Milford Opportunities Project

MILFORD OPPORTUNITIES PROJECT NATURAL HAZARDS ASSESSMENT

PART A: PRELIMINARY SCREENING ANALYSIS

26 MARCH 2024

CONFIDENTIAL

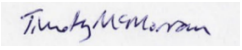
MILFORD OPPORTUNITIES PROJECT NATURAL HAZARD ASSESSMENT

PART A: PRELIMINARY SCREENING ANALYSIS

Milford Opportunities Project

WSP
Christchurch
52c Hayton Road
Wigram
Christchurch 8011, New Zealand
+64 3 343 0739
wsp.com/nz

REV	DATE	DETAILS
A	16-2-24	DRAFT for discussion and comment
B	8-03-24	FINAL for issue
C	19-03-24	FINAL for issue
D	26-03-24	FINAL for issue

	NAME	DATE	SIGNATURE
Prepared by:	Harley Porter	26-03-2024	
Reviewed by:	Rob Bond	26-03-2024	
Reviewed by:	Tim McMorran	26-03-2024	
Reviewed by:	Sam Morgan	26-03-2024	

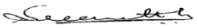
Approved for release by:	Sreenath Venkataraman	26-03-2024	

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The Milford Opportunities Project aims to develop the visitor experience of the Milford Road and in Milford Sound Piopiotahi located in the Te Rua-o-Te-Moko Fiordland National Park, New Zealand. The Milford Opportunities Master Plan includes the development of several key nodes, short stops, and walking/biking tracks located between Te Anau and Milford Sound Piopiotahi.

There is significant natural hazard risk in the Fiordland region due to steep mountainous terrain, active fault lines, and high annual precipitation and snowfall. Potential natural hazards include landslides, rockfall, debris flows, flooding, avalanches, tsunamis, and earthquakes (including earthquake-triggered hazards). The associated risk posed to road and site users as well as key workers is currently managed by the Department of Conservation (DoC), the Milford Road Alliance (MRA), and various tourism or business operators in the area. As part of the Milford Opportunities Project, there is a need to assess the visitor life safety risk for the proposed developments so that unacceptable levels of risk can be appropriately mitigated.

This phase of work follows the Stage 2 works completed by others and the objective of this Stage 3 work is to complete a natural hazard risk assessment for the MOP sites to further understand and assess the associated natural hazard risks. Stage 3, which includes this report, has been further divided into Part A (preliminary screening analysis), Part B (basic level risk analysis), and Part C (advanced risk analysis).

This report presents the results of the Preliminary Screening Analysis (Part A), which is then used to highlight areas of concern for further site-specific Basic Level risk assessment (Part B).

This report adopts the current GNS guidelines for completing natural hazard risk analysis in public conservation lands and waters ('GNS guidelines) to determine hazard Class and further the understanding of risk mitigation and management of the site. As part of the Preliminary Screening Analysis, the key sites and tracks have been assessed as either Class 1, Class 2, Class 3, or Class 3(a), where there is an increasing associated individual risk of fatality from Class 1 to Class 3(a).

Further Basic Level risk assessment is recommended for Class 2 and Class 3 sites and tracks.

Sites and tracks assessed as Class 1 are generally located away from hazard-prone areas such as waterways, steep hillslopes, or areas of potential avalanche or tsunami risk. As part of the analysis of site Class, hazard probabilities together with exposure times based on worker and visitor usage are used to determine the individual risk level. For Class 1 sites and tracks no further risk analysis is recommended, however, operators should continue to monitor and manage the hazard risk in accordance with current adopted management strategies.

Class 2 sites and tracks are generally those with semi-frequent flooding, landslide (including rockfall, and debris flow), and avalanche hazards. Exposure time at these sites varies. Nodes and short stops where overnight accommodation is available greatly increases hazard exposure. For Class 2 sites further basic risk analysis following the GNS guidelines is recommended. Advanced risk analysis may be required for higher-risk sites and tracks as part of a detailed design.

Class 3 sites and tracks are assessed to have higher frequency occurrences of landslide, flood, and avalanche hazards with larger hazard footprints. Ōtāpara Cascade Creek (Node 4) is a notable site exposed to flooding from Ōtāpara Cascade Creek and the upper Eglinton River. Landslide hazards and debris flow hazards are also known to occur in the area and theoretically could trigger lake tsunami in Lake Gunn or Lake Fergus. The Countess Range Track, Gertrude Valley Loop Track, and

the Hinepipiwai Lake Marian Loop Track are also assessed as Class 3 with sections of track crossing active debris flow and rock avalanche paths. For these sites, further risk analysis is recommended, and risk mitigation options should be considered as Part B of this stage of works.

The proposed Te Anau Downs to The Divide cycle trail is predominantly assessed as Class 1 and Class 2 with small sections of the trail assessed as Class 3. Visitors on the trail may be exposed to flooding, rockfall, landslides, debris flows, and tree slides. The key areas of concern are Limestone Gorge to Eglinton River Floodplain, sections of trail on the Eglinton River Floodplain, East Eglinton River Confluence, and Ōtāpara Cascade Creek to the Divide. Further risk analysis is recommended for this track.

All Class 3(a) sites in this preliminary analysis are associated with tsunami risk in Milford Sound Piopiotahi. The developed areas of the basin reside on the low-lying Cleddau River delta which extends out into a steep Fiord where extensive landslide risk has been identified. Landslides entering the Fiord are capable of producing tsunami waves with significant runup heights at the delta and would most likely impact the main area of Piopiotahi and further up the Cleddau River. Tsunami hazard probability at sites in Milford Sound Piopiotahi is, based on existing available data, assessed as high using the GNS guidelines. For these sites, further risk analysis is recommended, and a range of risk mitigation options should be considered.

Part B and Part C (where determined as necessary) of the Natural Hazards assessment will develop the Basic and Advanced-level risk analysis accordingly and will be presented in additional reports once an external Peer Review of the Part A findings has been completed. Parts B and C will include estimations of life safety risk, societal risk and further discussion on risk acceptability and, where appropriate, management and mitigation options.

Table 1: Assessed Site Hazard Class for each MOP site (point feature) with key nodes in bold.

Site Class	MOP Sites
Class 1	Te Anau Hub, Henry Creek DOC Campsite, Te Anau Downs, **Te Rua-o-Te-Moko Fiordland National Park Gateway (Node 1)**, **Eglinton Reveal (Node 2)**, Upper Eglinton DOC Campsite, Walker Creek DOC Campsite, Totara DOC Campsite, Mirror Lakes Waiwhataata, Lake Gunn and Lake Fergus lookouts, **Cleddau Cirque (Hundred Falls viewpoint) (Node 7)**,
Class 2	Countess Range Hut, Deer Flat DOC Campsite, Mackay Creek DOC Campsite, **Te Huakaue Knobs Flat (Node 3)**, **the Divide (Node 5A)**, **Whakatipu Trails Head (Node 5B)**, **Gertrude Valley (Node 6)**, the Chasm, Little Tahiti
Class 3	**Ōtāpara Cascade Creek (Node 4),** Milford Sound Lodge
Class 3(a)	Milford Sound Piopiotahi Visitor Hub, Freshwater Basin, Cleddau Delta, Deepwater Basin

Table 2: Assessed Site Hazard Class for each MOP track (linear feature).

Site Class	MOP Sites
Class 1	Eglinton River Trail Mirror Lakes Waiwhataata Walk, Lake Gunn and Lake Fergus lookouts, Lake Mistletoe Track, Divide Creek Link Track, Pass Creek Link Track, Falls Creek Falls and Christie Falls - Monkey Creek, Barren Peak Spur Track
Class 2	Te Huakaue Knobs Flat Short Walks, Key Summit to Ōtāpara Cascade Creek, Hinepipiwai Lake Marian Falls Loop Track, Chasm to Cleddau Horse Bridge Track, Milford Sound Lodge to Tutoko River Bridge Track, Hine-te-awa Bowen Falls – Upper Walks.
Class 3	Countess Range Track, Gertrude Valley Loop Track, Hinepipiwai Lake Marian Loop Track, Te Anau Downs to the Divide cycle trail
Class 3(a)	Cleddau Delta Walks, Hine-te Awa Bowen Falls – Lower Walk pontoon and tracks.

In addition to completing the GNS based assessment of landslide and tsunami hazard analysis we have also considered avalanche hazard occurrence at each of the proposed MOP master plan sites.

The assessment of avalanche risk is not covered by the GNS methodology, and the Department of Conservation (DOC) has its own methodology for assessing avalanche hazards which considers the type of user for each track or trail potentially affected.

For sites where an avalanche hazard is considered likely to be present the Part B analysis will assess the requirement for further AHI (Avalanche Hazard Index) or ATES (Avalanche terrain exposure scale) assessment dependent on DOC visitor type.

In line with the general GNS methodology the following key sites have been preliminary screened as being potentially affected by avalanche:

- Gertrude Valley Node 6
- Gertrude Valley Loop Track
- Cleddau Cirque
- The Chasm
- Chasm to Cleddau Horse Bridge Track
- Lake Marian Loop Track
- Countess Range Hut
- Countess Range Track

These sites are therefore considered to have a hazard Class of at least Class 2 and warrant further assessment in terms of either an AHI or ATES assessment. For Cleddau Cirque, however, avalanche risk is managed by the Milford Road Alliance (MRA) and hence this site does not need further risk analysis or mitigation in this study.

1 INTRODUCTION

The Milford Opportunities Project (MOP) has engaged WSP New Zealand Limited (WSP) to undertake a natural hazard risk assessment for several key sites located along the Milford Road in the Te Rua-o-Te-Moko Fiordland National Park, New Zealand. The purpose of the assessment is to assess the natural hazard risk at each site and determine the individual life risk posed to visitors and workers.

This natural hazard risk assessment adopts the current GNS Guidelines for Natural Hazard Risk Analysis on Public Conservation Lands and Waters ('GNS Guidelines'). The GNS Guidelines propose a multi-phase approach to assessing hazard risk including a Preliminary screening analysis, Basic risk analysis, and Advanced risk analysis.

1.1 PROJECT BACKGROUND

The purpose of the Milford Opportunities Project (MOP) is to develop a collaborative Master Plan for the Milford corridor and Milford Sound Piopiotahi sub-regional area to ensure:

> *"that Milford Sound Piopiotahi maintains its status as a key New Zealand visitor 'icon' and provides a 'world Class' visitor experience that is accessible, upholds the World Heritage status, national park and conservation values and adds value to Southland and New Zealand Inc."*

1.2 WORKSTREAM OBJECTIVES

As part of the previous Stage 2 works Stantec and Boffa Miskell produced a report titled Hazards and Visitor Risk Review, dated March 2021. This previous report identified a number of natural hazards that were present along the MOP corridor that required further assessment and possible mitigation as part of the detailed design stage.

The key aim of this Stage 3 work is to build upon the previous review completed and develop the risk assessment to further refine and understand the occurrence and associated consequence of natural hazards previously identified.

The Stage 3 work, therefore, aims to further assess the footprint or occurrence of the key hazards in relation to the proposed Nodes, Short stops, Tracks and Trails, and assess the individual risk of fatality in terms of temporal and spatial probability, adopting current recognised New Zealand methodologies and best practice.

The Stage 3 assessment will further assess the severity of natural hazard impacts on the MOP masterplan proposals and advise on future risk management strategies or further actions such as specific mitigation requirements where appropriate to do so.

The Stage 3 works will be reviewed by an expert technical review panel appointed by the Department of Conservation and MOP to ensure the identified critical risks are appropriately assessed and that recommendations made for future risk management or mitigation are appropriate and incorporated into the masterplan design considerations.

This natural hazard risk assessment underpins Stage 3 and builds on the analysis carried out by Stantec and Boffa Miskell in Stage 2.

The natural hazard risk assessment for Stage 3 is staged into three parts as follows:

- Part A: Preliminary screening analysis
- Part B: Basic risk analysis, and if deemed necessary,
- Part C: Advanced risk analysis.

This report presents the results of the Part A Preliminary screening analysis for the risk assessment.

1.3 SCOPE OF WORKS

As part of the derivation of the brief for this Stage of work, early discussions were held with MOP together with a drive-through of the Milford Corridor to understand the location and surrounds of the key sites.

The scope of works for this Stage were then assessed and agreed to comprise:

1. Complete a Site visit and walkthrough of key Nodes and Short Stop sites.
2. Review provided information including Stage 2 reports and identify key natural hazard aspects for the Stage 3 assessment.
3. Adopt the methodology produced by GNS for the completion of Preliminary Screening Analysis and Basic Level Risk Analysis on Public and Conservation Lands and Waters.
4. Complete a Preliminary screening analysis of relevant natural hazards (Part A).
5. Complete a Basic Level risk assessment of hazards as required by the GNS methodology adopting initial quantitative estimations of risks that workers or visitors are exposed to using simple and limited data sets and data analysis (Part B).
6. Where appropriate provide comment or recommendation for the completion of any site-specific Advanced level analysis for specific hazards, any specific modelling requirements or recommendations in respect of mitigation or management controls required during the detailed design phase (Part C).

At the commencement of the Stage 3 phase of works and throughout its compilation, consultation and review shall be completed by the appointed external Peer Review panel.

2 DATA SOURCES

Multiple reports, presentations, published papers and previous assessments have been collated as part of the MOP development (Table 3). This background data has been reviewed and adopted as part of this assessment to determine the occurrence of key hazards and the likely associated consequences.

In addition to the background data made available for this assessment, the footprint or extent of a hazard has been further assessed using topographical, geological, UAV, aerial imagery and mapped data.

Table 3: Examples of data sources used for the semi-quantitative risk assessment.

Source	Dataset	Usage
1m DEM	Southland LiDAR 1m DEM (2020-2023)	Terrain Analysis
0.75m Aerial Photos	Southland 0.75m Rural Aerial Photos (2005-2011)	Hazard Mapping
Google Earth	Google Earth imagery and terrain	3D visualisation of hazards
GNS Science	Geological Map of New Zealand	Geology, landslide inventory
NZ landslides database	NZ landslides database	Landslide inventory
Homer tunnel vehicle count	MOP hazards and visitor risk review report	Exposure
Milford Road Avalanche Atlas	Avalanche Atlas MRA	Assessment of Avalanche collection areas and run-out areas

2.1 PREVIOUS RISK ASSESSMENTS

Table 4 below summarises the key previous risk assessments previously undertaken that have been used to inform this Stage 3 assessment. The findings and data previously presented have been adopted and used to complete the semi-quantitative risk assessment presented in this report.

Table 4: Overview of existing hazard and risk assessments in the study area.

Summary of Content	Area Covered	Reference
Hazard and visitor risk assessment for MOP	Milford Road	Stantec. (2021). MOP Hazards and Visitor Risk Review Report.
Hazard assessment for Te Huakaue Knobs Flat	Te Huakaue Knobs Flat (Node 3)	Geosolve. (2019). Natural Hazards Assessment Report for Resource Consent.
Qualitative hazard assessment for walking and cycling experiences in the MOP project	Milford Road	Southern Land. (2023 - DRAFT). Walking and Cycling Experiences Report December 2023.
Milford Road natural hazard risk assessment	Milford Road	GNS. (2014). Framework for Assessing Life Risk to Road Users from Natural Hazards: A Pilot Methodology Using the Milford Road.

Summary of Content	Area Covered	Reference
Avalanche hazards assessment for MOP sites	Milford Road	MRA. (2023). Avalanche Hazard Assessment for proposal sites along the Milford Road - Milford Opportunities Group.
Tree slide and rockfall risk in the freshwater basin, Milford Sound	Freshwater Basin, Milford Sound	URS. (2007). Milford Freshwater Basin – Reassessment of Tree Slide and Rock Fall Risk for New Operating Procedures.
Societal risk assessment for rockfall at Bowen Falls	Bowen Falls, Milford Sound	AECOM. (2015). Bowen Falls Walkway, Rockfall Risk Mitigation Options Site Investigation and Preliminary Costing.
Qualitative risk assessment of debris flow hazard at Howden Hut, Routeburn Track	Routeburn Track	Geoconsulting. (2020). Assessment of Debris Flow Impact on Howden Hut, Routeburn Track.
Qualitative risk assessment of landslides on Routeburn Track	Routeburn Track	England and Company. (2020).
Preliminary risk assessment for Little Tahiti	Little Tahiti	Tonkin and Taylor. (2017). Preliminary Natural Hazards Risk Assessment, Little Tahiti, Milford Sound.
Modelling of evacuation scenarios for a landslide-generated tsunami in Milford Sound	Milford Sound Piopiotahi	Harris, L. (2023). Agent-based Modelling of Evacuation Scenarios for a Landslide Generated Tsunami in Milford Sound. University of Canterbury Master's Thesis
Milford Sound bathymetry and geological assessment	Milford Sound Piopiotahi	Great South. (2023). Milford Sound seabed bathymetry and geological assessment.
Post Last Glacial Maximum (LGM) evolution of Milford Sound and implications for hazards	Milford Sound Piopiotahi	Dykstra, J (2012). The post-LGM evolution of Milford Sound, Fiordland, New Zealand: Timing of ice retreat, the role of mass wasting & implications for hazards
Milford Sound tsunami risk	Milford Sound Piopiotahi	Taig, T., & McSaveney, M. J. (2015). Milford Sound risk from landslide generated tsunami, GNS Science Consultancy Report 2014/224.

3 STAGE 3 RISK ASSESSMENT METHODOLOGY

3.1 OVERVIEW

Risk is a function of the likelihood of a hazard occurring and its consequence, where consequences are dependent on the vulnerability of exposed assets or individuals. This report is primarily concerned with the risk posed to visitors at each proposed site that has been defined in the Milford Opportunities Project Master Plan.

The scope does not include assessing visitor risk travelling between short-stop sites or nodes. These risks are deemed to be managed by the key operators as Average Day or Seasonal / Periodic hazards as previously assessed in Stage 2. The hazards and associated risks of travelling the Milford Road between short-stop sites and nodes is therefore beyond the scope of this report.

To determine visitor risk, the GNS Guidelines for Natural Hazard Risk Analysis on Public Conservation Lands and Waters[1] are adopted. These guidelines present a multi-stage methodology for Quantitative Risk Analysis (QRA) for point and linear sites.

The first stage in the methodology (Part A) is to complete a Preliminary Analysis of hazards and exposure. The Preliminary Analysis will then determine whether or not further risk analysis is required. This report (Part A) presents the findings of the Preliminary Analysis completed for the key Nodes, Short Stops, and primary proposed walking tracks identified in the Milford Opportunities Project.

For the purposes of this report natural hazards are grouped into landslide (that includes rockfall, tree slide, and debris flow), flood, avalanche hazards, and tsunami hazards.

The preliminary risk assessment does not address any risk to individuals aboard cruise ships or other vessels in Milford Sound Piopiotahi.

The Department of Conservation (DoC) has developed visitor group Classes to describe visitor typology that includes an assessment of risk tolerance[2]. The majority of visitors to the Milford Road are likely to be in the Short Stop Traveller (SST) or Day Visitor (DV) category. These groups typically consist of visitors who expect a low-risk experience associated with safe facilities and are generally looking for relatively short or quick experiences.

There will be a minority of Overnighter (ON) and Backcountry Comfort Seeker (BCC) visitors on multi-day walks who accept a greater level of risk and then a minority group of Backcountry Adventurers (BCA) or Remoteness seekers (RS) who tend to have a higher level of backcountry skills and seek experiences that pose a challenge or have a sense of freedom. These forms of visitor groups tend to accept risk to a degree and have experience passing through hazardous and remote areas.

[1] De Vilder, SJ., Massey, CI. (2020). Guidelines for Natural Hazard Risk Analysis on Public Conservation Lands and Waters.

[2] Department of Conservation (Unpublished – DRAFT). Hazard management guidelines for visitor sites on public and conservation lands and waters.

Table 5: DoC visitor group classes (source: DoC 2023).

Term	Definition
Visitor Group	Term used internally within DOC to broadly define the characteristics of the users of facilities, services and places on land managed by DOC. In the context of this document, it is the predominant visitor group.
Predominant Visitor Group	The visitor group with the highest numbers using the site.
Risk Tolerance	The amount of risk that is acceptable for the predominant visitor group at a visitor site. Risk tolerance is defined by DOC's risk evaluation matrices.
Site Control Plan	A plan for how visitor risk is managed at a visitor site. It sets out the hazard management tasks for the site.
SST	'Short Stop Traveller' visitor group. Seeks an 'instant immersion" in nature experience, associated with a high degree of scenic value or historical interest. Expects a low-risk experience associated with safe facilities.
DV	'Day Visitor' visitor group. Seeks experiences in natural or rural settings with a sense of space and freedom. Expects an outdoor experience with a low level of risk, and safe facilities.
ON	'Overnighter' visitor group. Seeks an overnight experience in a predominantly natural setting. Expects the camping and overnight experience, and the associated activities they undertake, to be generally low risk. Includes the traditional New Zealand family holiday experience.
BCC	'Backcountry Comfort Seeker' visitor group. Seeks an outdoor experience in a backcountry environment that has low risk due to the provision of safe, comfortable facilities. For many this may be their first introduction to the New Zealand backcountry.
BCA	'Backcountry Adventurer' visitor group. The traditional New Zealand backcountry experience. This group has a higher level of backcountry skills and experience than backcountry comfort seekers. Seeks an experience that has challenge and a sense of freedom, and they accept a degree of risk and discomfort.
RS	'Remoteness Seeker' visitor group. Seeks a wilderness experience with limited interaction with other parties. Seeks the challenge and complete sense of freedom that comes from prolonged contact with wild nature. Because of their high skill level and experience, they accept the higher level of risk associated with travelling through remote areas.

3.1.1 LANDSLIDE RISK

The GNS guidelines lay out the methodology to determine whether sites are considered either Class 1, Class 2, Class 3 (or Class 3a) sites, with an increasing level of risk and significance (Table 6) for each Class.

Table 6: Site Classification for risk assessment (GNS Methodology).

Class	DOC Risk Significance Level	DOC Evaluation Category	Risk Management Actions
Class 1	Insignificant	Tolerable	No further risk analysis required. DOC should develop appropriate risk management plans and re-evaluate the risk management plan if there is a change in hazard activity or the number of people exposed.
Class 2	Significant to Substantial	Tolerable if reduced as low as reasonably practicable (ALARP)	Basic level of risk analysis required. The analysis should highlight and identify the potential impacts to persons on the public conservation lands and waters. Identified high-risk sites may require further advanced risk analysis and consideration of mitigation options.
Class 3	Substantial to High	Tolerable if reduced ALARP and Intolerable	Urgent action is required. This may involve interim risk management solutions (e.g. closures) while solutions are developed. Basic-level risk analysis must be undertaken, and an advanced-level risk analysis may be required.
Class 3(a)	High to Extreme	Intolerable	Urgent action is required. This may involve interim risk management solutions (e.g. closures) while solutions are developed. Basic-level risk analysis must be undertaken, and an advanced-level risk analysis may be required. Class 3(a) represents the highest priority for further risk analysis and risk management actions.

Site Class is determined by the indicative recurrence interval of the hazard at the site (Table 7) and the typical exposure time of the individual most at risk (Table 8).

The recurrence interval of the hazard at each site is determined by reviewing geological, topographical, and published information on key hazards present in the study area. We predominately assess hazard recurrence based on judgment and expert elicitation referencing previous assessments where we can. This was considered appropriate for this preliminary risk assessment.

Exposure time of individuals is estimated based on the type of activity at each site and the likely visitor group using the site. This is further qualified through discussions with the authors of the previous tourism and user assessment reports produced as part of the Stage 2 assessments.

In addition to the desk-based assessment, a site walkover and drive-through were completed by a WSP Geotechnical Engineer at each Node and Short Stop in December 2023 with a representative of MOP which was then followed up with additional aerial imagery, photographs and discussions held with the trail designers and DoC representatives. Site photographs, notes, and anecdotes collected from the previous stages of assessment are used to estimate hazard footprints, intensity and occurrence.

Table 7: Hazard recurrence interval bands with associated levels of hazard probability (source: de Vilder & Massey 2020).

Indicative Recurrence Interval (Years)	Relative Temporal Probability
<1	Extremely High: hazard event will very likely occur multiple times per year
1–10	Very High: hazard event will very likely occur in the near future
10–100	High: hazard event is likely to occur
100–1000	Medium: hazard event could possibly occur
1000–10,000	Low: hazard event is unlikely to occur
>10,000	Very Low: hazard event occurs rarely

Table 8: Levels of exposure used to determine risk in Table 9 (source: de Vilder & Massey 2020).

Proportion of Time Spent at a Given Hazard Level in 24 Hours	This Approximately Equals:	Example Activity
>0.1	More than 3 hours	Staying at a hut
0.1–0.01	From ½ an hour to 3 hours	Picnic spot
0.01–0.001	From 2 minutes to ½ an hour	Stopping at viewing area
0.001–0.0001	From 10 seconds to 2 minutes	Crossing a swing bridge
<0.0001	Less than 10 seconds	Walking past a given point (e.g. 1 m^2)

Table 9: Classification matrix of sites due to hazard level and exposure time (source: de Vilder & Massey 2020). *Class 2 designation should have a lower priority of risk management actions, including any mitigation. Class 3(a) sites would receive consideration for the highest priority of investigations and analysis.

Spatio-Temporal Probability of the Visitor	Temporal Probability					
Proportion of time over a trip per day that an individual spends at a given hazard level	Very Low	Low	Medium	High	Very High	Extremely High
>0.1	Class 1	Class 2*	Class 3	Class 3(a)	Class 3(a)	Class 3(a)
0.1–0.01	Class 1	Class 1	Class 2*	Class 3	Class 3(a)	Class 3(a)
0.01–0.001	Class 1	Class 1	Class 1	Class 2*	Class 3	Class 3(a)
0.001–0.0001	Class 1	Class 1	Class 1	Class 1	Class 2*	Class 3
<0.0001	Class 1	Class 1	Class 1	Class 1	Class 1	Class 2*

3.1.2 TSUNAMI RISK

The GNS Guidelines also provide a risk assessment methodology for Tsunami. Tsunami risk is calculated slightly differently from landslide and rockfall hazards. Local evacuation maps and tsunami wave height calculations are used to determine hazard levels (Table 10). The 2021 National Tsunami Hazard Model (NTHM) is used to determine tsunami wave height (H in Table 10) for a site. Hazard curve data from the NTHM is used to find H^{50}_{1000} (50th percentile 1000-year return period wave height), and H^{50}_{100} (50th percentile 100-year return period wave height).

For sites not on rivers, tsunami height is calculated as:

$$S_{overland} = \frac{h}{2} + \frac{x}{400}$$

Where:

- $S_{overland}$ = minimum tsunami height at the coast that is potentially capable of inundating a site at elevation *h* above MHWS at a distance *x* from the coast, assuming the tsunami travels over land.

For sites on rivers, tsunami height is calculated as:

$$S_{overriver} = \frac{h}{2} + \frac{u}{800} + \frac{d}{400}$$

- $S_{overriver}$ = minimum tsunami height at the coast that is potentially capable of inundating a site at elevation *h* above MHWS at a distance *u upstream* from the coast by river at a distance *d* from a river bank.

Table 10: GNS criteria for tsunami hazard (source: de Vilder & Massey 2020).

Criteria	Hazard Level
Site is outside of all mapped tsunami evacuation zones	Very Low
$S > H^{50}_{1000}$ but site is within mapped evacuation zone	Low
$H^{50}_{1000} > S > H^{50}_{100}$	Medium
$H^{50}_{100} > S$	High

Table 11: Site Class for tsunamis (source: de Vilder & Massey 2020). *Sites outside of the tsunami evacuation zone, so risk mitigation by evacuation is not expected.

Table 3.3 Matrix for calculating Individual hazard and exposure class using the hazard level and proportion of time *P* as inputs.

Exposure			Hazard Level			
Proportion of time spent at point location in 24 hours	Equivalent to:	Example activity	Very Low	Low	Medium	High
>0.1	More than three hours	Staying in a hut	Class 1*	Class 2	Class 3	Class 3(a)
0.1–0.01	Half an hour to three hours	Picnic spot	Class 1*	Class 1	Class 2	Class 3
0.01–0.001	Two minutes to half an hour	Stopping at viewing area	Class 1*	Class 1	Class 1	Class 2
<0.001	Less than two minutes	Crossing a swing bridge	Class 1*	Class 1	Class 1	Class 1

*Class 1 sites are outside of the tsunami evacuation zone so risk mitigation by evacuation is not expected.

Tsunami waves have multiple triggers including earthquakes (fault-induced), landslides, avalanches, and volcanoes. The NTHM only provides tsunami hazard for fault-induced tsunami. In Milford Sound, tsunami hazard is dominated by landslide-induced tsunami. To more accurately determine the return period of tsunami, the recurrence of landslide-induced tsunami for the Milford Sound sites has been used. This is explored in more detail in Section 4.3.

3.1.3 FLOOD AND AVALANCHE RISK

The GNS Guidelines are only designed to be used for landslide and tsunami risk. Flooding and avalanche risk are not covered and is therefore assessed using different commonly adopted risk assessment techniques.

Due to lack of available flood hazard data for water bodies along the Milford Road, we have assessed flood hazard using judgment and expert elicitation based on site observations and recent hazard occurrence. This preliminary assessment identifies sites potentially exposed to flooding hazard. Further analysis of flooding hazard, if deemed necessary will be addressed in Part B.

For those sites where avalanches are identified as posing a potential risk, further hazard assessment will be undertaken in Part B. For low to medium risk tolerant visitors (SST, DV, BCC, ON) avalanche hazard assessment will use the established Avalanche Hazard Index (AHI) DOC methodology. For higher risk tolerant visitors (BCA, RS), avalanche hazard assessment with use the Avalanche Terrain Exposure Scale (ATES). This preliminary assessment will firstly establish sites with an avalanche risk.

3.2 HAZARD EXPOSURE

Approximately 870,000 people visited Milford Sound Piopiotahi in 2019, 83% of which were international visitors[3]. With the exception of the COVID-19 pandemic, this number is forecast to continuously grow to approximately 1.5 million by 2050.

There is strong seasonal variation in visitor numbers with the summer months seeing considerably more visitors compared with the winter months (Figure 1). The maximum number of people on the Milford Sound Piopiotahi side of the Homer Tunnel during peak times is estimated to be over 3,000 (possibly up to as high as 6000), compared with less than 1,000 per day in winter.

The above estimates exclude additional visitors arriving by foot or non-tour-related air travel. Visitors on cruise ships do not disembark. Hence, all visitors considered as part of this assessment will most likely be travelling the Milford Road in a bus, a high occupancy vehicle, or private vehicles, and would most likely visit some of the key nodes. Visitors are exposed to hazards in vehicles, on walking/biking tracks, in accommodation, and at the nodes and short stops. The MOP is looking to improve the visitor experience at the key Nodes and Short Stops in order to limit the mass population of the Milford waterfront (Piopiotahi) and enable a greater number of visitors to spend a longer period of time on the journey. This dispersion of the population increases risk profiles in certain areas of the corridor and reduces it in others.

In understanding the population distribution and associated exposure times for each Node, discussions were held with the MOP team and a review of previous visitor assessments completed as part of the Stage 2 works were undertaken.

In addition, to assess the risk tolerance levels of the visitor groups that would be using the Nodes and Short Stops, an assessment of user type has been completed. This aids in the understanding of future management and mitigation of hazards as well as determining the spatial and temporal components of how each site is likely to be used.

[3] Stantec. (2021). Milford Opportunities Project Masterplan.

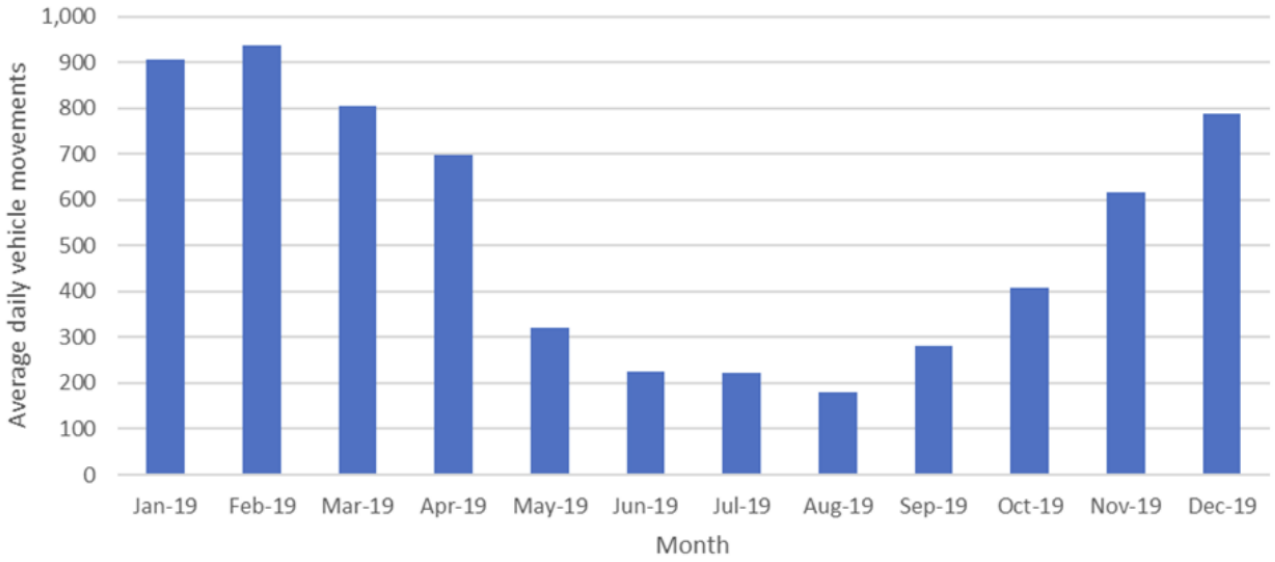


Figure 1: Homer Tunnel monthly in-bound vehicle movements in 2019 (source: MOP master plan 2019).

3.3 UNCERTAINTY

There are key assumptions and estimations made in this preliminary risk assessment that affect the certainty of the results. Firstly, hazard recurrence intervals are based on observational/anecdotal evidence and previous hazard assessments rather than larger datasets. This was assessed as suitable for a Preliminary Analysis of hazards. Further analysis should use detailed hazard inventories and published literature to estimate hazard recurrence.

For tsunami hazard, simple distance and elevation relationships have been used to determine tsunami waves capable of inundating each site. Several other factors influence tsunami inundation such as slope roughness which could affect the tsunami hazard at each site increasing the uncertainty of values presented in this report. However, these equations are outlined in the GNS Guidelines and have been developed with expert elicitation. They provide an efficient and useful representation of tsunami hazard.

Visitor typology and exposure times are estimated based on anecdotal evidence and may not reflect the true range of visitor types and exposure at each site. Where possible, we have opted for the visitor group with the lowest risk tolerance and conservative exposure times to allow for slower-moving individuals. We also use the exposure time brackets presented in the GNS Guidelines which have been developed with expert elicitation. Further risk analysis should more clearly define the exposure time of visitors at each site.

4 SETTING

4.1 SITE DESCRIPTION

As previously reported and highlighted in the MOP masterplan, the Milford Road (State Highway 94) from Te Anau to Milford Sound Piopiotahi is a scenic journey in Te Rua-o-Te-Moko Fiordland National Park, New Zealand. The 119 km highway travels through mountainous terrain with dense beech forest and steep glacial valleys with several tourist attractions along its length.

As part of the MOP seven key 'Nodes' have been identified[4], these are accompanied by short stops, walking/biking tracks, accommodation locations, and viewpoints (

Figure 2). These sites and the surrounding area are defined as the study area for this Stage 3 report.

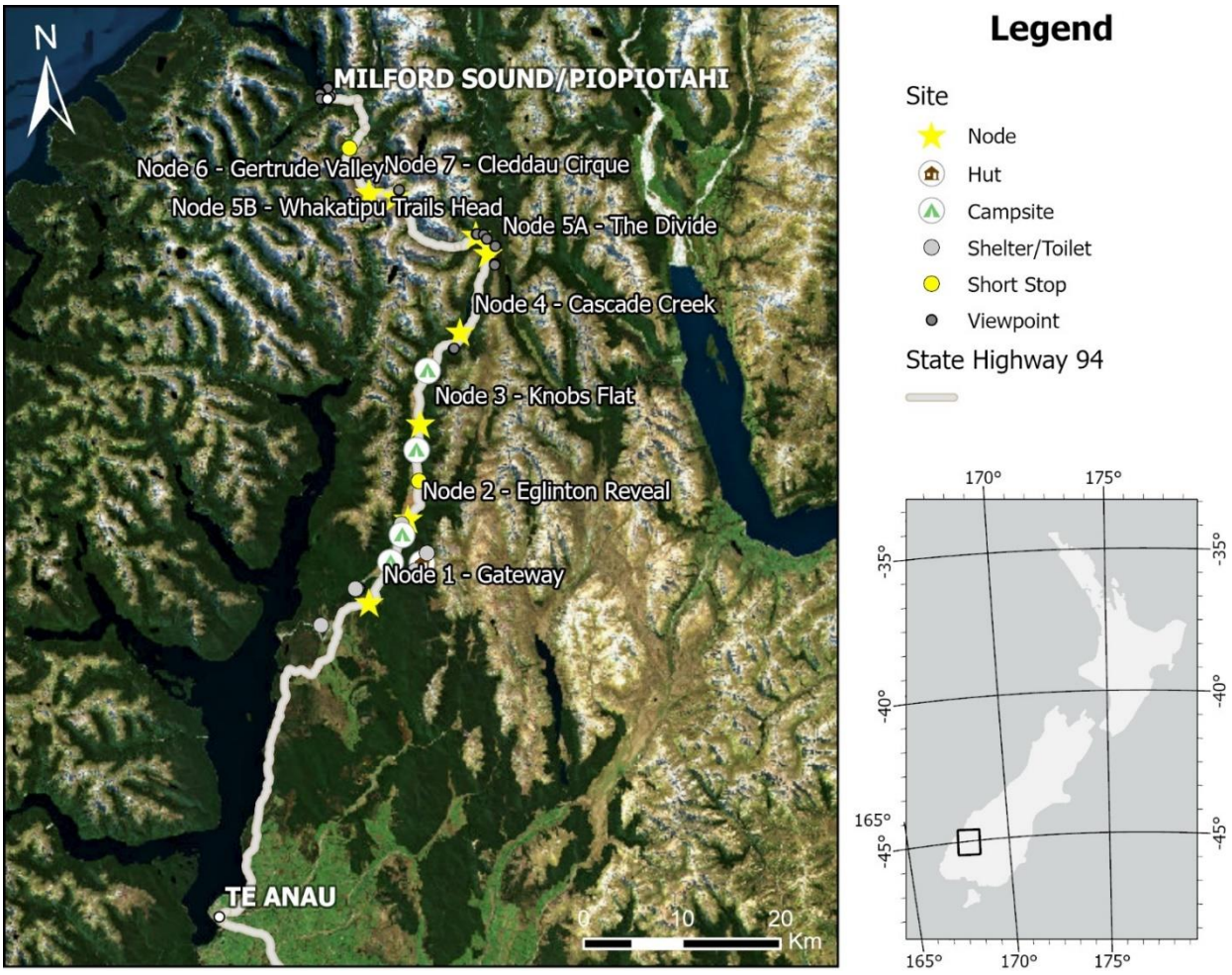


Figure 2: The Milford Road with key nodes and features of the Milford Opportunities Project labelled.

[4] Stantec (2021). Milford Opportunites Project: a masterplan for Milford Sound Piopiotahi and the journey.

4.2 GEOLOGICAL CONTEXT

Much of the Fiordland area is underlain by the plutonic rocks of the Median Batholith which formed due to repeated subduction along the southern margin of the ancient supercontinent Gondwana[5].

Fiordland separated from Gondwana in the middle to late Cretaceous and was uplifted as the Fiordland massif in the late Cenozoic. The Fiordland massif has been deeply eroded by Quaternary glaciers which have formed 'U' shaped valleys, steep mountain ranges, and deep Fiords throughout the region.

Fiordland has a varied and complex present-day geology due to multiple phases of plutonism, volcanism, deformation and metamorphism, sedimentation, uplift, and glaciation.

Much of the tectonic movement in this region is associated with the Australian and Pacific plate boundary which forms a major subduction zone along the western margin of Fiordland (Figure 3). The associated Alpine Fault is a largely strike-slip fault line that is located along this plate boundary and has been determined as being capable of producing large earthquakes in excess of Magnitude 8.

[5] Turnball et al. (2010). Geology of the Fiordland Area. GNS Science, Lower Hutt, New Zealand.

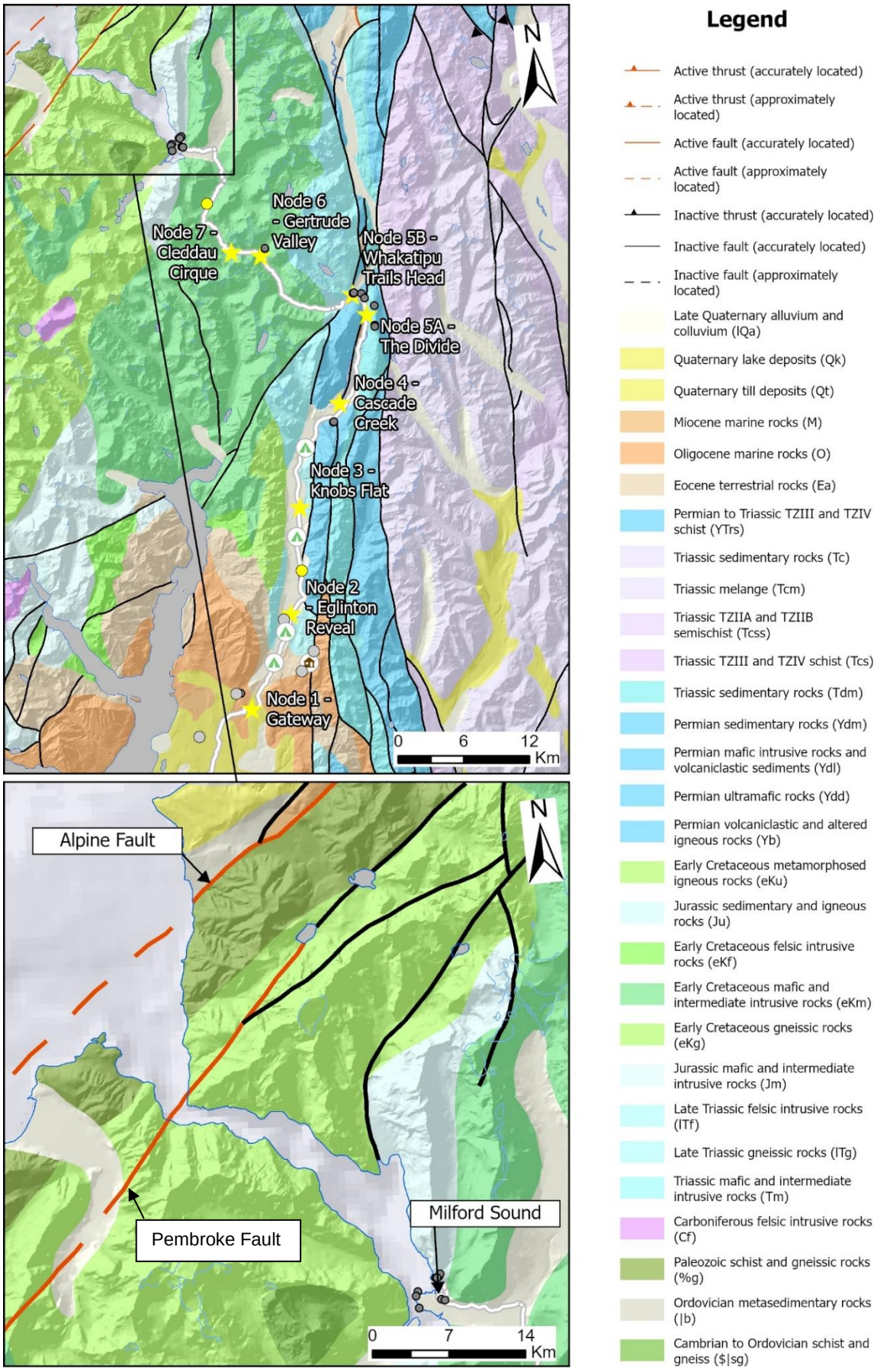


Figure 3: The GNS 1:1M Geological Map of the study area with a zoomed in inset map of Milford sound and the Alpine Fault (bottom).

4.3 NATURAL HAZARD OCCURRENCE

The Milford Road and surrounding area is well known for the occurrence of extensive, often large-scale natural hazards. These include landsliding and rockfall, tree slides, tsunami/seiche, avalanche, flooding/debris flow, earthquake shaking and liquefaction (Figure 4). Any of these hazards can have severe impacts on infrastructure, structures, wildlife the environment and can pose a life risk to visitors and workers.

Many of the hazards in the study area are influenced by factors such as rock strength, geological defects, fault and seismic activity, precipitation and climate change.

There have been numerous earthquakes in the Fiordland area in recent decades, ranging from infrequent large-magnitude events such as the 2009 Dusky Sound Mw 7.8 earthquake to frequent small-magnitude earthquakes distributed throughout the region.

It is well documented[6] that earthquake shaking may also trigger landslides and that the size of landslide is strongly dependent upon magnitude, intensity and distance. The term 'landslide' incorporates land movement such as rockfall, debris flow as well as landslide. The cumulative effect of a large shaking intensity earthquake may then also initiate avalanches, liquefaction effects and tsunamis or flooding.

The steep topography of the Milford area with slope angles generally steeper than 50° suggests that under high shaking intensities landslides are likely to occur. Historical seismicity shows that shallow Mw 5 and Mw 6 earthquakes that trigger damaging landslides are more likely in northwest Nelson, the central Southern Alps, Fiordland, Marlborough, Wellington, Wairarapa, Hawkes Bay and East Cape (GNS, 1997).

The geology of the area also influences the potential for landslides to occur. In the Milford region, the geology is typically a hard igneous rock with limited colluvium cover. This restricts the nature of landsliding with tree sliding being the prevalent form of failure and the larger landslide or rock avalanche form of failure being driven by major discontinuities within the rock mass. The 1993 Mw 7 and 2009 Mw 7.8 earthquake resulted in only sparsely distributed small slides over the Fiordland area. Across much of Fiordland, landslides are more frequently triggered by intense periods of rainfall and snowmelt.

The study area receives an average annual rainfall of approximately 7 m with frequent intense periods of rainfall, wind, and snowfall. Precipitation and freeze/thaw cycles are known triggers for natural hazards including landslides and avalanches. Avalanche hazards are common along the Milford Road and tend to be prevalent at higher altitudes near the Homer Tunnel in winter months (May through to November), particularly during changeable weather fronts of snow and rain.

[6] GNS. (1997). Earthquake-induced landslides in New Zealand and implications for MM intensity and seismic hazard assessment.

Figure 4: Hazards within the study area. Top left: Rock avalanche/landslide damage to Lake Howden Hut following a storm (source: Luke Bovill – Department of Conservation). Top right: Scouring of the Milford Road due to flooding (source: Dylan O'Neill/Waka Kotahi). Bottom left: The eastern portal of the Homer tunnel damaged by an avalanche (source: Conway et al. 2000). Bottom right: A damaged bridge on the Routeburn track due to flooding (source: Department of Conservation).

Milford Sound Piopiotahi is prone to both fault zone (seismic) initiated and landslide-induced tsunami due to its position on a low-lying area at the end of a steep Fiord within close proximity to the Alpine Fault and the Indian/Pacific plate boundary.

Tsunami wave heights are assessed using either the vertical deep-water wave amplitude (amplitude) or the vertical height of the wave above sea level at its furthest point inland (run-up).

Due to local bathymetry and topography of the basin, tsunami wave amplitudes are inflated in the shallow basin environments. Runup height (tsunami wave height at the shoreline with respect to bathymetry/topography) is a more useful metric when determining the extent of potential impact.

The Alpine Fault has been proven to produce large earthquakes capable of triggering landslide-induced tsunamis in the Sound. The Alpine Fault is estimated to have a recurrence interval of approximately 300 years. The last Alpine fault event is estimated to have occurred in 1717 AD.

Based on the recurrence interval it is estimated that in 2024 there is a 75% probability of an Alpine Fault earthquake occurring within the next 50 years[7], for which there is a 44% probability of a landslide entering the Fiord[8]. Therefore, the return period for a landslide-induced tsunami in Milford Sound is 150 years.

Work completed by Dykstra (2012)[9] identified at least 18 very large post glacial rock avalanche deposits blanketing the base of the Milford Fiord and a further 10 very large to giant terrestrial landslide deposits were mapped in the lower Milford catchment. This work estimated tsunami maximum local run-up at the Cleddau Delta in Milford Sound to be circa 17 m. In this scenario, several thousand people in Milford Sound could be exposed to tsunami waves and much of the infrastructure would be at risk of total damage. Dykstra estimated the long-term life risk due to landslide-induced tsunami at Milford Sound as 0.38 deaths/year. Work completed by Taig and McSaveney (2015) estimated that for the Alpine Fault triggering a tsunami event, wave heights of 0.3-10 m and runup heights of 1.1 – 47 m can be expected at Freshwater Basin. This work also established a relationship between wave amplitude and annual probability.

Submarine mass failures can also generate large displacement waves. Four submarine density flows tsunami have been modelled for Milford Sound with maximum amplitudes of 0.7 – 9 m and runup heights of 0.1 – 43.2 m.

The 2021 National Tsunami Hazard Model (NTHM) for New Zealand[10] identified that Milford Sound/Piopiotahi is also exposed to other sources of tsunami, namely the main subduction zone features of the Puysegur trench located offshore to the west (Figure 6). The NTHM concluded that the return interval of tsunami wave amplitudes of 1-2 m at Milford Sound Piopiotahi from any fault source to be approximately 100 - 200 years (Figure 5).

Lakes surrounded by steep and undulating terrain are also at risk of landslide-induced tsunami. In the study area, there are three Lakes (Lake Gunn, Lake Fergus, and Lake Marian) where the potential for landslide-induced lake tsunami may impact MOP sites. Very little work has been completed on these areas and potential wave heights and associated impacts are largely unknown.

---

[7] Alpine Fault Magnitude 8 (AF8). (2024). AF8 Hazard Scenario. https://af8.org.nz/what-is-af8

[8] Taig and McSaveney. (2015). Milford Sound risk from landslide-generated tsunami.

[9] Dykstra. (2012). The Post-LGM Evolution of Milford Sound, Fiordland, New Zealand.

[10] Power et al. (2023). Tsunami hazard curves and deaggregation plots for 20 km coastal sections, derived from the 2021 National Tsunami Model

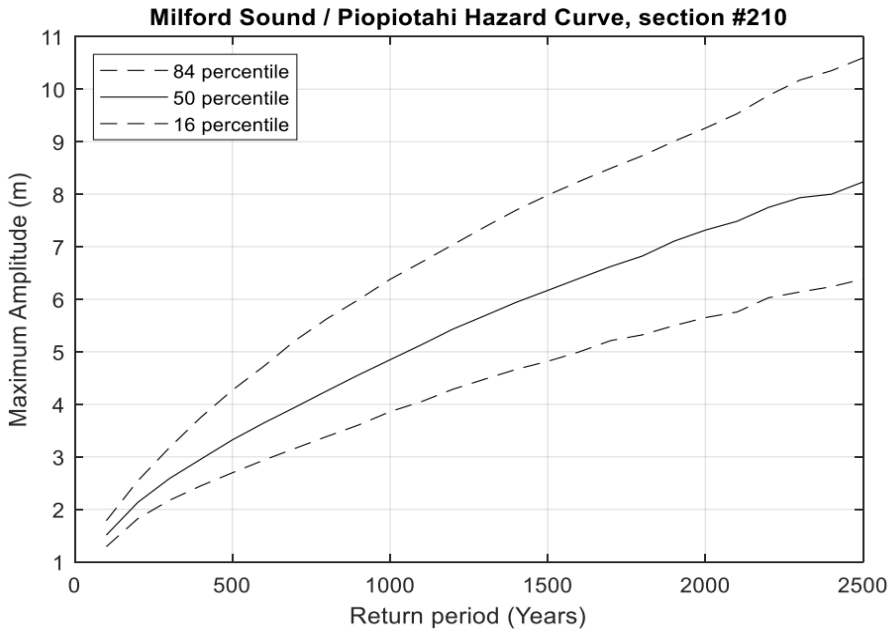


Figure 5: Return period of different tsunami waves heights at Milford Sound Piopiotahi (source: GNS science 2021 National Tsunami Model).

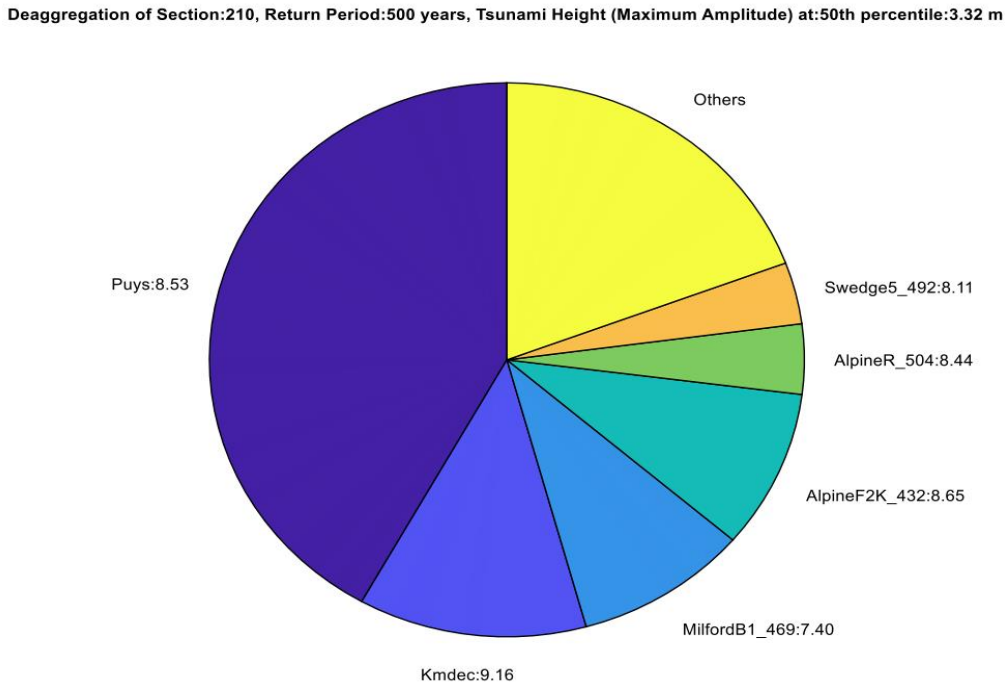


Figure 6: A graph of contributions (de-aggregation) of tsunami wave source for a 500-year return period tsunami wave at Milford Sound for different faults (source: GNS Science 2021 National Tsunami Model).

5 PREVIOUS HAZARD AND RISK REVIEW

In March 2021 as part of the Stage 2 works consultants Stantec and Boffa Miskell prepared a Hazards and Visitor Risk Review.

The report concluded that the MOP study area was subject to a number of natural hazards and that the occurrence of the hazard was likely to be substantially affected by climate change effects that included, sea level rise, changing weather patterns and increased human activity.

The Stage 2 work identified key natural hazards to be associated with:

- Landslide (including tree fall/slide).
- Rockfall.
- Flooding.
- Debris flow.
- Avalanche (including snow and ice).
- Earthquake (Alpine fault and ground shaking).
- Tsunamis and lake tsunamis (seiche).
- Contaminated Land.

The report also identified the key receptors or populations considered to be at risk from the hazards to be:

- Workers (both commuting and working along the corridor)
- Visitors
- Existing infrastructure and structures (including utilities and lifeline connections)
- Transport connections (land, sea and air)
- Proposed development

The report provided key information that could aid in the natural hazards assessment of the Stage 3 works including:

- An initial assessment of hazard risks (natural and human) for Milford Sound Piopiotahi and the national park road corridor to, and including, the Te Anau Basin.
- Maps identifying hazards where appropriate.
- An evaluation and summary of existing information to inform Master Plan development and outcomes.
- A specific evaluation of locations through the project area linked to the 'strategic options' included in the Master Plan and other workstreams including Land Capability Analysis, and Infrastructure Assessment.
- Preliminary comments on the level of hazard risks posed to visitor safety and experience and infrastructure development.

The previous study concluded that there are numerous natural hazards present across the MOP project footprint that require further consideration and assessment in terms of risk exposure of the population distribution, allowing for forecasted and planned increases in tourism, development and the likely effects of climate change.

In order to structure the approach of the assessment Stantec introduced the concept of three scales of hazards based on their typical location of occurrence, associated trigger activity and frequency. These were then generalised as:

1) Average Day – Lower Impact Hazards,

   These hazards were described as typically inherent to routine operations in the region and covered a wide range of natural and human sources. A large portion of these hazards were identified as being somewhat managed by operators and key stakeholders with a duty of care or responsibility through legal framework to manage or mitigate the risk posed to users, operators and associated assets as far as reasonably practicable to do so.

2) Seasonal and Periodic - Moderate Impact Hazards,

   These hazards were assessed as having a higher level of impact than the Average Day. These hazards would typically pose a greater challenge to the controlling authorities/operators and were typically associated with either seasonal variations (both in weather patterns and in visitor number distribution) or moderate periodic occurrences, such as major storm events. These events would impact a much wider area and potentially result in moderate levels of consequence.

3) Rare - Severe Impact Hazard Scenarios,

   Much of the Rare severe hazards are typically associated with trigger event scenarios that occur on a scale greater than a single lifetime. Much of the hazard scenarios present in the Milford basin and along the Milford Road corridor that are anticipated under this scenario would be triggered as a direct result of a major earthquake such as that anticipated along the Alpine Fault (AF8). These scenarios are likely to result in widespread (regional if not national) scale impacts with multiple cumulative effects that may result in major impacts and greater levels of fatality and loss.

This initial screening provided the MOP team with a qualitative means of understanding the distribution of hazards in relation to key receptors and the likely level of consequence of an event.

Based on the Stage 2 works and initial screening several hazard types and associated impacts have been assessed as Average Day – Lower Impact Hazards. These hazards are deemed to pose only low or medium risks to key receptors, structures and assets and are typically managed through existing management procedures or mitigation measures. As such these hazards are not considered to pose a Moderate, High or Critical risk of loss of life. Whilst the effects of climate change and human activity are likely to increase the likelihood of the occurrence of an event, the level of consequence is unlikely to alter significantly.

In addition, key stakeholders and operators such as (but not limited to) DoC and Waka Kotahi NZTA are continuously assessing the impact of these types of hazard and are, over time, reducing the risk posed to acceptable or more tolerable levels through targeted interventions, controlled management plans and improved levels of resilience to such events or occurrences.

The Seasonal and Periodic Moderate Impact Hazard Scenarios pose a greater level of risk of loss of life or loss of asset and warrant more detailed consideration and assessment accordingly.

The initial assessment of natural hazard occurrence along the project corridor identified key hazards to be either seasonal or most likely triggered by seasonal/annual events, mainly snowfall and heavy rainfall.

Seasonal occurrence of avalanches and heavy snowfall was identified as posing a risk to the Milford Road and various valleys and high-country areas across the MOP study area and consequently to several of the proposed Nodes and Short Stops. However, the seasonal distribution of visitor numbers and operators combined with transport route availability limits the exposure and subsequent risk level at several of these sites. Changes in tourism distribution, seasonal distribution and increased route availability would however potentially increase the risk of fatality or loss associated with this hazard group.

Improvements in the management of the hazard (such as snow, ice and avalanche occurrence or landslide monitoring and rockfall occurrence) combined with improvements to the resilience of key transport routes (such as the development of the new avalanche shelter at the Homer Tunnel) would also impact the overall assessed societal risks.

The Rare – Severe Impact Scenarios are however more complex and could result in region-wide impacts that may also include multiple fatalities as a result of cumulative or cascading effects of natural hazards. The most severe hazard scenario considered in the project area is that of a landslide-induced tsunami occurring as a result of a major earthquake event in close proximity to Milford Sound (AF8 type event).

This form of event scenario is considered to have a recurrence interval of several hundreds of years at least and the impacts are likely to be severe if not catastrophic.

In order to manage the Rare – Severe impact scenarios, staged and detailed assessment of the nature of the hazards, the trigger event scenarios and population distribution are required to facilitate a qualified risk assessment. Once the risk levels for the associated hazards and cumulative effects are considered then risk avoidance (or acceptance), mitigation or management can be considered.

As noted above in the previous section the Stage 2 hazard report produced by Stantec (2021)[11] for the Milford Opportunities Project described the relevant hazards and their typical triggers in depth. Table 12 below summarises the identified potential hazards at each Node site.

[11] Stantec. (2021). Milford Opportunities Project – Hazards and Visitor Risk Review Report. Dated 10 March 2021.

Table 12: Overview of the potential hazards at each Node.

Node Site	Identified Key Natural Hazard					
	Flooding	Rockfall	Debris Flow	Landslide/ tree slide	Avalanche	Tsunami/Seiche
Gateway (Node 1)						
Eglinton Reveal (Node 2)						
Te Huakaue Knobs Flat (Node 3)						
Ōtāpara Cascade Creek (Node 4)						
The Divide (Node 5A)						
Whakatipu Trails head (Node 5B)						
Gertrude Valley (Node 6)						
Cleddau Cirque (Node 7)						
Piopiotahi Visitor Hub						
Freshwater Basin						
Cleddau Delta						
Deepwater Basin						

6 SEMI-QUANTITATIVE RISK ASSESSMENT

In accordance with the published GNS methodology a semi-quantitative risk assessment has been completed and is presented here for the Milford Opportunities Project key Nodes, Short Stops and key proposed walking tracks and trails.

A site hazard Class has been determined for each node, short stop, and three of the proposed walking tracks on the Milford Road; the Countess Range Track, Gertrude Valley Loop Track, and Hinepipiwai Lake Marian Loop Track. Table 15 in Appendix B documents the usage, hazard, exposure, site Class, and recommended actions for each site.

For the purposes of this Part A report, the sites in the MOP are separated into sites located along the Milford Road (excluding Milford Sound Piopiotahi), sites in Milford Sound Piopiotahi and walking tracks and trails located away from the Milford Road and Milford Sound Piopiotahi area.

6.1 MILFORD ROAD SITES

The Part A Preliminary Screening Analysis uses a Semi-Quantitative Risk Assessment methodology and identifies a number of Class 1, 2 and 3 sites to be present along the Milford Road.

The majority of the Nodes and Short Stops are typically impacted by hazard footprints associated with landslide, flood and avalanche impacts.

Each is described in detail below.

6.1.1 LANDSLIDE, FLOOD, AND AVALANCHE RISK

6.1.1.1 CLASS 1 SITES

Class 1 sites are those with a sufficiently low hazard probability or exposure time so that risk to visitors is minimal.

Typically for sites away from steep slopes and rivers/streams, the probability of a hazard impacting the site is deemed to be very low (>10,000-year return interval) to medium (100 – 1000-year return interval).

Shorter exposure times reduce risk at the medium-level hazard sites.

Sites assessed as Class 1 are:

Table 13: Class 1 Sites

Site	Short Stop or Node	Temporal Probability	Site Class	Risk Rating
Te Anau Hub	Node 0	>180mins	Class 1	Insignificant
Te Rua-o-Te-Moko Fiordland National Park Gateway	Node 1	2-30mins	Class 1	Insignificant
Eglinton Reveal	Node 2	2-30mins	Class 1	Insignificant
Walker Creek DOC Campsite	Short Stop	>180mins	Class 1	Insignificant
Totara DOC Campsite	Short Stop	>180mins	Class 1	Insignificant
Upper Eglinton DOC Campsite	Short Stop	>180mins	Class 1	Insignificant
Mirror Lakes Waiwhakaata	Short Stop	30-180mins	Class 1	Insignificant
Lake Gunn and Lake Fergus lookouts	Short Stop	2-30mins	Class 1	Insignificant
Falls Creek Falls and Christie Falls, Monkey Creek	Short Stop	30-180mins	Class 1	Insignificant
Cleddau Cirque	Node 7	2-30mins	Class 1	Insignificant

For Class 1 sites no further risk assessment is considered necessary and existing mitigation or hazard management plans are considered sufficient to manage the exposure to acceptable levels. This is discussed in detail in Section 7.

6.1.1.2 CLASS 2 SITES

Class 2 sites generally have a greater probability of hazard occurrence or impact on the site area coupled with a longer exposure time.

Some campsites and accommodation facilities on the Eglinton River are likely to be exposed to flooding with a low probability of occurrence (1000 – 10,000-year return interval). These sites are located within close proximity to the active river channel or flood plain of the Eglinton River and may be inundated during intense rainfall events. Longer exposure times at these locations also increases the risk posed to visitors and users of the sites.

Te Huakaue Knobs Flat (Node 3) is situated on an active alluvial fan located in the Eglinton River Valley and is assessed as being exposed to flood and debris flows from Kiosk Creek and Waterfall Creek which are tributaries of the Eglinton River (Figure 7[12]).

This site is assessed as a low probability of hazard occurrence due to its distance from Kiosk Creek and Waterfall Creek and the implementation of various earthworks comprising formed bunds and cut drainage ditches along the eastern extent of the site to mitigate the potential flooding hazard. However, the site serves as accommodation, as such the exposure time is assessed as greater than 180 minutes which, when considering the hazard footprint, occurrence interval and exposure time the site Class is determined as being Class 2.

The following sites have been determined as being Class 2 Sites:

Table 14: Class 2 Sites

Site	Short Stop or Node	Temporal Probability	Site Class	Risk Rating
Mackay Creek DOC Campsite	Short Stop	>180mins	Class 2	Significant to Substantial
Countess Range Hut	Short Stop	>180mins	Class 2	Significant to Substantial
Deer Flat DOC Campsite	Short Stop	>180mins	Class 2	Significant to Substantial
Te Huakaue Knobs Flat	Node 3	>180mins	Class 2	Significant to Substantial
The Divide	Node 5a	30-180mins	Class 2	Significant to Substantial
Whakatipu Trails Head	Node 5b	>180mins	Class 2	Significant to Substantial
Gertrude Valley	Node 6	>180mins	Class 2	Significant to Substantial
The Chasm	Short Stop	30-180mins	Class 2	Significant to Substantial

[12] Geosolve. (2019). Natural Hazards Assessment for Report for Resource Consent. Knobs Flat, Fiordland. Dated July 2019.

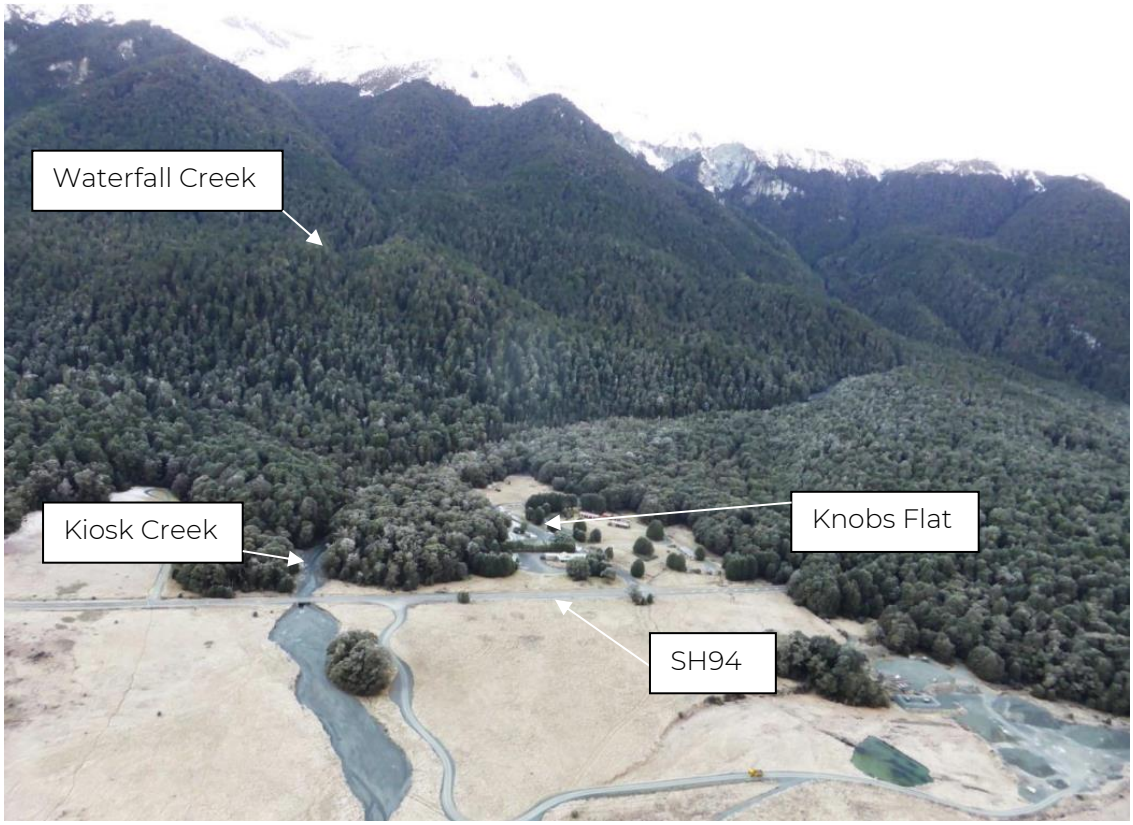


Figure 7: An aerial photo of the Te Huakaue Knobs Flat site (source: Geosolve 2019).

The Divide (Node 5A) is a recognised shelter location and trailhead stop point located on the roadside north of Lake Gunn and Lake Fergus. There is evidence of active debris flows in the gully located to the west of the site which may have the potential to impact the site, however no known impact at the site has been recorded. Debris flows are therefore estimated to be a medium-level hazard with a return interval of 100 – 1000 years. Exposure at this site is estimated to be 30 to 180 minutes as people use it as a start/finish point for nearby trails including the Greenstone and Routeburn Tracks. On this basis the site is assessed as being a Class 2 Site.

The Whakatipu Trails Head (Node 5B) and Gertrude Valley (Node 6) are both situated on the Hollyford River and are exposed to flooding, rockfall/rock avalanche. The hazard footprint and recurrence interval is estimated to have a low probability of impacting the sites, whilst exposure is reasonably high as visitors use shelters/toilet and Homer Hut facilities. While Node 5B is not exposed to avalanche hazards, the adjacent Lake Marian Tracks are.

Gertrude Valley (Node 6) is exposed to avalanches[13], particularly during the winter and avalanche season (May-November). The Node itself is located in the lower Gertrude Valley close to the road and car park area situated within a forested area and has a natural resilience to avalanches. Avalanche hazard is likely to increase further up the Gertrude Valley with increasing elevation, reduced vegetation cover and proximity to the steeper mountain sides. Visitors are predominantly Short Stop Travellers (SST) and therefore an AHI is recommended for this site.

[13] Milford Road Alliance. (2023). Avalanche hazard assessment for proposal sites along the Milford Road – Milford Opportunities Group.

There is the potential for avalanche hazards at The Chasm. Visitors are predominantly Short Stop Travellers (SST) and therefore an AHI is recommended for this site.

6.1.1.3 CLASS 3 SITES

Ōtāpara Cascade Creek (Node 4) is the only site outside of Milford Sound Piopiotahi assessed as Class 3. Ōtāpara Cascade Creek is identified as a short stop and campsite location that is situated at the southern end of Lake Gunn on the confluence of Ōtāpara Cascade Creek and the upper Eglinton River.

The campsite is low-lying and is potentially exposed to flooding from both waterways.

Large but infrequent landslides are also known to occur in the area such as the large-scale Lake Gunn landslide (Figure 9).

Figure 8: Drone image of Ōtāpara Cascade Creek Campsite with Lake Gunn in the top left of the image (source: Boffa Miskell).

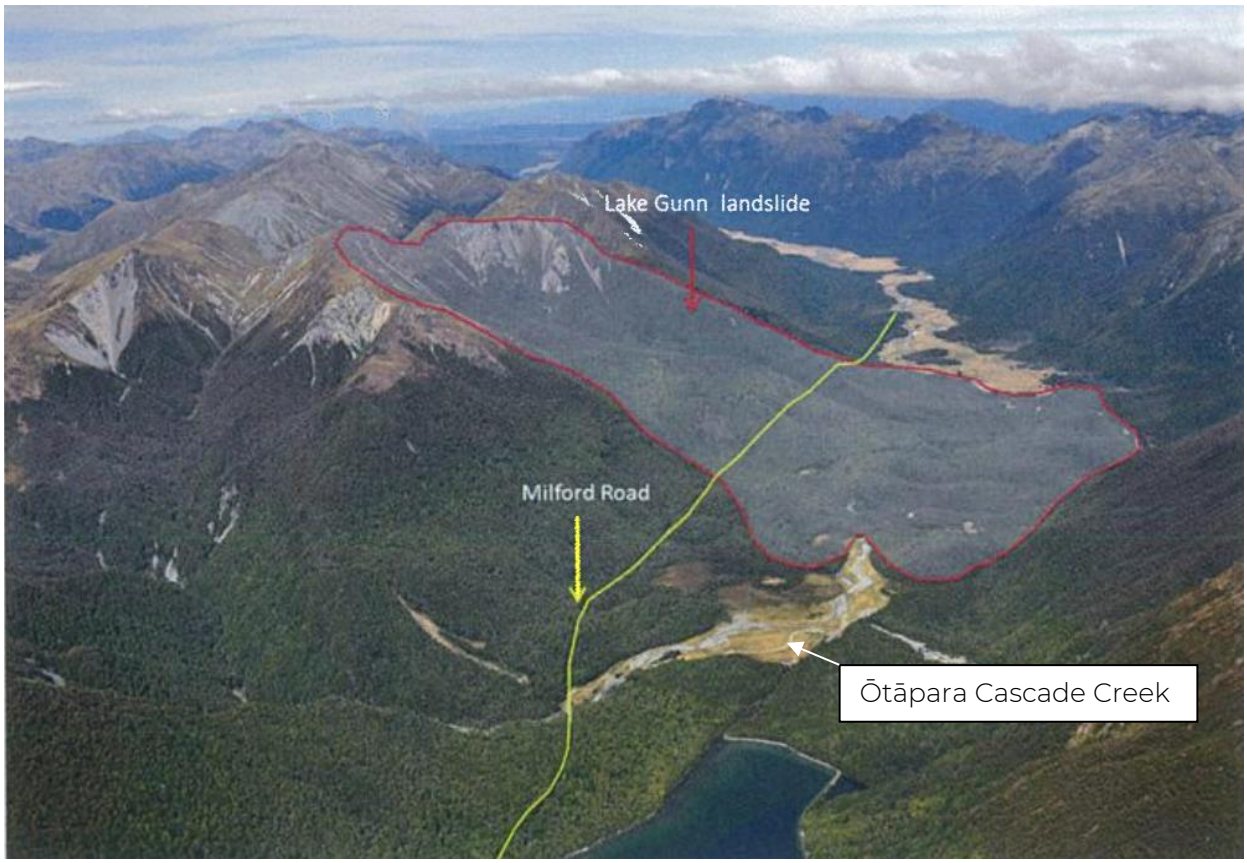


Figure 9: An aerial photograph of the Lake Gunn landslide (source: GNS Science).

6.1.2 TSUNAMI RISK

Tsunami risk along the Milford Road is generally not a concern. However, lake-based tsunami is a recognised hazard and various studies have been completed to determine the risk posed by tsunamis and lake tsunamis or seiche occurrence across the region, (Environment Southland, Tsunamis and Seiche Study GNS, 2012).

Lake tsunami can be triggered by either fault line activation or by landslide impacts. Landsliding caused by either earthquake or heavy rainfall into Lake Marian, Lake Gunn or Lake Fergus may in theory trigger a lake tsunami wave which could therefore impact the Ōtāpara Cascade Creek site or the Lake Marian walking track and Lake outlet. The hazard is assessed as a low-probability hazard in terms of recurrence interval or probability of occurrence. Exposure at the Ōtāpara Cascade Creek site is estimated at over 180 minutes and therefore the site is assessed as a Class 2 site for landslide induced lake tsunami risk. The exposure at Lake Marian is also likely to much lower and as such at this stage the hazard has been assessed as Class 2 as the visitors would be located within the potential hazard footprint.

6.2 MILFORD SOUND PIOPIOTAHI

For the purposes of this report, Milford Sound Piopiotahi area is defined as the area west of the Tūtoko and Cleddau River confluence.

This area includes the following key sites: Little Tahiti, Milford Sound Lodge, Deepwater Basin, Cleddau Delta, and Freshwater Basin (Figure 10).

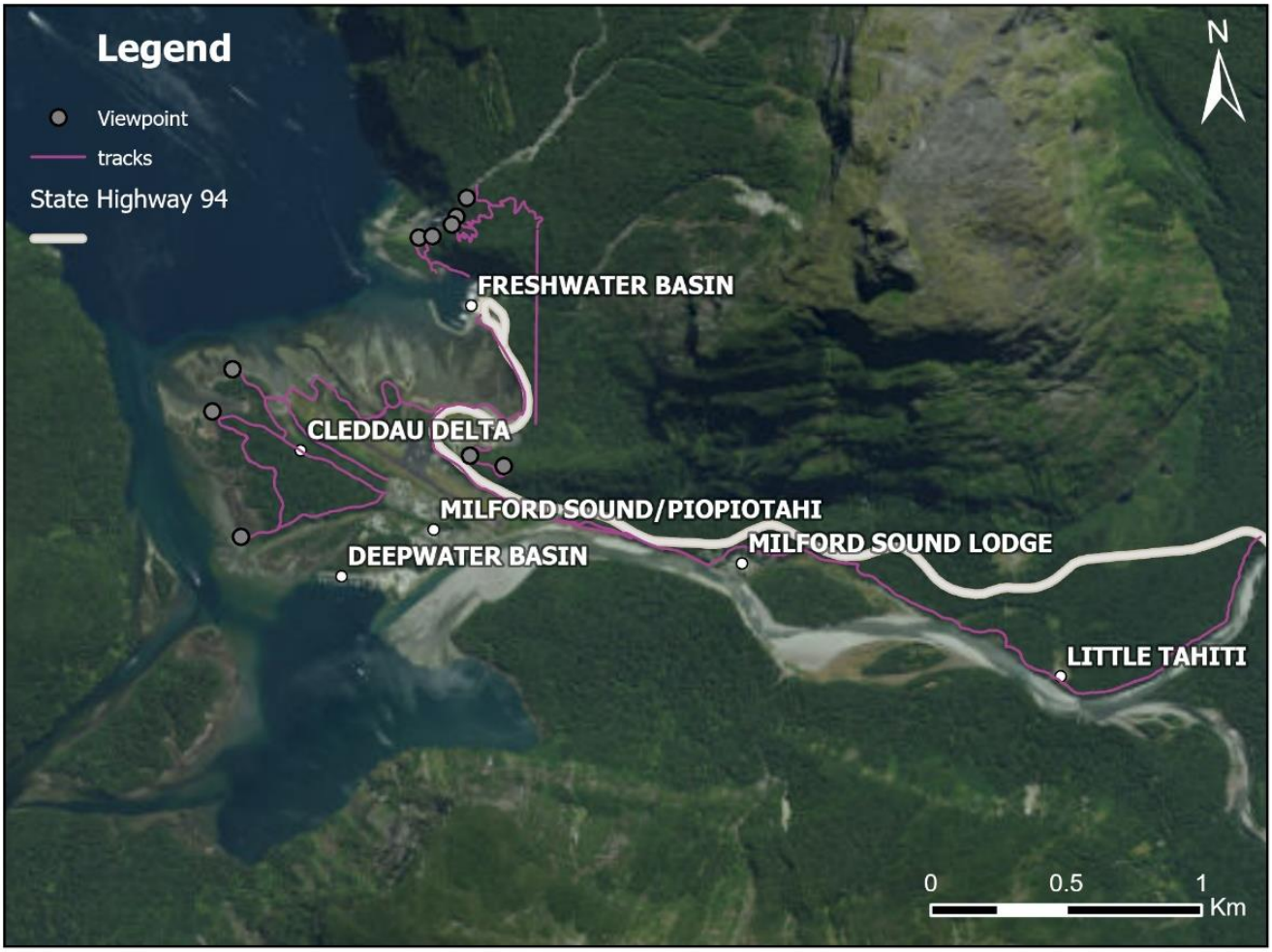


Figure 10: Aerial map of Milford Sound Piopiotahi.

Figure 11: Milford Sound Piopiotahi sites under the MOP Master Plan (source: Stantec and Boffa Miskell).

6.2.1 *LANDSLIDE, FLOOD, AND AVALANCHE RISK*

6.2.1.1 CLASS 2 SITES

The Deepwater Basin and the Milford Sound visitor areas are situated on the Cleddau River delta which forms a reasonably flat peninsula surrounded by Milford Sound Piopiotahi.

The surrounding terrain is typically described as being steep heavily vegetated mountainous terrain (Figure 10). Previous studies and reports detail the extent of flood risk at Deepwater Basin and across the Cleddau Delta associated with the Cleddau River. There is extensive stop bank and rock armouring mitigation and control measures in place along the banks of the Cleddau at this site as a direct result of previous investigations and assessments of flood risk (Figure 12).

Flood mitigation is, based on existing data and reports, estimated to reduce the identified flood hazard to a low probability of occurrence, although exposure time remains high currently at these sites due to the presence of staff accommodation. If the proposal in the masterplan to relocate staff accommodation from this area is implemented, then exposure times will significantly reduce.

The Deepwater Basin and Cleddau Delta are assessed as Class 2 sites for flood risk associated with the Cleddau River.

Visitors also use the constructed walkway between the Milford Sound visitor centre and the ferry terminal in Freshwater Basin. This area is typically low-lying and at the bottom of steep to very steep mountain side with near vertical faces such as that at the Bowen Falls areas north of Freshwater Basin (Figure 13). This area is prone to landslides, tree slides, and occasional rockfall which have occurred in recent years. Notably a tree slide and rockfall event caused significant damage to a storage building in 2016 (Figure 14 and Figure 15).

Landslide and rockfall hazard probability at the Freshwater Basin is assessed qualitatively as medium. Rockfall and landslide hazard footprints in this area are mostly restricted to narrow chutes within existing gullies and on failed slopes while treeslides can occur in areas with mature vegetation outside of gullies.

Based on current usage of these areas site visitors and workers are expected to pass through hazard footprints in relatively short spaces of time and are unlikely to spend any significant time directly within the hazard footprint. Typical exposure windows of between 30 and 180 minutes have been determined in discussion with current site workers and operatives and future visitor use. The Freshwater Basin is assessed as a Class 2 site for landslides, tree slides, and rockfall.

On the Milford Sound Piopiotahi side of the Homer Tunnel, there are two sites on the Cleddau River assessed as being Class 2; Little Tahiti and Milford Sound Lodge. These sites are assessed as being exposed to flooding from the Cleddau River with a low probability of occurrence. However, the hazard at these sites is now somewhat mitigated due to the elevation of the sites above the existing river level and recent additional rock armouring placed along the riverbank at Little Tahiti and the Milford Sound Lodge. These sites were impacted by flood related scour and resulted in loss of the river bank during the February 2020 storm events that impacted the Milford region. However, neither the Little Tahiti or Milford Sound Lodge site were flooded or inundated during the event.

In addition to flood risk, there is an established risk of contaminated land and associated impacts at Little Tahiti where previous investigation and reporting has determined the site to have been previously used as a dump site for construction wastes including asbestos containing materials. The associated risks with contaminated land hazards is not covered by this report and is addressed in the contaminated land assessments and planning for remedial works is currently underway. The contaminated land hazard occurrence and risk assessment is assessed and reported separately.

Figure 12: The flood mitigation stop bank on the northern margin of the Cleddau River looking out towards Milford Sound.

Figure 13: Freshwater basin with an old tree slide scarp to the right of the image.

Figure 14: Tree slides and landslides in the hillslope next to freshwater basin in Milford Sound (source: Stantec 2021).

Figure 15: Damage to a storage building in Milford Sound from a rockfall in 2016 (source: Tim Holland).

6.2.2 TSUNAMI RISK (CLASS 3A)

The previous Stage 2 reporting identified the extent of tsunami risk in the Milford Sound area. Extensive studies and assessments of the occurrence of tsunamis within the sound or affecting the Milford Sound basin area have already concluded that there is a proven record of events having occurred over geological time.

As noted above there are typically two distinct sources of tsunami:

1) Landslide (rock avalanche) induced.
2) Earthquake induced sea floor rupture.

These are discussed and differentiated further in the Part B report, however for the purpose of the screening analysis a review of the data presented in the Stage 2 works concluded that for the Milford Sound Piopiotahi area, the wave amplitude of a 100-year return interval tsunami ($H_{50/100}$) was of the order of 1.3 – 1.9 m (Figure 5). This is based on the NTHM and only incorporates fault-induced tsunami.

For the Alpine Fault triggered landslide tsunami event, there is 150-year return interval for tsunami amplitudes ranging between 0.3 and 10 m at Freshwater Basin[14]. For the Visitor Hub, Freshwater Basin, Deepwater Basin, and Cleddau Delta $S_{overland}$ (tsunami wave amplitudes required to impact the site) has been calculated as being 1.52 m, 1 m, and 0.5 m which are tsunami events all estimated to occur at least once every 100 years. Given the current use of the basin and population distributions around the area exposure times across the three sites in Milford Sound Piopiotahi have been determined as being greater than 180 minutes. Adopting the GNS methodology the Preliminary Analysis of tsunami risk as detailed in the tables presented in Section 2, determines the site as being Class 3(a) for tsunami risk.

Due to the elevation and distance from the coast of the Milford Sound Lodge (~ 11 m above sea level and 1200 m away) and Little Tahiti (~19 m above sea level and 2400 m away), it is anticipated that a much larger tsunami wave at the Cleddau River Mouth would be needed before an actual impact at either site would occur.

For the Milford Sound Lodge $S_{overriver}$ has been calculated as 7.03 m which is equivalent to a tsunami with a return interval of 150 years (AF8 event). This hazard is qualitatively assessed as having a medium probability of occurrence. Exposure time at this site is also anticipated to be greater than 180 minutes. On this basis the Milford Sound Lodge is categorised as a Class 3 site for tsunami risk.

For the Little Tahiti site, $S_{overriver}$ has been calculated as 12.5 m. This is outside of the range of potential amplitudes from an AF8 event. A 12.5 m amplitude tsunami wave at Milford has been assessed as having a return interval of 555 years according to Dykstra (2012), > 2500 years according to Taig & McSaveney (2015), and >2500 years using theNTHM. This is assessed as a hazard with a low probability of occurrence and as such Little Tahiti is categorised as a Class 2 site for tsunami risk.

[14] Taig and McSaveney (2015)

6.3 TRACKS & TRAILS

There are several walking tracks and trails proposed as part of the MOP. As part of the Preliminary Screening Assessment (Part A) they have been assessed in terms of their location in relation to identified or known hazard footprints and classed using the same risk classification matrix as the nodes and short stops.

Tracks are linear sites, and they typically cross hazard footprints as well as areas of no hazard occurrence. As such, as part of this Preliminary Screening Assessment, the maximum assessed Class at any point of the track is used to define the overall hazard Class of the entire track. For example, the Cycle trail is assessed as Class 3 as there is a 100 m section of track assessed as Class 3 near to the East Eglinton confluence. This approach is considered to be conservative, as some tracks may have only limited sections exposed to a hazard, however this allows for screening out of tracks where there is little to no risk.

Those tracks or trails identified to have areas of potentially significant risk will then be analysed as part of the Part B or Part C risk analyses required (Basic or Advanced Analysis). For the purposes of this Part A report, three of the higher-risk tracks have been identified for preliminary screening.

6.3.1 CLASS 1 TRACKS

Initial screening and assessment of the identified walking tracks in the lower Eglinton Valley including Lake Mistletoe Track, Eglinton River Trail, and Mirror Lakes Walk have determined that the trails are generally located on relatively flat terrain at lower elevations with no major changes in slope. Flooding is a possible concern at these sites but exposure times along river/stream channels is assessed as being relatively low due to short or controlled crossings.

Flooding is also a potential hazard at the Chasm track, however recurrence probability is assessed as low due to the elevation of the track.

The proposed tracks at the Divide in the upper Eglinton Valley are likely to be susceptible to possible rockfall, landslides, and tree slides, however, the terrain is well forested and previous occurrence of these hazards has not been identified, suggesting a lower hazard recurrence interval.

In Milford Sound Piopiotahi the Barren Peak Spur Track (see Figure 11) is the only track assessed as Class 1. This is due to its elevation above any flooding or tsunami sources, and lack of identified immediate rockfall/landslide sources.

Class 1 tracks are not considered to present a significant risk to potential trail users and workers and as such no further risk assessment is required for these tracks and trails.

6.3.2 CLASS 2 TRACKS

On the Milford Road, Te Huakaue Knobs Flat Short Walks, Key Summit to Ōtāpara Cascade Creek Track, Hinepipiwai Lake Marian Falls Loop Track, the Chasm to Cleddau Horse Bridge Track, and the Milford Sound Lodge to Tutoko River Bridge Track are all considered to pass through or be located within hazard footprints that pose a risk to track/trail users. These tracks are assessed as having a maximum site hazard Class of 2.

Visitors on the Te Huakaue Knobs Flat Short Walks and Key Summit to Ōtāpara Cascade Creek Track are likely to be exposed to medium probability flooding, debris flow, and rockfall hazards.

Based on discussions with the MOP team and assessing visitor user types for these areas, the visitor groups are anticipated to spend 30 to 180 minutes in the hazard-prone areas.

Visitors on the Chasm to Cleddau Horse Bridge Track are likely to be exposed to rockfall, debris flow, flooding, and avalanche hazards. Sections of the track traverse through steep undulating terrain prone to rockfall. There are several active stream channel crossings which are prone to flooding and debris flow. Sections of the track are near to or above the tree line where avalanches are known to occur from the southeast facing slopes west of the track. Visitor typology for this trail is likely to be predominately DV. Based on discussions with the MOP team and assessing visitor user types for these areas, the visitor groups are anticipated to spend 30 to 180 minutes in the hazard-prone areas.

Visitors on the Milford Sound Lodge to Tutoko River Bridge Track are likely to be exposed to medium probability flooding from the Cleddau and Tutoko Rivers. Visitors are also anticipated to spend 30 to 180 minutes in flooding-prone areas.

In Milford Sound Piopiotahi the Hine-te-awa Bowen Falls – Upper Walking Tracks are Preliminary assessed as Class 2. This is due to the tracks crossing potential rockfall and landslide areas and the area being prone to tree slide. Tsunami risk is assessed as very low for these tracks due to the elevation of the track above the sound.

6.3.3 CLASS 3 TRACKS

Along the Milford Road four tracks are assessed as having a maximum site hazard Class of 3: the Countess Range Track, Gertrude Valley Loop Track, Hinepipiwai Lake Marian Loop Track, and the Cycle Trail.

The hazard and exposure on each of these tracks is detailed below. Exposure to each hazard is defined as the estimated time it takes for a visitor to pass through hazard areas.

In Milford Sound Piopiotahi the Hine-te-awa Bowen Falls – Lower walking tracks, and the Cleddau Delta tracks are also assessed as Class 3(a) due to tsunami risk, the dominant hazard for this area of the site.

Class 3 sites are considered to present a Significant or Substantial risk rating based on the GNS methodology and warrant further Basic or Advanced Risk Assessment. As such these sites are to be covered in more detail as part of the Part B Basic Analysis risk assessment reporting that will follow this Part A analysis.

6.3.3.1 COUNTESS RANGE TRACK

The proposed Countess Range Track in the Eglinton Valley is a steep undulating track with significant elevation gain and exposure to rockfall, landslides, debris flow, and potentially flooding, where streams or river channels are to be crossed. In the winter, sections of the track above the tree line may also be exposed to heavy snow fall and avalanche.

Based on provided trail details from the trail designer and aerial imagery, the track is predominantly assessed as Class 1 with sections assessed as Class 2 or Class 3 as shown below in Figure 16.

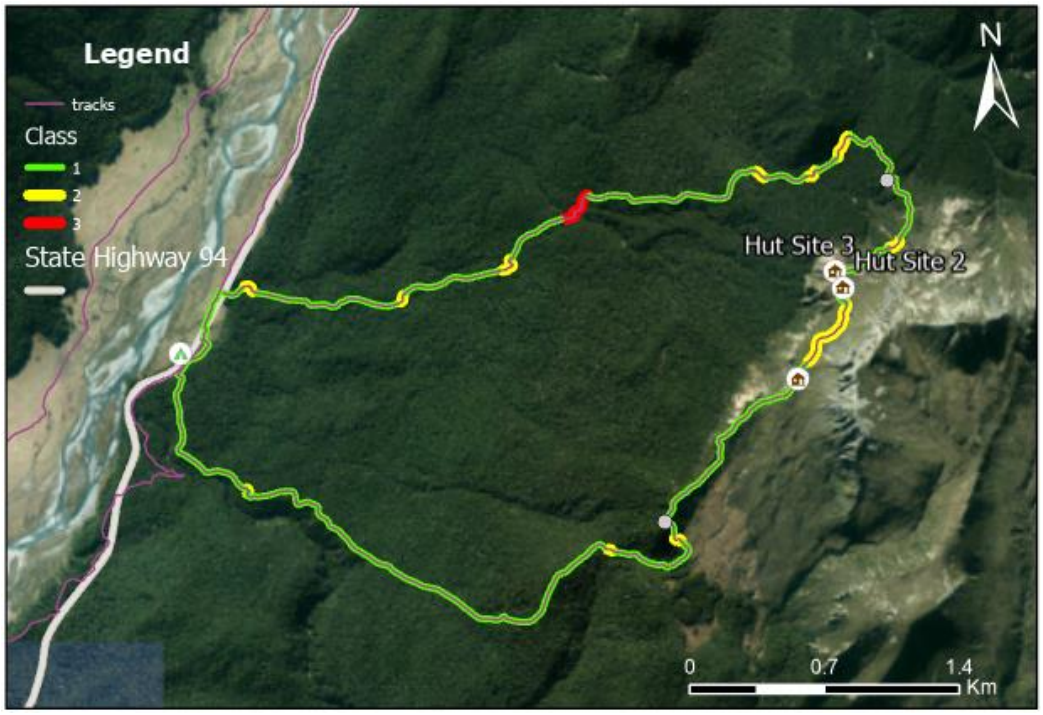


Figure 16: Plan of the Countess Range Track with sections marked with Preliminary Assessed hazard Class.

The track is assessed as having several potential stream crossings where visitors are likely to be exposed to flooding and debris flow hazards. Exposure time is however relatively low on these sections, but hazard frequency is likely to be high.

The track climbs away from the State Highway towards the east and an exposed plateau located below the Countess Range summit (Figure 17). On the higher sections track users are likely to be exposed to rockfall and landslides and are likely to be exposed to the hazard for a longer period of time.

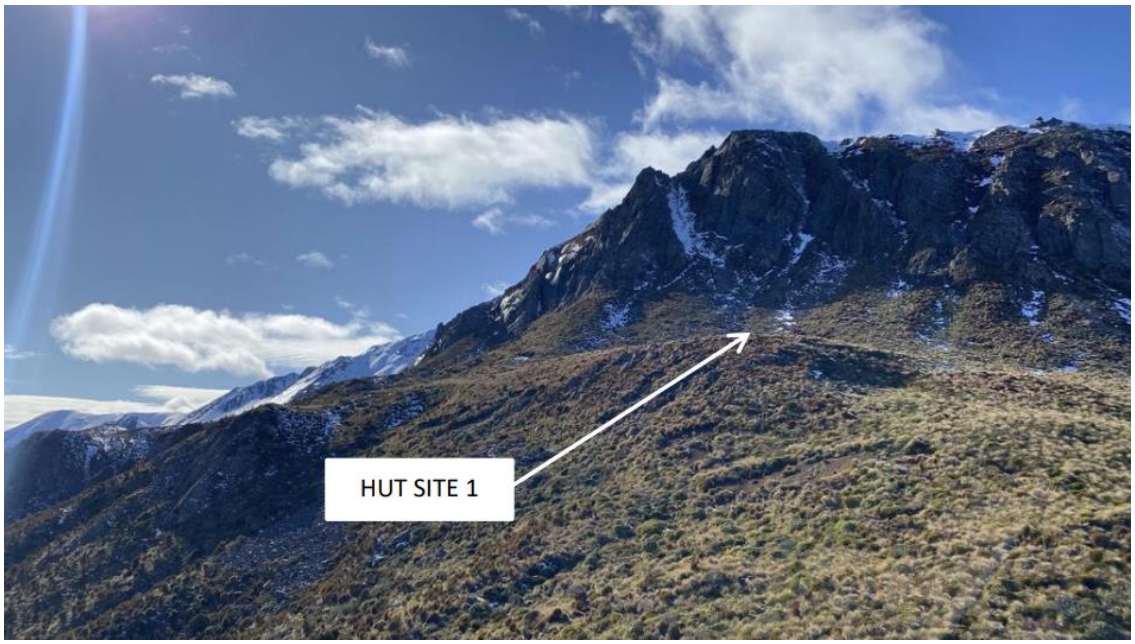


Figure 17: A proposed hut site along the ridge below the Countess Range (source: Southern Land 2023)

The proposed hut locations have been identified by the trail designer, DoC representatives and MOP representatives as being areas of relatively lower risk of rockfall, landslide, and avalanche.

However, based on provided data and assessed hazard footprints the sites are preliminary assessed as Class 2. Visitors to the hut may comprise either BCC and BCA and therefore an ATES assessment of the site is recommended.

6.3.3.2 GERTRUDE VALLEY LOOP TRACK

The proposed Gertrude Valley Loop Track is located near the eastern portal of the Homer Tunnel at the mouth of the Gertrude Valley.

The proposed circular loop track route commences and ends at the Gertrude Valley car park and is typically described as an undulating track cut through a sparsely vegetated valley along the lower reaches of the Darran Mountain range, namely West Peak (2203m) of Mt Crosscut.

The proposed track crosses a small stream east of the carpark and then traverses several active and dormant rock avalanche/debris flow fans at the toe of the eastern slopes of West Peak. The steep slopes are prone to identified hazards such as rockfall, landslide, snowfall and avalanche. The probability of occurrence is considered greater where the track exits the existing areas of bush and crosses active rock avalanche/debris flow paths (Figure 19).

In the winter, sections of the track may also be exposed to heavy snow fall and possibly avalanche. Visitor typology at this site is predominately Short Stop Traveller (SST) and therefore an AHI is recommended for this site.

On this basis the track is predominantly assessed as Class 2 with sections assessed as Class 1 and Class 3 as shown on Figure 18 below.

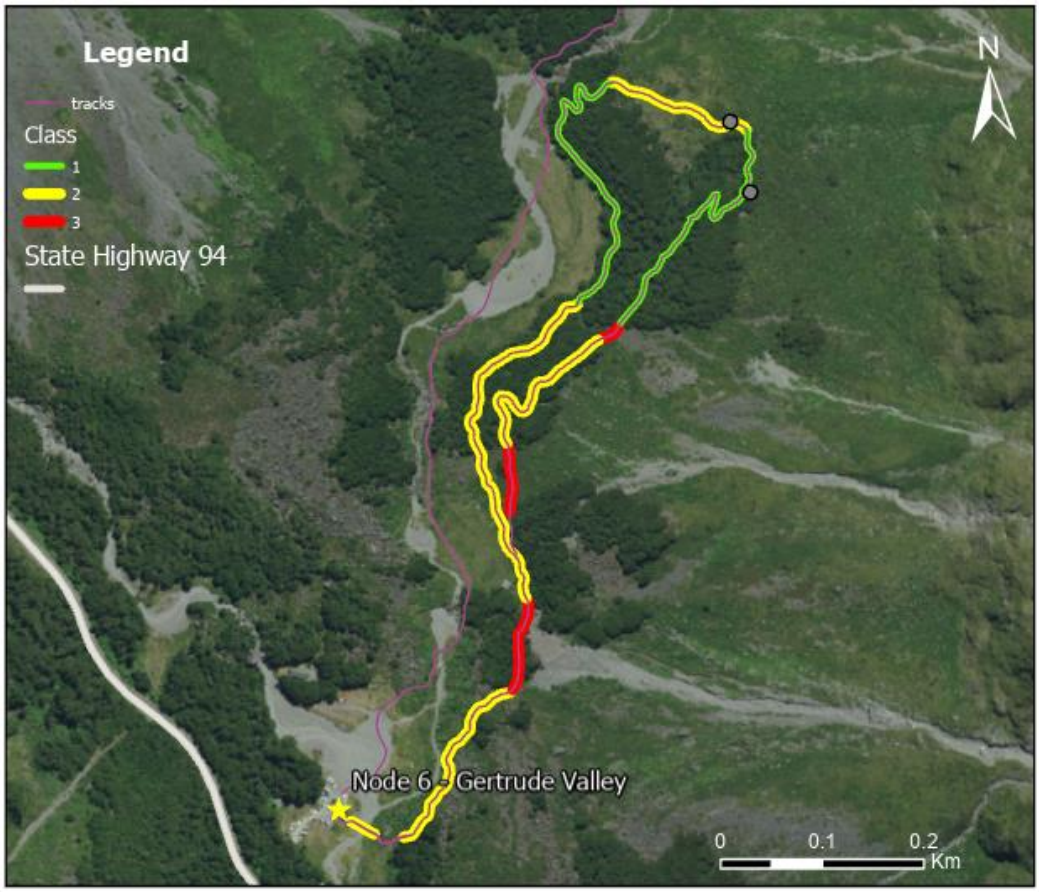


Figure 18: The proposed Gertrude Valley Loop Track and associated viewpoints.

Figure 19: The active debris flow/rock avalanche path on the proposed Gertrude Valley Loop Track.

6.3.3.3 HINEPIPIWAI LAKE MARIAN LOOP TRACK

The Hinepipiwai Lake Marian Loop Track is likely to be a more advanced hiker trail, a steep day long walk starting from Node 5B – Whakatipu Trails Head.

From the trailhead, the track crosses the Hollyford River and makes it way up steep terrain to the Lake shore. The track is a loop climbing up the western side of the valley and returning down the east side (Figure 20). The trail is described as a steady climb with some steep sections.

The existing trail has sections of boardwalk, bridges and fenced trail. A majority of the track location is over areas of boulders caused by rockfall.

Where the track crosses active debris flow channels on the western side of the valley it is preliminary assessed as Class 3.

At Hinepipiwai Lake Marian, visitors are known to overnight camp and whilst the rockfall/debris flow hazard is comparatively low in the central part of the valley, staying overnight here increases the potential exposure time (temporal probability). Visitors may also be exposed to landslide - induced tsunami waves from Lake Marian during large (Alpine Fault Event) earthquakes.

There is the potential for avalanches affecting the Lake Marian Loop Track particularly along sections of track above the tree line and where the track crosses existing stream/debris flow channels. Avalanches and ice collapse into the Lake may also produce smaller lake tsunami.

Whilst the track is mostly cut above the stream channel various sections run along next to the stream. Due to the high flows the assessed hazard class for these sections is preliminary screened as Class 3.

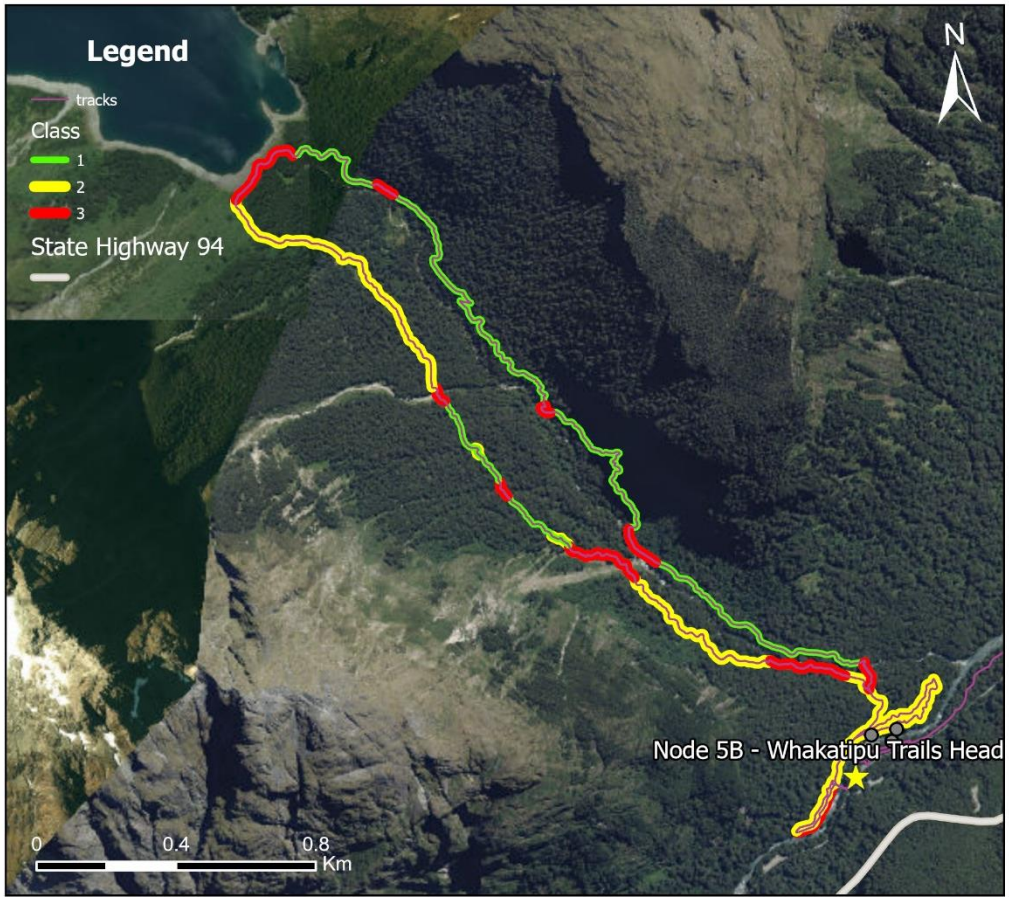


Figure 20: The Lake Marian Loop Track highlighted with preliminary hazard Classes for natural hazard risk.

6.3.3.4 CYCLE TRAILS

As part of the MOP there is a proposal to develop a Grade 2 cycle trail along parts of the Milford Road. The trails can be linked to form a continuous off-road route from Te Anau Downs to The Divide. Southern Land presented the proposed cycle trail routes in their 2023 report which also highlighted potential hazard areas[15].

From Te Anau Downs to Black Creek there are two trail options. Option 1 which is the preferred route, heads north from Te Anau Downs and travels along the western extent of the Eglinton River. Trail users can be expected to be exposed to landslides/tree slides, flooding, debris flows, and rockfall along this route. Areas of concern include the Limestone Gorge viewpoint turnoff to Eglinton River floodplain, sections of trail on the Eglinton River floodplain, and the East Eglinton River confluence landslide.

[15] Southern Land. (2023). Milford Opportunities Project – Walking and Cycling Experiences Report.

A potential for tree slides has been identified in the area north of Limestone Gorge with ancient Beech Forest on steep terraces and various breaks in slope (Figure 21). Tree slides are assessed as a hazard with a high probability of occurrence.

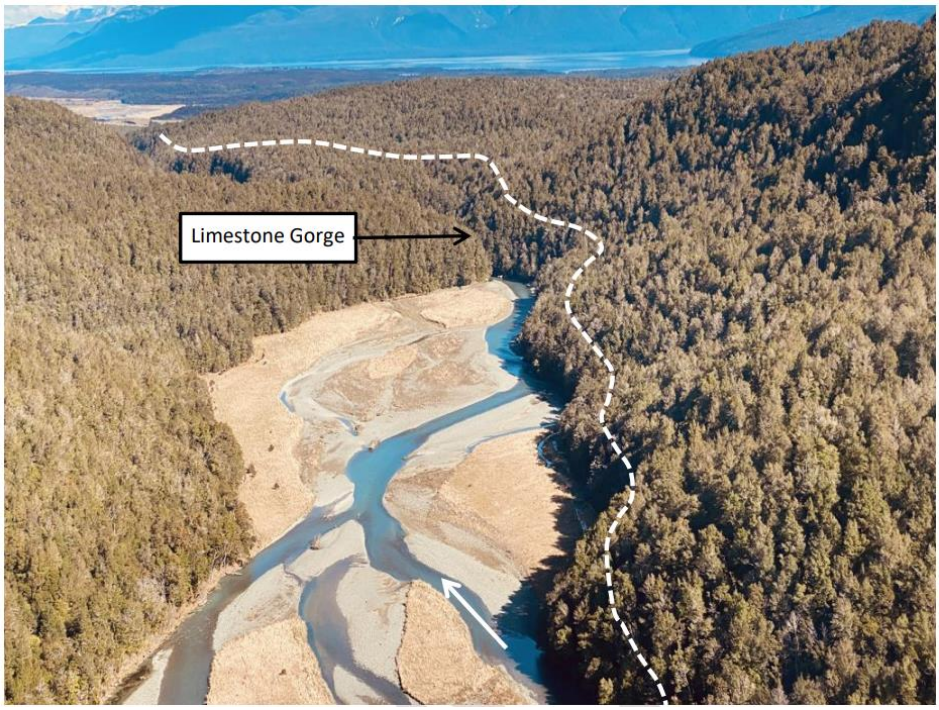


Figure 21: A section of the Option 1 trail looking south towards Limestone Gorge and Te Anau Downs. The vegetated area to the right of the image is prone to tree sliding (source: Southern Land (2023).

In terms of hazard class this section of trail has been assessed as being Class 2.

Option 1 crosses the Eglinton River floodplain in several locations. The trail is positioned mostly on the grassed areas of the floodplain and is elevated from the incised active river channel. Flooding has been assessed as a hazard with a medium probability along these sections of trail with a recurrence interval of 100-1000 years.

As part of the preliminary screening assessment trail users are estimated to take between 30 and 180 minutes to cross the floodplains. On this basis these sections of trail are assessed as being a Class 2 hazard. However, flooding along trail sections can be relatively easily managed which may decrease the site class. This will be discussed further in the Part B report.

At the confluence of the East Eglinton River Option 1 crosses an active landslide site.

Trail users will be potentially exposed to further landslide, rock fall, as well as flood hazards from the adjacent Eglinton River. The preferred option is for the trail to run along the base of the slip requiring benching works and rock armouring to protect the trail from scour (Figure 23). Rock fall, landsliding, and flooding at this site are assessed as hazards with very high probability.

Estimated exposure times for this section of the trail is expected to be 2 to 30 minutes. However due to the likelihood of occurrence of a landslide/rockfall this section of trail has been assessed as being Class 3.

Figure 22: A section of the Option 1 trail from the Countess Range (source: Southern Land (2023)).

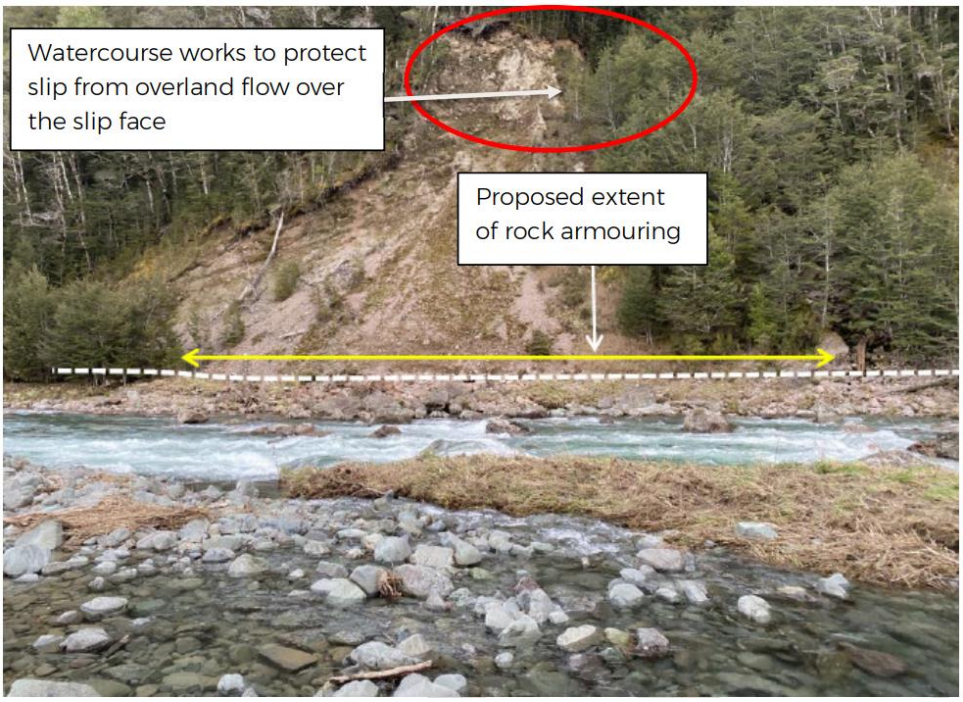


Figure 23: View of the East Eglinton River Landslide (Source: Southern Land (2023) with additional annotation by WSP).

The alternative route from Te Anau Downs to Black Creek (Option 2) is directly adjacent to SH94. The preliminary hazard screening for this route has identified the potential for trail users to be exposed to tree slide hazards with sections of the trail being cut into developed beech forest on steep slopes and onto the Eglinton River floodplain. Areas of concern for tree slides include where the trail veers off SH94 before Node 1 – Gateway and just north of Totara Campsite. These sections of trail have been preliminary screened as Class 2.

The trail from Black Creek to Ōtāpara Cascade Creek generally follows SH94 and remains elevated above the Eglinton River and away from the steep hillslopes at the valley edges. The majority of this trail section has been assessed as Class 1. The proposed trail crosses the Eglinton Valley at the Hut Creek/Mistake Creek Bridge and follows the true right side of the outlet of Lake Gunn. Users on this section of trail may be exposed to flooding.

Approximately 200 m south of Ōtāpara Cascade Creek Campsite the trail crosses a series of active debris flow fans and stream channels capable of producing debris flow and flooding hazards. These hazards are estimated to have a high probability of occurrence and as such the sites have been preliminary assessed as Class 2.

The trail from Ōtāpara Cascade Creek Campsite to The Divide travels along the western margins of Lake Gunn and Lake Fergus. This area is prone to frequent landslides and tree slides and has had several recent landslides which have inundated the State Highway. At this stage of the assessment the trail through this section has been assessed as Class 2.

The proposed cycle trail from Te Anau Downs to The Divide passes through several areas of known hazard occurrence with areas of high likelihood of occurrence. On this basis the cycle trail route is considered to be prone to multiple hazards of which many pose a relatively high risk to trail users. As part of the preliminary screening analysis the cycle trails are assessed as being at least Class 2.

7 DISCUSSION AND CONCLUSIONS

7.1 INTRODUCTION

As part of the Stage 2 work of the MOP a Hazards and Visitor Risk Review was completed by Boffa Miskell and Stantec. This report identified the typical occurrence of natural hazards across the project corridor and identified three hazard scenarios to be considered as part of the subsequent project stages, namely Average Day Lower Impact, Moderate Impact Periodic or Seasonal Scenarios or Rare Severe Hazard Scenarios.

As part of this Stage 3 work the previously identified hazard scenario and natural hazard occurrence has been further refined in respect to the Nodes and Short Stop sites, tracks trails and cycle trails together with projected visitor usage.

Natural hazards along the project corridor have now been further detailed and assessed in order to understand the occurrence, extent and potential impact on proposed visitor sites and visitor type. This assessment has focussed on the occurrence of the Moderate Impact Periodic or Seasonal Scenarios and the Rare Severe Hazard Scenario hazards previously identified.

This Preliminary Risk Screening Analysis (Part A) has therefore further identified the Nodes, Short Stops and proposed walking tracks and cycle trail sites in the MOP where natural hazard risk is either considered to be insignificant or requires further Basic or Advanced analysis.

In addition, this assessment has also considered the occurrence of avalanche hazards with respect to select sites and trails and completed preliminary screening analysis of the associated impact on the MOP proposals. Where an avalanche hazard has been identified the area potentially affected has been determined as Class 2 hazard requiring further consideration in the Part B assessment.

7.2 PART A: RISK SCREENING

The published GNS methodology adopted for this stage of works assesses the risk posed by identified hazards through a staged approach. The first stage (Part A) screens the sites using a semi quantitative methodology based on the occurrence of a natural hazard footprint and anticipated temporal probability of exposure. Sites are then assessed as Class 1, 2 or 3 and 3a for Tsunamis hazards.

For Class 1 sites, further risk assessment and specific hazard mitigation is not recommended. No further analysis is therefore considered necessary for the identified Class 1 sites.

The Preliminary Risk Screening Analysis completed herein has identified sites with significant to extreme natural hazard risk to exist at various locations within the MOP corridor (site Class greater than or equal to 2). For these sites, further risk assessment is required in order to assess the quantitative life safety risk (Part B).

For Class 2 sites and tracks/trails a Basic Level of risk analysis is recommended in order to further qualify the site-specific natural hazard risk in accordance with Part 3 of the GNS guidelines. Basic Level risk analysis should include further assessment of risk tolerance and risk acceptability and recommend site specific risk mitigation or controls required to reduce unacceptable levels of risk to acceptable ranges. For higher-risk Class 2 or 3 sites, an advanced risk analysis may be required.

GNS notes that for site assessed as being Class 3, urgent action is required. This may involve interim risk management solutions (e.g. closures) whilst specific solutions are developed. Basic-level risk analysis must be undertaken, and an advanced-level analysis of risk may be required. The preliminary screening assessment completed has identified Ōtāpara Cascade Creek as being such a site.

This Preliminary Analysis has assessed the proposed tracks and trails highlighted in the MOP corridor as being Class 2/3. For these trails the initial semi quantitative analysis has concluded that a Basic Level risk analysis is required to fully assess the risk to trail users. This Part B assessment will also need to consider the DoC visitor types and trail use together with seasonal and climate changes in risk profile, namely associated with snowfall (avalanche risk) and increased rainfall.

The Preliminary Analysis completed has identified some areas of tracks where Class 3 hazards are considered to be present. These areas are likely to require specific controls or detailed design to reduce or remove the risk to acceptable levels for the target visitor group. In extreme cases this may require relocation or temporary closure of the track during parts of the year when the hazard occurrence is likely.

The Part B Basic Risk Assessment that follows this Preliminary Screening will focus on determining quantitative societal risk and life safety risk posed to visitors and workers. Where appropriate to do so it will suggest potential mitigation options or refer to existing management procedures produced by DoC.

Based on the findings of the previous Stage 2 report and this Preliminary Analysis the Part B Basic Level Risk Assessment will present:

- A hazard inventory or existing hazard inventory.
- An assessment of hazard intensity/frequency relationship.
- A risk analysis considering visitor typologies and their individual risk tolerance level.
- Where appropriate to do so, determine an appropriate risk threshold levels for key sites and short stops

In addition, as noted above the current GNS methodology does not include the assessment of avalanche hazard in its methodology. The Department of Conservation (DOC) has its own methodology for assessing avalanche hazards which considers the type of user for each track or trail potentially affected.

For sites where an avalanche hazard is considered likely to be present the Part B analysis will assess the requirement for further AHI (Avalanche Hazard Index) or ATES (Avalanche terrain exposure scale) assessment dependent on DOC visitor type.

In line with the general GNS methodology the following key sites have been preliminary screened as being potentially affected by avalanche:

- Gertrude Valley Node 6
- Gertrude Valley Loop Track
- The Chasm
- Chasm to Cleddau Horse Bridge Track
- Lake Marian Loop Track
- Countess Range Hut
- Countess Range Track

7.3 CLASS 3(A) SITES

All Class 3(a) sites identified in this Part A assessment have been determined due to a credible tsunami hazard impact and were assessed using Part 5 of the GNS guidelines. For these sites the GNS methodology suggests that an advanced risk analysis is undertaken. However, the risk of tsunami is well documented for the Milford Sound Piopiotahi basin and immediate surrounds. Substantial work has already been completed in terms of determining the triggers and occurrence of both earthquake induced and landslide induced tsunamis, as well as in determining the likely wave height and run out length of associated waves. The conclusion of these studies is clear, that the risk of tsunamis and the hazard warrants mitigation and development of control measures as well as evacuation procedures.

Further Basic Level risk assessment and advanced risk assessment will, as previously reported result in a requirement to move to mitigation of the hazard.

Individual and societal risk due to tsunami in Milford Sound is likely to be high and there is a need to ascertain what is an acceptable level of risk. Some risk may be able to be reduced through positive measures as highlighted in the previous Stage 2 works to a level considered to be ALARP (as low as reasonably practicable).

Detailed development of mitigation measures and control procedures will most likely reduce the perceived risk level but is unlikely to reach acceptable levels of societal risk. Furthermore, the cost of achieving adequate levels of mitigation is likely to be extreme, which may make achieving acceptable or desired levels of risk reduction unrealistic.

Further modelling of wave amplitude, run out lengths etc is unlikely to alter or reduce the levels of risk already assessed. In discussion with coastal development engineers and GNS as well as considering international approach to tsunami risk, the value of additional modelling without detailed construction design options is considered academic and subject to variable peer review responses.

On this basis the risk of tsunamis and the potential impacts on the proposed Milford Opportunities Project development options is clear and that future mitigation is required through detailed design.

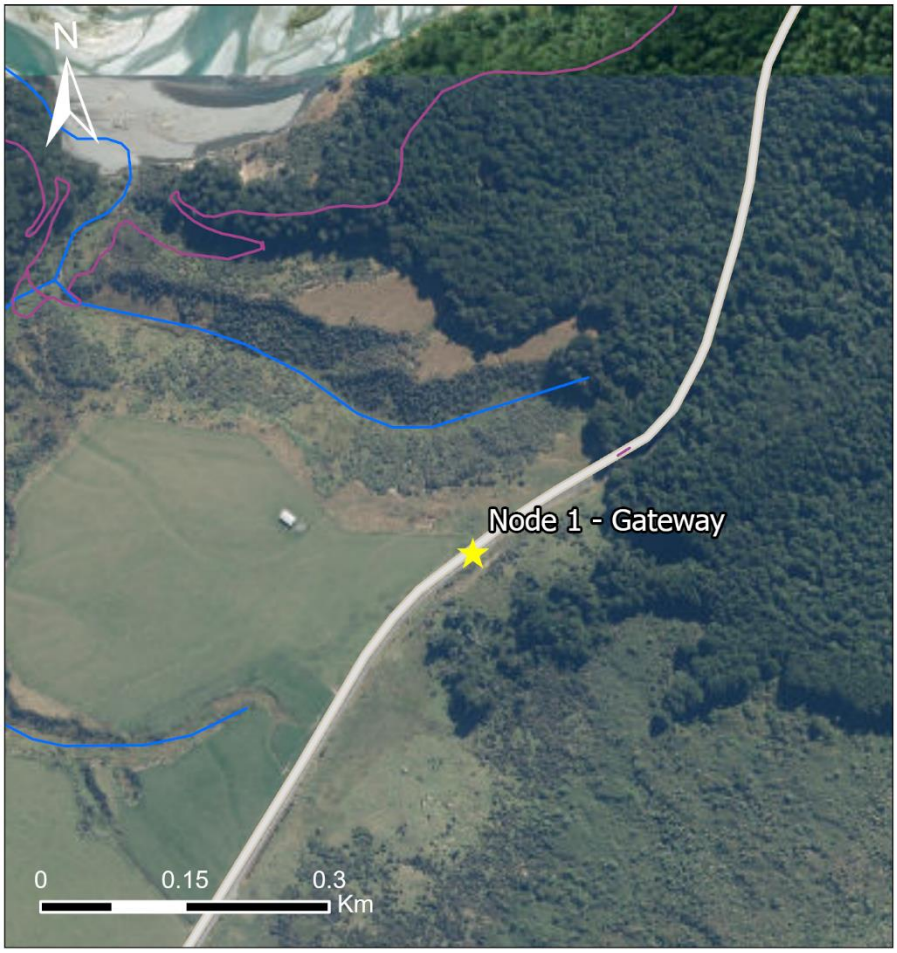
Once design options have been determined an assessment of the likely reduction in fatality risk can be completed and modelling of both tsunami occurrence and population distribution and movement used to verify the proposed design and qualify survival rates.

8 LIMITATIONS

This report ('Report') has been prepared by WSP New Zealand Limited ('WSP') exclusively for the Milford Opportunities Project (MOP) ('Client') in relation to a natural hazard risk assessment of the MOP sites ('Purpose') and in accordance with the revised reverse brief agreed with the MOP and the project instruction ('Agreement') dated November 2023. The findings in this Report are based on and are subject to the assumptions specified in the Report. WSP accepts no liability whatsoever for any use or reliance on this Report, in whole or in part, for any purpose other than the Purpose or for any use or reliance on this Report by any third party.

In preparing this Report, WSP has relied upon data, surveys, analyses, designs, plans and other information ('Client Data') provided by or on behalf of the Client. Except as otherwise stated in this Report, WSP has not verified the accuracy or completeness of the Client Data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in this Report are based in whole or part on the Client Data, those conclusions are contingent upon the accuracy and completeness of the Client Data. WSP will not be liable for any incorrect conclusions or findings in the Report should any Client Data be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to WSP.

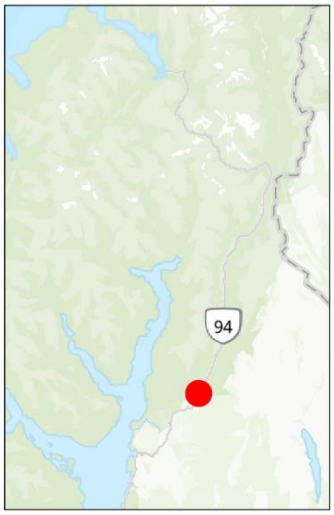
APPENDIX A – NODE SITE MAPS

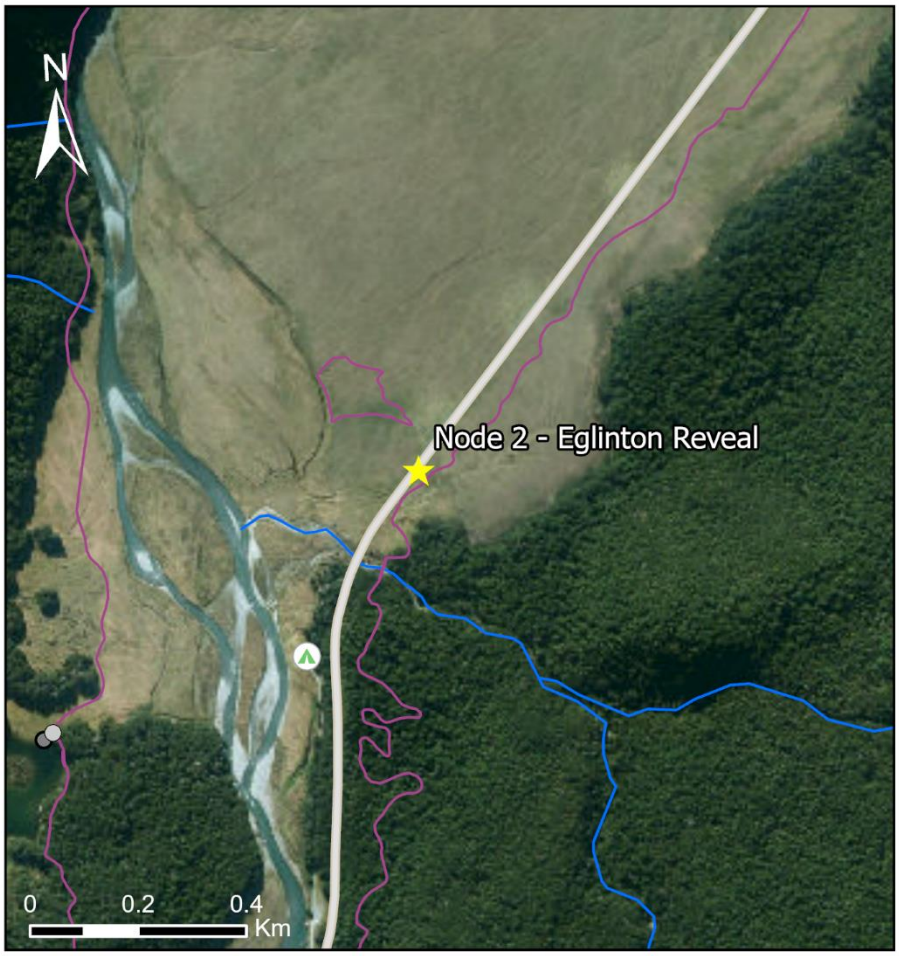


Legend

Site
- Hut
- Campsite
- Node
- Shelter/Toilet
- Short Stop
- Viewpoint
- tracks
- River

State Highway 94

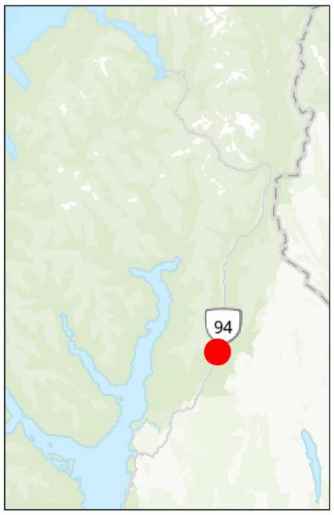


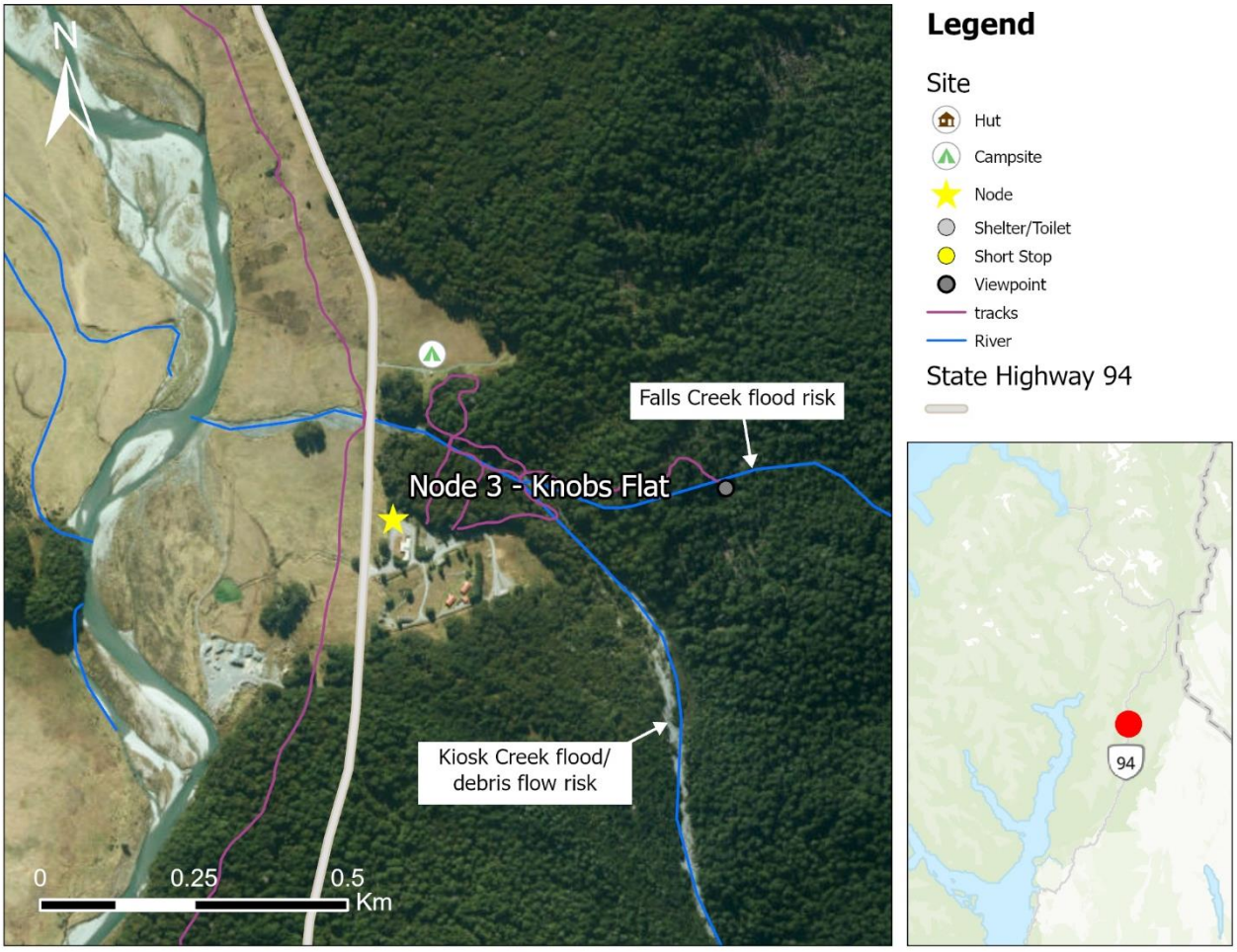


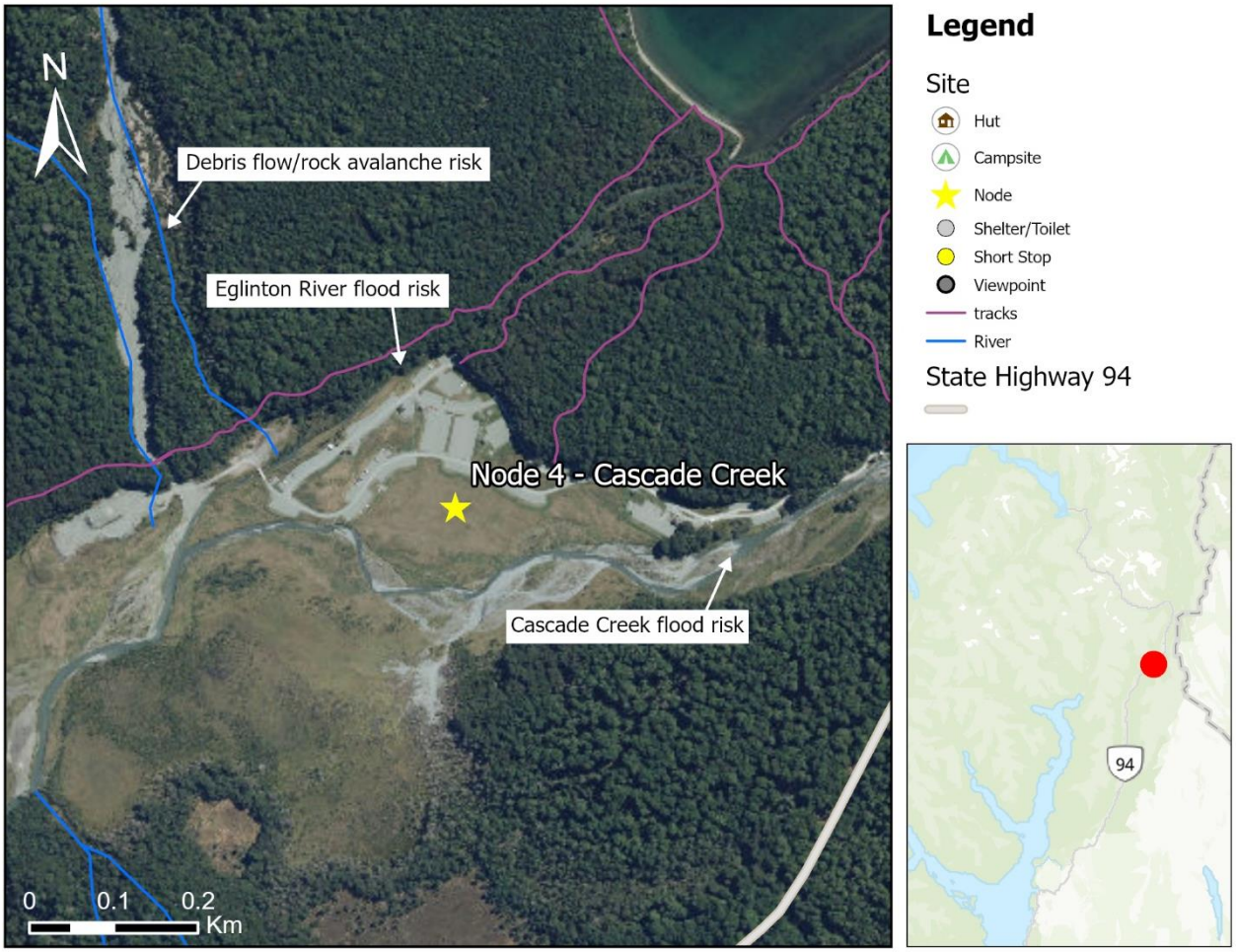
Legend

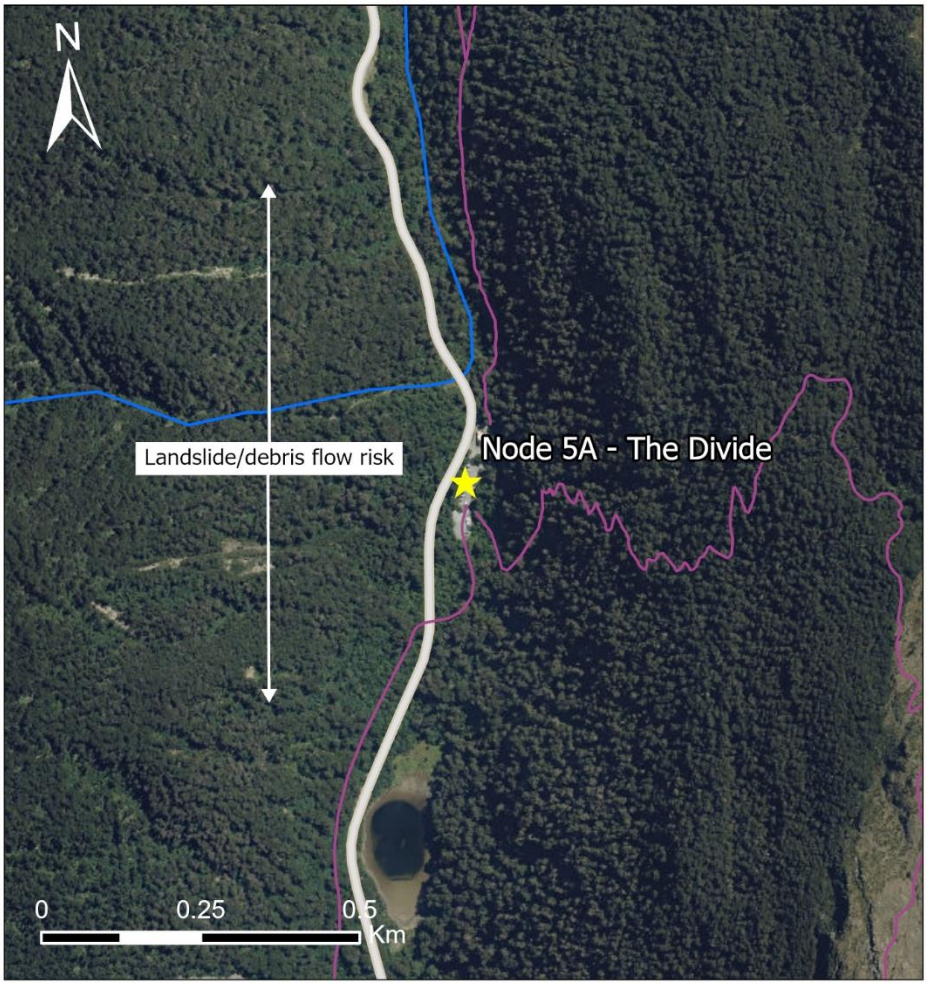
Site
- Hut
- Campsite
- Node
- Shelter/Toilet
- Short Stop
- Viewpoint
- tracks
- River

State Highway 94




N
Falls Creek flood risk
Node 3 - Knobs Flat
Kiosk Creek flood/
debris flow risk
0
0.25
0.5
Km
Legend
Site
Hut
Campsite
Node
Shelter/Toilet
Short Stop
Viewpoint
tracks
River
State Highway 94
94


N
Debris flow/rock avalanche risk
Eglinton River flood risk
Node 4 - Cascade Creek
Cascade Creek flood risk
0
0.1
0.2
Km
Legend
Site
Hut
Campsite
Node
Shelter/Toilet
Short Stop
Viewpoint
tracks
River
State Highway 94
94

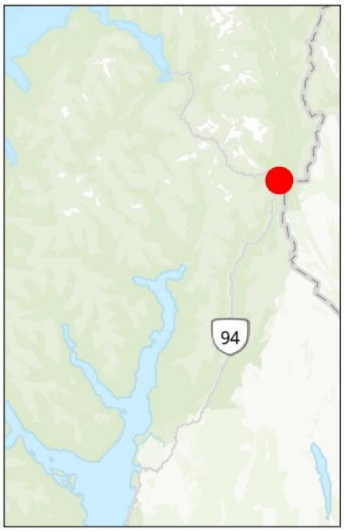


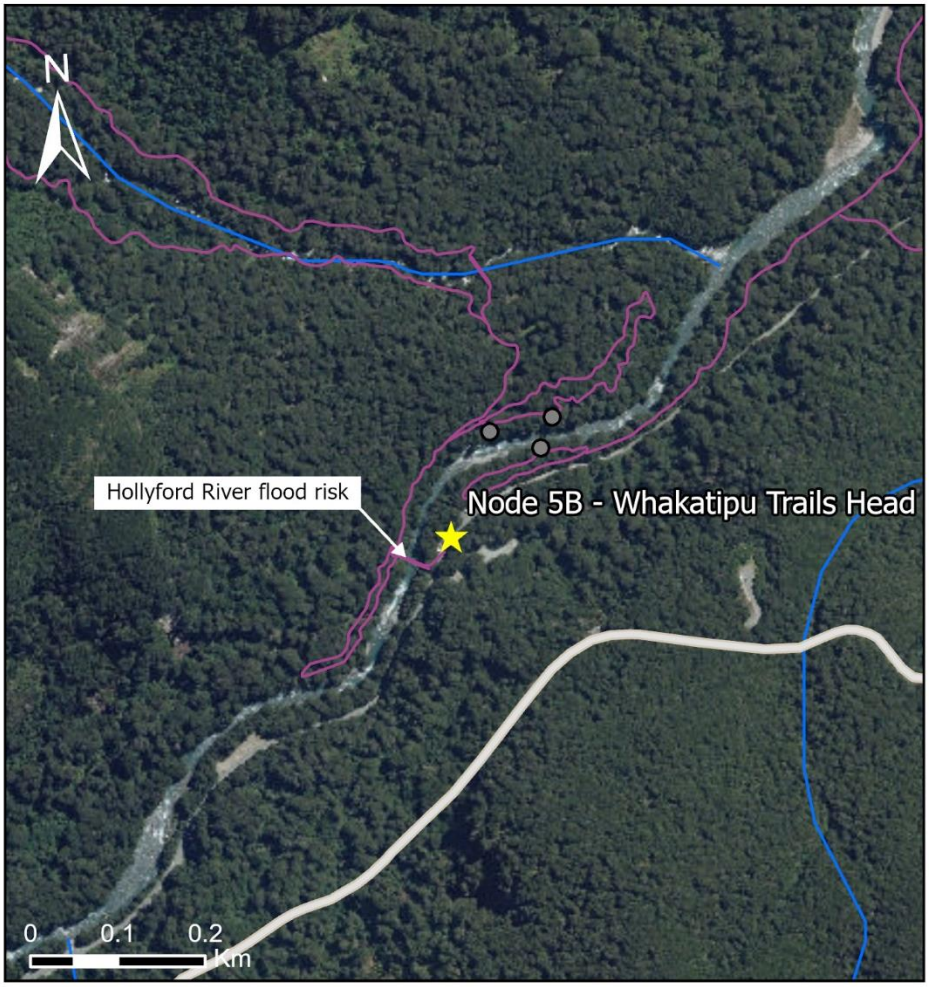
Legend

Site

- Hut
- Campsite
- Node
- Shelter/Toilet
- Short Stop
- Viewpoint
- tracks
- River

State Highway 94



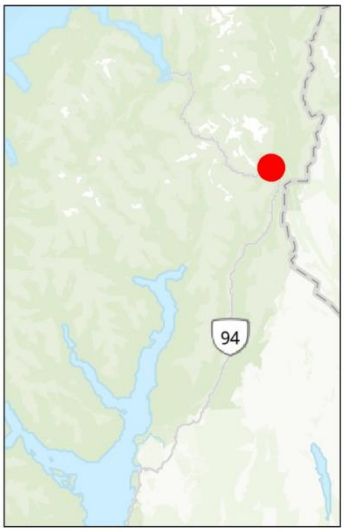


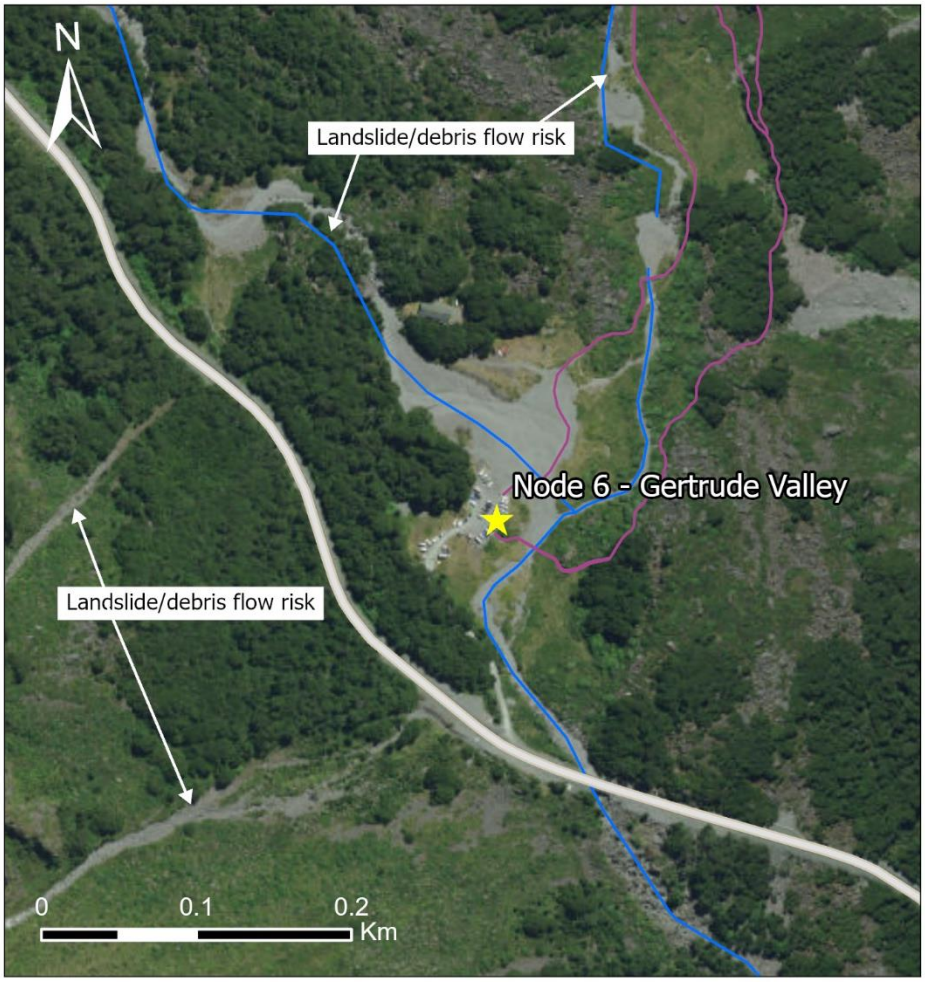
Legend

Site

- Hut
- Campsite
- Node
- Shelter/Toilet
- Short Stop
- Viewpoint
- tracks
- River

State Highway 94



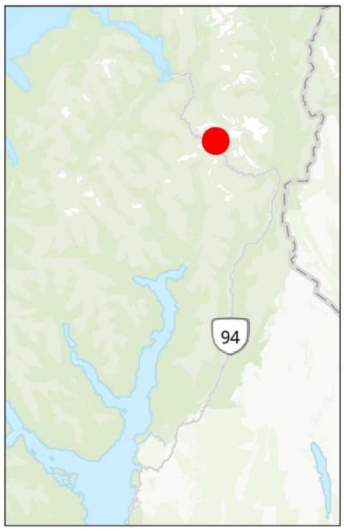


Legend

Site

- Hut
- Campsite
- Node
- Shelter/Toilet
- Short Stop
- Viewpoint
- tracks
- River

State Highway 94

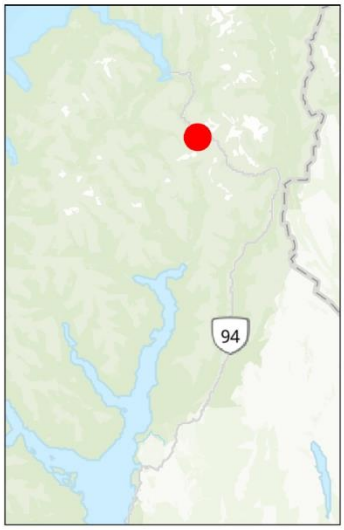


Legend

Site

- Hut
- Campsite
- Node
- Shelter/Toilet
- Short Stop
- Viewpoint
- tracks
- River

State Highway 94



APPENDIX B – RISK TABLES

Table 15: Preliminary risk assessment for the Milford Opportunities Project nodes, short stops, and tracks.

Type	Site	Usage	Hazards	Exposure time	Probability of occurrence	Site Class (landslide/rockfall/inundation)	Site Class (tsunamis)	Action
Nodes and short stops	Te Anau Hub	Bus hub & visitor centre.		>180 mins	Very Low	Class 1	Class 1*	No further risk analysis required
	Henry Creek DOC Campsite	Campsite		2 mins to 30 mins	Very Low	Class 1	N/A	No further risk analysis required
	Te Anau Downs	Boat ramp, walking track, toilet/shelter		2 mins to 30 mins	Very Low	Class 1	Class 1*	No further risk analysis required
	Te Rua-o-Te-Moko Fiordland National Park Gateway (Node 1)	Large drive through signage, marker or artwork, shared trail off Milford Rd		2 mins to 30 mins	Very Low	Class 1	N/A	No further risk analysis required
	Walker Creek DOC Campsite	Campsite, walking track, shelter/toilets	Flooding	>180 mins	Very Low	Class 1	N/A	No further risk analysis required
	Totara DOC Campsite	Campsite	Flooding	>180 mins	Very Low	Class 1	N/A	No further risk analysis required
	Mackay Creek DOC Campsite	Campsite	Flooding, debris flow	>180 mins	Low	Class 2	N/A	Basic Level of risk analysis required

Type	Site	Usage	Hazards	Exposure time	Probability of occurrence	Site Class (landslide/rockfall/inundation)	Site Class (tsunamis)	Action
	Eglinton Reveal (Node 2)	Walking trail, toilet, carpark, viewpoint		2 mins to 30 mins	Low	Class 1	N/A	No further risk analysis required
	Mirror Lakes Waiwhakaata	Bus stop, shelter/toilet		30 mins to 180 mins	Low	Class 1	N/A	No further risk analysis required
	Deer Flat DOC Campsite	Campsite	Flooding	>180 mins	Low	Class 2	N/A	Basic Level of risk analysis required
	Te Huakaue Knobs Flat (Node 3)	Campsite, visitor accommodation, bus service stop, walking tracks, viewing platform	Flooding and debris flow	>180 mins	Low	Class 2	N/A	Basic Level of risk analysis required
	Upper Eglinton DOC Campsite	Campsite	Flooding	>180 mins	Very Low	Class 1	N/A	No further risk analysis required
	Ōtāpara Cascade Creek (Node 4)	Campsite, walking tracks, accommodation	Flooding, debris flow, landslide, rockfall, tree slide, tsunami	>180 mins	Medium	Class 3	Class 2	Advanced Level of risk analysis required
	Lake Gunn and Lake Fergus lookouts	Viewpoints	Flooding, landslide	2 mins to 30 mins	Medium	Class 1	Class 1*	No further risk analysis required
	The Divide (Node 5A)	Carpark, shelter, walking tracks	Debris flow, landslide	30 mins to 180 mins	Medium	Class 2	N/A	Basic Level of risk

Type	Site	Usage	Hazards	Exposure time	Probability of occurrence	Site Class (landslide/rockfall/inundation)	Site Class (tsunamis)	Action
								analysis required
	Whakatipu Trails Head (Node 5B)	Carpark, walking tracks, shelter/toilets	Flooding, rock avalanche, landslide, avalanche only on trails	>180 mins	Low	Class 2	N/A	Basic Level of risk analysis required
	Gertrude Valley (Node 6)	Carpark, walking track, hut, viewpoints, shelter/toilets	Flooding, rock avalanche, landslide, avalanche	>180 mins	Low	Class 2	N/A	Basic Level of risk analysis
	Cleddau Cirque (Node 7)	Carpark, viewpoint, bus stop	Rockfall, avalanche	2 mins to 30 mins	Medium	Class 1	N/A	No further risk analysis required
	The Chasm	Walking track, carpark, viewpoint shelter/toilet	Flooding, avalanche	30 mins to 180 mins	Medium	Class 2	N/A	Basic Level of risk analysis required,
	Little Tahiti	Staff accommodation	Flooding, rockfall, tsunami	>180 mins	Low	Class 2	Class 2	Basic Level of risk analysis required
	Milford Sound Lodge	Accommodation and campervan parking	Flooding, tsunami	>180 mins	Low	Class 2	Class 3	Basic Level of risk analysis required

Type	Site	Usage	Hazards	Exposure time	Probability of occurrence	Site Class (landslide/rockfall/inundation)	Site Class (tsunamis)	Action
	Milford Sound Piopiotahi Visitor Hub	Visitor centre, car park, walking tracks, accommodation, viewpoints	Rockfall, tree slides, tsunami	>180 mins	Low	Class 2	Class 3(a)	Advanced Level of risk analysis required
	Freshwater Basin	Ferry terminal, viewpoints, walking tracks	Rockfall, tree slides, tsunami	30 to 180 mins	Medium	Class 2	Class 3(a)	Advanced Level of risk analysis required
	Cleddau Delta	Walking tracks, viewpoints	Flooding, tsunami	>180 mins	Low	Class 2	Class 3(a)	Advanced Level of risk analysis required
	Deepwater Basin	Boat ramp, viewpoint, car park	Flooding, tsunami	>180 mins	Low	Class 2	Class 3(a)	Advanced Level of risk analysis required
Tracks and Trails	Countess Range Track	Walking track, shelter/toilet, and hut	Flooding, rockfall, landslide, avalanche	Varies dependent on hazard footprint	Low – High	Maximum of Class 3	N/A	Advanced Level of risk analysis required
	Countess Range Hut	Hut	Rockfall, landslides, avalanche	>180 mins	Low	Class 2	N/A	Basic Level of risk analysis
	Gertrude Valley Loop Track	Walking track, viewpoints	Flooding, rock avalanche, landslide, avalanche	Varies dependent on hazard footprint	Med – Very High	Maximum of Class 3	N/A	Advanced Level of risk analysis

Type	Site	Usage	Hazards	Exposure time	Probability of occurrence	Site Class (landslide/rockfall/inundation)	Site Class (tsunamis)	Action
	Hinepipiwai Lake Marian Loop Track	Walking track, viewpoints	Flooding, debris flow, rockfall, landslide, avalanche	Varies dependent on hazard footprint	Low – Very high	Maximum of Class 3	N/A	Advanced Level of risk analysis
	Te Anau Downs to The Divide Cycle Trails	Cycle trails with viewpoints, toilets, and shelters	Flooding, debris flow, rockfall, landslide	Varies dependent on hazard footprint	Very low-High	Maximum of Class 3	N/A	Advanced Level of risk analysis required
	Lake Mistletoe Track		Flooding	2 mins to 30 mins	Medium	Class 1	N/A	No further risk analysis required
	Eglinton River Trail		Flooding	2 mins to 30 mins	Medium	Class 1	N/A	No further risk analysis required
	Mirror Lakes Walk		Flooding	30 mins to 180 mins	Low	Class 1	N/A	No further risk analysis required
	Te Huakaue Knobs Flat Short Walks		Flooding, debris flow	30 mins to 180 mins	Medium	Class 2	N/A	Basic Level of risk analysis required
	Divide Creek Link Track		Flooding	30 mins to 180 mins	Low	Class 1	N/A	No further risk analysis required
	Pass Creek Track and Pass Creek Link Track			2 mins to 30 mins	Low	Class 1	N/A	No further risk analysis required

Type	Site	Usage	Hazards	Exposure time	Probability of occurrence	Site Class (landslide/rockfall/inundation)	Site Class (tsunamis)	Action
	Key Summit to Ōtāpara Cascade Creek		Flooding, rockfall, avalanche	30 mins to 180 mins	Medium	Class 2	N/A	Basic Level of risk analysis required
	Falls Creek Falls and Christie Falls, Monkey Creek	Walking track, viewpoint		30 mins to 180 mins	Low	Class 1	N/A	No further risk analysis required
	The Chasm Walk		Flooding	30 mins to 180 mins	Low	Class 1	N/A	No further risk analysis required
	Chasm to Cleddau Horse Bridge Track	Walking track	Flooding, debris flow, rockfall, avalanche	30 mins to 180 mins	Medium	Class 2	N/A	Basic Level of risk analysis required
	Milford Sound Lodge to Tutoko River Bridge Track		Flooding	30 mins to 180 mins	Medium	Class 2	N/A	Basic Level of risk analysis required
	Barren Peak Spur Track		Rockfall, landslides	30 mins to 180 mins	Low	Class 1	N/A	No further risk analysis required
	Hine-te-awa Bowen Falls – Lower Walk		Flooding, rockfall, treeslide/landslide	2 mins to 30 mins	High	Class 2	Class 3(a)	Advanced Level of risk analysis required

Type	Site	Usage	Hazards	Exposure time	Probability of occurrence	Site Class (landslide/rockfall/inundation)	Site Class (tsunamis)	Action
	Hine-te-awa Bowen Falls – Upper Walks		Flooding, rockfall, landslide treeslide	2 mins to 30 mins	High	Class 2	N/A	Basic Level of risk analysis required
	Cleddau Delta Walks		Flooding, tsunami	30 mins to 180 mins	Low	Class 1	Class 3(a)	Advanced Level of risk analysis required