the base station approximately 15m from the bluff shoulder as this places the station beyond unstable joint sets which are potentially unstable. Visual inspection of the site did not detect evidence of significant joint sets which could pose a risk of block toppling. As part of detailed design further

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investigation is recommended to confirm this. Should investigation identify joint sets be located which may compromise the founding of the Gondola Return Station this risk can be mitigated by drilled ground anchors to secure any such blocks to the underlying rock mass.

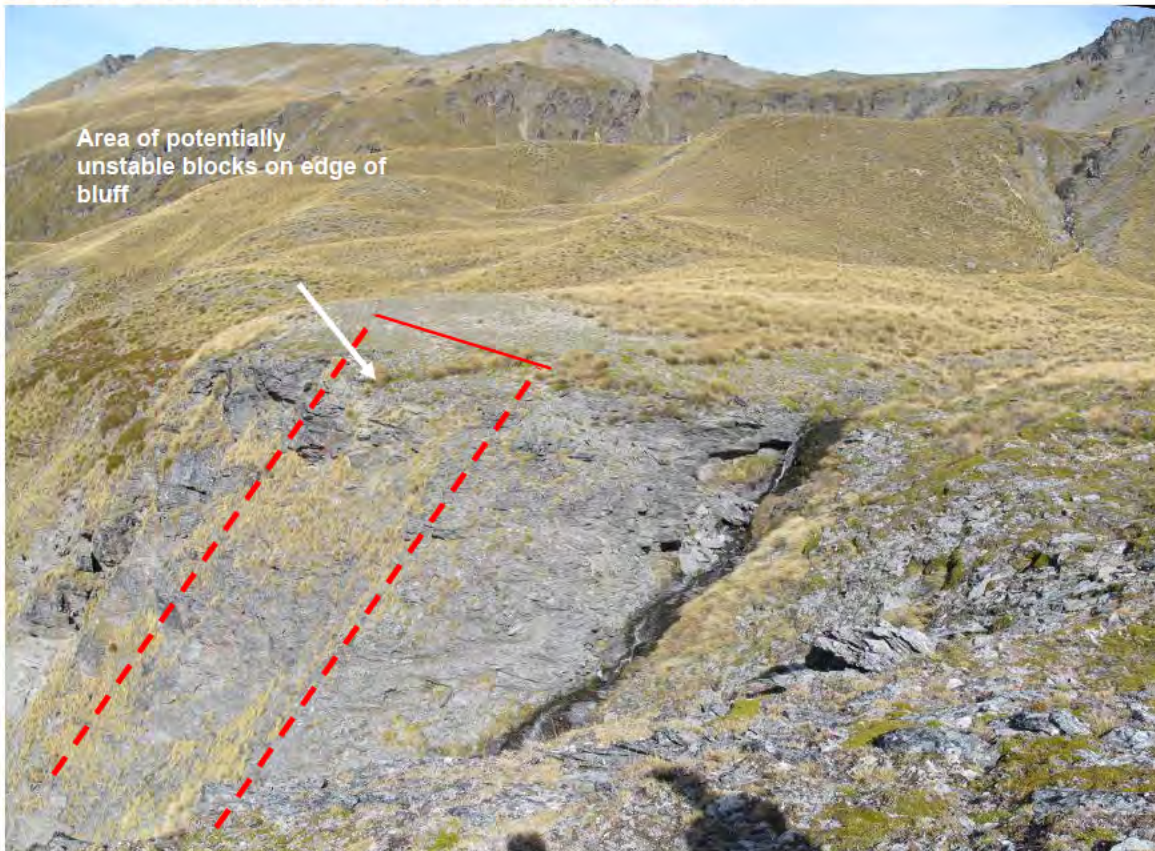


Figure 31. Bluff and nominal location of Doolans Terminal structure



Figure 32. Nominal Doolans terminal location viewed looking east

10.2 Doolans Creek Right Branch Global Land Stability Risk Matrix

The Likelihood of a Global Land Stability issue occurring within the Upper Doolans Creek Right Branch is considered to be very rare. The Consequence of such an occurrence would have potentially Major consequences to infrastructure. Thus, this is assessed as a Medium level risk as per the matrix below.

Table 13. Doolans Creek Right Branch Global Land Stability Risk Matrix .

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

10.2.1 Doolans Creek Right Branch Global Land Stability Risk Mitigation

As noted previously the risk assessments in this document relate to residual risks after mitigation measures have been implemented. The likelihood of global landside in the Doolans Basin is assessed to be Very Rare. Should propagation of a large landslide begin, this will be associated with initial land displacement. Such an event is likely to be evident and is likely to sever or obstruct infrastructure such as piped services, optical fibre cables or the Gondola cable. Consequently, the initiation of land movement is likely to be immediately apparent and appropriate inspection and subsequent action can be taken. Irrespective of this, the likelihood of a large landslide is a Very Rare event.

10.3 Global Land Stability Risk in the Upper Rastus Burn Basin

Extensive development has already been undertaken in the Upper Rastus Burn basin where the existing Remarkables Ski Area facilities are located. There are no identified areas of significant global instability in the existing ski area operations in the Remarkables. Multiple investigations have been undertaken for previous infrastructure in the area. These previous studies have not identified areas of significant global instability that would adversely affect the proposed infrastructure. These previous studies include the following.

- Curvey Basin Top Station Preliminary Site Engineering Report, MWH limited, 2013
- Remarkables Ski Area Upgrade, Base Building and Curvey Basin Lift Bottom Station Site Investigation Report, MWH limited, 2013
- Rockfall Assessment Above Proposed Curvey Basin Top Station, MWH Limited, 2013

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- Remarkables Ski Area Site Risk Assessment for Proposed New Base Building, MWH limited, 2014
- Remarkables Ski Area, Undergrounding of Snow Making Pipe Adjacent to Lake Alta, report, MWH limited, 2016
- Sugar Bowl Lift Replacement Natural Hazards Assessment, Stantec, 2018
- Cut Batter Slope Review for the new Sugar Bowl Trail, Stantec, 2021
- Design of Chair Stacking Building for Shadow Basin Lift, site investigations, Stantec, 2022
- Remarkables Maintenance Building Natural Hazards Assessment, Stantec, 2024
- Proposed Remarkables Shadow Basin Replacement Lift Geological Risk Assessment, Stantec, 2023
- Proposed Remarkables Access Road and Carpark 2 Works, geotechnical and stormwater concept review, Stantec, 2022
- Remarkables Road Risk Report, 2025, Stantec
- Doolans Basin Development Natural Hazards Assessment for Gondola and Chairlift Lines, 2025, Stantec

Thus, the risk of global instability affecting the Rastus Burn ski area facilities is assessed to be low.

The Likelihood of a Global Land Stability issue occurring within the Upper Doolans Creek Right Branch is considered to be very rare. The Consequence of such an occurrence would have potentially Major consequences to infrastructure. Thus this is assessed as a Medium level risk as per the matrix below.

The risk of Global Land instability in the upper Rastus Burn Basin is assessed in the Risk Matrix below. The risk of global land movement within the area of the development is assessed to be Very Rare as there are no identified areas of significant instability within the Upper Rastus Burn. The consequence of global land movement would be Major as significant damage to infrastructure is the potential result. Thus, this has been assessed as a Medium Risk

Table 14. Global Land Stability Upper Rastus Burn Risk Matrix.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

10.3.1 Rastus Burn Global Land Stability Risk Mitigation

Similar to the Upper Doolans Creek Right Branch global landslide risk the risk likelihood of such an event is considered to be Very Rare. Similar circumstances apply, to the Rastus Burn Basin. It is anticipated that any large-scale landslide event will commence with initial deformation which is likely to have an immediate effect on existing infrastructure. Thus any such movement is expected to be nearly immediately obvious and appropriate inspection and action can be taken. Such an event is likely to have major implications for infrastructure within the area.

10.4 Gondola Rockfall Risk Rastus Burn Side

Some areas of minor rockfall risk exist along the gondola rope alignment, but there are no towers proposed to be located in areas threatened by potential rockfall and consequently we do not anticipate towers being struck by falling rocks.

On the north-western (the existing Remarkables Rastus Burn Ski Area) side of Helicopter Ridge, the gondola line passes over bluffs known as the Gallipoli Chutes. This area is shown in the figure below.



Figure 33. Gallipoli Chutes

Within the chutes there are a number of perched rocks which are at risk of becoming unstable, particularly in an earthquake. These features are shown in the figures below.



Figure 34. Potentially unstable rocks in the Gallipoli Chutes

The risk of damage to gondola infrastructure from rocks falling from Gallipoli Chutes is low because the lift towers will not be located in an area identified as being threatened by rockfall. This is demonstrated in the figure below.

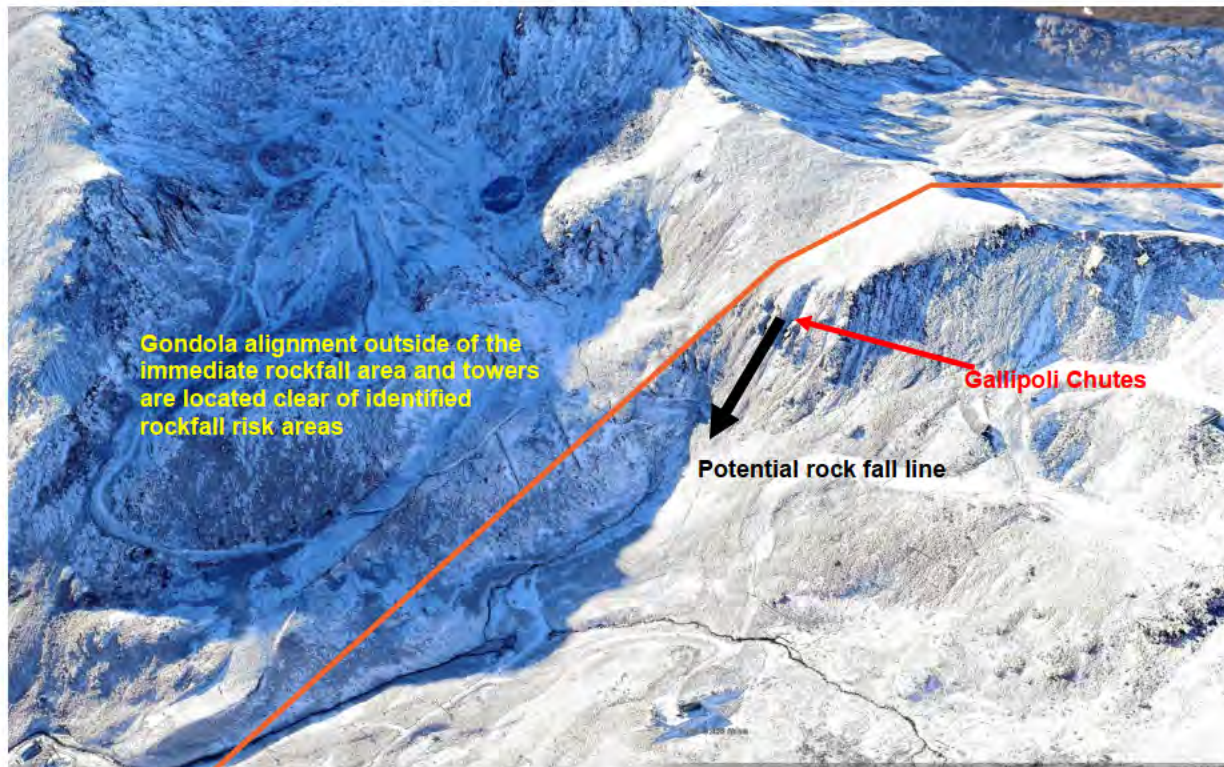


Figure 35. Gondola alignment vs potential rockfall line from Gallipoli Chutes

10.5 Gondola Rockfall Risk Doolans Side

On the south-eastern side of Helicopter Ridge there is a rocky spine where there are a number of perched rocks. These are shown in the figure below. There has been rockfall from this area in the past. Some of the rocks remaining higher on the ridge may be mobilised by a sufficiently large earthquake and remain a risk to gondola towers. The risk to the gondola towers from the lower section of the ridge is mitigated by the potential rockfall being directed to the east of the gondola line.

We recommended that either

- towers are not located in the area indicated below which is threatened by the higher of the two rock features, or
- remove potentially unstable rocks during construction of the gondola to remove the risk. We anticipate that it will not be a difficult task for a sufficiently large excavator.



Figure 36. Rock spine with previous rockfall and the approximate alignment of the rope shown



Figure 37. Potentially unstable rocks viewed from immediately below the ridge line

10.5.1 Rockfall Risk Matrix for Gondola Alignment

The risk of Rockfall along the proposed gondola alignment is assessed in the Risk Matrix below. The Likelihood of global land movement within the area of the development is assessed to be Unlikely if the potentially loose rocks identified in this report are removed. The likelihood of rockfall to the structure on

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the Rastus Burn side is assessed as very Rare as the gondola structures are clear of areas of potential rockfall risk. The consequence of a rockfall is assessed as Major because of the potential structural damage to the structure or the risk to human life, although the risk to life is mitigated by rockfall being both less common during winter and being attenuated by the presence of snow. Thus, this has been assessed as a Medium Risk

Table 15. Gondola Alignment Rockfall Risk Matrix .

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

10.5.2 Gondola Alignment Rockfall Risk Mitigation

The risk to the Gondola infrastructure will be reduced by tower location selection and removal of specific rocks which may threaten tower locations. There is no apparent rock fall risk to the Gondola Stations. The towers themselves are robust structures and while rock fall has the potential to cause significant damage to a tower by bending it, collapse of a tower resulting from rockfall is considered to be a very unlikely as the towers are ductile and bending and deflection of the rock is far more likely.

10.6 Rockfall Risk from Ridge Above 'Swan Lake'

An access route is proposed to be constructed between the top of Sugar Bowl lift and Helicopter Ridge. This alignment traverses below a steep rocky ridgeline. This rocky ridgeline contains numerous large and potentially unstable, rocks. The apron below this area contains numerous large rocks which have fallen from the bluffs above. Immediately above 'Swan Lake' is a very large rockfall feature where a significant part of the ridgeline has collapsed and fallen to Swan Lake Below. These features are indicated in the figures below.

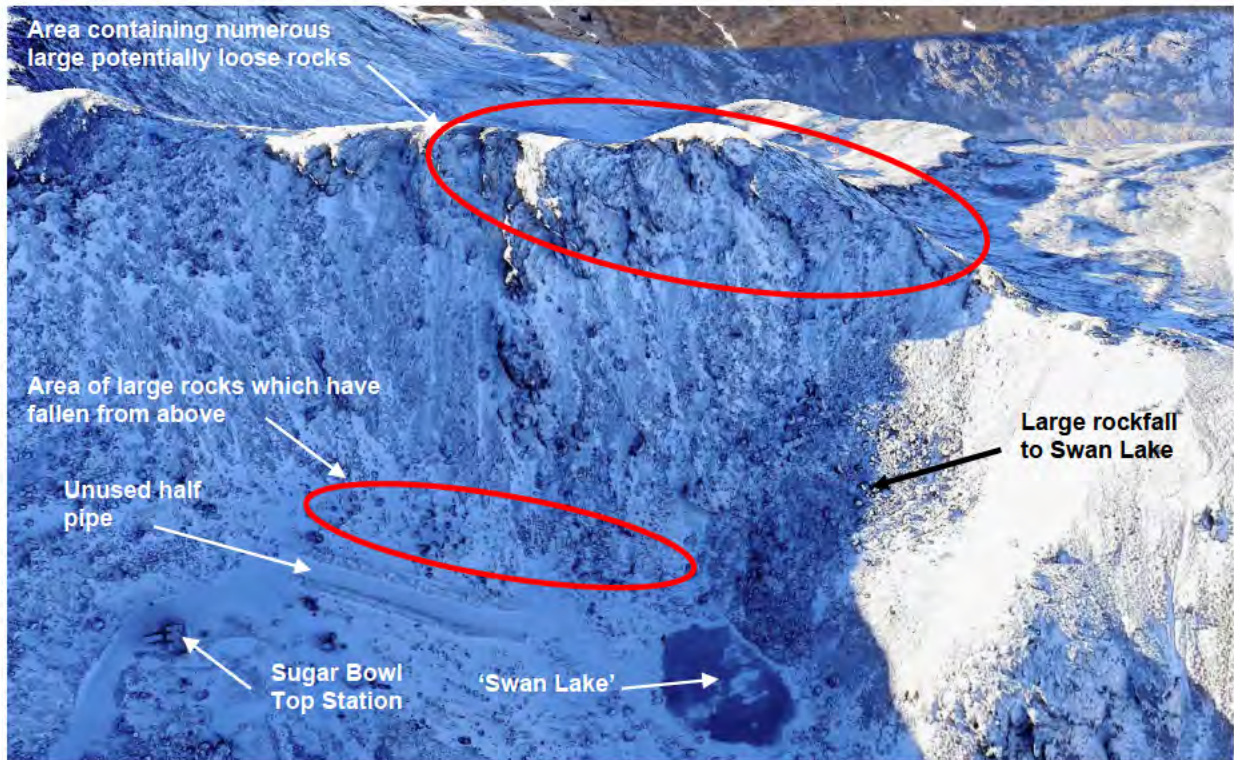


Figure 38. Ridge features between Sugar Bowl and Helicopter Ridge

The debris field, where large rocks have fallen from above, is shown in the figure below.



Figure 39. Debris field of large fallen rocks (and part of the unused half pipe) below the ridge line. Nominal route of proposed temporary access shown as broken line.

Large and potentially loose boulders along this ridge line are shown in the figure below.



Figure 40. Locations of potentially unstable rock along the ridgeline



Figure 41. Numerous perched blocks along the ridge line



Figure 42. Perched boulders on western side of ridge

It is certain that rocks will fall from the ridgeline to the west. This rockfall will threaten the proposed temporary construction access route. The risk of rockfall is increased by rainfall, freeze thaw conditions or earthquake. Significant multiple rockfall is almost certain during an earthquake. The rock mass instability in this location is not a function of sliding on the dip of the schistosity but is controlled by conjugate joint sets in the rock mass. This has resulted in multiple wedge failures and resulting in block toppling. The size of the potential falling rocks is large, potentially up to 20 tonnes, and there appears

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to be numerous rocks in the one tonne range. The fall to the road below is up to approximately 120m of elevation over a distance of as short as 160m. Consequently, during summer falling rocks may be bouncing and airborne as they intersect with the potential road alignment.

10.6.1 Rockfall Risk Matrix for Ridge above Swan Lake

The risk of Rockfall beneath the ridgeline above Swan Lake is assessed in the Risk Matrix below. The Likelihood of rock fall along this route is assessed hitting a vehicle or person is assessed as Possible due to the relatively low traffic volume. A rock impact on a vehicle or person is likely to be fatal. The Consequence is assessed as Major because of the risk to human life, although the risk to life is mitigated by rockfall being both less common during winter and being attenuated by the presence of snow. Thus, this has been assessed as a High Risk.

Table 16. Ridge Above Swan Lake - Rockfall Risk Matrix .

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

10.6.2 Road Above Swan Lake Rockfall Risk Mitigation

The High Risk identified in the matrix above is the residual risk considering the mitigating circumstances. These mitigating circumstances include:

- Expected low use of the road in the summer, initially by construction vehicles and then intermittent ongoing summer use by maintenance vehicles.
- In winter the route may be used by groomers or as a return ski trail. During winter the risk of rockfall is reduced by rocks being frozen in and fall impacts attenuated by the presence of snow.

We note that the risk of rockfall may be increased by spring thaw.

A significant earthquake is likely to release numerous rocks from the bluff above, and the road below would be a dangerous place in such an event. The primary mitigation measure is the short duration and relatively low usage of the road, as road users cannot practically be protected from the effects of a possible rock impact. After these considerations the route remains a High Risk.

10.7 Rockfall Risk from Ridge Above Snow Making Reservoir

There is a rocky ridge extending southeast toward the proposed snow making reservoir. This ridge contains a number of rocky tors and has been inspected to identify rockfall risk. This ridge line is indicated in the view below.



Figure 43. Ridgeline above snow making reservoir

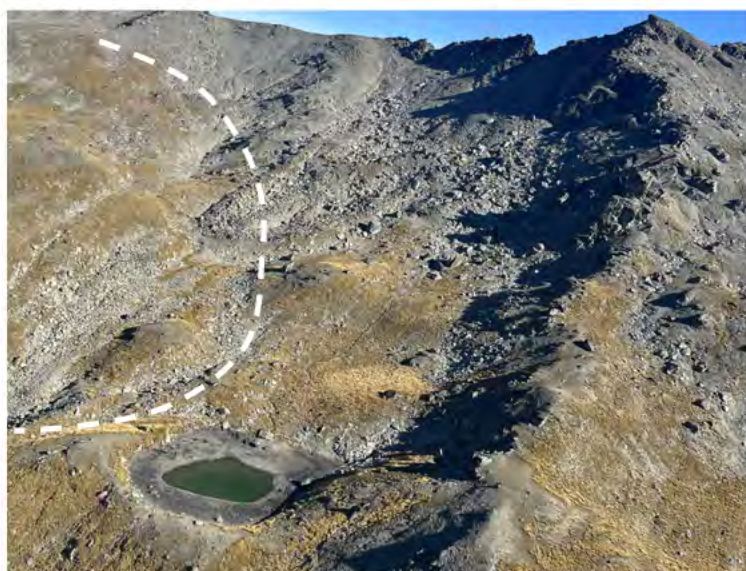


Figure 44. Ridgeline above Snow Making Reservoir, nominal route of trail and access marked in white

Rock mass stability along this ridge is controlled by block sliding along the dip of the schistosity. There are numerous large blocks which have detached from the rock along the ridge and slid/toppled to the scree slopes below. Most blocks which are potentially unstable appear to have previously detached

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from the ridge and there are few significant remaining blocks. This is shown on the figure above and below.



Figure 45. Ridge line and schistosity dipping to bottom left

At the upper part of the ridge, there are a variety of large blocks above a blocky talus slope. These blocks may become unstable in either an earthquake or during heavy rainfall, but this risk is less than the blocks in the area above Swan Lake. This is shown in the figure below.

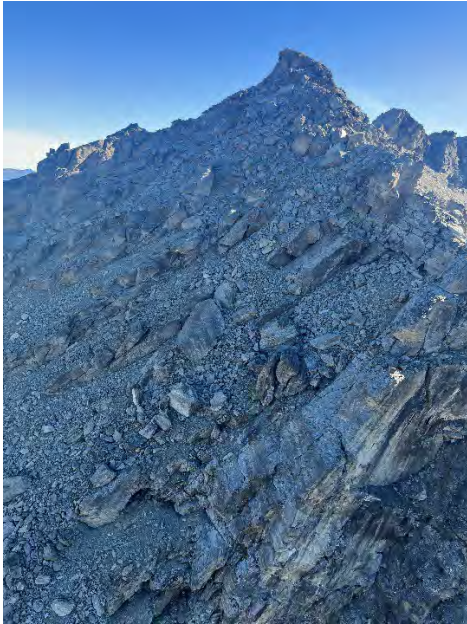


Figure 46. Upper part of the ridge above the snow making reservoir

On the bottom section of the ridge there are a number of tors above talus slopes. There are few perched blocks in this area, and larger blocks are embedded within the scree. The tors and scree blocks are shown in the figure below.



Figure 47. Tor section of ridge above snow making reservoir

There is a boulder on the west shore of the tarn. It is likely that this fell from the slope above. Most previous rockfall has collected on the talus slope below the ridge line or on the terrace above the tarn. This is shown in the figure below.



Figure 48. Tarn area with Terrace above and rock which may have rolled to the tarn

10.7.1 Rockfall Risk Matrix for Ridge above Snow Making Reservoir

The risk of Rockfall beneath the ridgeline above the Snow Making Reservoir is assessed in the Risk Matrix below. The Likelihood of rock fall along this route causing either damage or injury/death is assessed as Unlikely as the frequency of significant rock movement is assessed to be between 50 and 100 years and the likelihood of a person or vehicle being within this area is low. This can be seen in the figure above which shows the distance between the trail and the ridgeline. The Consequence of a rock impact is major as death is a possible outcome. Thus, this has been assessed as a Medium.

Table 17. Ridge Above Snow Making Reservoir - Rockfall Risk Matrix .

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

10.7.2 Ridge Above Reservoir Rockfall Risk Mitigation

Rockfall risk from this feature is mitigated by the low occupancy of both guests and staff below this feature. The risk from features such as this remain an accepted risk of alpine regions.

10.8 Snow Avalanche Risk

The Remarkables operate a robust avalanche control programme and maintain an avalanche atlas for the ski area. The avalanche atlas is a living document, subject to updates, and identifies possible avalanche paths run out zones and the conditions that may develop avalanche conditions. The avalanche control programme will be extended to include the Upper Doolans Creek Right Branch and the skiable terrain therein. The control programme involves slope closure during potential avalanche conditions, land based and aerial bombing, and monitoring of the risk by weather monitoring and snowpack inspection.

Most snow avalanches occur on slopes with a slope angle of between 30 and 45 degrees. As shown in the published guidance below.

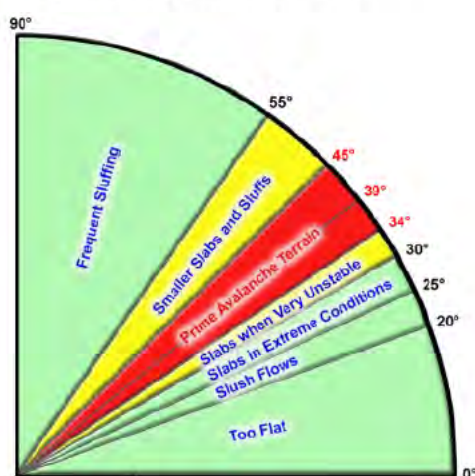


Figure 49. Guidance on slopes most prone to avalanche

The risk of a slope avalanching is dependent on multiple factors including.

- Gradient, as noted above
- Snow fall history
- Wind direction and speed during snow deposition
- Air temperature and change in temperature
- Precipitation
- Time and moisture movement within the snowpack
- Slope aspect and sun exposure

The western side of Upper Doolans Creek Right Branch is a known snow avalanche risk area. This slope is lee to the westerly wind and thus develops lee slope slab risk. Avalanches from this slope do not directly threaten the proposed Gondola infrastructure but potentially threaten the skiable terrain which will be managed by the Remarkables Ski Patrol as part of the active avalanche control programme.

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Along the gondola alignment within Upper Doolans Creek Right Branch, below the headwall to Helicopter Ridge, the slope averages approximately 13 degrees (a change in level of 300m over 1,300m) and consequently there is a reduced occurrence of natural avalanches occurring. A map of the slope gradient is shown below which indicates that the slope is less than 27 degrees and consequently naturally occurring or human triggered snow avalanches are rare in this area.

The slope to immediate south-east of Helicopter Ridge is sufficiently steep that localised natural or human triggered avalanches do occur on this slope. This is also a known risk and will be managed as part of the Remarkables Ski Patrol's active avalanche management programme. In this area the gondola rope will span over the slope and there is little risk to either the towers or other infrastructure. This is shown in the figure below.

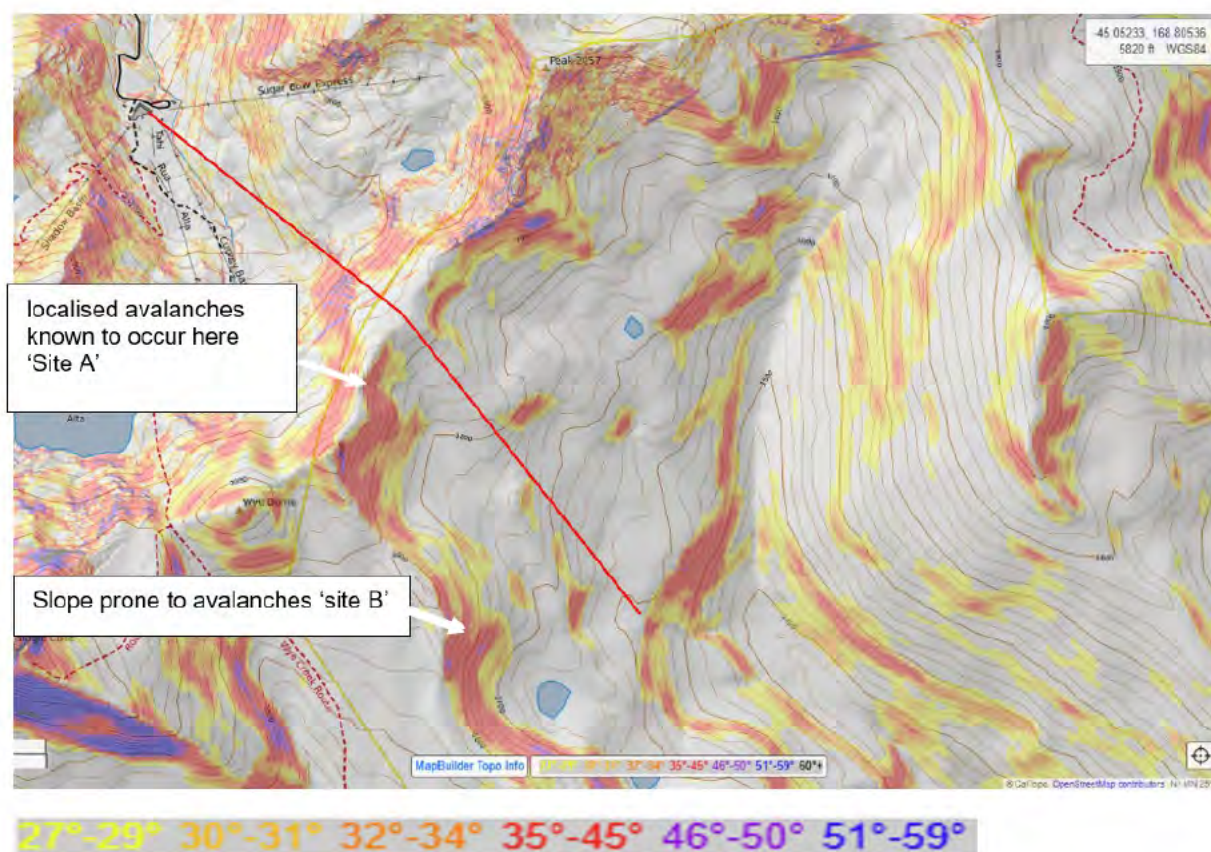


Figure 50. Slope angle map showing gondola alignment in Upper Doolans Creek Right Branch showing a slope of less than 27 degrees

Avalanches in the above indicated sites are shown in the figures below. Both sites may be reached from above without difficulty, or danger, as part of an avalanche control programme.



Figure 51. Spring and winter avalanches at 'Site B' into on the western side of the Upper Doolans Creek Right Branch.



Figure 52. 'Site A' Lee slope slab avalanche from Helicopter Ridge near to the proposed mid station site.

10.8.1 Snow Avalanche Risk Matrix

The risk from snow avalanche within the Upper Doolans Creek Right Branch is assessed in the Risk Matrix below. Avalanches are certain to occur within the ski area and most of these avalanches will be controlled releases deliberately propagated by avalanche control activities. The likelihood of a person being caught in an avalanche within the ski area boundary is very low. This is because of robust avalanche control programmes operated in the Remarkables (and most other New Zealand Ski Areas). We are aware of only one avalanche fatality in infield-controlled terrain in New Zealand when Neville Ryde, a groomer operator, was killed in an avalanche at Broken River in 1992. Between 1998 and 2023 there were 27 avalanche deaths in New Zealand, none of which are recoded as being on

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controlled ski area infield terrain. People being caught in avalanches in uncontrolled terrain, such as ski mountaineering, or heliskiing is not uncommon and occurs annually in New Zealand.

Consequently, the risk of a person being caught in an inbound terrain avalanche is assessed as Unlikely. The Consequence is assessed as Moderate as a fatality is possible but also unlikely on a controlled ski area. Thus, this has been assessed as a Medium.

Table 18. Snow Avalanche Risk Matrix.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

10.8.2 Snow Avalanche Risk Mitigation

As noted previously the Remarkables operates a robust snow safety programme and deaths due to avalanches in controlled infield terrain in New Zealand are very uncommon. Whereas deaths and entrapments in uncontrolled backcountry terrain due to avalanches are relatively common and occur annually in New Zealand. This difference demonstrates the effectiveness of New Zealand ski area avalanche control programmes and caution taken to opening terrain within ski area boundaries. However, the residual risk of avalanches remains and is associated with being in alpine terrain.

11 Localised Land Instability Risk

The most common area of localised land instability within the development is the area of solifluction immediately east of Helicopter Ridge. This risk has been addressed separately.

Within the upper Rastus Burn area within the Remarkables Ski Area Boundary no significant areas of existing natural land instability have been identified. Reference the existing Natural Hazard and Geotechnical Reports identified in section 9.2.

Within the Upper Doolans Creek Right Branch the area of development is in relatively benign terrain. There are some significant and spectacular ancient 'Rock Glacier' features, but these are no longer active. The rock glacier and the upper basin is shown in the figure below.



Figure 53. Ancient and inactive rock glacier feature in the Upper Doolans Creek Right Branch, with some solifluction lobes on the left of the image

The proposed access route between the top of Sugar Bowl and Helicopter Ridge traverses steep scree terrain. We anticipate that over parts of this route the formation will be difficult to support to current accepted standards. This area is considered to be at the area of greatest potential for localised slope instability. Cutting the access formation into the slope likely to cause areas of upslope instability. Down slope the scree is sufficiently steep that retaining of the formation on the downhill side is also difficult to achieve with a practical and economic solution. This area is shown below.



Figure 54. Nominal route of proposed temporary construction access immediately north of Helicopter Route shown in white. Area of very steep scree indicated in red

It is proposed to provide a service corridor and potential trail route between Helicopter Ridge and Curvey Basin. This route traverses a scree slope above the existing Curvey Basin trails. This is shown in the figures below.



Figure 55. Nominal permanent access and service route between Helicopter Ridge and Curvey Basin

The gradient and existg slope on the route between Helicopter Ridge and Curvey Basin is consistent with other accesses constructed at the Remarkables as part of recent developments which have remained stable.

11.1.1 Localised Slope Stability Risk Matrix

The risk from localised slope instability for the complete development is assessed in the Risk Matrix below. Excluding the proposed access between Sugar Bowl and Helicopter Ridge we assess that the risk of localised slope instability is Low. The likelihood of instability within the formation between Sugar Bowl and Helicopter Ridge is Possible. The Consequences of such an occurrence is assessed as Moderate. Thus, this has been assessed as a Medium.

Table 19. Localised Land Stability Risk Matrix.

Likelihood ARI (years)	Almost Certain <1/10	Very Likely 1/10-1/20	Likely 1/20-1/50	Possible 1/50-1/100	Unlikely 1/100-1/500	Rare 1/500-1/5,000	Very Rare >1/5,000
Catastrophic	Very High	Very High	Very High	High	Medium	Medium	Medium
Major	Very High	Very High	High	High	Medium	Medium	Medium
Moderate	High	High	High	Medium	Medium	Low	Low
Minor	Medium	Medium	Medium	Medium	Low	Low	Low
Negligible	Low	Low	Low	Low	Low	Low	Low

11.1.2 Localised Land Instability Risk Mitigation

Mitigation measures in regard to local land instability include appropriate geotechnical design of road cuts and retaining structures and siting structures or infrastructure away from areas of potential instability such as over steepened slopes. The residual risk in such a steep alpine environment is Medium.





Stantec is a global leader in sustainable engineering, architecture, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.

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