Guidelines for DOC on dealing with Natural Hazard Risk

a report produced for GNS Science

by Tony Taig

TTAC Limited

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This report has been produced by TTAC Limited for the NZ Department of Conservation under a sub-contract to GNS Science.

Executive Summary

This is the report of a research project for the New Zealand Department of Conservation (DOC) carried out largely during 2019-20 by GNS Science and TTAC Ltd (UK), under the leadership of Tony Taig (TTAC Ltd). The aim is to help develop guidance for DOC on the appropriate response to different levels of natural hazard risk assessed for visitors to and workers on NZ Public Conservation Land and Waters (PCL). The report was finalised in January 2022 following a substantial period of testing and consultation within DOC.

A companion report has collected information on the levels of risk experienced by visitors and workers on NZ Public Conservation Land and in comparable outdoor/leisure situations in New Zealand and elsewhere. A parallel project led by GNS Science has developed guidance on carrying out the natural hazard risk analysis which quantify risk levels for visitors and workers. This report addresses how DOC might evaluate natural hazard risk levels and use them in support of its safety management policy. The report contains:

- Presentation and discussion of the DOC policy background, and of some precedents for decision making based on natural hazard risk assessments to visitors and staff at outdoor leisure locations in New Zealand (Section 2).
- A discussion of the principles involved in using quantitative risk information in safety management and regulation and the types of decision and risk metrics most appropriate to them (Section 3).
- A summary of experience and lessons learned in developing risk-based safety regulation and management elsewhere, and of policy and practice in some overseas National Park organisations (Section 4).
- A summary of risk levels experienced on PCL and of the comparators addressed in the companion report (Section 5).
- Discussion of the principles to be applied in adopting risk-based guidelines for workers and visitor safety management decisions in DOC, informed by consultation with DOC staff at a workshop held in Wellington on 4 December 2019 (Section 6).

The conclusions are

1. A decision framework for natural hazards risk on NZ Public Conservation Land should include guidance on
   a) upper tolerable levels of visitor, worker and major event risk
   b) lower “de minimis” levels of such risk, and
   c) what to do about risks intermediate between such levels.

2. The appropriate metrics of risk to use in this framework are
   - annual individual fatality risk for workers at their regular place of work
   - fatality risk per day for workers on one-off or occasional hazardous tasks and for volunteers
   - individual fatality risk per day for visitors, and
   - major event risk in terms of specific events per year.

3. Values of risk threshold levels should be established by comparison with appropriate risk levels as developed in the companion report to this document. By implication, different comparators and different risk thresholds are appropriate for different DOC visitor groups.

4. Opportunities to reduce risk where the levels involved are intermediate between "de minimis" and intolerable levels should be prioritised across DOC in accordance with the Visitor Safety Principles.

My suggested processes DOC might adopt for decision making in respect of workers are shown in Figure ES1, and for visitors and major events in Figure ES2. My suggestions as starting points for DOC's consideration in setting numerical guidelines for evaluation of risk levels to workers, visitors and for evaluation of major event risk are shown in tables ES1, ES2 and ES3 respectively. Table ES3 is predicated on the assumption that a "major event" is defined as one killing 5 or more people.

I wish to make clear that the choice of numerical guidelines is very much a matter for DOC, and not for me or any other consultant however expert. I will be pleased rather than disappointed if, after serious testing, consideration and debate within DOC these suggested processes and/or values are modified before finally being adopted (with appropriate explanation of any changes being provided).

Figure ES1: DOC Natural Hazards Decision Process – Workers

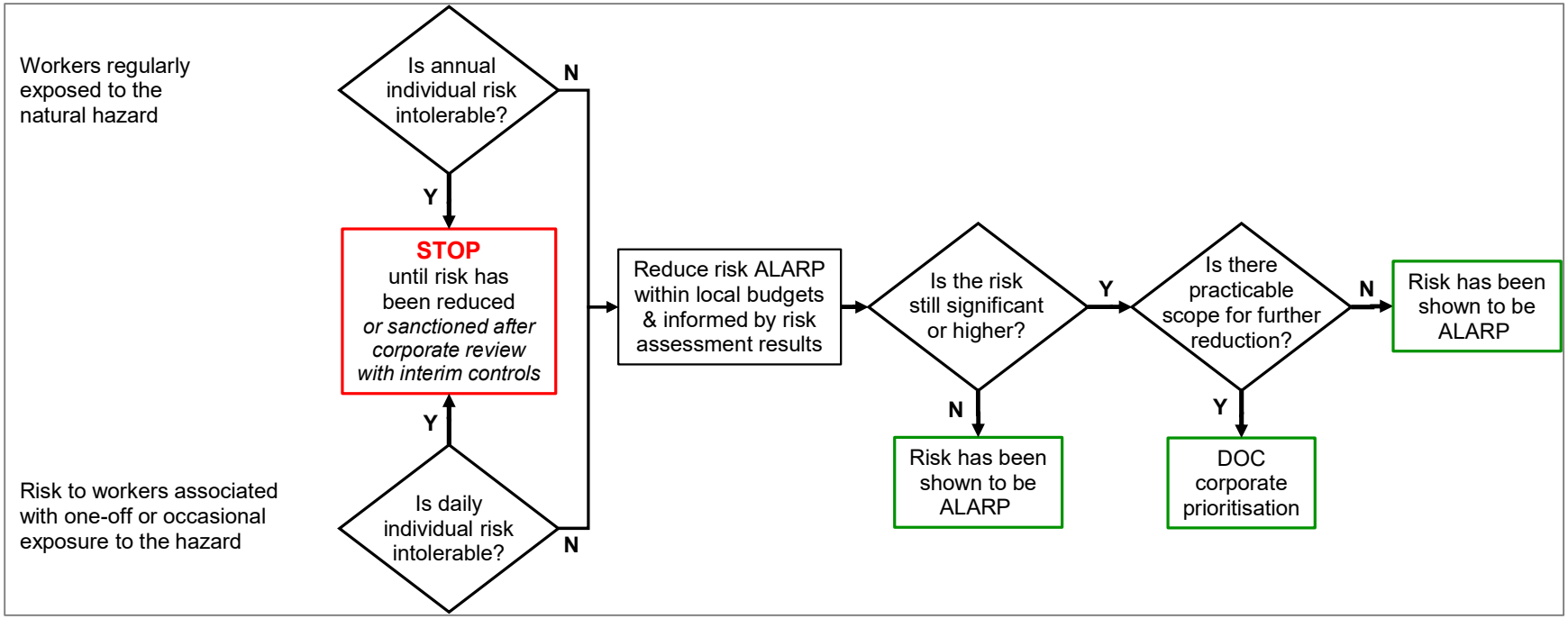


Figure ES2: DOC Natural Hazards Decision Process – Visitors & Major events

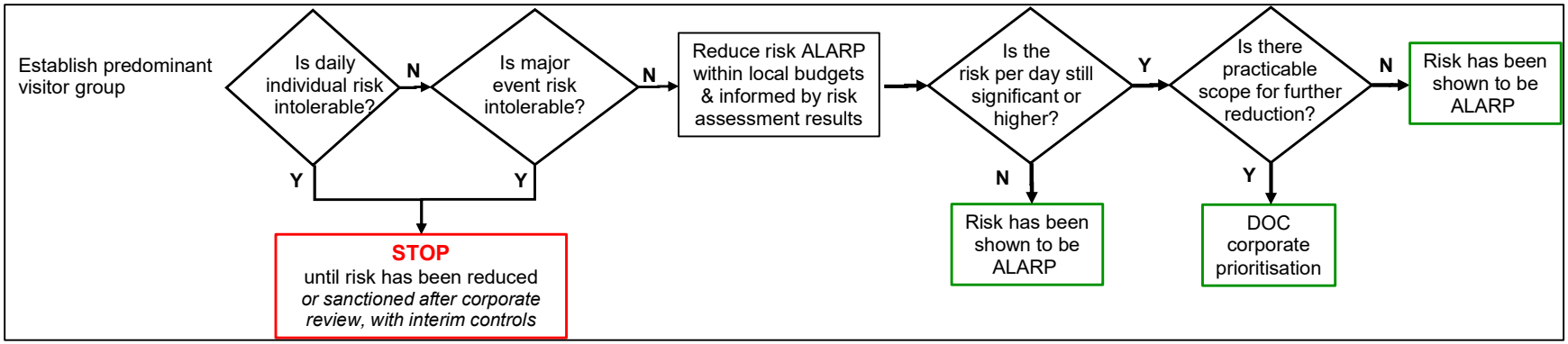


Table ES1: Suggested Values for Evaluation of DOC Workers' Natural Hazard Risk

Significance Level	**Evaluation Category**	**Action Required**	**Annual Fatality Risk** Permanent or Temporary Staff Regularly Exposed to Natural Hazard	**Daily Fatality Risk** One-off or Occasional exposure to Natural Hazard
Extreme	Intolerable	HALT until risk reduced	$>3x10^{-4}$	$>3x10^{-5}$
High		Continue ONLY after corporate review etc	$>10^{-4}$	$>3x10^{-6}$
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	10^{-5} to 10^{-4}	$3x10^{-7}$ to $3x10^{-6}$
Significant			10^{-6} to 10^{-5}	10^{-7} to $3x10^{-7}$
Insignificant	Tolerable	None	$<10^{-6}$	$<10^{-7}$
cf Current Risk Levels, All Hazards*			**$3x10^{-5}$ to 10^{-3}**	**$2x10^{-6}$ to $2x10^{-5}$**

** These are the historically observed average risk levels and do not include predicted risk from all natural hazards.*

The values in Table ES1 are predicated on controlling overall annual fatality risk for workers to a level below 10^{-3}/year, which is the maximum considered tolerable in many overseas guidelines and is also approximately the level experienced by DOC workers in the past 20 years. The allowable risk due to natural hazards must be controlled to a lower level to achieve this overall goal.

The goal per day recognises that workers sometimes need to undertake more hazardous tasks on a one-off or occasional basis, and is also intended to be appropriate for application to volunteers whose services DOC measures by the day rather than by whole years. Further guidance on dealing with staff whose jobs involve small proportions of time carrying out particularly hazardous tasks is provided in the report.

The values in Tables ES2 are derived from the risk comparisons itemised at the bottom of the table. The basis of the values in Table ES3 are explained in the table and are predicated on the definition of a major event as one killing 5 or more people. Uncertain estimates of major event frequency should be treated more cautiously (i.e. towards the upper reasonable possible values) in situations where exacerbating factors (such as children being at risk, or DOC being particularly at fault) might apply.

Further explanation is provided in the Discussion section of the report (Section 6).

Table ES2: Suggested Values for Evaluation of Visitor Individual Risk from Natural Hazards

			Fatality risk per Day/Single Visit		
Significance Level	**Evaluation Category**	**Action Required**	**Lower Risk**	**Medium Risk**	**Higher Risk**
Extreme	Intolerable	HALT until risk reduced	$>10^{-5}$	$>3x10^{-5}$	$>10^{-4}$
High		Continue ONLY after corporate review etc	$>10^{-6}$	$>3x10^{-6}$	$>3x10^{-5}$
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	10^{-7} to 10^{-6}	$3x10^{-7}$ to $3x10^{-6}$	$3x10^{-6}$to $3x10^{-5}$
Significant			$3x10^{-8}$ to 10^{-7}	$>10^{-7}$ to $3x10^{-7}$	$3x10^{-7}$ to $3x10^{-6}$
Insignificant	Tolerable	None	$<3x10^{-8}$	$<10^{-7}$	$<3x10^{-7}$
Typical National Park/walk selection & risk/day			Safest National Parks **$<10^{-7}$**	Great Walk or higher risk Park **$3x10^{-7}$ to $3x10^{-6}$**	Remote tramp with rivers/scrambles **$3x10^{-6}$ to $3x10^{-5}$**
Typical means of travel there & risk doing so			Bus or car with safe driver **10^{-7} to 10^{-6}**	Car with typical driver **$3x10^{-7}$ to $3x10^{-6}$**	Younger car driver or safe motorbiker **$3x10^{-6}$ to $3x10^{-5}$**
Typical activities they might enjoy & risk levels			Bowls, golf, tennis, a stroll **$<10^{-7}$**	Walk, swim, bike or jet boat ride **$3x10^{-7}$ to $3x10^{-6}$**	Rafting, caving, climbing, gliding **10^{-6} to $3x10^{-5}$**

Critical assumptions underpinning the proposals in Table ES2, which need to be tested by DOC before their adoption or adaptation, are:

a) that visitors can be grouped according to their general appetite for risk as is currently assumed by DOC, and

b) that visitors' appetite for risk generally (which is largely within their own control) will be similar to that for natural hazard risk (which is largely outside their own control).

Table ES3: Suggested Values for Evaluation of Major event Risk

Significance Level	Evaluation Category	Action Required	Frequency of Major Natural Hazard Events (per year)		Basis/Comparators
			All Public Conservation Land	Individual Visitor Site	
Extreme	Intolerable	HALT until risk reduced	>0.1	>0.01	A major event on PCL is anticipated every 3-10 years. Natural hazards should contribute no more than 30% of this (i.e. 1 event per 10-30 years) Guidance for individual visitor sites is suggested as 10% of this level
High		Continue ONLY after corporate review etc	0.03 to 0.1	0.003 to 0.01	
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	0.01 to 0.03	0.001 to 0.003	At the "substantial" level, natural hazards would add 10% to the WHOLE major event risk on public conservation land; at the "significant" level they could be adding a few % Guidance for individual visitor sites is suggested as 10% of this level
Significant			0.001 to 0.01	10^{-4} to 10^{-3}	
Insignificant	Tolerable	None	$<10^{-3}$	$<10^{-4}$	Given the scale of natural hazard events foreseeable in NZ, trying to reduce below once in 1000 years for DOC (1 in 10,000 yrs for a single site) is unlikely to be worthwhile

My recommendations are that DOC should

1. Review, adapt as appropriate and adopt
   a) the risk metrics suggested in conclusion 2
   b) the decision processes described in Figures ES1 and ES2, and
   c) the threshold values for risk decisions suggested in Tables ES1, ES2 and ES3.

2. Allow individual sites or regions to implement site-specific risk reduction measures when the risk is above “de minimis” levels and below “tolerable” limits, if measures can be managed within existing local budgets. Other broader, or more costly, opportunities for risk reduction identified in or following on from natural hazard risk assessments should be flagged as for prioritisation nationally. Risk reduction measures where risk is already “de minimis” should be strongly discouraged unless there are other compelling reasons for them.

3. Ensure that it has the resources available corporately to facilitate the adoption of this framework, to provide ongoing advice and support to those commissioning and interpreting natural hazard risk analysis, to maintain an overview of results and to prioritise risk reduction opportunities across the estate.

4. Treat risk levels as providing guidance, rather than as the sole determinants of safety decisions. Many other factors than risk levels may be relevant, and warrant particular weight when risk levels are uncertain and their significance accordingly difficult to assess.

5. Consider using graphic, visual ways of presenting and setting visitor risk from natural hazards (and perhaps also from other sources) as used in this report, in order to
   a) avoid the need to explain small numbers in terms such as "10 to the minus 5"
   b) help convey the uncertainty associated with risk information
   c) illustrate relativity of natural hazard to other, comparator or reference risk levels, and
   d) reduce reliance on the English language for conveying risk information.

Tony Taig

TTAC Ltd
February 2022

Contents

1. Introduction

This is the report of a research project for the New Zealand Department of Conservation (DOC) carried out during 2019-20 by GNS Science and TTAC Ltd (UK), under the leadership of Tony Taig (TTAC Ltd). The aim is to help develop guidance for DOC on the appropriate response to different levels of natural hazard risk on Public Conservation Lands and Waters (PCL). The report was finalised in January 2022 following a substantial period of testing and consultation within DOC.

A companion report[1] has collected information on the levels of risk experienced by visitors and workers on NZ Public Conservation Land (PCL) and in comparable outdoor/leisure situations in New Zealand and elsewhere. A parallel project led by GNS Science has developed guidance on carrying out the natural hazard risk analyses which quantify risk levels for visitors and workers (including employed staff, volunteers, contractors and concessionaires)[2].

This report addresses how DOC might evaluate natural hazard risk levels and use them in support of its safety management policy. The report contains:

- Presentation and discussion of the DOC policy background, and of some precedents for decision making based on natural hazard risk assessments to visitors and workers at outdoor leisure locations in New Zealand (Section 2).
- A discussion of the principles involved in using quantitative risk information in safety management and regulation and the risk metrics most appropriate to them (Section 3).
- A summary of experience and lessons learned in developing risk-based safety regulation and management elsewhere, and of policy and practice in some overseas National Park organisations (Section 4).
- A summary of risk levels experienced on NZ PCL and of the comparators addressed in the companion report (Section 5).
- Discussion of the principles to be applied in adopting risk-based guidelines for workers and visitor safety management decisions in DOC, informed by consultation with DOC staff at a workshop held in Wellington in December 2019 (Section 6).
- Conclusions and recommendations regarding starting points for DOC's consideration as guidelines for
  - worker and visitor individual fatality risk on NZ Public Conservation Land
  - aggregate risk and major event risk on NZ PCL, and
  - presentation of natural hazard risk information to visitors (Section 7).
- Acknowledgements (Section 8).

[1] A Taig, "Risk Comparisons for DOC Visitors and Staff, TTAC Ltd report for GNS Science, February 2022
[2] S J deVilder et al, "Guidelines for Natural Hazard Risk Analysis on Public Conservation Lands and Waters", GNS Science Consultancy Report 2020/50, June 2020.

This study owes much to the contributions of others, but the observations made, opinions expressed and conclusions drawn are the author's own and should not be attributed to GNS Science or any other party.

2. Background

This section outlines DOC's current visitor safety policy position, and highlights some of the issues raised by assessments of natural hazard risk to workers and visitors in recent years.

2.1 DOC Policy

DOC has laid out the principles it will adopt in its Visitor Risk Management policy[3], as shown in Figure 1.

Figure 1: DOC Visitor Safety Principles

1. The range of outdoor recreation experiences available to visitors will be preserved wherever possible.
2. DOC is responsible for assessing the risks at visitor destinations and providing information to inform visitors of those risks.
3. All practicable steps will be taken to ensure DOC facilities are appropriate for the predominant visitor group and/or activity, and meet all statutory obligations.
4. The level of skill and competence required for visitors to manage risks will be accurately represented.
5. Visitors are responsible for their decisions about the risks they take and for any others under their care and responsibility.
6. Visitors are responsible for providing the skills, competence and equipment they require to effectively manage hazards.
7. DOC will prioritise management at popular sites which have a high level of risk and a high volume of low skilled visitors.
8. DOC is responsible for working with partners to continually improve visitor risk management practices.

DOC will:

- undertake visitor risk management in accordance with the eight principles outlined above and the relevant legislation, policies, plans and standards that govern it.
- apply the principles below in a manner consistent with its visitor management work.

Thus DOC's general policy on visitor safety is that visitors are responsible for their own decisions about the risks they take, while DOC is responsible for assessing risks at visitor sites, informing visitors about them and ensuring that DOC facilities are fit for their purpose and the types of visitors they serve.

[3] DOC, "Visitor Risk Management Policy", DOC Wellington, June 2017

Principle 5 makes it clear that visitors are responsible for their own decisions about the risk they should take, while Principle 2 obliges DOC to provide information about those risks. Principle 7 defines how DOC will prioritise management in order to reduce risk. Principles 2, 5 and 7 thus force us to consider

a) how best DOC should present information about risks to visitors so as to ensure they fully understand and appreciate them, and

b) appropriate ways to characterise risk so as to fulfil Principle 7.

There are also good reasons for DOC to consider whether some risks are intolerable, thus requiring action regardless of Principle 5. Reasons include:

a) Principle 3 obliges DOC to make facilities appropriate (which should clearly include "suitably safe") for the predominant visitor group.

b) Explaining risk levels is difficult and many people struggle to understand and appreciate small numbers (potentially more so if they lack fluency in English as do many visitors).

c) DOC might wish to limit people's ability to force others (those under their care and responsibility – Principle 5) to take on significant risk.

d) Even if the individuals putting themselves at risk are fully comfortable with the risk, DOC might wish to limit the likelihood of major events which could potentially damage not only DOC but also the reputation of New Zealand as a good place to visit or do business.

DOC has already given substantial consideration to the issue of risk tolerability, and has recently developed charts relating the tolerability of risk at a site to the likelihood and consequence of events as part of the Standard Operating Procedure[4] which supports the application of the Principles above. This includes definition of visitor groups (in order of increasing risk appetite):

- Short stop traveller
- Day visitor
- Overnighter
- Back country comfort seeker
- Back country adventurer, and
- Remote seeker.

For each group a risk tolerability chart has been developed of the form shown in Figure 2, which is the chart for sites with predominantly Back Country Adventurer users.

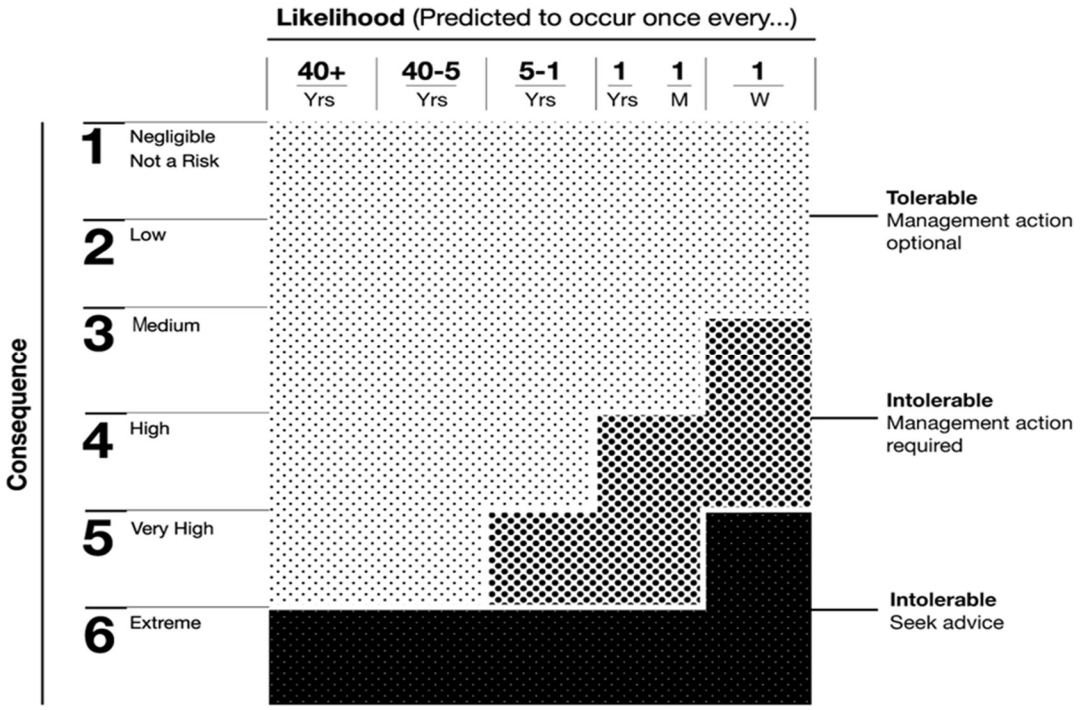
These charts are under review for application to natural hazards in light of the several substantial risk assessment studies completed for DOC in the last 2-3 years, and the ensuing policy debates about the appropriate response to the assessed risks. Those studies and debates have triggered this study and the parallel GNS Science study of good practice in natural hazards risk analysis, which will inform that review.

[4] DOC: "Managing risks to visitors on Public Conservation Land & Waters: Standard Operating Procedure", DOC Wellington, May 2018

It is assumed in this report (a) that the different risk appetites of these visitor groups currently assumed by DOC is valid, and (b) that visitors' appetite for risk generally (which is largely within their own control) will be similar for natural hazard risk outside their own control. These are critical assumptions which need to be tested by DOC before adopting or adapting the guidelines suggested here.

I note further (see also Section 3) that DOC does not at present have good information on the occurrence of accidents and incidents on PCL stretching back several years so may find it difficult to populate parts of the charts dealing with medium or lower frequency events.

Figure 2: Risk Tolerability – Back Country Adventurer Sites



As they stand, these charts imply a societal type risk criterion, in that they describe the tolerable frequency of specified events. The consequence scale combines injuries, fatalities and numbers of people affected, ranging from

- negligible (1) via
- minor injury treatable at the visitor site (2) up to
- a single serious injury or multiple minor injuries (4),
- a single fatality or multiple serious injuries (5), up to
- multiple fatalities (6).

As such the charts do not directly incorporate the metrics of life safety risk (individual fatality risk, aggregate probable lives lost per year and societal risk in terms of f/N curves) that are most often used in natural hazard risk assessments. Moreover, in relation to natural hazards, the events

of concern are largely clustered at the bottom left of the scale (high consequence events with frequencies well below 1 in 40 years).

These charts are a relatively new concept within DOC, and to date decisions on visitor safety, whether to do with natural hazards or otherwise, have been taken largely at local level, with significant DOC corporate involvement and consultation. The following section provides an overview of some relatively recent assessments made of natural hazard risk on NZ PCL and elsewhere at visitor attractions in the New Zealand outdoors, and summarises some of the issues these have raised in applying the existing DOC principles and guidance.

2.2 Recent Natural Hazard Life Safety Risk Assessments in New Zealand

In recent years quantitative risk assessment has increasingly been used as a tool to characterise natural hazard life safety risk associated with events that have not yet been encountered (as well as those that have). This section presents a summary of results of some such assessments and discusses their significance for the DOC worker and visitor risk profiles developed in sections 3.2 and 3.3. The assessments chosen are those of which I have become aware in the course of work in New Zealand over the past 20 years or so, and are by no means comprehensive.

Most such assessments have been carried out in the context of risk to residents in their homes. While these are of lesser interest in the context of visitor risk it is worth noting some examples of the fatality risk levels involved. These include

- 10^{-4}/year was the level above which the NZ government made offers to purchase homes in the Port Hills area of Christchurch following the 2010-11 Canterbury earthquake swarm (many 100's of homes were involved[5]).
- The tsunami risk at 4m above sea level in major North Island cities (Auckland, Wellington, Tauranga, Napier) is estimated to lie in the range $3x10^{-5}$ to $8x10^{-4}$/yr assuming no warning is given[6].
- Earthquake risk to building occupants in Wellington is estimated as between $9x10^{-7}$ and $2x10^{-5}$/yr depending on the building type and location[7].
- Flood risk for homes on the Thames Coast is estimated as $8x10^{-6}$/yr for medium hazard and $5x10^{-5}$/yr for high hazard areas[8].

In all these cases action has been taken to reduce risk at the upper levels of the ranges shown. Note that 10^{-4}/year corresponds to just under $3x10^{-7}$ per day. It is also worth noting that the background natural hazard risk to New Zealanders is quite significant. The long term average individual fatality rate for **all** New Zealanders from both earthquakes and volcanic hazards is well

[5] See for example "Lessons from the Canterbury earthquake sequence", NZ Department of the Prime Minister & Cabinet, July 2017

[6] N Horspool et al, "Review of Tsunami Risk Facing New Zealand: A 2015 Update", GNS Science Consultancy Report 2015/38, March 2015 (figures are the range from 16th to 84th %ile of risk across the 4 cities mentioned)

[7] A R Taig & GNS Science, "A Risk Framework for Earthquake-Prone Buildings Policy", report produced for the New Zealand Department of Building and Housing, TTAC Ltd, 2012

[8] "Thames Coast Flood Risk Assessment", URS Report 48305-027-573/R001-E.DOC, prepared for Environment Waikato and Thames-Coromandel District Council, 2003

above 10^{-6}/yr (of order 10^{-8}/day), and natural hazards studies have regularly identified substantial communities living with natural hazard risk levels above 10^{-5}/yr, implying large numbers of people living with natural hazard risk well above this level[7].

Of greater interest for this study are assessments of risk to people visiting tourist/leisure locations. Table 1 shows a selection of assessments of risk to staff (in terms of annual individual fatality risk, or AIFR) and to visitors (in terms of fatality risk per visit or per day/night).

Table 1: Assessed Risk at some Popular Visitor Locations

		AIFR (staff)		Visitor Risk per trip/visit	
Note	**Scenario/Situation**	lower	higher	lower	higher
1	Waiho holiday camp, prior to relocation	3.4E-03	1.1E-02	3.0E-05	9.6E-05
2	Thames Coastal Flooding - campsites			6.0E-07	1.0E-05
3	Port Hills Heathcote Valley Park Track			3.0E-06	1.5E-05
4	Plateau Hut, Mt Haast, Aoraki NP			1.1E-06	1.1E-05
5	Milford Sound tsunami - staff	3.8E-05	5.7E-04		
	Milford Sound tsunami - day visitor			2.1E-08	2.0E-07
	Milford Sound tsunami - o'night visitor			5.4E-08	1.4E-06
6	Tongariro Alpine Crossing			1.3E-05	7.0E-05
7	Franz Glacier - regular guide; day trip visitor	2.0E-04	2.0E-03	1.5E-06	7.1E-06
	Franz Glacier - senior guide; overnight visitor	3.0E-04	5.0E-03	2.8E-05	1.3E-04
8	Mintaro Hut (Milford Track) at existing site	1.0E-05	1.2E-02	6.0E-08	7.0E-05
9	Fox Glacier Access following 2018 landslides	2.3E-04	5.6E-04	4.7E-07	1.5E-06
10	Conical Hill Rockfall Hazard, Routeburn Track			3.4E-06	7.8E-06

Notes on Table 1

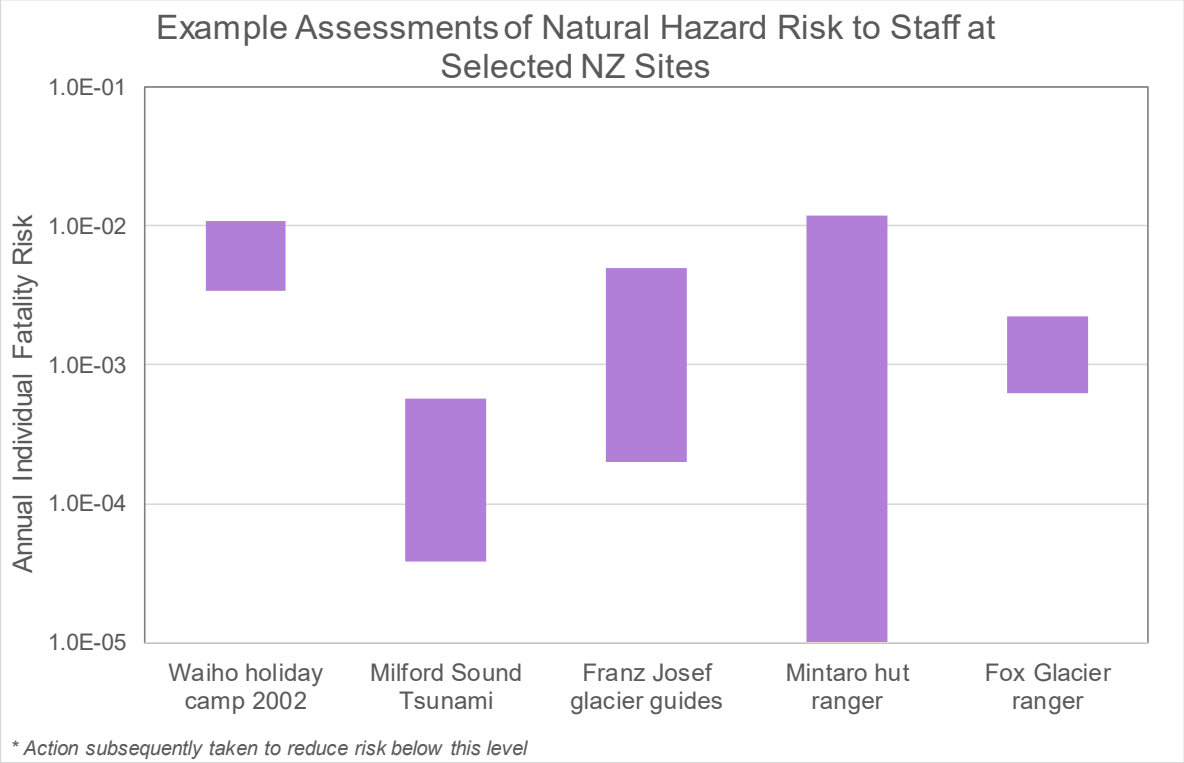
1. *Individual risk calculated by the author from hazard and occupancy information in report for MCDEM[9]; range corresponds to reasonable range of (uncertain) input assumptions.*
2. *Range shown is from that for medium hazard to very high hazard camping areas[10]*
3. *Range corresponds to reasonable range of (uncertain) input assumptions[11] and to heightened seismicity following major earthquakes (current risk is significantly lower)*
4. *Individual risk calculated by the author from hazard and occupancy information in report for DOC[12]*

[9] A Milligan, "Waiho River Flooding Risk Assessment", Optimx Report 80295/2 for MCDEM, August 2002
[10] "Thames Coast Flood Risk Assessment", URS Report 48305-027-573/R001-E.DOC, prepared for Environment Waikato and Thames-Coromandel District Council, 2003
[11] C Massey & A Taig, "Risk Assessment for Park Tracks in the Christchurch Port Hills", GNS Science letter report CR2011-325, 2011
[12] G Hancox & R Thomson, "Reassessment of Geological Hazards and Risk at Plateau Hut following the Rock Avalanche from Mt Haast on 21 January 2013 in Aoraki/Mt Cook National Park", GNS Science report CR2013/58, May 2013

5. *Ranges correspond to reasonable ranges of inputs; wave attenuation is particularly uncertain*[13]
6. *Risk calculated assuming the volcano was in an eruption period at the time*[14].
7. *Ranges reflect reasonable ranges of uncertainty in input parameters; routes have subsequently been modified to reduce risk levels substantially*[15].
8. *Wide range of uncertainty reflects large uncertainties in both frequency and boulders generated by landslides of different scales*[16].
9. *Ranges reflect reasonable ranges of uncertainty in input parameters and assume effectiveness of measures to close tracks at times of elevated risk*[17].
10. *Risk per single return trip to/from the hut; range reflects reasonable range of uncertainty in input parameters*[18].

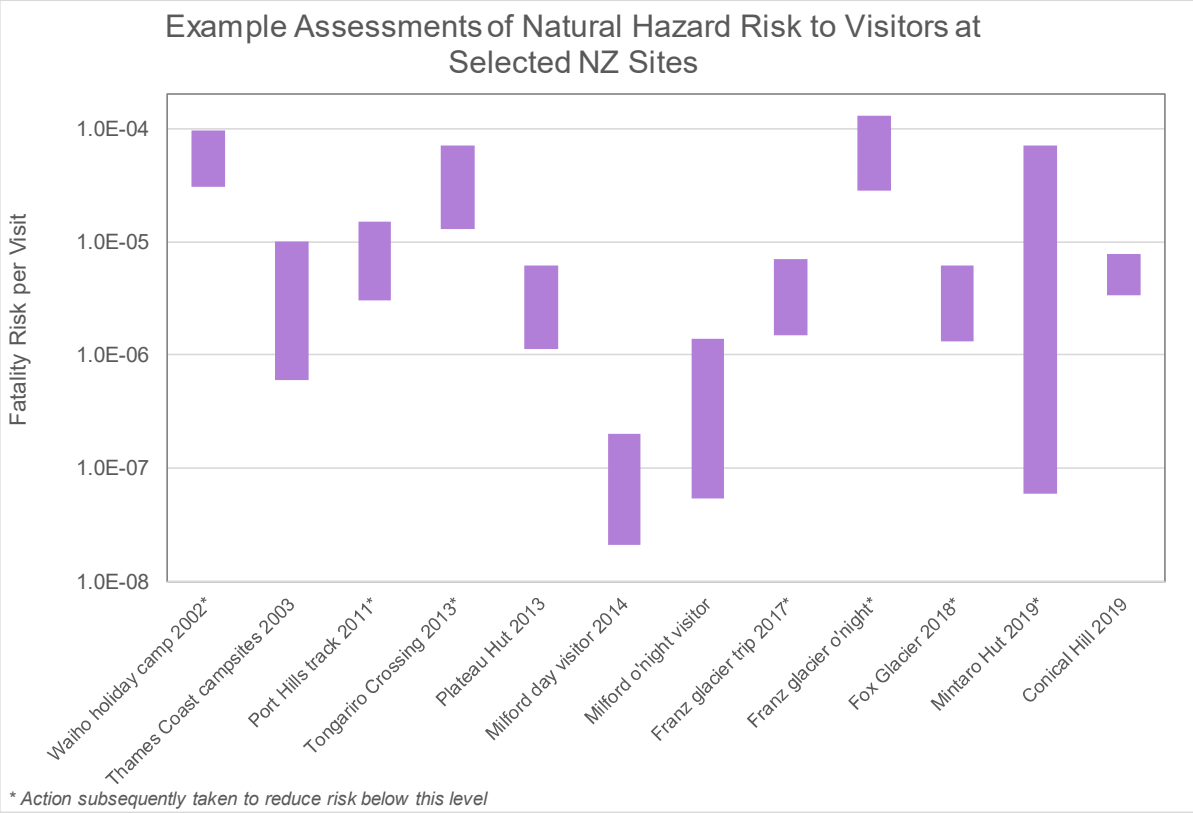
The workplace and visitor risk estimates are shown graphically in Figures 3 and 4 respectively.

Figure 3: Assessed Risk to Workers based at Selected Popular Visitor Sites



[13] M McSaveney & A Taig, "Milford Sound risk from landslide-generated tsunami", GNS Science report CR2014/224, Oct 2014
[14] G Jolly & A Taig, Update of "Risk Assessment for Visitors walking on the Tongariro Alpine Crossing, Feb 2013", GNS Science letter report 2013/38LR, May 2013
[15] C Massey et al, "Franz Josef Guiding Area Landslide Risk Assessment", GNS Science report CR2017/56, Aug 2017
[16] A Taig, "Mintaro Hut – Risk Comparison for Existing & Proposed Sites", TTAC Ltd report for DOC, Feb 2019
[17] C Massey et al, "Landslide hazard and risk assessment for the Fox and Franz Josef Glacier valleys", GNS Science report CR2018/206, May 2019
[18] S Cox, "Conical Hill Rockfall Hazard, Routeburn Track", GNS Science Letter Report CR 2019/05LR, Jan 2019

Figure 4: Assessed Risk to Visitors at Selected Popular Sites



It should be noted that all of these assessments were initiated because of concerns about high risk levels, and most if not all have been the subject of action, informed by the risk assessments, to reduce risk.

Some of these assessments also estimated "societal risk" in terms of frequency/no. of fatalities (f/N) curves. Some results are shown in Table 2; the companion report[1] contains further results.

Table 2: Some Assessed Societal Risk Event Frequencies

	Events/yr with >= N fatalities					
Site/Hazard	**N=1, lower**	**N=1, upper**	**N=10, lower**	**N=10, upper**	**N=100, lower**	**N=100, upper**
Thames Coast floods (all assessed sites)	~0.01		~$5x10^{-4}$		N/A	N/A
Waiho village flood	0.3	0.7	0.06	0.12	N/A	N/A
Mintaro Hut landslide/rockfall	$8x10^{-4}$	0.9	$2x10^{-7}$	$6x10^{-3}$	N/A	N/A
Milford Sound Tsunami	$2x10^{-3}$	$3x10^{-3}$	$8x10^{-4}$	$2x10^{-3}$	$4x10^{-4}$	$9x10^{-4}$

These numbers illustrate the difference between a situation where those at risk are largely individuals or households such as the first case in Table 2, and those where the lethal event (though perhaps rare) has significant potential to cause multiple fatalities as in the other cases in Table 2. They also illustrate the need to scale any ideas on tolerability of events with particular

numbers of fatalities to the situation in question. It would be inappropriate to apply the same standards in respect of, for example, the allowable annual frequency of fatal accidents to a tourist site with millions of visitors each year and to one with a handful of visitors.

DOC suffered its own experience of dealing with a particularly major event following the Cave Creek disaster in 1995, in which a viewing platform in Paparoa National Park collapsed killing a DOC staff member and 13 university students. To kill 14 people in one event was horrendous in itself, and particularly tragic in that so many of the victims were young students. What made this even worse for DOC was that the subsequent Commission of Inquiry identified a number of causal factors to do with the design, construction, maintenance and use of the platform – all of which were ultimately DOC's responsibility.

These assessments and situations have raised important questions with respect to the DOC guidance and principles discussed in Section 2.1, including

1. At what level does visitor risk become so high that it should be considered intolerable, and sites should be closed to visitors (over-riding principles 1 and 5)?
2. How should wider considerations, such as the number or nature of people killed at one time, or the degree of responsibility borne by DOC, be factored into such decisions?
3. Above what level of risk are site-specific warnings or advice appropriate or necessary (or, conversely, below what level are they inappropriate)?
4. How should risk levels be communicated to visitors (principle 2)? Challenges here include most people's unfamiliarity with statistics and numbers such as "ten to the minus 5", and the rapid growth in visitors to NZ PCL with limited knowledge of English.
5. How safe is "safe enough" for DOC facilities to be appropriate for the predominant visitor group and/or activity (principle 3)?
6. In prioritising management (principle 7), how should DOC prioritise improvement opportunities across NZ PCL, and how should different metrics of risk figure in such prioritisation?

Before discussing these issues in relation to workers and visitors, we consider

- Some general principles of risk-based decision making (Section 3)
- Key features and lessons learned from other risk-based safety regulation and management regimes and from selected National Park bodies overseas (Section 4). and
- The information available from the companion report on risk levels on NZ PCL and relevant comparator risks (Section 5).

3. Risk-Based Decision-Making

This section addresses

- Who should make decisions about their or other people's safety (Section 3.1)
- The nature of the decisions to be made (Section 3.2), and
- Choosing the most appropriate risk metrics for DOC (Section 3.3).

3.1 Who Decides?

Organisations and individuals make decisions in which risk is balanced against other factors every day. Where many people's safety is concerned, those decisions tend to become more formalised. The way in which such formalism is introduced, and the level of risk considered tolerable or intolerable, depends on the context. Consider, for example, the situations in Table 3.

Table 3: Some Different Risk Contexts

a) A patient suffering from a painful terminal condition is offered surgery involving a 50% chance of death but otherwise offering the prospect of many years of good quality life
b) A member of the military or emergency services has the opportunity of a high chance of success to rescue many innocent people from certain death, but at the cost of extreme risk to their own life
c) A person who enjoys activities involving considerable risk to themselves but whose actions might involve - no risk at all to other people - putting others at risk if something goes wrong (e.g. a mountain rescue team) - forcing others (e.g. their children) to accompany them in the risky activity.
d) Someone managing roads or other infrastructure who has many options for investing to save lives but only a limited budget each year with which to do so
e) Someone working in a hazardous environment, who has a degree of control over the risk they face, at least some choice whether to work there or not, and derives some benefit from doing so in terms of their wages and job satisfaction
f) A family with young children and frail elderly relations enjoying a day out at a National Park subject to appreciable natural hazard risk.
g) A chemical or nuclear plant which, while benefiting society as a whole, creates hazards for people living nearby who oppose its being there, have no control over the risk and derive no direct benefit from it,
h) Someone who takes pleasure in putting other people at risk, with no attached benefit for society.

Clearly towards the top of this list, almost any level of risk could be acceptable, so long as the individual involved understands the risk and agrees with or is free to make the decision that the

benefit outweighs the risk. At the bottom of the list, no level of risk is acceptable simply because it is very small. Generally speaking, the level of risk that might be considered acceptable decreases in working down the list.

At some point in moving down the list in Table 3, the decision about whether the risk is acceptable and what to do about it gets taken away from the individual exposed to the risk or the organisation creating it and we expect the law and/or regulation to become involved.

How far down to go before taking the decision away from workers or visitors is at the heart of the DOC debate on intolerability. For DOC the levels from (c) to (f) are particularly important. If we leave decisions to the individual, how can we be sure they understand the risk? Or that they will not inappropriately impose it on others? Clarity in understanding and communicating risk levels plays a vital part in policy in this area – the more effectively risk can be communicated and understanding confirmed, the greater the confidence with which DOC can leave decisions to the individuals involved.

3.2 The Nature of Risk Decisions

In making decisions on what to do about risk, the tolerability of risk framework developed by the UK Health & Safety Executive[19] provides a useful context, dividing risk levels into three:

a) an upper threshold of tolerability, above which the risk is so high that the risk must be reduced or the activity giving rise to it must be stopped

b) a lower threshold, below which the risk is small relative to many other comparable risks that people accept in their everyday lives, and for which there is no special pressure to reduce risk further (indeed it may be counterproductive to divert resources that could be better used elsewhere to reducing risk at such levels), and

c) in-between, an area where, though risk levels are not intolerable, it is desirable to reduce risk to the lowest practicable level. Almost inevitably this means prioritising among alternative possible risk reduction actions to achieve the lowest practicable risk level consistent with resources, stakeholder preferences and other factors.

By analogy, when conveying information about risk levels at a particular site to visitors, the aim is to help those visitors decide

a) Do I want to go ahead and expose myself (and my party) to this risk at all?

b) Can I comfortably go ahead visiting this site without taking precautions over and above the general good sense needed when visiting outdoor/remote locations? Or

c) If I go ahead and visit, what special hazards should I be aware of and how can I best control them?

While DOC, Ministers or newspapers might have a strong focus on how often accidents occur or how many people get killed, the first consideration for a visitor is always going to be "What risk level will I or my party face?"

[19] Most recently in "Reducing Risks, Protecting People – HSE's Decision Making Process", UKHSE, 2001

Other regulatory and risk management decision frameworks also generally focus first on the level of risk to the individual, giving differential consideration to people depending on factors such as

- their degree of choice in whether to undertake the activity,
- their opportunity and/or ability to control the risk, and
- the benefit they gain from the activity giving rise to it.

Most established risk-based decision guidelines or criteria relate to the protection of people in workplaces and to those outside hazardous installations, adopting different levels for workers and for members of the public. In considering risk to workers, DOC can usefully compare the risk its own workers face with the risk faced by workers in other New Zealand or outdoor workplaces. In considering risk to visitors, other guidance on risk to members of the public is less useful, as the context is so different. Table 4 outlines some of the different contextual issues that need to be considered in developing risk comparisons for DOC workers and visitors in comparison with other "hazardous installation" type situations.

Table 4: Potentially Important Contextual Issues in Risk Comparisons

Issue	Member of public near a hazardous installation	DOC (or any other) Worker	DOC Visitor – outdoor hazards generally	DOC Visitor or Worker – Natural hazards
Choice over whether to accept the risk	Typically little or no choice	Workers can (more or less) choose where to work	Free to decide whether to visit or not	Not visible and often not really considered when choice is made
Control over the risk	Typically little or no opportunity to control	Typically good opportunity to control	Plenty of advice & guidance available – may ignore it	No control over occurrence; may be able to mitigate outcome but may not know how.
Benefit from the source of the hazard	Typically no particular benefits	Salary and other benefits of employment	Highly valued part of many peoples' lives	None (but broad link between landscape beauty and activity)
Acceptance of responsibility for risk control	None	Generally well recognised	Wide range from well recognised to complete unawareness	Even very skilled outdoor adventurers may lack relevant knowledge

There may also, though, be issues over and above the risk faced by individuals. For example, DOC recently took action to relocate the Mintaro Hut on the Milford Track, which was at risk from rockfalls and landslides. While the individual risk was significant in triggering this decision, it was also highly relevant both:

a) That when the hut is occupied it generally has 40 people booked in every night through the Great Walk season – so the issue in the event of a landslide is not just "someone might die" but "40 people might all be killed", and

b) That the hut is a facility owned and maintained by DOC, a department of the NZ government, and visitors might legitimately feel that whatever risks they face out on the track they should be entering a place of safe refuge when they walk through the door.

Returning to the HSE framework, DOC needs to consider not only what level(s) of risk are intolerable, but also whether there are lower levels below which risk is insignificant, and to decide what to do in-between the two. A common approach will be to provide site-specific warnings of particular local hazards – but if DOC does this where risk levels are too small then DOC may be accused of "crying wolf" and warnings could lose their effect. For visitor risk in particular it would therefore be valuable to define lower "de minimis" levels of risk below which no action would normally be taken (unless there were other associated benefits besides visitor safety).

In-between the intolerable and insignificant levels of risk there are some important general considerations as to how to factor in the number and type of visitors at risk, how to communicate risk both at a local and national level, and how to prioritise opportunities for risk reduction across NZ Public Conservation Land.

In making decisions on what to do about natural hazard risk, DOC thus needs to consider

a) The risk faced by its workers

b) The risk faced by visitors as individuals

c) Major events of significance above and beyond the risk to individuals

d) Both intolerable levels of risk, and (for visitors in particular) lower levels of insignificant risk below which specific warnings and actions would be inappropriate

e) For risks which are significant but not intolerable, how best to help visitors (and workers) understand the risk and manage it for themselves, and how to prioritise opportunities for risk reduction.

3.3 Appropriate Risk Metrics

As regards risk faced by workers, the fatality risk per year at work is widely used as a metric in other contexts and is appropriate for DOC to use in assessing and evaluating risk to its workers. DOC has large numbers of temporary and volunteer workers, for whom it would be appropriate to scale any risk guidelines pro rata to time worked. For example a guideline for volunteers might be expressed in terms of a risk per day as opposed to per year worked. Such a guideline might be derived pro rata to the days worked by a full-time staff member, or there might be additional considerations related to the nature of the task involved.

As regards the individual risk faced by visitors, annual individual fatality risk is not particularly relevant, as most visitors will spend only a small proportion of a year visiting NZ PCL. Several recent assessments of visitor risk both on NZ PCL and elsewhere (see Section 2.2) have focused

on the individual fatality risk per day and/or per experience of a particular outdoor activity that could be experienced within a part of a day. This provides a more relevant and meaningful basis for comparisons between, for example, a day spent tramping in a National Park and a day when a visitor goes jet boating, gliding, swimming or bungy jumping.

In considering major events of significance beyond that to the individual, the most widely used metric of "societal risk" is an "f/N curve" relating the frequency of events killing N or more people to N (the number killed in an event). While this can be useful in some contexts (see Section 4.1) it does not take into account several other attributes of an event besides the number killed which may be important in deciding what is or is not tolerable, and is difficult to scale to different sites.

In my view it would be more helpful for DOC to establish its own definition(s) of "major events of particular concern" to take into account not only the number of people killed at one time but also factors such as the nature of people involved (e.g. valuing young children/school trips more highly than adults) and the degree of DOC responsibility (e.g. visitor facilities such as huts or viewing platforms vs other DOC-provided infrastructure such as tracks and bridges vs open countryside).

I understand that in the wake of the Whakaari (White Island) tragedy in December 2019 the debate on adventure activity safety in New Zealand is beginning to focus particular on major events defined in terms of those killing 5 or more people. This has accordingly been adopted as the definition around which to formulate numerical guidelines for this report, though it remains important to recognise that the implications for DOC of an event on PCL may be very different for different events which each kill the same number of people, depending for example on who are the victims (e.g. children on a school trip vs free climbers attempting an extreme ascent) or the degree to which liability attaches to DOC (e.g. an event caused by direct failure of equipment or facilities provided by DOC vs a "blue skies" volcanic eruption with no warning).

In considering what to do in situations in-between intolerable and insignificant levels of risk both the levels of risk and the numbers of people involved need to be considered. DOC needs to apply consistent principles across NZ PCL in order to avoid resources being inappropriately distorted towards safety projects of relatively minor benefit. This implies weighing the benefits of risk reduction against costs and any other benefits/disbenefits involved. In practice I would expect this to be achieved through a mix of

a) General standards and guidelines on widely applied risk controls such as signage and visitor advice (where the optimisation of the benefits/costs/other aspects of the approach was carried out centrally),

b) Guidance on situations where the risk level and number of people at risk warranted exploration of broader options for risk reduction, informed by

c) Ongoing evaluation of visitors' understanding of and response to such guidance.

As regards (a) the guidance/standards should be proportionate to local individual risk levels and visitor types. Central evaluation in (a) and local evaluation in (b) should be based on the totality of safety benefits associated with risk reduction, set against costs and any other aggregate

benefits and disbenefits. The simplest metric of safety benefits for this purpose is the expected lives saved (either per year or over a defined period, as appropriate), or reduction in "probable lives lost" (PLL).

Ideally injury as well as death should be included in risk-based safety decisions. In practice this is difficult, as (a) definitions of injury levels and arrangements for reporting and recording injuries vary so widely from country to country and from one context to another, making comparisons difficult, and (b) DOC does not currently have access to good quality information on injury incidents on NZ Public Conservation Land. In developing guidelines for DOC this study therefore focuses on fatality risk throughout.

4 Practice and Experience Elsewhere

This study set out to explore relevant policy, practice and experience outside DOC. This section describes:

- Practice and experience developed in some other, established risk-based safety regulation and management regimes (Section 4.1),
- policy and practice in dealing with visitor risk in some National Park organisations outside New Zealand (Section 4.2), and
- my observations for DOC, informed by consideration of practice elsewhere (Section 4.3).

4.1 Established Risk-Based Regulatory and Safety Management Processes

There is a vast literature on risk criteria used in different contexts. I have selected here some of the longest established and most widely referenced in studies I have encountered of natural hazard risk in New Zealand, relating to

a) the protection of the workforce and members of the public from hazardous installations such as nuclear and chemical plants in the UK and the Netherlands,

b) rail safety in the UK and road safety in the UK, New Zealand and many other developed countries, and

c) a number of risk-based decision frameworks that have been developed relatively recently, relating specifically to natural hazards.

The UK and the Netherlands were selected for (a) as they are among the longest established risk-based safety regulatory regimes globally, and their published risk criteria or guidelines have been widely used to underpin various proposed risk criteria in Australia and New Zealand.

The context of rail/road safety is perhaps of greater relevance to visitor safety for DOC than are hazardous installations, as the public have a high degree of choice over whether and how to travel by road and rail (as they do over whether/when to visit Public Conservation Land).

The natural hazards risk guidelines selected are those I have encountered most often in the course of my work in this area with GNS Science and other New Zealand organisations. All relate to people in their homes or going about their daily lives in situations where they do not have a choice about the risks involved. None relate to leisure activities undertaken on a voluntary basis.

Appendix 1 provides a brief history of the use of risk in regulatory and other decision regimes in the contexts (a) to (c) above. My summary is as follows:

1. Most of the established literature and practice in relation to setting risk targets, guidelines or criteria relates to people exposed on a daily basis to unavoidable risk in their homes or while travelling. As such it is not suitable for, or applicable to, DOC visitors making voluntary decisions to partake in leisure activity, though parts can be more readily related to risks to DOC workers.

2. Risk tolerability criteria or guidelines are typically established to provide a minimum level of protection for people who live near to significant hazards associated either with industrial activity of wider community and economic benefit, or with natural hazards that cannot entirely be avoided.

3. The most widely used metric of risk when setting risk tolerability targets or guidelines is annual individual fatality risk. It is important when using such targets to clarify how individual risk is to be calculated – for example based on an average for the real population close to a hazard, or based on a hypothetical worst-case person.

4. Individual risk targets in many cases distinguish between the workforce (who derive personal benefit from employment, have a degree of control over risk and a degree of choice in whether to work there or not) and the general public (who may have none of those attributes). Some targets also distinguish between new and existing installations, on the basis that it is more practicable and affordable to design a new installation to a lower risk target than to retro-fit an existing one to the same target.

5. Widely used annual individual fatality risk reference levels for an upper threshold of tolerability are

   - 10^{-3}/year for workers
   - 10^{-4}/year for members of the public generally
   - 10^{-5}/year for members of the public (new installations)
   - 10^{-6}/year for members of the public around hazardous installations such as nuclear or chemical plants representing clear major potential hazards.

6. The most widely used measure of community-wide risk (and thus of the safety benefits of risk reduction) is the annual burden of fatalities (or fatalities and weighted injuries, or casualties). This is extensively used

   a) In situations where the tolerability of risk to individuals is not really an issue, as the primary metric of safety for the community,

   b) To help choose between options for risk reduction and determine which will deliver the lowest reasonably practicable risk, and

   c) To help optimise the results of programmes of risk reduction where the budget available is limited and cannot fund all desirable initiatives.

7. Several regulators and industry bodies have also adopted societal risk targets or criteria as an expression of society's concern for events involving different numbers of fatalities. These are typically defined in terms of an f/N curve showing the frequency of events leading to N or more deaths as a function of N, generally shown as lines on log-log plots, characterised by

   a) a defined point such as the target frequency of events with 10 or more fatalities, and

   b) the slope of the plot, where
   - a slope of -1 implies that for every 10x increase in N there should be a 10x decrease in f

- a slope of -2 (or other number >1) implies proportionately lower allowable frequency of 1 event involving 10 fatalities rather than 10 events involving 1 fatality.

Many other factors besides scale of casualties are involved in characterising society's concerns and may be important in particular decision contexts. The use of f/N curves as the sole or major expression of society's concerns and preferences is controversial.

8. The numerical levels at which targets or guidelines are set are generally determined
   a) For individual risk, by comparison with other relevant risks that individuals face
   b) For balancing community risk reduction against cost, in terms of a value of preventing a statistical fatality, by combining estimates of monetary costs with estimates of people's willingness to pay (for which methodologies are well established), and
   c) For societal risk, in situations where the criteria are in regular use, by reference to a balance of what is feasible and/or desirable[20].

9. Some community or societal targets and guidelines incorporate the idea of scale aversion – that is, the assumption that society would prefer to avoid 1 accident killing 10 people than 10 accidents killing 1 person. This can be incorporated into f/N curves (by using a slope steeper than -1 on a log-log plot) or by using higher values of preventing a fatality for events involving larger numbers of casualties. There is no consensus on this topic.

10. Individual risk targets and values of preventing a fatality can more or less be compared directly across different groups and contexts. The community or societal risk appropriate for a single site cannot be simply compared with what is appropriate for a major airport or for natural hazards in New Zealand.

11. Quantitative risk targets and guidelines should be used to inform decisions but not normally as their sole determinant. Evaluation of assessed risk against criteria needs to take into account the provenance and uncertainty of the risk information, and factors other than the numerical level of risk that may be important locally or nationally.

12. There is an emerging body of risk assessments relevant to DOC visitors which uses fatality risk per visit, per day or per single experience of an activity as the most relevant metric.

3.2 National Parks Overseas

I am very grateful to the Lake District National Park (the UK's largest national park), to Parks Tasmania and Parks Canada for sharing their experience and approaches to visitor risk management in the course of this research. Case studies on each are provided in Appendix 2. My summary and observations for DOC are as follows.

1. All of the other national park organisations consulted during this work are clear that visitors should make their own decisions about whether to accept risk, and all accept that this implies

[20] T here are also several cases where in my view societal risk targets have been "lifted" from literature relevant to different contexts and applied inappropriately,

a duty on them to inform visitors about particular risk at any given location.

2. National Park bodies face very different pressures in terms of intervening to reduce risk. The UK is at one extreme (limited wild spaces, strong pressure to conserve wilderness, strong resistance to restrictions on access and to any on-site provision of information that might spoil the natural environment). New Zealand is probably at the other (extensive wild spaces, rapid growth in visitor numbers, evidence of visitor unawareness or lack of capability to deal with outdoor hazards leading to greater pressure to reduce visitor risk).

3. None of the Parks bodies involved face geological hazards on the scale faced by DOC and New Zealand, but severe weather is a key trigger for operational decisions. Parks Canada regularly closes access to areas of parks and camp sites subject to avalanche, tsunami and wildlife hazards based on the judgment of local staff and advice from weather and other natural hazard organisations. Such closures may also be on the grounds of ensuring the quality of visitors' experience (as in Parks Canada) or for environmental protection (e.g. in Tasmania at times of elevated fire risk).

4. None of the Parks organisations consulted make regular use of quantitative risk assessment, or have quantitative risk guidelines in place, to support decisions related to closure or other requirements for risk reduction.

5. This said, the Tasmania Parks & Wildlife Service has an established risk scoring system in place for evaluation of general visitor hazards at particular sites. This does not directly quantify risk and would not be suitable for application to natural hazard risk involving relatively infrequent but high consequence events.

6. In comparison with countries where access to National Parks is controlled and charged for, and where reporting systems for incidents are better established, DOC has relatively weak information on both:
   a) visitor numbers to particular parks and/or sites of special interest, and
   b) accidents and incidents.

7. In Canada and Tasmania, where relatively good quality information on visitor incidents is available, incident information is routinely used both to identify and to prioritise sites/ hazards for which risk reduction should be considered.

8. While there is no established practice on which to draw when using quantitative natural hazard risk information to steer visitor safety decisions, the general policies and principles adopted in other Parks appear consistent with DOC's visitor safety policy. There is considerable interest in DOC's innovative approach in using risk comparisons to set National Park risks in context and support decisions on what to do about them.

4.3 Observations for DOC Based on Practice Elsewhere

1. For workers, annual individual fatality risk is the most suitable metric for evaluating risk across a wide range of workplaces and situations.

2. Guidelines for workplace risk from natural hazards can sensibly be developed by comparing risks faced by DOC workers with other groups of people at work in New Zealand, taking note of established workplace risk criteria and guidelines overseas.

3. The whole context of "risk criteria" for visitors is very different from that for people living near major hazard installations, to which most established guidelines and criteria overseas relate. In particular there is a major issue of whether (and if so when) DOC should effectively remove individuals' choice as to whether they visit areas subject to high natural hazard risk.

4. Factors other than life safety risk are important in overseas National Parks' decisions on visitor safety in respect of natural hazards, in particular the quality of visitors' experience and environmental protection.

5. Comparisons with relevant other risks, balanced in many cases with judgment of what is practically achievable, are the primary means used to develop appropriate risk criteria and guidelines.

6. Care needs to be taken in defining the comparative risk used – for example there is often a big difference between the population average risk (which is used in many cases) and the risk to most-exposed groups of the population.

7. In setting targets or guidelines for one particular hazard or group of hazards, their contribution to overall risk in relation to other hazards needs to be taken into account (for example the UK nuclear industry intolerable workplace accident risk is set at 10^{-4}/year though the overall tolerability limit is 10^{-3}/year, because 90% of the total risk is "budgeted" for the risk due to radiation exposure in normal operating conditions). This is important for natural hazards, which make up only part of the risk to people on PCL.

8. Non-fatal injuries should also be incorporated into visitor risk management and are routinely used in Parks Canada and Parks Tasmania. These are less important in the context of individual and societal risk thresholds of tolerability but are important when balancing priorities in terms of where to use limited resources to manage risk.

9. In developing policy in relation to visitor risk from natural hazards this review of practice elsewhere reinforces my view that the risk metrics on which DOC should focus are:

   a) Individual fatality risk per day's visit or per activity carried out within a day or less,

   b) The collective risk expressed in overall fatalities per year (or PLL – probable lives lost), and

   c) Societal risk, in terms of the frequency of major events of particular societal concern for DOC/New Zealand. These might include examples such as
      - how often a fatal accident is expected to occur,
      - how often an event killing particular numbers of people at once occurs,
      - how often an event occurs killing one or more people of particular concern, or
      - how often an event occurs where DOC is specifically liable.

5. DOC Risk Levels and Comparators

This section provides a summary of the findings of the companion report on

- Workforce risk on NZ PCL and elsewhere in New Zealand (5.1)
- Visitor individual risk on NZ PCL and comparators (5.2), and
- Aggregate/societal risk on NZ PCL in comparison with NZ as a whole (5.3).

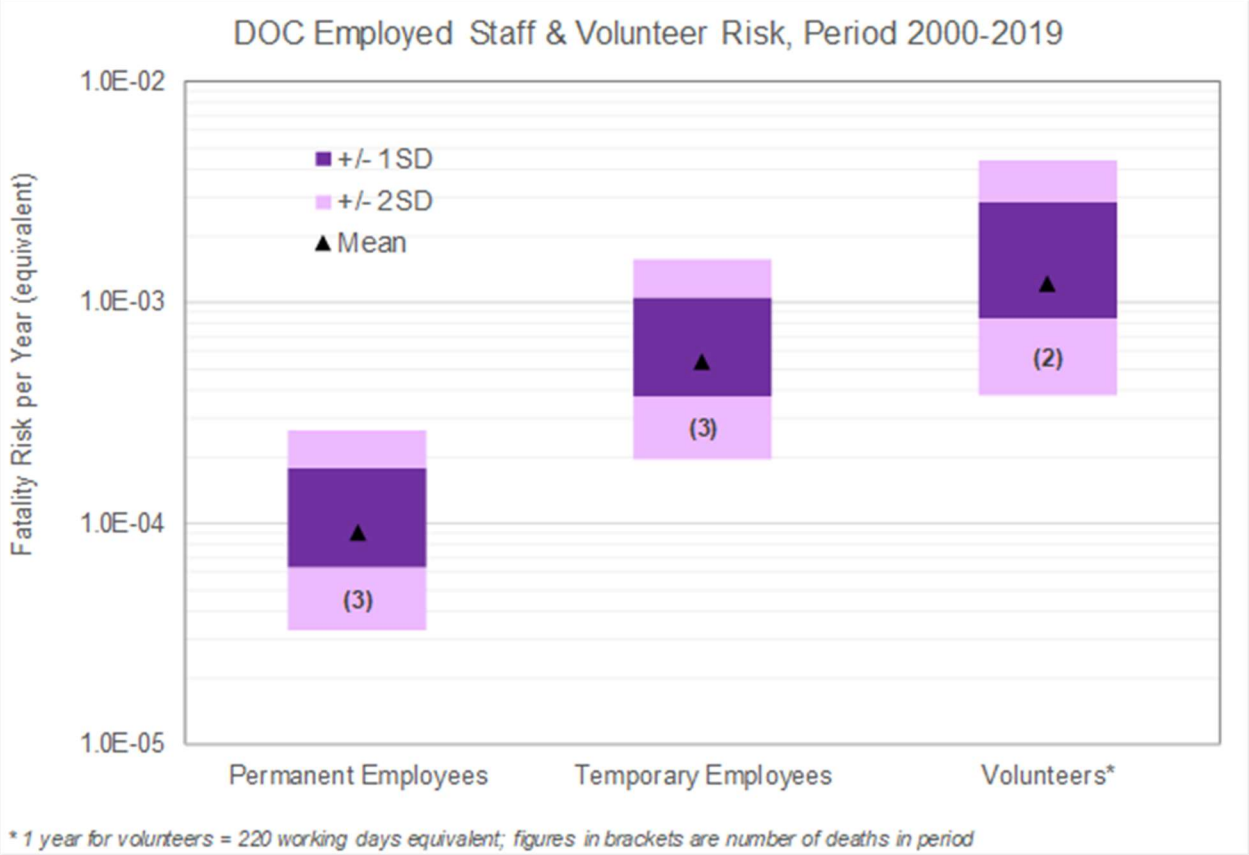
5.1 Workforce Risk

Like other employment sectors where most people work in an active, outdoor environment, the Arts & Recreation Services (A&RS) sector of which DOC is part experiences relatively high workplace risk, of order 10^{-4}/yr. The numbers of staff working for DOC and the associated numbers of deaths are small, but given the associated uncertainties it appears that

a) DOC permanent staff fatality risk over the past 20 years has been similar to the A&RS average of about 10^{-4}/yr, though
b) The main hazard for DOC permanent staff has been travel by helicopter (which is not included in the Workforce NZ statistics on which these comparisons are made), and
c) The fatality risk for temporary and volunteer workers is higher than that for permanent.

Risk levels among the DOC workforce are illustrated in Figure 5.

Figure 5: DOC Workforce Individual Risk, Average over period 2000-2019



The high level of risk among volunteer workers (though the numbers are small so the statistical significance is not high) serves as a valuable reminder that we need to consider not only workers at their regular place of work, but also those carrying out diverse tasks in the field and volunteers and contractors under the Health and Safety at Work Act (2015). There will inevitably be tasks (and by their nature many of the occasional or one-off tasks undertaken by volunteer or temporary workers may well be of this sort) which form only a small part of anybody's duties but which are more hazardous than the average. In considering guidelines for workplace risk we therefore need to consider not only

a) Annual individual fatality risk to permanent or temporary workers at their regular place of work, but also

b) Fatality risk associated with one-off or occasional tasks, or with tasks undertaken by volunteers who offer their services to DOC a day at a time rather than over longer periods.

In respect of (b), fatality risk per day rather than per year would be the appropriate metric to be used. Special cases involving longer periods volunteering should be considered on a case by case basis.

5.2 Visitor Individual Risk

The average individual fatality risk experienced by visitors to NZ PCL over the past decade was between about $6x10^{-7}$ and $2x10^{-6}$ per visitor day. More detailed breakdowns were able to be made for visitors to National Parks and are shown in comparison with other risks in Figure 6. Notable points include:

a) Risk levels vary across National Parks, from below 10^{-7} to more than 10^{-6} per day, with Abel Tasman and Paparoa at the lowest and Kahurangi at the highest end of this range.

b) The accident risk per day spent in a National Park is broadly similar to the average accident risk per day spent living in New Zealand for residents, or per day spent in New Zealand for visitors.

c) International visitors and New Zealanders face similar overall risk levels per visitor day to National Parks. Climbers (whether NZ or from overseas) face substantially higher risk levels than the average visitor. Risk per day on the Great Walks is similar to that experienced by visitors tramping within National Parks generally.

d) Analysis of detailed data assembled on deaths to trampers and swimmers shows that the fatality risk per day for international visitors is substantially greater than that for New Zealanders (some 5-6x for trampers and over 10x for swimmers, though the ratios should be treated with caution given the different provenance of information on frequency of swimming and tramping).

e) The risk per day's participation in most sports by New Zealanders (with the exception of sailing/boating) appears similar to or lower than that experienced per day spent in National Parks.

f) Leisure journeys on New Zealand roads may involve lower risk than a day spent in a National Park for safer walkers and drivers, but involve higher risk for less safe drivers or pedestrians and many cyclists – and much higher risk for motorcyclists.

g) Most popular "adventure" activities for visitors to New Zealand involve similar or greater risk per experience than a day spent in a National Park, with climbing/mountaineering risk levels extending well above 10^{-5} per day. A notable exception is bungy jumping which, with no fatalities to date in many millions of jumps, has involved lower risk than a day spent in any but the safest National Parks.

h) Unless travelling by bus, the risk travelling to and from National Parks is comparable to or greater than that spending a day there for travellers using private cars/vans or scheduled flights in small aircraft. For travellers by charter flight or by motorcycle the risk getting to and from National Parks is much greater than that experienced in a day there.

i) The risk per day to NZ National Park visitors is similar to that experienced by visitors to more or less comparable National Parks in North America. The range of risk per day in North American parks is considerably wider than that in New Zealand, as parks there include at one extreme parks in/around cities where visitors almost all arrive by car and undertake little physical activity, and at the other extreme parks that are in large part the province of specialist climbers, divers or participants in other high risk activities. The risk per day experienced on the New Zealand Great Walks is similar to that experienced by walkers on comparable iconic walks in Tasmania and Great Britain.

j) Serious mountaineers overseas (and in New Zealand) involved in high altitude or particularly challenging climbs regularly experience fatality risk at levels in the range 10^{-4} to 10^{-3} per day or higher.

5.3 Aggregate/Societal Risk

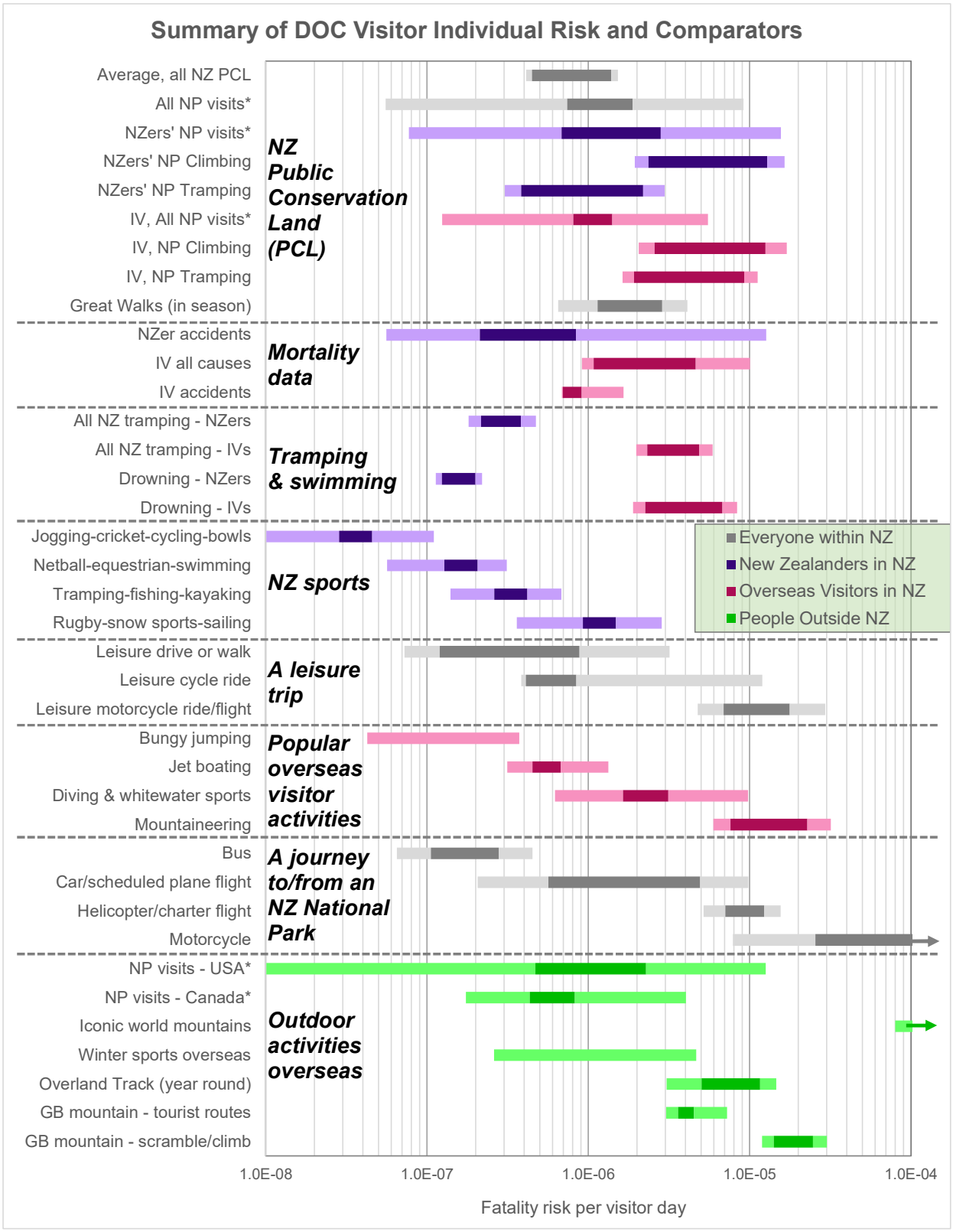
The aggregate annual burden of fatalities on NZ PCL is around 22 deaths per year (excluding aviation accidents). For New Zealanders the burden of fatalities on PCL is less than 1% of the overall burden of accident fatalities per year. For international visitors it is much more significant (around 14% of accident fatalities), as would be expected from their much higher proportion of time spent at National Parks (20-40% of time spent in New Zealand).

Major events, defined as those killing 5 or more people, can be expected around once a year or more in New Zealand from all causes. Natural hazards are a significant contributor to the frequency of such events, accounting for perhaps 10-20% of their total frequency. Outdoor activities also contribute significantly to the national frequency of major events, with activities on and around PCL leading to a major event every 3-10 years.

Natural hazard risk at individual DOC visitor sites has had the potential (prior to those risks being assessed and reduced) significantly to add to the risk of major events on PCL. This highlights the importance of DOC being able to screen and identify visitor sites with significant potential for natural hazard risk, and to assess those risks appropriately.

There are significant quantitative as well as qualitative differences between "major events" in terms both of their potential to involve much larger numbers of casualties, and their significance in terms of their degree of attributability to DOC. This being the case, uncertain estimates of major event frequency should be treated more cautiously (i.e. towards the upper reasonable possible values) in situations where exacerbating factors (such as children being at risk, or DOC being particularly at fault) might apply.

Figure 6: Summary of Individual Fatality Risk for DOC Visitors and Comparators



***Notes**: IV = International Visitor, NZer = New Zealander; see companion report for details & assumptions*
** Range shown is from lowest risk to highest risk park; other data are averages across parks/walks.*

6. Discussion

This section discusses in turn what needs to go into the DOC process for making decisions about natural hazard risk (6.1), deciding on the values to use in that process (6.2), and applying the process once established (6.3). A final section discusses presentation of quantitative risk information to visitors (6.4).

6.1 Key Elements of the DOC Decision Process

All the discussions with other parties throughout this project have at some point reached the same conclusion: that visitors to National Parks (or any other NZ PCL) are responsible for their own safety. Many visitor deaths are associated with visitors making poor personal choices. The legal and moral responsibilities DOC has to its workers as an employer are different from its duty of care to visitors.

The first major point for discussion is whether the concept of "intolerable risk" should apply to visitors to Public Conservation Land at all. DOC's first visitor safety principle is to preserve the range of outdoor recreation experiences available to visitors wherever possible. So it might be argued that by assessing risks at its sites and informing visitors of them, then leaving them to take their own decisions, DOC has completely fulfilled its responsibility to them. There are undoubtedly many libertarians who would support such a view and argue that NZ PCL should remain fully open, without restrictions, at all times (which is close to the situation that applies in UK National Parks).

In practice, though, there are substantial problems with such an approach, in particular:

a) It is difficult to be sure that visitors understand the risk information presented to them,

b) NZ and DOC face large and rising numbers of visitors with limited knowledge of English, which compounds this problem,

c) DOC recognises its responsibility to ensure, as far as practicable, that visitor facilities are appropriate (which by implication includes "suitably safe" and "practicable") for those using them,

d) By adopting a laissez faire attitude, DOC would open itself to charges of having allowed deaths and injuries to occur which could readily have been prevented by simple, practicable actions on its part, and

e) There is the potential at several sites on NZ PCL for severe, multiple fatality events which, were they to occur (and in particular if they were directly attributable to DOC's actions or omissions), might seriously compromise DOC's and New Zealand's reputation and DOC's ability to pursue its mission.

For these reasons I conclude that it would be appropriate, as part of a risk-based approach to dealing with natural hazards, for DOC to adopt thresholds of intolerability for visitor, as well as for workplace, risk.

At the other end of the scale, many managers and workers around DOC feel uneasy about being held responsible for the realisation of hazards that present little risk to visitors, despite DOC's

principle that visitors should take their own decisions about risk. This can lead to a tendency to over-warn visitors about hazards which could be greatly counter-productive. If every track and car park is smothered in notices about storm, earthquake and volcanic risk then the effectiveness of those notices will be diluted, and DOC will rightly be accused of "crying wolf".

For this reason I conclude that it would be appropriate, in addition to adopting thresholds of intolerability of visitor risk, for DOC to adopt lower or "de minimis" levels of risk, below which no special action should be taken to warn visitors or otherwise reduce risk.

In its Visitor Safety Principles DOC goes further than accepting its responsibility to assess risks and advise visitors about them, and commits to prioritising management action at sites with high levels of risk and high volumes of low skilled visitors. This leads me to conclude that the three key elements of a risk-based framework for dealing with natural hazard risk on NZ Public Conservation Land should be

a) Intolerable risk levels, appropriately set for visitors and workers
b) "De minimis" lower risk levels below which no action beyond general messaging is appropriate, and
c) Risk-based prioritisation of opportunities to reduce risk where risk levels lie in-between.

On this last point, DOC in my view should limit the ability of individual sites or regions to make their own decisions where any significant expenditure (or other adverse issues) might be involved in further reducing risk that is already tolerable. A risk assessment will often reveal quick, simple opportunities for risk reduction that could readily be accommodated within local budgets (for example improvements in signage, small areas of fencing or minor re-routing of tracks or routes for guided walks). These opportunities should be taken up promptly at local level. However, if more substantial issues are at stake – for example a significant capital project is needed, or a project is identified that would have significant landscape or conservation impacts as well as reducing visitor risk – then those decisions should be referred to the DOC corporate centre[21]. Thresholds for what constitutes "significant" should be agreed through a clear internal process.

My logic here is that it is likely that DOC will have many more opportunities to reduce visitor risk on PCL than it will be able to fund. If individual sites/regions are empowered to make their own decisions about which improvements to adopt where risk is already tolerable and resources required are significant, then DOC will not be fulfilling the commitment in its Visitor Safety Principles to prioritise management actions where there are high risk levels alongside high volumes of low-skilled visitors. Opportunities for risk reduction requiring significant resources (or involving other potentially significant negative impacts) should be collected and prioritised centrally to make best use of limited budgets.

To enable this to happen, local managers and workers need a way of identifying whether there are realistic opportunities available for further risk reduction that should be referred for corporate

[21] The companion GNS reports on risk analysis guidance have proposed that DOC should establish an Expert Panel to oversea natural hazard risk assessments – I support this proposal, which would provide an appropriate forum to develop recommendations for DOC priorities.

prioritisation. A good risk assessment may already have identified such opportunities, or at the least made it straightforward for local staff to identify them[22]. As a simple test of how realistic they are, I suggest that they are screened using the current NZ Treasury value of a statistical life (VOSL, currently a little under $5 million[23]) to see whether they might possibly represent value for money. This should be quick and easy, and should not require any degree of detailed costing of potential risk reduction projects. The formula to be used to estimate the value of a project is

Value ($) = (PLL/yr saved by project) x VOSL x (Years of benefit) [eq 1]

In applying this formula I suggest that DOC err on the high side for workers (towards whom they have particular duties of care) and on the low side for visitors (for whom I would expect there to be far more opportunities to reduce risk than can be afforded, and on whom DOC needs to limit its expenditure in reducing already tolerable risk levels if it is to achieve its overall objectives).

To use the formula workers would thus need to know

- The project title and what it would involve
- A very rough estimate of its cost
- The PLL/year at the site that it would help to reduce
- The VOSL (my suggestion for the next several years would be to keep this simple and use a value of $5m – this is a simple screening tool and does not need to be highly accurate)
- What proportion of those PLL it would remove (this could be as simple as L/M/H where anything under 20-30% is L, 30-70% M and >70% H)
- The duration of the effect (for example a public communication programme might last a year or two, whereas re-routing a track might last for decades).

To keep estimates within sensible timescales I suggest the duration of benefit is capped at 10 years for visitors and 30 years for workers.

Local staff can then compare the approximate cost with the approximate benefit. If the cost significantly exceeds the benefit then they would record this as part of closing out the actions following the risk assessment. If it does not then the risk reduction opportunity would be referred on for corporate prioritisation, which would take into account the risk reduction value of opportunities, their other benefits and disbenefits, and the budget available for this purpose.

In considering visitor risk, the threshold values adopted will need to be tailored to the relevant user group at a given site. In considering workplace risk, consideration will need to be given not only to permanent or temporary workers at their regular place of work, but also to occasional tasks that might involve particular risk for a short period of time (or indeed to volunteers whose time is offered and taken up by DOC by the day rather than over longer periods). In such cases

[22] See guidance in the companion GNS Risk Analysis guidance reports, in particular:
SJ deVilder and CI Massey, "Guidelines for Natural Hazard Risk Analysis on Public Conservation Land and Waters, Part 3: Analysing Landslide Risk to Point and Linear Sites", GNS Science Consultancy Report 2020/62, June 2020.
[23] See the NZ Treasury CBAX tool at https://treasury.govt.nz/information-and-services/state-sector-leadership/investment-management/plan-investment-choices/cost-benefit-analysis-including-public-sector-discount-rates/treasurys-cbax-tool

risk for a worker or group of workers undertaking high risk tasks may be carried out for the whole of their year at work of which those tasks form a part – effectively providing a "risk budget" in which a short period of very high risk tasks might be offset against months of low risk work (for example virtually any office-based task involves very low risk).

As discussed earlier, the key appropriate metrics for use within this framework are

a) Intolerable risk levels in terms of
   - annual individual fatality risk for workers at their regular place of work
   - fatality risk per day for workers undertaking occasional or one-off more hazardous tasks
   - fatality risk per day for visitors, and
   - frequency of specified major events

b) "De minimis" lower levels (using the same metrics) – likely to be particularly valuable for visitor individual risk in helping avoid unnecessary and counterproductive measures.

c) Aggregate fatalities per year, or PLL (probable lives lost per year) for prioritising risk reduction opportunities where risk lies in-between (a) and (b). As and when good quality injury information becomes available this should be extended to include weighted injuries in addition to fatalities.

With these elements defined, a decision process for DOC on natural hazard risk can now be suggested for workers and visitors, as shown in Figures 7 and 8 respectively. The starting point in each case is assumed to be that local DOC management and staff have received a natural hazard risk analysis and are now considering the appropriate action in light of its results.

The end point in each case is either

- A decision that the risk is intolerable, or
- A demonstration that risk is as low as reasonably practicable (ALARP), or
- Referral to DOC corporately to prioritise any realistic scope for further risk reduction (with the site/activity allowed to continue indefinitely in the meantime).

The assumption is that any simple, practicable risk reduction opportunities that can be taken in light of the risk assessment results should be taken. The residual risk (which will hopefully also be provided by the risk assessment) can then be tested against the lower "de minimis" level, and then screened (as described above based on PLL) to identify whether it should be added to a corporate list of risk reduction opportunities to be evaluated and prioritised centrally.

The process diagrams also allow for some flexibility in interpretation and response to an evaluation that risk is intolerable. If the risk is clear and extreme I would expect prompt action to be taken to halt the activity giving rise to it. But if the situation is more marginal then it may be more practical, and more visitor-friendly, to allow activity to continue for a time, with appropriate interim measures in place.

An example of this approach was that used by DOC during the current project to relocate the Mintaro Hut on the Milford Track (see 3.2 above). My advice to DOC was that it was the visitors' unawareness of the risk that was the central moral issue here, rather than the level of the

risk itself. As an interim measure DOC wrote to all visitors who had booked into the hut, advising them of the level of risk involved and offering to refund their booking fees if they wished to withdraw.

Figure 7: DOC Natural Hazards Decision Process – Workers

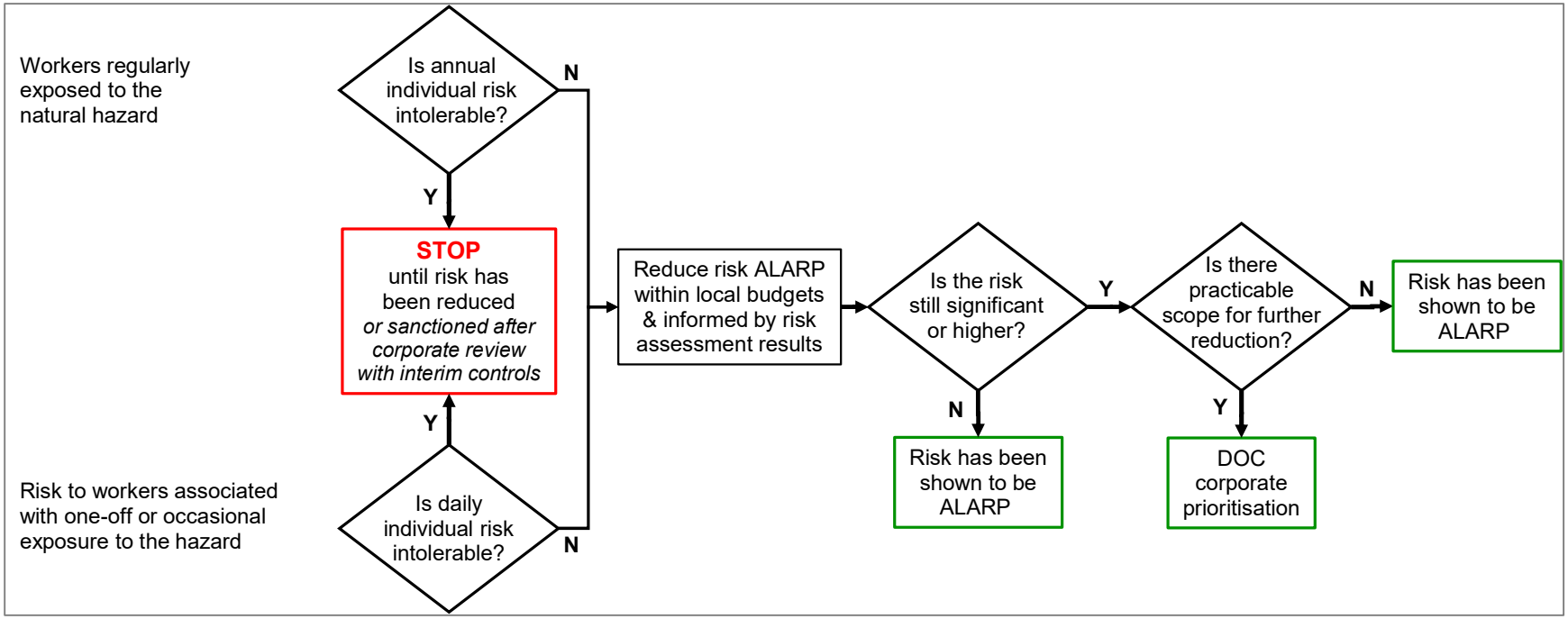
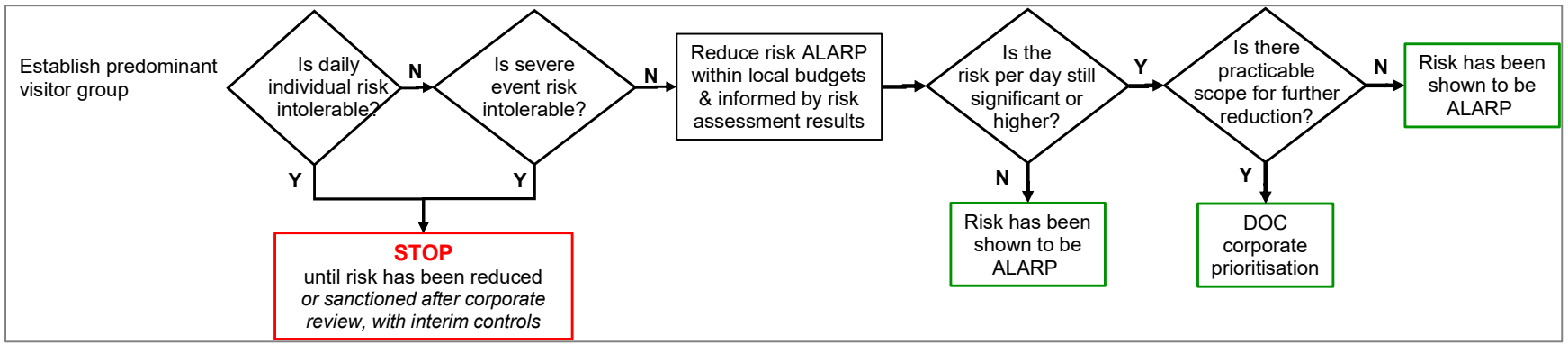


Figure 8: DOC Natural Hazards Decision Process – Visitors & Major events



The final aspect of this framework that has not been discussed earlier in this study is how DOC should define "Major events" whose risk needs to be considered regardless of individual risk to workers or visitors. This is something that DOC needs to decide for itself, but my suggestion as a starting point would be to include

a) Any event killing 10 or more people, regardless of cause or who is at risk

b) Any multiple fatality event whose victims are particularly valued, and

c) Any multiple fatality event directly attributable to failings by DOC.

On (b), building codes often include buildings such as hospitals, schools or vital emergency services. On NZ PCL the only regularly occurring people in this category that come to mind are parties of students.

It is perhaps worth noting that the Cave Creek disaster could have qualified as a "Major event" on all three of these criteria.

6.2 Deciding the Values to Incorporate into this Process

Some important issues to be taken into account have emerged during this study. In particular

a) Threshold risk levels can only really be derived by comparison with other genuinely relevant and (as far as possible) directly comparable risks.

b) This raises the question of what should be included as "in scope" for comparative risk – most notably I have chosen to include medical causes of death, but have taken into account that such deaths are part of the package people "bring with them" to NZ PCL in proposing values here.

c) Natural hazards contribute just part of the risk that visitors and staff face on Public Conservation Land, not the whole. So any thresholds set for natural hazard risk need to be lower than those appropriate for the totality of risk faced.

d) Natural hazards differ from the other important hazards that visitors or workers face on PCL in a number of significant ways, including:
   - It is easy to be unaware of rare events, or if aware to ignore them, discount them or put them out of mind,
   - Associated with this point, while visitors clearly make a wholly voluntary decision to visit NZ PCL, they may well do so in ignorance of natural hazard risk,
   - Natural hazard risk is in many cases much less controllable by the visitor or worker than the other outdoor or workplace risks they face,
   - Associated with this point, natural hazard risk is less discriminatory between the well-prepared and the ignorant or incapable than are other outdoor hazards. The most highly skilled remoteness seeker is just as vulnerable to a landslide erasing a hut during the night as is a city dweller with zero wilderness experience.

In considering these issues I was assisted by consultation with a substantial group of DOC staff at a workshop held in Wellington on 4 December 2019. The first part of the workshop included a presentation of the research to date and a valuable discussion of the principles involved with a group of managers and field staff who have to deal with these issues on a regular basis. The second part involved inviting participants to inspect wall charts containing preliminary drafts of the comparative risk information charts from the companion report, then allocate points (represented by different coloured stickers) to the charts they considered most relevant, marking on each the risk levels appropriate for

- Intolerable and "de minimis" risk threshold for short stop travellers, and
- The same thresholds for remoteness seekers (at the other extreme of the visitor spectrum).

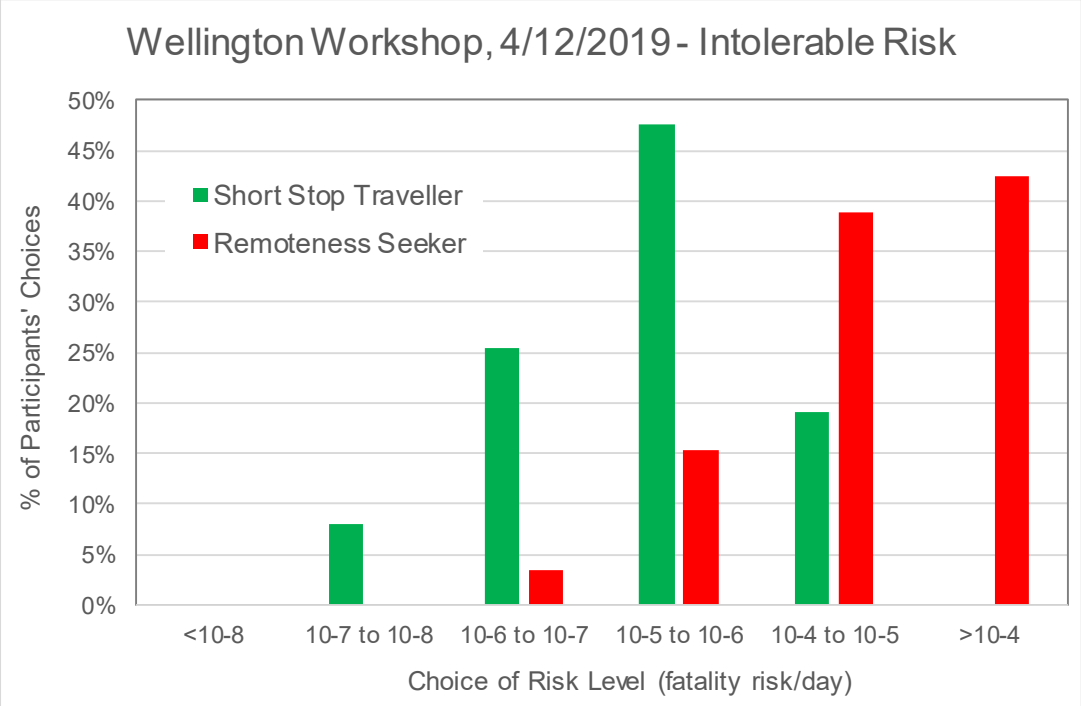
The intent was to garner a range of thinking rather than to run a process to determine what the values should be, and participants were reassured that their choices would not be incorporated directly into policy recommendations.

The comparisons considered most relevant were

- Visits to National Parks/ days on major walks (37% of all points)
- Other outdoor leisure/sporting activities (36% of all points), and
- Travel to and from National Parks and other PCL (14% of all points).

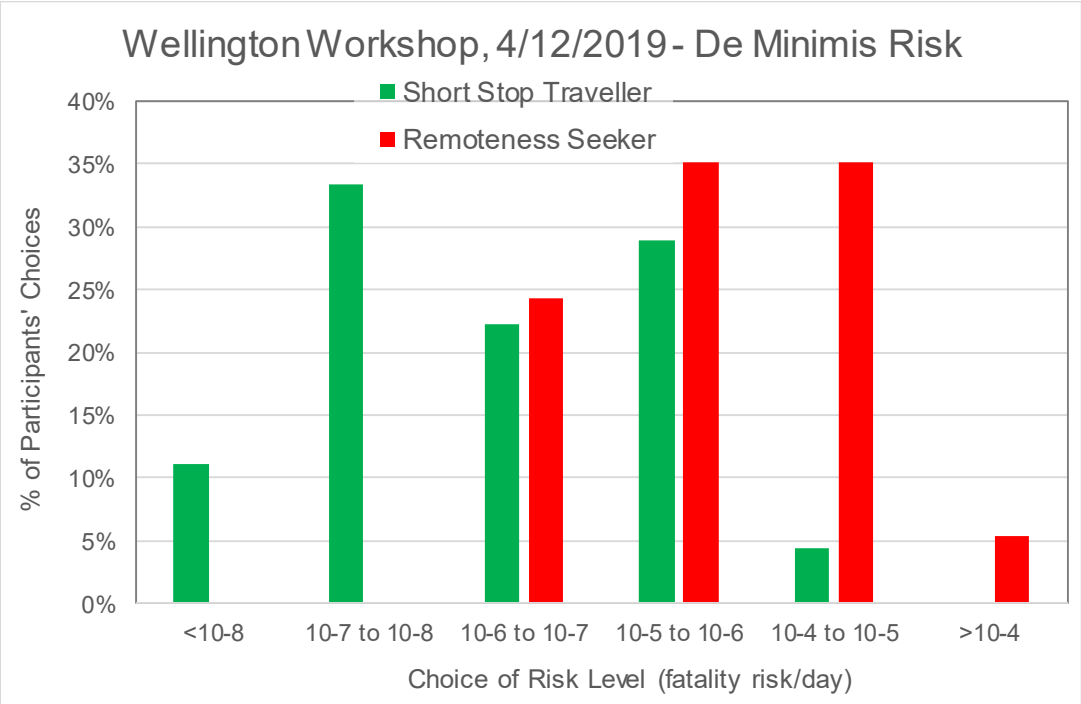
There was considerable variability in where people chose to set threshold risk levels. A summary of the values chosen is provided in Figure 9 for intolerable risk levels and Figure 10 for "de minimis" lower levels.

Figure 9: Workshop Participants' Thoughts on Intolerable Risk Levels



There was universal agreement that an upper threshold of risk tolerability was useful for lower skilled visitors, but disagreement on whether this was appropriate for remoteness seekers.

Figure 10: Workshop Participants' Thoughts on "De Minimis" Risk Levels



Another interesting observation was the link between the risk level chosen and the comparator used as the basis for the choice. In most cases the lower choices of risk thresholds involved comparisons with sport and leisure activities, while the higher choices involved comparisons with risk in National Parks or on Great Walks, or in travelling to and from NZ PCL.

I concur with the workshop participants as to the comparators most relevant in establishing DOC guidelines for different visitor groups and have taken those into account in formulating the suggested values below. My thought process here has been to take each metric of risk (workplace risk per year and per day, visitor risk per day for different visitor groups and major event frequency per year) and gauge risk levels as follows by reference to the risks experienced in relevant other visits/activities:

- Insignificant (corresponds to "de minimis" level)
- Significant (contributing one to several % to risk levels from comparators)
- Substantial (contributing 10's of % to comparator risk levels)
- High (adding 100% or more to comparator risk levels), and
- Extreme (adding several-many times comparator risk levels).

I have used the boundary between "Substantial" and "High" to mark the upper threshold of tolerability, and the boundary between "High" and "Extreme" to divide the intolerable region into "Stop now" and "Perhaps proceed temporarily subject to corporate review". These proposals

take into account all of the issues discussed in this section. They are intended to act as a starting point for DOC discussion – it is for DOC, not a consultant, to decide what its values should be.

My suggested evaluation scheme for workplace risk is shown in Table 5.

Table 5: Suggested Values for Evaluation of DOC Workers' Natural Hazard Risk

Significance Level	**Evaluation Category**	**Action Required**	**Annual Fatality Risk** Permanent or Temporary Staff Regularly Exposed to Natural Hazard	**Daily Fatality Risk** One-off or Occasional exposure to Natural Hazard
Extreme	Intolerable	HALT until risk reduced	$>3x10^{-4}$	$>3x10^{-5}$
High		Continue ONLY after corporate review etc	$>10^{-4}$	$>3x10^{-6}$
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	10^{-5} to 10^{-4}	$3x10^{-7}$ to $3x10^{-6}$
Significant			10^{-6} to 10^{-5}	10^{-7} to $3x10^{-7}$
Insignificant	Tolerable	None	$<10^{-6}$	$<10^{-7}$
cf Current Risk Levels, All Hazards			**$3x10^{-5}$ to 10^{-3}**	**$2x10^{-6}$ to $2x10^{-5}$**

My thinking here is that the upper threshold for the overall risk to workers should be no higher than the 10^{-3}/yr level that has been adopted as guidance by the UK Health & Safety Executive and many other bodies worldwide, and corresponds roughly to the level of risk faced by DOC permanent and temporary workers from all causes over the past 20 years. As there are many other hazards besides natural hazards which DOC workers face, natural hazards should not be allowed to contribute more than 10% of this target, hence the 10^{-4}/yr threshold of intolerability. In special cases (for example where there is strong evidence that other hazards make a proportionately smaller contribution to risk, or where there is a very powerful benefit in continuing or fulfilling a critically important task), a somewhat higher level might be allowed to continue on a temporary basis.

The equivalent thresholds per day for occasional tasks or occasional workers recognise that it should be allowable for workers to endure higher risk for short periods of time within their overall annual "risk budget". These levels are also intended to be applicable to volunteers, who I

have treated as equivalent to my "medium risk" visitor group. When they volunteer to work on for DOC they expect to be active, so it would be inappropriate to judge their risk by levels appropriate for a short stop traveller or day visitor. On the other hand they are not volunteering to enjoy the thrills of the more adventurous visitor groups; allowing them to experience risk similar to that that would be experienced by a visitor tramping or on a Great Walk seems about appropriate. I understand that volunteers are treated as equivalent to employed staff under NZ Health & Safety legislation, so it seems appropriate that the same risk target per day should apply to each when engaged in field tasks over short periods of time.

Table 6 shows my suggested values for three visitor groups corresponding to low, medium and higher risk appetites. Their typical choices of park type, travel, and activities they enjoy determine the levels of comparator risk used to establish the levels from insignificant to extreme.

Table 6: Suggested Values for Evaluation of Visitor Individual Risk

			Fatality risk per Day/Single Visit		
Significance Level	**Evaluation Category**	**Action Required**	**Lower Risk**	**Medium Risk**	**Higher Risk**
Extreme	Intolerable	HALT until risk reduced	$>10^{-5}$	$>3x10^{-5}$	$>10^{-4}$
High		Continue ONLY after corporate review etc	$>10^{-6}$	$>3x10^{-6}$	$>3x10^{-5}$
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	10^{-7} to 10^{-6}	$3x10^{-7}$ to $3x10^{-6}$	$3x10^{-6}$to $3x10^{-5}$
Significant			$3x10^{-8}$ to 10^{-7}	$>10^{-7}$ to $3x10^{-7}$	$3x10^{-7}$ to $3x10^{-6}$
Insignificant	Tolerable	None	$<3x10^{-8}$	$<10^{-7}$	$<3x10^{-7}$
Typical National Park/walk selection & risk/day			Safest National Parks **$<10^{-7}$**	Great Walk or higher risk Park **$3x10^{-7}$ to $3x10^{-6}$**	Remote tramp with rivers/scrambles **$3x10^{-6}$ to $3x10^{-5}$**
Typical means of travel there & risk doing so			Bus or car with safe driver **10^{-7} to 10^{-6}**	Car with typical driver **$3x10^{-7}$ to $3x10^{-6}$**	Younger car driver or safe motorbiker **$3x10^{-6}$ to $3x10^{-5}$**
Typical activities they might enjoy & risk levels			Bowls, golf, tennis, a stroll **$<10^{-7}$**	Walk, swim, bike or jet boat ride **$3x10^{-7}$ to $3x10^{-6}$**	Rafting, caving, climbing, gliding **10^{-6} to $3x10^{-5}$**

It is assumed in this report and in Table 6 in particular

a) that visitors can be grouped according to their general appetite for risk as is currently assumed by DOC, and

b) that visitors' appetite for risk generally (which is largely within their own control) will be similar to that for natural hazard risk (which is largely outside their own control).

These are critical assumptions which need to be tested by DOC before adopting or adapting the guidelines suggested in Table ES2.

Given these assumptions and the current DOC Visitor Group definitions, my presumption is that

- Short Stop Travellers and Day Visitors would be treated as Lower Risk,
- Back Country Comfort Seekers as Medium Risk, and
- Remoteness Seekers as Higher Risk.

Backcountry Adventurers might be included in either the Medium or Higher Risk category, at DOC's discretion.

For the higher risk group in particular there is considerable room for discussion in what "intolerable risk" means and how it should be interpreted. It is absolutely NOT the intention that DOC should be prohibiting high risk activities (for example guided ascents of Aoraki/Mt Cook). But, like any other visitors, remoteness seekers might reasonably expect that if DOC provides and maintains facilities for their use, then the use of those facilities should not expose them to more than a fraction of the risk they might experience in their (adventurous) outdoor activities. The key distinction here is between risk which is largely within, and that which is largely without, the control of the visitor experiencing it.

At the very top end of the risks people regularly take are serious climbers who challenge themselves to take on ascents at the limit of their (or anyone else's) ability. Here fatality risk levels as high as 10^{-3}/day or even higher might be experienced. My proposal here is thus that the risk level might be considered extreme if it exceeded 10% of this amount for the most extreme user of a DOC facility such as a hut, which would correspond to several times the daily risk for more mainstream adventurous types.

Finally, my proposals for evaluation of Major event risk are shown in Table 7.

Table 7: Suggested Values for Evaluation of Major event Risk

Significance Level	Evaluation Category	Action Required	Frequency of Major Natural Hazard Events (per year)		Basis/Comparators
			All Public Conservation Land	Individual Visitor Site	
Extreme	Intolerable	HALT until risk reduced	>0.1	>0.01	A major event on PCL is anticipated every 3-10 years. Natural hazards should contribute no more than 30% of this (i.e. 1 event per 10-30 years) Guidance for individual visitor sites is suggested as 10% of this level
High		Continue ONLY after corporate review etc	0.03 to 0.1	0.003 to 0.01	
Substantial	Tolerable if reduced ALARP	Explore practicable risk reduction options (prioritise SUBSTANTIAL)	0.01 to 0.03	0.001 to 0.003	At the "substantial" level, natural hazards would add 10% to the WHOLE major event risk on public conservation land; at the "significant" level they could be adding a few % Guidance for individual visitor sites is suggested as 10% of this level
Significant			0.001 to 0.01	10^{-4} to 10^{-3}	
Insignificant	Tolerable	None	$<10^{-3}$	$<10^{-4}$	Given the scale of natural hazard events foreseeable in NZ, trying to reduce below once in 1000 years for DOC (1 in 10,000 yrs for a single site) is unlikely to be worthwhile

The basis of these levels is, I hope, adequately explained in the right hand column of Table 7. The key principles are

1. It would not be tolerable for natural hazards to contribute more than 30% of the historic frequency of major events on PCL as a whole.
2. Adding 1% to several % to the totality of major event frequency across PCL would be significant; adding 10% would be substantial.
3. Guidelines for individual visitor sites need to be set at a significantly lower level in order for these levels across the whole of PCL not to be exceeded – a level of 10% of the guideline for the whole of PCL is suggested.

6.3 Applying the Natural Hazards Risk Framework

The suggested framework and approach is based on the premise that:

1. Guidelines on how to carry out natural hazard risk analysis and assessments and interpret their results are mandated centrally as DOC policy,
2. Natural hazard risk analysis may be commissioned or carried out either locally or centrally,

3. Initial interpretation of the findings of such assessments will be carried out, and low cost (and uncontentious) opportunities for risk reduction will be promptly grasped, by whoever commissioned or carried out the analysis,
4. Higher cost or potentially contentious opportunities for risk reduction will be flagged for corporate assessment and prioritisation
5. Some form of corporate oversight and/or collation of the results of analyses will be carried out so as to build up an overview of natural hazards risk across NZ PCL.

In making decisions within this framework I would like to emphasise two points that have emerged strongly in my own experience and in discussions in the course of this study.

The first is that any numerical guidelines should be treated as just that – they provide GUIDANCE but should not be treated as strict criteria which determine decisions in isolation from other factors.

The second is that many, if not most, decisions will have to be made in the face of considerable uncertainty over the risk levels involved. The frequency of natural hazards, the scale of events, impacts on the landscape, vulnerability and behaviour of people and occupancy of places are all subject to considerable uncertainty, and DOC should be extremely sceptical of any natural hazard risk analysis results which do not make this clear and provide a reasonable indication of the range of plausible or likely results. The companion risk comparisons report deliberately presents all comparator risk information as ranges rather than point values.

This then begs the question of how DOC should interpret a risk analysis result which, for example, might be either higher or lower than a threshold of tolerability. The answer is that "it all depends" – on the extent of the uncertainty either side of the threshold, and on all the other factors such as conservation values, visitor quality of experience and consistency with DOC's general principles and purpose that need to be brought into such decisions. The simple rule is that the greater the uncertainty in the risk information, the greater consideration should be given to other factors which might help determine the decision.

In adopting this framework, I find it difficult to imagine DOC succeeding without a small central unit being involved who would, for example

- Promulgate and provide training and advice on the framework and its use
- Provide ad hoc support in commissioning risk analysis and interpreting their results
- Collating an overview of analysis findings and natural hazard risk across DOC
- Prioritise opportunities for reduction of risk that is already within tolerable limits, and
- Monitor visitors' and workers' response to these guidelines, evaluate their effectiveness and feed back as appropriate.

The GNS Science companion reports providing guidance on natural hazards risk analysis[24] include advice on the treatment of uncertainty appropriate for different levels of analysis. They

[24] See reference (1) above and companion reports Parts 2-5.

also propose the formation of a DOC Expert Panel, a concept I strongly support as providing an appropriate unit to assist with the tasks itemised above.

6.4 Communicating Risk Information to Visitors

Throughout this study, not only DOC workers but also virtually every other organisation which has assisted have commented on the challenge of helping visitors understand the risk they will be facing and make good decisions on what to do about it.

In this respect I would commend to DOC the principles adopted throughout this and the companion report. The two key principles I have used are

1. To avoid, where practicable, presenting risk as a single number, but always as a graphic illustrating the range of uncertainty associated with the risk estimate (adopted throughout the companion report), and
2. To use a traffic-light style system to indicate the relative significance of different risk levels (as used in Tables 5, 6 and 7).

While the form of the graphics used would require adaptation before use in visitor information, the benefits of this approach include

a) Avoiding confusion over how to explain small numbers such as 10^{-5} or 1 in 100,000 (particularly useful for "rare but severe" natural hazard events)

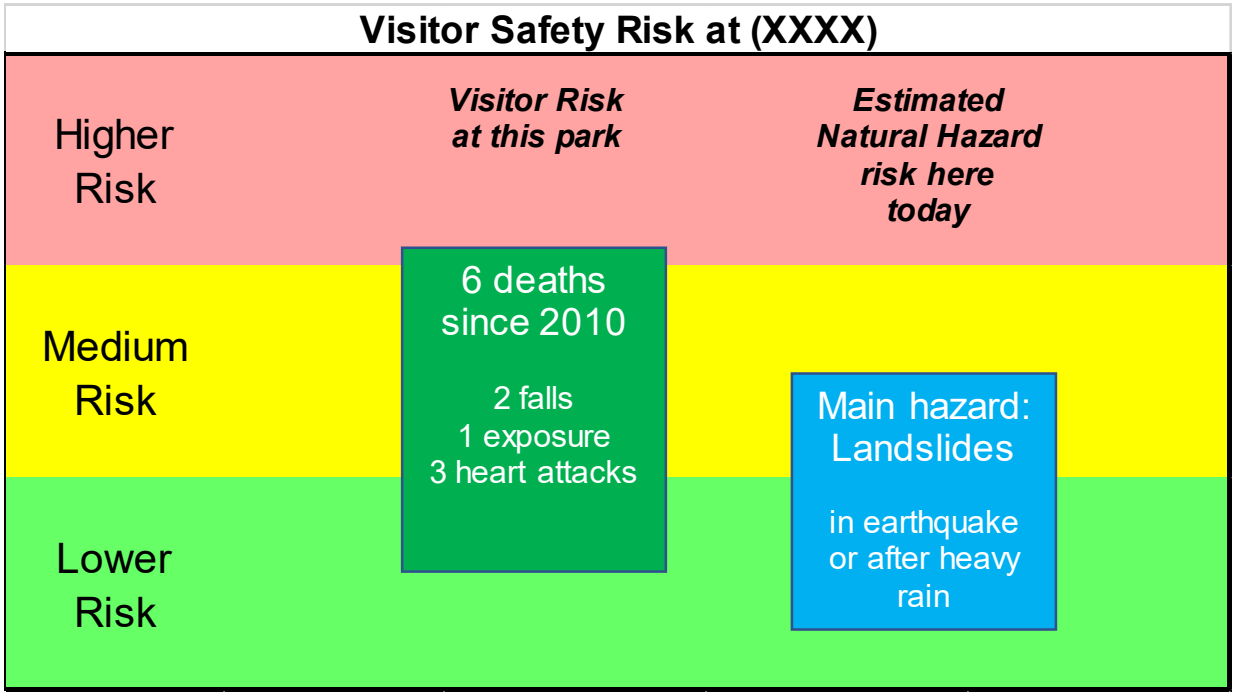
b) Helping visitors appreciate that risk is not something that can be quantified with precision, but is often rather uncertain

c) Making the presentation of risk information more independent of the visitor's understanding of the English language, and (for particularly interested parties)

d) Using a colour or other presentation scheme enabling the major sources of uncertainty in risk to be understood.

The approach is illustrated conceptually in Figure 11.

Figure 11: Risk Information Presentation Concept



The basic idea would be to represent visitors' previous risk experience at the park/site/walk alongside estimated natural hazard risk. Whether to provide further information, and if so what and via what media, would be informed by visitor research. My presumption would be that information provided through signage at parks or specific sites would be very simple, whereas parallel (consistent) information in a medium allowing interested visitors to explore in greater depth (e.g. via the DOC web site) could include greater depth in terms of the make-up of the risk (as illustrated simply in Figure 11), what was meant by "Higher, Medium, Lower" risk and how this was tailored to the park/site, and where the risk information came from and how it was derived.

There is a need for DOC to evaluate how best to communicate natural hazard risk in greater depth before implementation to ensure that the desired outcomes of helping visitors and workers understand, make decisions about and manage their own risk are met.

7. Conclusions and Recommendations

7.1 Conclusions

1. A decision framework for natural hazards risk on NZ PCL should include guidance on
   a) upper tolerable levels of visitor, worker and major event risk
   b) lower "de minimis" levels of such risk, and
   c) what to do about risks intermediate between such levels.

2. The appropriate metrics of risk to use in this framework are
   - annual individual fatality risk for workers at their regular place of work
   - fatality risk per day for one-off or occasional hazardous tasks and for volunteers
   - individual fatality risk per day for visitors, and
   - major event risk in terms of events per year.

3. Values of risk threshold levels should be established by comparison with appropriate risk levels as developed in the companion report to this document. By implication, different comparators and different risk thresholds may be appropriate for different DOC visitor groups.

4. Opportunities to reduce risk where the levels involved are intermediate between "de minimis" and intolerable levels should be prioritised across DOC in accordance with the Visitor Safety Principles.

7.2 Recommendations

1. DOC should review, adapt as appropriate and adopt
   a) the risk metrics suggested in conclusion 2, in particular the definition of a "major event"
   b) the decision processes described in Figures 7 and 8, and
   c) the threshold values for risk decisions suggested in Tables 5, 6 and 7

2. Allow individual sites or regions to implement site-specific risk reduction measures when the risk is above "de minimis" levels and below "tolerable" limits, if measures can be managed within existing local budgets. Other broader, or more costly, opportunities for risk reduction identified in or following on from natural hazard risk assessments should be flagged as for prioritisation nationally. Risk reduction measures where risk is already "de minimis" should be strongly discouraged unless there are other compelling reasons for them.

3. DOC should ensure (for example by adoption of the GNS Science recommendation in the companion Risk Analysis guidance reports to establish an Expert Panel) that it has the resources available at the corporate centre to facilitate the adoption of this framework, to provide ongoing advice and support to those commissioning and interpreting natural hazard risk analysis, to maintain an overview of results and to prioritise risk reduction opportunities across NZ PCL.

4. DOC should treat risk levels as providing guidance, rather than as the sole determinants of safety decisions. Many other factors than risk levels may be relevant, and warrant particular weight when risk levels are uncertain and their significance accordingly difficult to assess.

5. Consider using graphic, visual ways of presenting and setting visitor risk from natural hazards (and perhaps also from other sources) as used in this report, in order to
   a) avoid the need to explain small numbers in terms such as "10 to the minus X"
   b) help convey the uncertainty associated with risk information
   c) illustrate relativity of natural hazard to other, comparator or reference risk levels, and
   d) reduce reliance on the English language for conveying risk information.

Tony Taig

TTAC Ltd

February 2022

8. Acknowledgements

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- DOC
- GNS Science

(and in alphabetical order)

- Arup Group
- Jet Boating New Zealand
- Lake District National Park Authority
- Llanberis Mountain Rescue
- Maritime New Zealand
- Mountain Rescue (England & Wales)
- NIWA
- NZ Accident Compensation Commission
- NZ Civil Aviation Authority
- NZ Ministry of Health
- NZ Ministry of Transport
- NZ Mountain Safety Council
- Parks Canada
- RSSB (GB Rail Safety & Standards Board)
- Scottish Mountain Rescue
- Snowdonia National Park Authority
- Sport New Zealand
- Statistics New Zealand
- Swiss Federal Office for the Environment
- Tasmania Parks & Wildlife Service
- The John Muir Trust
- UK Office of Nuclear Regulation
- Ultimate Hikes New Zealand
- US National Parks Service
- Water Safety New Zealand
- Whitewater New Zealand
- WSL Institute for Snow and Avalanche Research Switzerland

Appendix 1: Examples of Risk-Based Safety Decision Regimes

This appendix provides a brief history (based heavily on the author's experience) of three groups of risk-based approaches to safety regulation and management:

a) the protection of the workforce and members of the public from hazardous installations such as nuclear and chemical plants in the UK and the Netherlands (Section A1)

b) rail safety in the UK and road safety in the UK, New Zealand and many other developed countries (Section A2), and

c) a number of risk-based decision frameworks that have been developed relatively recently, relating specifically to natural hazards (Section A3).

A1.1 Hazardous Installations in the UK and the Netherlands

A slightly dated but still useful overview of the UK and Netherlands approaches to control of risk from hazardous installations is provided by Ale[25]. The two countries' approaches are described in turn.

A1.1.1 UK Nuclear & Other Hazardous Installations

To my knowledge, the first specific numerical criterion for risk from an industrial plant was that proposed by Farmer in 1967[26], which related the allowable release of iodine-131 to the frequency of a nuclear reactor accident scenario. This had various limitations, and led to much debate during the 1970's over how it could be better expressed in terms of risk to people, and be extended to cover the totality of risk from a reactor. Much the same questions are asked today of many modern natural hazard assessments.

The UK's workplace health & safety regulator, the Health & Safety Executive (HSE), was created in 1974 under the Health & Safety at Work Act, which established the Health & Safety Commission (HSC) as the directing body for workplace safety, along with HSE as its executive arm. The Act swept away generations of prescriptive workplace safety in favour of a more general requirement to maintain risks to workers and the public to a level "As low as reasonably practicable" (ALARP). This inevitably led to much discussion of when a risk was or was not "ALARP".

HSE came under pressure to publish specific guidance on the risks it considered acceptable or otherwise, and first did so in the form of a policy document on the tolerability of risk from nuclear power stations (or TOR)[27]. This distinguished between levels of risk which were

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[25] Ale B.J.M. 2005, "Tolerable or Acceptable: A Comparison of Risk Regulation in the UK and in the Netherlands", Risk Analysis, Vol 25 no. 2, 2005.

[26] Farmer F R, "Siting Criteria – a New Approach", in "Containment and Siting of Nuclear Power Plants", Proceedings of a symposium, Vienna, April 1967, p.303, IAEA, 1973

[27] "The Tolerability of Risk from Nuclear Power Stations", UK Health & Safety Executive, London, 1988 (rev. 1992)

a) So high as to be intolerable in any circumstances

b) Tolerable given the benefit of the activity for society, so long as the risk was reduced ALARP, and

c) So low as to be broadly acceptable.

"Risk" here should be considered both from the viewpoint of the individuals exposed to it, and from a broader societal viewpoint.

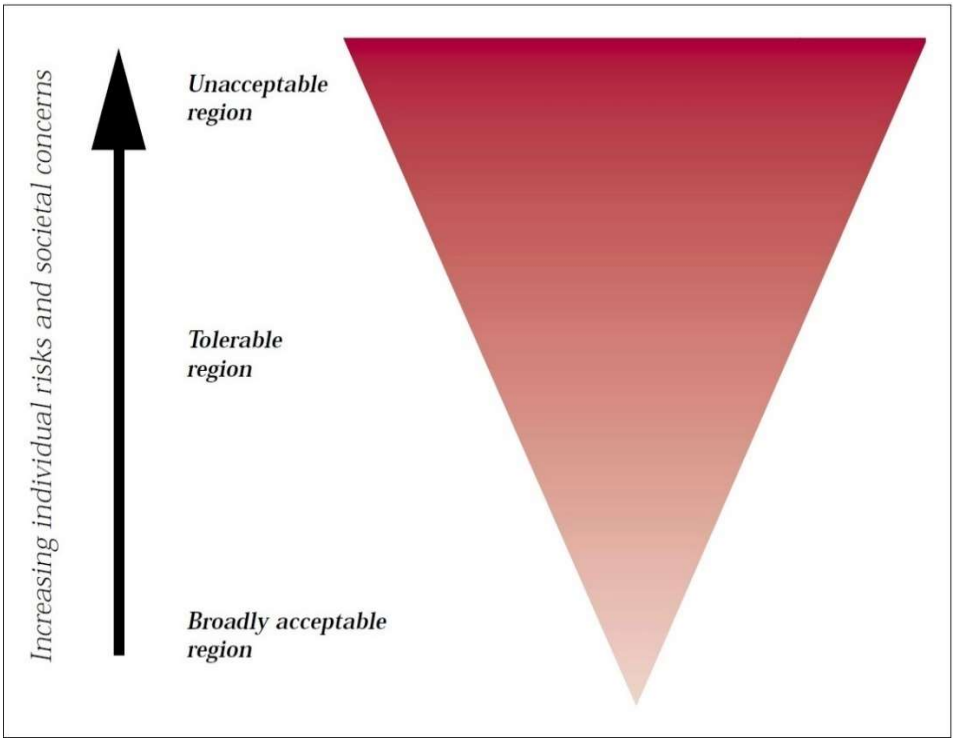
This broad framework has underpinned all subsequent HSE guidance on tolerability of risk, which was updated and generalised to other walks of life in the publication "Reducing Risks, Protecting People" (or R2P2)[28]. This emphasises the importance of any reference levels of risk being treated as guidelines rather than strict black/white criteria, and contains much useful discussion of the many other factors besides the magnitude of a risk that affect societal concerns and public acceptance of it. The very widely quoted (and adopted elsewhere) risk reference levels adopted in terms of individual fatality risk per year are

- 10^{-3} upper threshold of tolerability for workers in an industry
- 10^{-4} upper threshold of tolerability for members of the public, and
- 10^{-6} lower, "broadly acceptable" risk level for the public or the workforce.

The diagram used to illustrate the framework of risk tolerability has been widely used globally and is shown in Figure A1.

Figure A1.1: HSE's Framework for the Tolerability of Risk (from HSE 2011)

[28] "Reducing Risks, Protecting People – HSE's Decision Making Process", UK Health & Safety Executive, London 2001



The context here for members of the public is very much that of point (g) in Table 3 of the main report – that of people who have no control over the risk, no choice over whether to accept it, and derive no direct benefit from the activity giving rise to it. The actual levels were derived through comparisons with other risks people face in the workplace and in society more widely.

The TOR (nuclear) document explained that the safety assessment principles adopted for nuclear plant regulation should deliver risks to the most at risk member of the public of 10^{-6}/year or lower. Nuclear safety regulation was subsequently separated out from HSE into a separate Office for Nuclear Regulation (ONR). ONR's safety assessment principles[29] translate the HSE's TOR/R2P2 guidance into numerical Basic Safety Levels (upper tolerable level) and Basic Safety Objectives (target level), the derivation of which are documented separately[30]. For plant workers, the TOR limit of 10^{-3}/yr is split between risk associated with radiation exposure during normal operation of the plant (80%) and risk associated with accidents (10% or 10^{-4}/yr). Because the public outside are not exposed to radiation in normal operation, their upper accident risk limit is set at the TOR level, so is also 10^{-4}/yr.

Setting levels of tolerable or broadly acceptable societal risk is more difficult, and has often been couched in terms of the acceptable frequency of accidents involving particular numbers of fatalities (or "f/N curves"). The key question on societal risk is whether there should be an upper limit of tolerability which would require risk of adverse events to be controlled to a lower level than would the individual risk guidelines. HSE/ONR and associated advisory committees have made several attempts over the years to define such a level, most notably:

[29] "Safety Assessment Principles for Nuclear Facilities", UK Office for Nuclear Regulation, 2014 edition
[30] "Numerical targets and legal limits in Safety Assessment Principles for Nuclear Facilities - an explanatory note", UK Office for Nuclear Regulation, December 2006

i) The original TOR publication[22] derived an upper acceptable frequency of a "considerable accident" for an individual nuclear plant of 10^{-4}/yr, based on consideration of
- a programme of around 35 major nuclear plants in the UK
- estimated frequencies of very large accidents involving major chemical plants, air crashes and the Thames Barrier overtopping, and
- a desire for new/nuclear plants to do better overall than such existing infrastructure.
This guidance level was withdrawn in the 1992 revised version of the TOR document because of the difficulty (a) in deciding what was tolerable for the nuclear programme as a whole, and (b) in apportioning this between potentially very different plants.

ii) Proposal in 1991 of an f/N curve relating to transport of dangerous goods in the UK by the HSC's Advisory Commission on Dangerous Substances[31].

iii) Development of various alternatives to f/N curves for representation and control of societal risk around land-based hazardous installations, for example the ARICOMAH (approximate risk integral), none of which ever gained serious traction[32]

iv) The R2P2 publication[23], after making numerous qualifications about the difficulty in deciding a societal risk target for an individual installation, including
- understanding society's true preferences,
- defining the scope of events/installations to which the target should relate, and
- the numerous other factors besides number of people killed at once that affect society's concerns about risks,
proposed a tentative target frequency of no more than $2x10^{-4}$/year for events killing 50 or more people at a single major industrial installation.

v) The ONR[24] specifies an upper tolerable frequency of 10^{-5}/yr per installation for events killing 100 or more people, with a target level of 10^{-7}/yr (broadly consistent with the R2P2 proposal).

Research and debate has continued within HSE and more widely in the UK on the issue of societal risk, much of it with a particular focus on whether regulation should incorporate aversion to the scale of large events (i.e. requiring the allowable frequency of an event killing 10 people to be less than 1/10 of the allowable frequency of an event killing 1). This research has been inconclusive[33], and HSE's current policy position in giving advice on land use planning is that societal risk should be taken into consideration alongside individual risk, but that no scale aversion factor (such as that built into the Dutch VROM criterion – see below) should be applied [HSE 2010].

Using the HSE framework, the first requirement for a duty holder is to ensure that the risk their activities represent is not intolerable (i.e. is below the threshold guidance described above). But this is by no means the end of the story; it is also necessary to demonstrate the risk is being

[31] "Report on the Major hazard aspects of the transport of dangerous substances", UK Health & Safety Commission, HMSO UK, 1991.
[32] "Societal Risk: Initial briefing to Societal Risk Technical Advisory Group", Research Report 703, HSE Books UK, 2009.
[33] See for example ERM Ltd, "Evidence or Otherwise of Scale Aversion: Public Reactions to Major Disasters" Technical Note 03, prepared for & published by UK Health & Safety Executive, 2009. This and other HSE societal risk position papers are available online at https://www.hse.gov.uk/societalrisk/index.htm

controlled to a level that is ALARP. The general implication of this requirement is that options for risk reduction must be explored, and the option delivering the lowest practicable risk level should be adopted.

In principle, such a demonstration requires the benefits associated with each option (including risk reduction, non-safety benefits, stakeholder preferences etc) to be weighed against the disbenefits (including costs, practicability, stakeholder preferences etc). In some (relatively rare) cases, quantitative assessment of risks and costs may be used as part of the case for demonstrating risk control to an ALARP level. In the TOR document HSE suggests a general guideline that, all else being equal (and assurance that risk is not intolerable having been provided), risk reduction should be considered practicable if the cost of risk reduction is less than £1 million (in 2001 values) per fatality prevented. This "value of preventing a fatality" approach is discussed further in section 2.1.2.

In the vast majority of ordinary industrial activities and workplaces, demonstration of compliance with the legal requirement of ALARP boils down to a duty holder being able to show HSE that the risks involved in their activities are not unusual for that type of activity, and that they are adopting good practice in controlling them. No permission is needed from HSE before commencing ordinary industrial activities. For high hazard installations (chemical plants, pipelines, offshore oil platforms and nuclear plants), operators have to produce a safety case providing site-specific quantitative risk assessment and demonstrating how they will reduce risks ALARP. This safety case must be approved by HSE (or ONR for nuclear plants) before operations can begin.

Important general points repeatedly made by HSE/ONR in applying these quantitative guidelines include

1. In most cases they are unnecessary – a judgment on what is or is not ALARP can often be made by examining whether good practice risk control over a familiar, accepted activity is in place rather than by examining risk levels themselves.
2. They are guidelines, not strict criteria, and need to be interpreted in light of uncertainty and the context of specific situations ("people, not numbers, make decisions").
3. The key tolerability issue over and above individual risk is the extent of society's concerns about an issue, for which societal risk (in f/N terms) provides one representation, but there are many other aspects which this does not cover.
4. Demonstrating that risk is not intolerable is only part of the picture – risk must also be shown to be controlled to the lowest reasonably practicable level.

A1.1.2 Hazardous Installations in the Netherlands

In the Netherlands, policy evolved driven by flood risk and by hazardous chemical installations and transport rather than the nuclear industry. Almost 2000 people were killed when floods overtopped the dykes in 1953. A major explosion at a Dutch State Mines plant in 1975 killed 14 people, and 180 Dutch citizens were killed in Spain in 1978 when a road tanker carrying LPG crashed at their campsite (see Ale[20] for references).

An individual risk target of 10^{-6}/yr for flooding was derived from considerations that

- Dykes should not be overtopped more often than 10^{-4}/yr (once in 10,000 years)
- Dangerous dyke collapse should be no more than 10% likely in such circumstances, and
- The chance of death should be 10x lower again.

When LPG accidents received serious attention in the late 1970's and early 1980's, this 10^{-6}/yr also corresponded approximately both

a) to about 1% of the average risk of death on the roads, and

b) to the maximum risk level close to LPG filling stations.

A 10^{-6}/yr individual risk norm thus appeared sensible for members of the public.

The Dutch approach to societal risk developed for LPG filling stations was based on there being roughly 1000 such installations in the Netherlands, and on a strong desire to avoid accidents on the scale of the 1975 DSM explosion, and even more so the 1978 Spanish accident, to a degree greater than that accorded to individual fatality accidents. The criterion adopted was that an accident at one installation killing 10 or more people should have a frequency no greater than 10^{-5}/yr, and that for every 10x more people killed the events should be 100x less frequent.

Another significant difference between the Netherlands and the UK approach was that these risk criteria were enacted into law[34]. In order to make the criteria enforceable it was necessary also to specify the risk assessment tools and assumptions to be used in carrying out the analysis. Within the context of LPG filling stations and transport, the risk criteria along with general good practice risk control arrangements were considered sufficient demonstration of compliance and it would be unusual to find cost-benefit analysis being used.

Cost-benefit analysis is, though, extensively used in the Netherlands, for example in prioritising actions to be taken to mitigate flood risk nationally. In this context societal risk remains a topical issue with potentially major implications for the choice of risk reduction strategies[35]. It is clear that the societal risk criterion appropriate for a single LPG filling station cannot simply be applied as it stands to national level risks. For example the annual frequencies of an event killing 100 or more people are

- 10^{-7}/yr maximum allowable under the regulatory criterion for a single LPG plant
- About 10^{-5}/yr for accidents at Schiphol airport[36]
- Over 10^{-3}/yr for floods in many individual levee systems, and considerably higher nationally[37].

[34] See for example the TU Delft discussion paper "Risk Assessment in the Netherlands", Beroggi E G et al, 2007 for an overview of relevant Dutch legislation

[35] See for example Jonkmann S N et al, "The Use of Individual and Societal Risk Criteria Within the Dutch Flood Safety Policy—Nationwide Estimates of Societal Risk and Policy Applications, Risk Analysis, Vol. 31, No. 2, 2011

[36] Ale, B.J.M. and M. Piers, 2000. The assessment and management of third party risk around a major airport. Journal of Hazardous Materials 71, 1-6.

[37] The 2016 major national flood risk study commissioned by the Ministry of the Environment and the Water and Provincial authorities identified 18 levee systems EACH with an annual frequency of 100 or more deaths of 10^{-3} or

A1.2 Railways and Roads in the UK and Elsewhere

A1.2.1: Rail Safety Management in Great Britain

Prior to the major accidents at Kings Cross and Clapham in the late 1980s the British railways lagged far behind the hazardous industries regulated by HSE in terms of their risk awareness and management. In the nationalised British Rail (BR) at that time it was common practice for accident reports to be prepared and sent to their regulator as required, without British Rail retaining a copy. Risk control measures evolved, as in many other walks of life, by reviewing existing practices whenever a major accident occurred and amending rules and standards accordingly.

The public inquiries into the 1980s rail accidents recommended that the railways take greater care to understand safety risks and manage them more actively. British Rail started to collate accident and exposure data to estimate risks to passengers, their workforce and the public. The government allocated a specific budget to be spent on safety improvements which attracted proposals far in excess of the budget. In order to prioritise, proposals were assessed in terms of the lives they would be expected to save and their cost. By selecting the best value (most lives saved per pound spent) proposals, the overall safety benefit in terms of lives saved was maximised. It also made it possible for BR to counter demands for a very expensive (and of limited efficacy for only a sub-set of train crashes) automatic train protection system in favour of more affordable initiatives that would save many more lives (from less dramatic individual accidents such as passengers falling from train doors while trains were moving, and track workers being struck by trains).

The restructuring in anticipation of privatisation led to the creation of a single infrastructure controller, Railtrack, for the whole of the main line network. The (now substantially more risk-aware and capable) BR safety directorate largely moved into Railtrack and was able significantly to influence the requirements for train operation franchises and other rail equipment suppliers and maintainers. On privatisation (between 1994 and 1997), train operators were required to submit a safety case broadly analogous to those used in the permissioning regimes for hazardous installations (see above), and a condition of franchises was that train companies had to commit to some important safety obligations, including

- Reporting a wide range of specified accidents and incidents to Railtrack and cooperating to investigate their causes,
- Participating with Railtrack and other operators in developing an annual safety plan for the whole railway network, and
- Having their safety performance validated and published regularly by Railtrack to enable them to be compared with their peers.

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more, of which 2 had annual frequencies of 10^{-2} or more. "The National Flood Risk Analysis for the Netherlands Final Report", Rijkswaterstaat VNK Project Office, 2016.

The structure has since evolved with Railtrack transmuted into Network Rail in 2002, and its Safety Directorate migrating via a semi-stand-alone body (Railway Safety) to its current status as a separate company limited by guarantee, the Rail Safety and Standards Board (RSSB). With the leadership provided initially by Railway Safety and RSSB the rail industry has in my view transformed itself in 30 years from being a national laggard in terms of proactive safety risk management, to being a national leader. Key elements in this progress included

a) Acquiring high quality information on accidents and precursor incidents from across the whole railway,

b) Using this information to build and share a picture of safety risk from the railway system, broken down by event types and causes,

c) Providing tools to help estimate risk and evaluate the impact on risk of changes in equipment or operations, both at individual company and whole-industry level,

d) Development of safety improvement plans and regular publication of performance against the targets in those plans,

e) A substantial programme of safety research managed via Railway Safety/RSSB,

f) Ensuring routine consideration of safety/risk impacts by the committees reviewing and developing standards and operating rules,

g) Developing and publishing a framework for decision-making across the industry that ensured safety was given proper weight, not just on specific safety issues but on decisions generally, and

h) Building capability in rail operators and other industry organisations to understand risk and the principles of risk management.

Of particular interest for this project is the evolution of the targets set by and for the industry. In the early days there was a strong focus on reducing individual risk. The 1996/97 plan, for example, included objectives to reduce individual fatality risk

- For passengers to a level no greater than in in 50 million passenger journeys
- For the public (via trespass and road-rail interface events but excluding suicides) to no greater than 1 in 1 million per year, and
- For trackside workers to no greater than 1in in 10,000 per year.

As safety performance data and confidence in individual risk levels improved, this focus on individual risk gradually diminished as (with the possible exception of some groups of railway workers and level crossing users) it was clear that the railways were operating below intolerable risk thresholds. In some cases, in particular over the safety of trespassers, there was concern that the railways were forcing themselves beyond their remit, in tackling underlying social issues to try and reduce crime and trespass on the railway. The bigger issue for the railways and HSE, their safety regulator, was whether the railways had done/were doing enough to satisfy the "ALARP" principle, given that the risks were generally in the "tolerable" region of Figure 1.

A particular issue was the resources required to implement modern train crash protection systems. The railways adopted a "Value of Preventing a Fatality" for use in cost-benefit assessment based on the well-established value developed by the UK Department of Transport in the context of roads (see below). For several years a higher value was adopted if the fatalities being prevented involved a multiple-fatality train accident (involving 5 or more deaths at once), in an attempt to factor "societal concerns" over multi-fatality accidents into safety decisions. This practice was dropped after objections from the government's Strategic Rail Authority that there was insufficient evidence to distort resources away from maximising lives saved. The industry now routinely uses an aggregate "Fatalities and Weighted Injuries" (FWI[38]) measure to quantify overall changes to network safety.

Although safety performance was demonstrably improving, public and media concerns over safety in the privatised industry remained high. Railtrack and HSE had an uneasy relationship over several issues, most notably the introduction of train crash protection technologies. From the rail industry perspective they were trying to avoid expensive safety measures of limited effectiveness that would further damage the affordability of railways. From HSE's perspective Railtrack/Railway Safety appeared to be overly focused on cost-benefit arguments at the expense of reasonably practicable measures to improve safety performance.

The rail industry collectively sought clarification of what was really meant by "ALARP", and substantial research was commissioned in the early 2000's, in particular by RSSB through a programme of Safety Decisions research, but also by HSE and the UK Department for Transport. The results were summarised[39] [Elliott 2009] as providing a clear indication of what "we" (the people) expect from transport safety:

- *resources are limited, safety spending can be a bottomless pit, someone has to balance costs and risks (but it's very difficult to talk about the safety of "your child")*
- *there should be a proportionate response, not "safety at all costs"*
- *we don't weight one cause more than another – eg a death in a fire or in an accident in a tunnel is no worse than in an impact accident*
- *we don't weight multiple death accidents more than single – eg an accident in which 3 people die is no worse than 3 accidents in which one person dies*
- *we don't weight a death that is in part self-inflicted as highly as a passive death – eg a trespasser is less important than a passenger or worker.*

RSSB developed a document "How Safe is Safe Enough?"[40] for discussion and consultation which provided an overview of how railway companies in Britain took safety decisions and identified further areas for work – in particular on decision frameworks and on the value to be attached to safety risk reduction when balancing against cost and other priorities. Following the

[38] A measure in which weighted major and minor injuries as well as shock and trauma are added to the number of fatalities to produce an overall measure of harm from fatalities and injuries combined. The weights are decided based on research.
[39] Elliott, C, "Transport safety: is the law an ass?", RAC Foundation, London, 2009
[40] "How Safe is Safe Enough? An Overview of How Britain's Railways Take Decisions That Affect Safety", Rail Safety & Standards Board, London 2005.

Railways Act of 2005, responsibility for rail safety regulation was transferred from HSE to the Office of the Rail Regulator. After further research and much consultation RSSB then published a landmark document "Taking Safe Decisions" (TSD)[41]. This put forward a simple framework for safety related decisions (involving scoping the decision, analysing the options, testing the decisions against legal and business criteria, then reviewing against good practical judgment before implementing). The key criteria advocated for analysing and assessing decision options are

- testing against rules, standards and good practice
- qualitative and quantitative analysis (supported in particularly complex cases by cost-benefit assessment if appropriate)
- targeted engagement of stakeholders, and
- strategic analysis of the wider implications.

An interesting element of the TSD framework is that it refuted the idea that the industry should try and factor "society's concerns" into their decisions. The industry would assess what is reasonably practicable based on stated principles and criteria for ALARP, without trying to second guess special factors to account for "societal concerns". Company Boards (for business reasons), or Government/regulatory bodies (to respond to societal concerns) may then decide to go further than what is warranted under the stated criteria, using legislation or regulation in the latter case to make this happen.

The Taking Safe Decisions (TSD) document was updated in 2014 and again during the course of this research[42]. I took the opportunity to discuss lessons learnt and areas of improvement with those involved prior to the update being issued. The revision reaffirms rather than changes the principles of the original. Its key aims are to increase user-friendliness and thus help embed the decision framework more effectively into the entirety of industry decision-making, and to reflect changes in UK and European law and organisation.

The starting point of the new TSD document is to lay out the framework developed in the original document, with some expansion and clarification to cover the four key processes of

a) identifying the need to make a change and implement a decision
b) deciding what that change should be
c) making the change safely
d) checking it was the right decision,

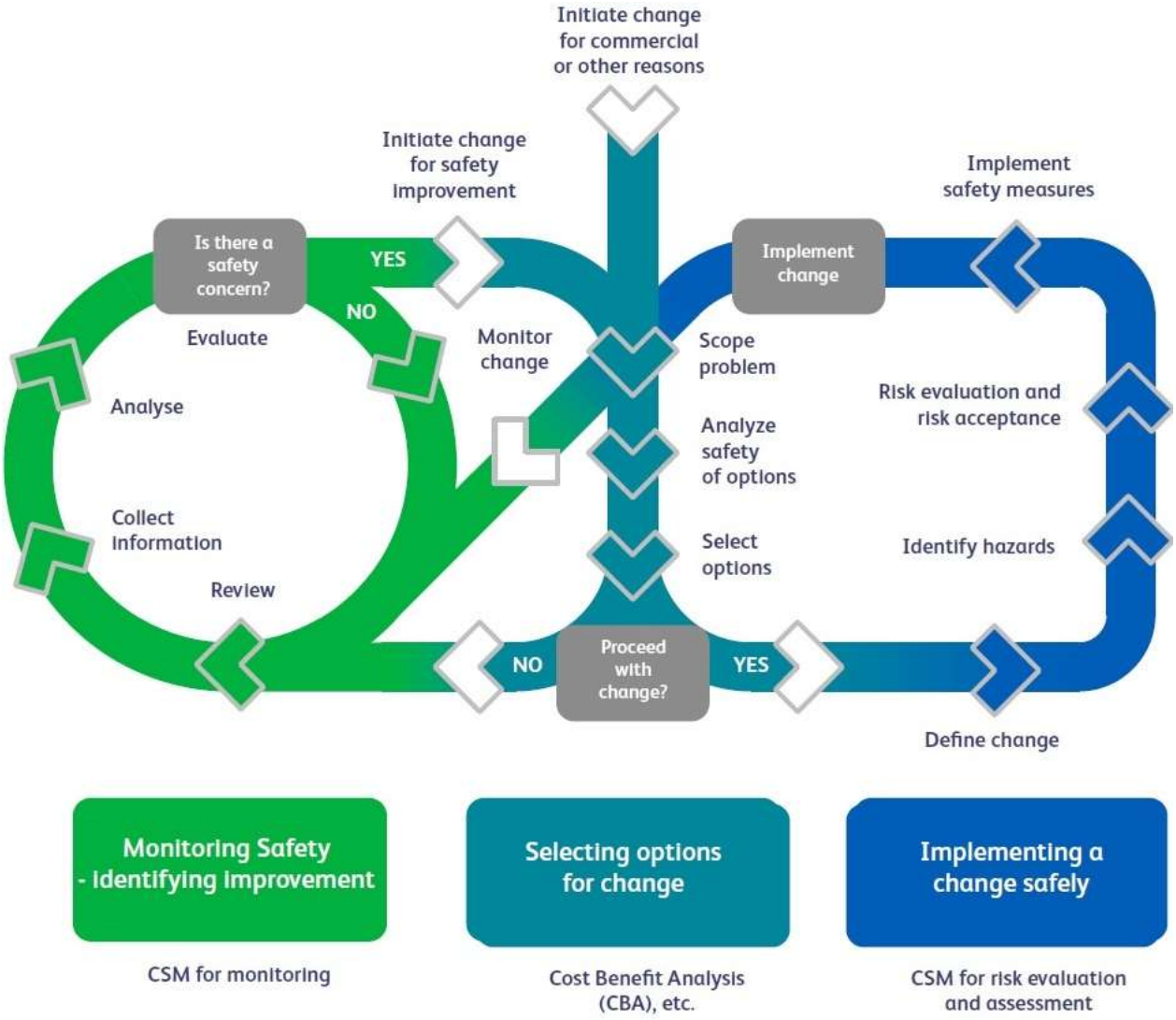
as illustrated in Figure A1.2 (from the TSD 2019 document),

Of particular importance are persuading people to monitor and assess the impact of their decisions, and of ensuring that safety risk impacts and improvement opportunities are given due weight during decision processes. RSSB provides a number of worked examples to illustrate

[41] "Taking Safe Decisions - how Britain's railways take decisions that affect safety", RSSB London, 2008
[42] 2019 edition available online via RSSB at https://www.rssb.co.uk/en/Standards-and-Safety/Improving-Safety-Health--Wellbeing/Applying-Guidance-and-Good-Practice/Taking-Safe-Decisions

how the decision framework can help with difficult decisions. Generally speaking, it is easier to ensure that the framework is applied in industry-wide projects (such as the standards review bodies which RSSB coordinates) than it is for managers and staff working in individual organisations.

Figure A1.2: The Taking Safe Decisions Framework



Since its establishment in 2003, RSSB has gradually evolved from providing industry leadership on safety, to providing facilitation, methods and support as the industry itself assumes greater leadership. Following a major review of the railways in 2011[43] a strong Rail Delivery Group (effectively a government-mandated alliance of all the train operators along with Network Rail) has, among many other things, assumed responsibility for the development and publication of the industry strategic safety plan[44]. RSSB publishes a quarterly review of progress against the strategic safety plan. The plan is less explicit than the former annual Railway Group Safety Plans about risk to particular stakeholder groups; it is organised around themes of practical relevance to

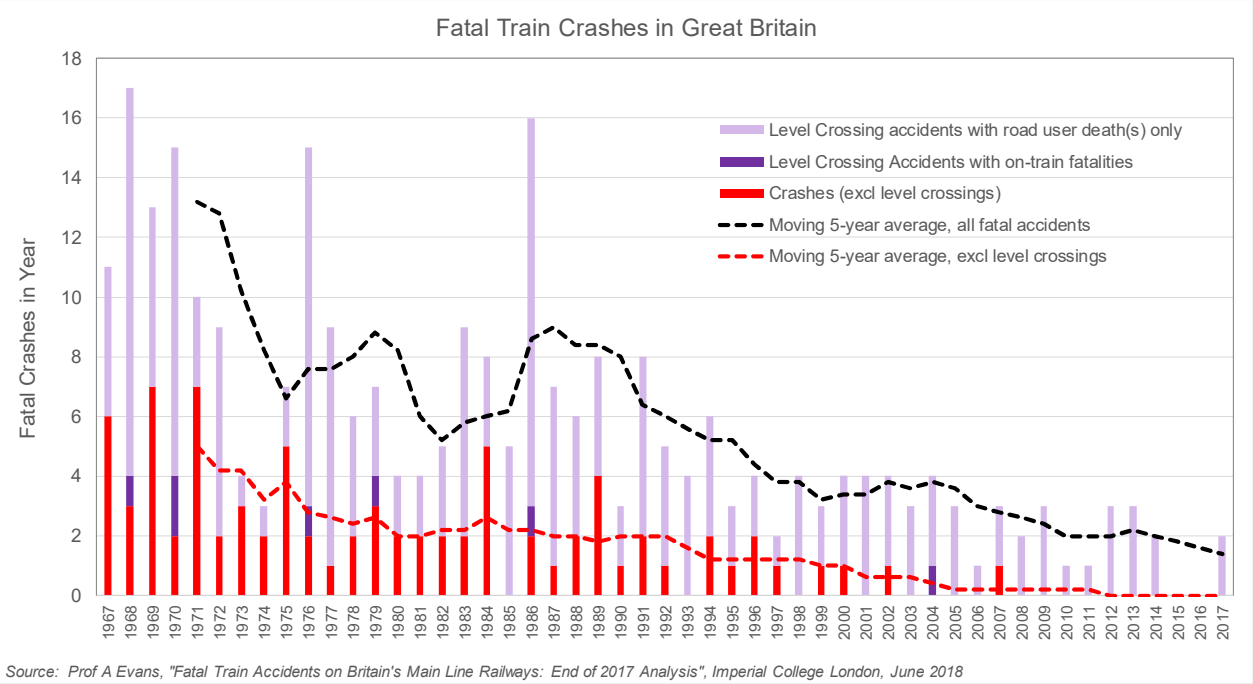
[43] "Realising the Potential of Rail in Great Britain", report of a study chaired by Sir Roy McNulty and commissioned by the Secretary of State for Transport, UK 2011

[44] An overview of the various bodies involved in rail safety and links to the strategy document "Leading Health & Safety on Britain's Railways" is available online at https://www.raildeliverygroup.com/uk-rail-industry/about-my-journey/railway-safety.html

the industry such as “station operations”, “road risk” and “staff health and wellbeing”. In the quarterly reviews of progress RSSB reports on progress against key associated metrics.

The railway risk methods and approaches developed by the UK rail industry have been highly effective, as illustrated by the past 50 years’ trend in fatal train accidents shown in Figure A1.3.

Figure A1.3: Fatal Train Accidents on the British Railways, 1967-2017



These methods and approaches have also been extremely influential outside the rail industry in Britain, in particular among railways in Europe and globally. The European Union enacted a Railway Safety Directive in 2004, and established the EU Agency for Railways to develop procedures within the framework of railway safety and interoperability. More recently the EU has introduced regulations requiring member states to adopt Common Safety Methods (CSMs) for risk evaluation and assessment, conformity assessment, monitoring and supervision. The CSM for Risk Assessment is a framework that describes a common mandatory European risk management process for the rail industry[45]. Amendments are concerned with ‘risk acceptance criteria’, which are now called ‘harmonised design targets'. These CSMs effectively generalise much of the risk assessment work carried out by the British railways and promulgate similar approaches across Europe.

A1.2.2 Road Safety

Road authorities in the UK and elsewhere often report on individual risk to road users in terms of casualties (which may be reported as deaths, “killed plus seriously injured” or total casualties

[45] See the Office of Rail Regulation web site for latest information on Common Safety Methods and related topics – currently at https://orr.gov.uk/rail/health-and-safety/health-and-safety-laws/european-railway-safety-legislation/csm-for-risk-evaluation-and-assessment

including more minor injuries) per unit of travel (typically km, hours or journeys). To my knowledge these individual risk metrics have never been used as a basis for setting of targets or standards, though are implicit in many cases. Virtually everybody is a road user in one way or another, and the inevitability of substantial numbers of deaths and injuries associated with the roads is generally recognised and tolerated by society, if not accepted. Perceptions of the high individual risk per kilometre for vulnerable road users[46] is a significant factor in many individual decisions not to use (or allow children or others to use) modes of transport such as walking or cycling which offer great health benefits to individuals and wider benefits to society. A broad overview of the application of risk assessment and measurement across the modes of transport in the UK is provided in a Transport Research Laboratory study for the UK Department for Transport[47].

The primary focus of road safety in the UK, as in many other countries, is on casualty reduction – focussing on maintaining or reducing the overall annual burden of deaths and injuries. Using the rich data available on road accidents, tools have been developed to predict the impact on casualties of possible changes to vehicles, to road infrastructure and initiatives to influence driver behaviour (whether through regulation or public communication). In practice such tools are inevitably risk-based as they have to combine estimates of incident rates based on past experience with estimates of current or future road usage.

Both national and local road authorities have a huge number of possible measures available to improve safety and reduce casualties. Cost-benefit assessment is used extensively both at national level (where decisions on vehicle and road standards, driver licensing and government publicity campaigns are decided, and decisions made on major trunk road improvements) and at local level (where most of the focus is on changes that can be introduced on local roads). The UK Department for Transport publishes extensive guidance on transport analysis[48], which includes detailed advice on cost-benefit assessment and the value attached to preventing a statistical fatality (currently just under £2 million), serious injury (just over £220,000) or minor injury (just under £17,000).

In practice, most local road authorities in the UK are faced each year with a plethora of candidate safety schemes which would represent good value for money based on cost-benefit assessment, but which collectively would exceed the available budget. Prioritisation is typically based on a blend of value-for-money assessment (which scheme will save the most lives per £ spent?) and community preferences (elicited via consultation and debate among elected representatives). There is little or no predictive analysis of locations which have not experienced serious accidents; the rates of accidents are sufficiently high that there can be high statistical confidence that the major locations contributing to risk have been identified.

In summary, land transport in the UK has made some use of individual risk and societal risk concepts over the past 30 years, but by far the most widely used risk metric in decision making for both roads and railways is the annual casualty burden. Where risk reduction has to be

[46] The individual risk associated with cycling, walking and motorcycling is many times higher than that for motor vehicle occupants – see recent NZ statistics in Section 3.
[47] Kennedy J et al, "Cross-modal safety: Risk and Public Perceptions – Phase 1 Report", TRL report PPR521, 2010
[48] https://www.gov.uk/guidance/transport-analysis-guidance-webtag

balanced against other desirable issues such as affordability or budget, cost benefit assessment is used with a monetary value ascribed to deaths and injuries saved. Individual risk is monitored and has in the past been used in railways as a basis for target setting, but this is no longer the case. Societal risk has been explored on the railways and for hazardous goods transport, but has not become established.

A1.3 Selected Risk-Based Approaches to Natural Hazards

In the course of working with GNS Science I have encountered proposed risk criteria for use in the context of natural hazards from Australia and from Hong Kong. I have briefly explored the approach being adopted by the Swiss National Platform for Natural Hazards (PLANAT). I have also collated recent examples of New Zealand natural hazard situations which have been the subject of particular assessment (see Section 2.2 of the main report), and while there are no established targets or criteria in place in New Zealand have summarised here what appear to be the emerging precedents for decisions corresponding to different levels of risk.

It should be noted that ALL of these cases are in the context of life safety risk to people in their homes or daily lives; none of them relate to people undertaking voluntary leisure or social activity nor are they assessment of economic losses or other risks such as environmental degradation.

A1.3.1 Australia:

The criteria proposed by the Australian National Committee for Large Dams[49] distinguish between new and existing dams, on the basis that it may not be practicable to raise older dams to the same standard as new-built ones. For individual fatality risk the upper limit of acceptability for people living below the dam is 10^{-4}/year for existing and 10^{-5}/year for new dams, calculated for the person most at risk. A societal risk f/N criterion is also proposed, with upper allowed frequencies of accidents killing 1 or more people (N=1) of 10^{-3}/year (existing dams) and 10^{-4}/year (new dams). These allowable frequencies fall in inverse proportion to the number of fatalities, to 10^{-5}/yr (existing) and 10^{-6}/yr (new dams) for accidents killing 100 or more people, with no further frequency constraint beyond N=100. What this says in practice is that the worst case possible accident should be no more frequent than is allowed for N=100. The derivation of these criteria involves comparisons with risk targets set elsewhere, with particular reference to the UK.

The Australian Geomechanics Society[50] similarly reviewed risk criteria in use elsewhere and adopted the same individual risk criteria as ANCOLD, also in the context of people resident on/near a hazard which more or less imposed a risk on them. In earlier guidance the AGS proposed that individual risk be calculated for average individuals in the most-exposed area; in the more recent update they adopt the ANCOLD premise that risk should be calculated for the most at risk person. The practice guidance states that usually societal risk need not be considered in assessing single dwellings, but should be evaluated (with reference to the ANCOLD approach

[49] ANCOLD, "Guidelines on Risk Assessment", ANCOLD February 2003
[50] AGS, "A Natonal Landslide Risk Management Framework for Australia", in Australian Geomechanics, Volume 42 No 1, March 2007

and criteria) for buildings having high numbers of occupants, such as schools, hospitals, hotels or motels where many lives are at risk.

A1.3.2 Hong Kong

Hong Kong is subject to frequent landslides which are a major hazard to life as well as property. The government's Civil Engineering and Development Department commissioned work in the 1990's to develop proposals for risk criteria. The result[51] was proposals for individual risk criteria with numerical levels equal to those proposed by ANCOLD and AGS. These individual risk criteria and levels had already been adopted in Hong Kong for potentially hazardous installations (PHIs). The risk is to be calculated for the most vulnerable population – so if particularly vulnerable people (e.g. the very young or frail elderly people) are potentially at risk then the criteria for the general population may in practice be more restrictive.

A proposal for societal risk was adapted from that proposed for PHIs, which is an f/N curve with an upper limit of tolerable risk line from 10^{-3}/yr for a single fatality up to 10^{-6}/yr for 1000 fatalities[52]. For application to landslides it was recommended that this line be extended (in a straight line on a log-log plot) up to 5000 fatalities, and that any landslide with an f/N curve falling in the area beneath the threshold between 1000 and 5000 fatalities should be subject to intense scrutiny. It was strongly recommended that the societal risk criterion should not be mandatory and should be used as a guideline only.

In applying the criteria, the area to be considered is recommended to comprise a 500m length of natural terrain which presents risk to the community. Risk assessment for sites within the tolerable risk criteria should be tested against ALARP using cost-benefit analysis to balance cost of risk reduction measures against probable lives saved. A higher value of preventing a fatality is recommended where a site falls into the "intense scrutiny" zone of the f/N curve.

Extensive risk assessment studies on landslide sites in Hong Kong have been carried out to test the feasibility of the criteria[53] and annual reports are produced on landslides in Hong Kong which help to test and validate the risk assessment findings. Overall landslide risk in Hong Kong, expressed in probable lives lost per year (the top level risk metric used) was considered to have been reduced by over 80% from 1977 to 2010 (GEO195).

A1.3.3 Switzerland

Switzerland is subject to a wide range of natural hazards, with landslides, storms and avalanches among the most obvious. In 1993 the federal government established the national natural hazards platform PLANAT[54] to provide leadership and coordination of the national approach to reducing risk. PLANAT works as an extra-parliamentary commission of the Federal Department of the

[51] ERM Hong Kong Ltd, "Landslides and Boulder Falls from Natural Terrain: Interim Risk Guidelines", GEO Report 75, 1977
[52] https://www.epd.gov.hk/epd/english/environmentinhk/air/data/risk_mgt.html
[53] See for example CEDD reports GEO 195 and GEO 297, at https://www.cedd.gov.hk/eng/publications/geo/geo-reports/index.html
[54] http://www.planat.ch/en/planat/

Environment, Transport, Energy and Communications (DETEC), which has adopted PLANAT's proposed strategy[55] and risk guidelines[56]. This strategy steers a national programme involving expenditure of around 3 billion Swiss francs annually, of which roughly 60% is provided by insurance companies, households and companies and 40% by government.

The strategy advocates an integrated risk management approach, addressing risks to people, assets and the environment. Key elements involve

- Risk identification and periodic assessment for all hazardous processes
- A "Uniform approach" – meaning that consistent principles for risk protection are applied nationally, tailored locally taking into account local boundary conditions and interests
- Identification and assessment of possible courses of action, including planning, organisational, biological and technical measures, to be combined in an integrated framework for optimising their effects, benefits, costs and reasonableness.
- Maintenance of the measures put in place and periodic review of their effectiveness,
- Consideration of uncertainties, and
- Weighing of interests and setting priorities, recognising that what is optimal for one group or locale may not be optimal overall.

The primary life risk criterion adopted is that the risk of death should not be significantly increased by natural hazards. In particular, the annual risk of being killed as a result of natural hazards should be significantly lower than the average probability of death for the age group with the lowest mortality rate in Switzerland. This linking to the lowest risk group in the population is significant; the development of individual risk criteria in the UK and the Netherlands discussed above (2.1.1) was based on population average risk of accidents, rather than generally mortality risk to a specific group. As can be seen in Section 5 of the companion "Risk Comparisons" report, different groups of the population face very different levels of risk. In Switzerland, as in New Zealand, young children are the lowest risk level groups in the population, with annual mortality rates (whether considered across all causes or just for accidental causes of death) typically a factor of 10 or more below the population average. Societal risk featured in an earlier version of the PLANAT strategy and guidance[57] but does not feature in the more recent documents.

I was keen to understand more about how these criteria were applied, and was advised by the Federal Office for the Environment[58] that

a) The individual fatality risk value not to be exceeded has been agreed to be 10^{-5}/yr
b) This is applied to the most at risk individuals from particular hazards, who are typically either people in their homes, or regular travellers over at-risk road or rail routes

[55] PLANAT, "Management of risks from natural hazards: Strategy 2018", Bern, 2018
[56] PLANAT: Security Level for Natural Hazards. PLANAT 2014, Bern. 15 p.
[57] PLANAT, "Protection against Natural Hazards: Vision and Strategy, Bern 2004
[58] Personal communication, Reto Baumann, October 2019

c) Individual risk is used as a "trigger" for action being required, while collective risk is then used in assessing possible solutions and choosing the preferred option

d) No collective risk targets are set, in view of the difficulty scaling these to the population or assets at risk, though this could in principle be done by adopting targets per unit of at-risk population or asset.

Tools for estimating natural hazard risk, and thus evaluation of risk across all hazards and development of risk overviews for the whole country, are still under development and will take many years to complete. Given the high-level commitment to delivering on an integrated risk management approach to natural hazards, Switzerland will in my view be a particularly interesting country to follow for New Zealand generally. From DOC's perspective they are perhaps slightly less interesting as the focus is very much on residents who are most-exposed to risk, rather than visitors whose exposure is inherently more limited.

A1.3.4 New Zealand

There have not to my knowledge been any specific national risk targets set in relation to natural hazards, though some risk levels are implicit in building codes. However, there is an emerging body of decisions that have been taken based on or informed by quantitative risk assessments of such hazards. An overview of results is provided in Section 2.2 of the main report in Table 1 and Figures 3 and 4.

In relation to people in their homes, the most definitive example of firm government action to address intolerable risk is perhaps the decision in the wake of the 2010-11 Canterbury earthquake swarm to offer to buy homes in the Port Hills where the annual individual fatality risk (AIFR) was assessed to be in excess of 10^{-4}/yr. Generally speaking

a) any situations involving AIFR to residents in excess of 10^{-5}/yr have been the subject of reasonably prompt action to reduce risk, and

b) there are some situations where significant numbers of people face AIFR in the range 10^{-6} to 10^{-5}/yr which are subject to ongoing or planned risk reduction.

The population average AIFR from natural hazards is well in excess of 10^{-6}/yr in New Zealand, and many people live with risk levels around 10^{-5}/yr or higher. The attractions of living in New Zealand come with inherent natural hazard risk that can be reduced but not eliminated altogether.

As regards visitors to holiday sites, national parks and popular outdoor recreational areas, risk is generally measured in fatality risk per day's visit or activity. Responses have generally been fairly consistently graded in relation to the assessed risk, with

- Individual risk levels > 10^{-5}/day subject to prompt, active risk reduction and/or strengthened visitor information about risk.
- Significant risk reduction planned or in progress where risk levels are >10^{-6}/day, and
- Some situations where action has been taken in response to risk levels in the range 10^{-7} to 10^{-6}/day.

Appendix 2: Case Studies - Overseas National Parks

I am very grateful to the Lake District National Park (the UK's largest national park), to the Parks & Wildlife Service Tasmania and Parks Canada for sharing their experience and approaches to visitor risk management in the course of this research. These are described in turn (Sections A2.1 to A2.3).

A2.1 The Lake District National Park (UK)

Respondent: Richard Leafe, CEO, Lake District National Park Authority (LDNPA)

A2.1.1 Background

The Lake District is the largest and longest established of the UK National Parks, which have some important differences from NZ PCL, in particular

a) They do not own most of the land making up the parks (LDNPA owns just 4%), which prevents them acting as decision maker on many of the sorts of issues of interest to DOC (when to close a route or upgrade an asset, for example)
b) There is no central National Parks body – each park is independent of the others though senior staff meet regularly to discuss common issues and good practice.

The LDNPA employs around 200 staff whose main roles are to develop and maintain access to land and water, to provide information and other services for visitors, and actively to manage planning applications and decisions across the park. Like DOC, the park staff coordinate a much larger network of volunteers who assist in these various roles.

Around 19 million people visit the park annually, and call-outs for Mountain Rescue services have increased from under 100 per year in the 1960's to over 500 per year today. Deaths occur regularly, some from existing medical conditions, but several from visitors lacking the equipment, route knowledge or weather knowledge to keep themselves safe.

A2.1.2 Policy & Practice in relation to Visitor Safety

The broad policy, as in other UK and NZ parks, is to allow visitors to make their own decisions on what to do and where to go (so long as it is not putting others at risk), and to provide information to help them with these decisions.

On the lakes themselves, strict regulations are in place to control access and limit speeds. LDNPA employs wardens who enforce these regulations. The logic here is that it is not acceptable to allow people to behave so as to put others at risk. Wardens will occasionally intervene to prevent swimmers getting themselves into difficult or hazardous situations but by and large people swim at their own risk.

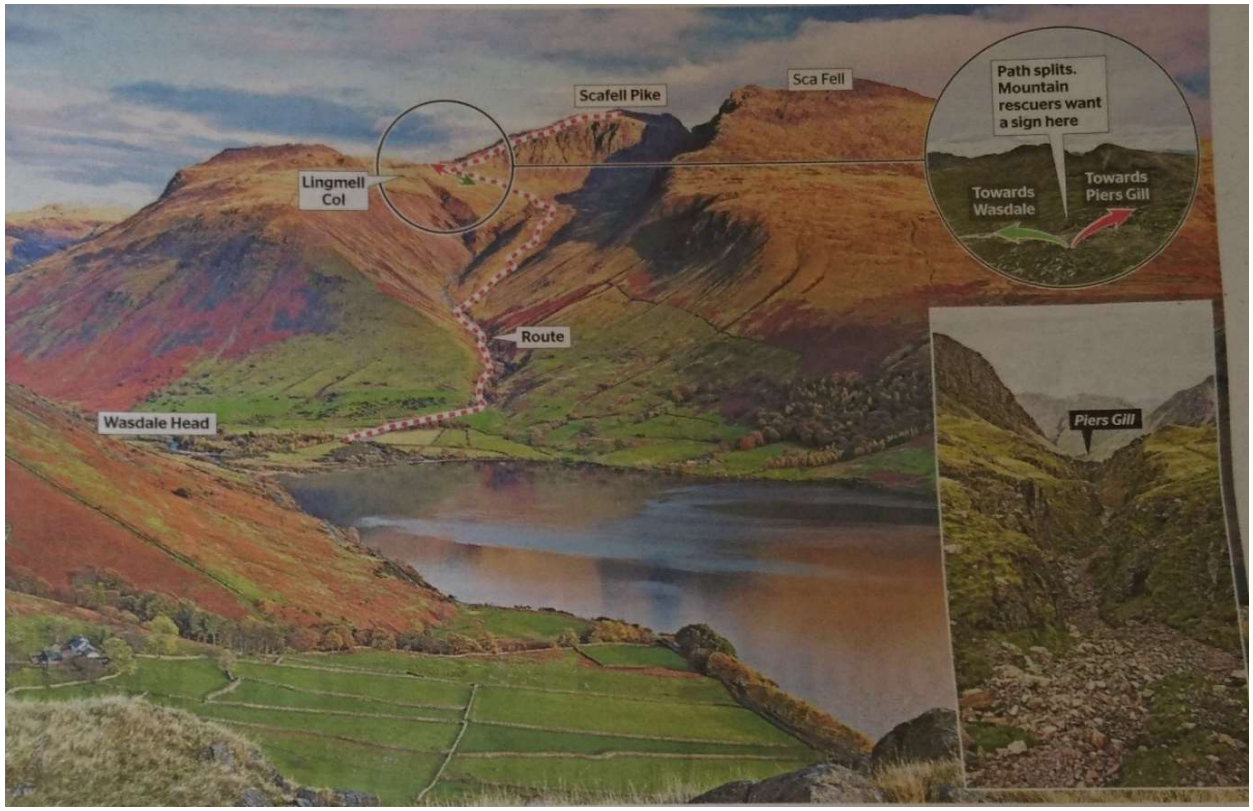
On the hills the situation is somewhat different. The issue of signage on footpaths is highly topical, with some stakeholders (e.g. the Mountain Rescue teams) inclined towards greater signage to reduce visitor risk, while others (e.g. the Wainwright Society and other

conservationists keen to preserve the wild character of the high fells) disinclined to accept any form of signage. There was a long-standing tradition in the Lake District of walkers building stone cairns to mark paths; these are now regularly taken down and scattered. Any proposals for additional signage or works to facilitate safer access on difficult routes are sure to attract strong opposition.

A2.1.3 Case Study – Piers Gill/Lingmell Coll

Piers Gill is a steep gully running down from Lingmell Coll, on the approach to England's highest mountain, Scafell Pike. The popular descent from Scafell Pike into Wasdale requires walkers to turn left on the Coll before reaching Piers Gill, which leads down a straightforward path into the valley. If they miss the left turn, though, they head towards the steep and stony Piers Gill which has been the subject of over 50 call-outs for Mountain Rescue teams since 2003 and claimed three lives in 2017-18. The situation is illustrated in Figure 1 (taken from The Times, 6 March 2019, which ran a prominent feature plus editorial on this issue).

Figure A2.1: Scafell Pike, Lingmell Coll and Piers Gill



The Mountain Rescue team has proposed placing a sign at the critical junction of the paths, which are maintained by the LDNPA. But the LDNPA and the landowner (the National Trust) are acutely aware of the strong preference of conservationists to avoid signage on the high fells of the Lake District. In an earlier case on the same mountain, signs erected to warn walkers and climbers of a particularly precarious boulder presenting a clear hazard to people scrambling up a narrow gully (Lord's Rake) were removed on multiple occasions by conservationists. In the

Piers Gill case it appears that a compromise may be reached whereby the junction is marked on a suitably engraved stone on the ground, but no post is erected.

A2.1.4 Provision of Public Information

Signage is just one example of the LDNPA's efforts to inform the public about risk. They operate a safety service to provide daily information about weather on the fell tops, and on the major mountain they own (Helvellyn) send an assessor to the summit every day and broadcast views around the mountain on social media. Visitor information centres provide more detailed local information on particular mountains and walking routes. But it is a constant challenge to get safety messages to visitors and persuade them to avoid putting themselves at risk via lack of appropriate equipment or expertise for their selected route.

A new initiative, Adventure Smart, has just been rolled out in the Lake District during May/June 2019. This initiative began in Wales and involves a partnership between numerous public and private bodies to provide safety information on a web site promoting (rather than with a flavour of attempting to inhibit) vigorous outdoor activity. The top level of the site hammers home the general requirements to have the correct gear, to know what the weather will do, and to have the right skills and experience for the day's activity. Current weather and tide information is provided at several locations within the area covered. As the user drills down into the area they want to visit, hazardous routes/sites are flagged up along with advice on how to visit them safely. The initiative has been very positively received in Wales though it is too early to be able to evaluate its success in terms of influencing public behaviour – a reduction in Mountain Rescue call-outs will be a key indicator of success.

A2.1.5 Accident, Incident and Usage Data

Information on accidents and incidents is collated by the Mountain Rescue teams dotted around the Lake District. These join forces to issue an annual publication summarising incidents attended during the year.

Information on parks usage is not centrally collated because of the range of different landowners involved. So the LDNPA might in principle collect information on numbers of walkers taking different routes up Helvellyn (which it owns) but not Scafell Pike (which it doesn't). Some effort will be required to work around the different landowners to collect relevant information, which may be of different provenance for different areas.

A2.1.6 Lake District - Summary

Like DOC, the LDNPA

a) starts from the policy of allowing visitors to make their own safety decisions, and
b) recognises their implied duty to provide visitors with relevant safety information.

The LDNPA actively enforces rules and behaviours where visitors could put others at risk (e.g. boating on lakes) but cannot generally either enforce the adoption of standards on land it does not own, or enforce standards of behaviour among hill walkers, climbers and others.

There are strong stakeholder groups who will resist initiatives by the LDNPA or anyone else to increase interventions to safeguard visitors in wild areas, but compromises can be achieved when there is good evidence of excessive risk.

What constitutes "excessive risk" is a matter of considerable debate and interest among the UK National Park authorities generally and the DOC project will be of great interest.

A2.1.7 Lake District - Further Information

Lake District National Park:	https://www.lakedistrict.gov.uk/
AdventureSmart UK:	http://www.adventuresmart.uk/
Lake District Mountain Rescue:	http://www.ldsamra.org.uk/

A2.2 Parks and Wildlife Service Tasmania

Respondent: Mark Bryce, Director Landscape Programmes, Parks & Wildlife Service Tasmania

2.2.2.1 Parks & Wildlife Service Tasmania Background

The Parks & Wildlife Service Tasmania (PWS) manages 19 national parks and over 800 reserves around Tasmania. There are several similarities with New Zealand's situation in terms of climate and landscape diversity, though on a smaller scale in terms of visitor numbers and with a lower level of geological activity. The most popular parks (Cradle Mountain and Freycinet) have around 300,000 visitors annually, and Cradle Mountain suffers a fatality roughly every 2-3 years. Visitor numbers have been steadily increasing over the past 20 years and a growing proportion of visitors (now approximately 16%) are from overseas; many visitors do not speak fluent English or understand local climatic conditions and other hazards. An issue shared with DOC is the proximity of many high hazard areas to accessible sites with large numbers of visitors with a low appetite for and capability to manage risk. One area of difference is that there is a charge to enter any National Park in Tasmania, so that PWS has greater control over access to the Parks (and better records of visitor numbers) than does DOC.

There is a well-established visitor safety policy in place, under which parks and specific areas within them are zoned according to the numbers and types of visitors. Hazards are identified based on monitoring of visitor incidents, reported visitor or staff concerns and the judgment of local staff. A scheme adapted from that of the National Safety Council of Australia (NSCA) is used to assess risk at locations, compare risk with targets set for different visitor zones, and evaluate options for countermeasures as appropriate. This provides a consistent framework within which to assess sites and prioritise resources devoted to visitor safety. While the NSCA-based scheme does not directly address many of the DOC issues to do with geological and other relatively infrequent natural hazard events it is of particular interest in that it does provide a risk-related way to assess sites and compare with criteria. Two examples of its use and a discussion of its features are provided in this note.

2.2.2.2 Policy & Practice in relation to Visitor Safety

Policy is laid out in the Visitor Risk Management Policy[59] and can be summarised as follows:

> *"The primary mission of the Parks and Wildlife Service (PWS) is to conserve the natural and cultural heritage of the parks and reserves under its management, while also providing recreational opportunities for visitors.*
>
> *As managers and controllers of land, the PWS owes a duty of care to visitors; definition of the degree or scope of that duty is most important. The scope of the duty is* ***to take reasonable care to avoid foreseeable risks of injury to visitors****. This responsibility is made more complex by the fact that the goal of many visitors is to challenge themselves. It is important that in controlling risk that PWS does not take away visitors' sense of freedom and adventure or unnecessarily restrict access. Therefore the management of visitor risk is a partnership between the PWS and visitors."*

[59] Parks and Wildlife Services Tasmania, "Visitor Risk Management Policy", PWS P- 002, June 2008

PWS has a well established, structured approach to evaluation of its visitor sites, involving

- Identification of hazardous areas to be assessed
- Classification of areas in terms of visitor type and acceptable risk score
- Assessment using the NSCA tool.

The approach in each area has points which I think are of interest and relevance to DOC.

Hazard Identification: In addition to issues and incidents flagged up by visitors and its own staff, PWS receives advice from Ambulance Tasmania of all cases in which a person is removed to hospital from a National Park. A location or facility may be flagged up for assessment either

a) Because the rate of incidents of itself is large, or
b) Because the rate of incidents per visitor is high (because access is controlled and charged for, visitor numbers can be estimated with reasonable confidence).

This approach flags up issues of both high aggregate risk for visitors collectively (a) and high individual risk (b).

Zoning and Target Setting: The Recreational Opportunities Spectrum, which is widely used in the USA, Canada and elsewhere in Australia, is used to classify areas into 4 management zones corresponding to 5 broad user types as shown in Table 2.

Table A2.1: Parks & Wildlife Tasmania User Types & Management Zones

User Type	Management Zone
Day Use – Comfort	Visitor Services
Easy-Access Camping	Recreation
Day-Use Get Away	Natural
Bushcamping Get-Away	Protection
Bushcamping Backcountry	

Definition of the appropriate management zone for a given location uses a multi-dimensional framework taking into account managerial, physical and social aspects of the site. The current framework is shown in Figure 2.

The management zone/user type determines a target acceptable risk level which is compared with a risk score calculated using the NSCA-based assessment method to determine the risk acceptability/priority for action at a site. Alongside this, typical expectations are established in terms of hazard warnings and signage, hazard management and frequency of hazard inspections. The scheme is shown in Table 3.

Figure A2.2: DRAFT PWS Recreational Standards Framework – Recreational Settings Spectrum

		Management Zone:	Visitor Services		Recreation		Natural		Protection
		Recreation Zone:	Visitor Services		Recreation		Self - Reliant Recreation		Wilderness
	Recreation Standards Framework Category	**Day Use - Comfort**	**Visitor Centre**	**Complex**	**Mid**				
		Easy-Access Camping		**Complex**	**Mid**	**Basic**			
		Day-Use Get Away			**Mid**	**Basic**			
		Bushcamping Get-Away			**Mid**	**Basic**	**Remote**		
		Bushcamping Backcountry						**Remote**	Primitive
Recreational Setting Attributes	**Managerial**	**Access Difficulty**	Very Easy - Motorised - vehicle, aircraft and vessel	Moderate - Very Easy Motorised - vehicle, aircraft and vessel	Moderate Motorised - vehicle, vessel and aircraft?	Moderate - Difficult Motorised - vehicle and vessel	Difficult Non-motorised		Very Difficult Non-motorised
		Roads P-066 Road Classifcation System	Class A & B 2WD Sealed & Unsealed	Class A-C1 2WD Sealed and Unsealed	Class C1-C2 Unsealed 2WD - 4WD	Class C2 - D Unsealed 4WD	No		No
		Walking Tracks P-036 Walking Track Classification System	Class 1 W1 - W2	Class 2 W2-T1	Class 3 T1-T2	Class 4 T2-T3	Class 5 T3-T4	Class 6 T4-R	R
		Modifications	Obvious, extensive modifications		Some modifications	Limited modifications	Not noticeable	No modifications	
		Facilities	Many comfort conveniences/facilities		Some comfort conveniences/facilities		Limited - safety and site protection only		No facilities
		Control of use	Many on-site control facilities		Some on-site control facilities		Limited on-site control facilities	No on-site all off-site.	
		Maintenance	Regular, frequent - staff presence obvious			Occasional maintenance - not noticeable			Nil
	Physical	**Naturalness**	Highly modified natural environment		Primarily natural environment		High degree of naturalness		Very High
		Impact	Obvious impact sometimes extensive		Moderate level of impact - noticeable		Local limited impact - noticeable		No sign of human impact
		Space	Limited natural areas						Largely 6km from motorised access points or at least half-day travel on foot.
	Social	**Level of use Social Interaction / Encounters**	High (Frequent) > 50 groups per day	50 groups per day	Regular 40 groups per day	10 groups per day	Low (Infrequent) 5 groups per day	<1 group per day	Non-existent or rare
		Type	Large groups, formal gatherings		Medium - small groups max 13		Small groups - 2-4		
		Level of outdoor recreation experience	Novice	Some Experience	Some Experience		Experienced	Very Experienced	Very Experienced
		Acceptable Risk Level P-002 Visitor Risk Management Policy	Neutral	Neutral - Moderate	Moderate	Moderate - Substantial	Substantial - Severe	Severe	Severe

Table A2.2: PWS Risks and Management Expectations

Typical Management Zones	Visitor Services	Recreational	Natural		
Recreational Experience	Rural/Urban in natural setting.	Natural environment, motorised access.		Self Reliant Recreation	Wilderness
RSF Category[5]	Day Use Comfort	Easy Access Camping	Day Use Getaway	Bushcamping Backcountry	Bushcamping Remote
Recreational Risk Level	Low		Moderate		High
Acceptable Risk Level (ARL)	Neutral <10 NSCA		Moderate <30 NSCA	Substantial <100 NSCA	Severe ≥100 NSCA
User skills and experience	No skills or experience expected.				High level skills and experience required.
Hazard Warnings/Signs	Not required unless hazards are not manageable within ARL or not obvious	Not required unless hazards are not manageable within ARL or not obvious	Not required unless hazards are not manageable within ARL or not obvious	Generally hazard signage only provided at strategic access sites. On-site only if hazards are above ARL or not obvious.	Generally hazard signage may be provided at strategic access sites On-site hazard signage is not required.
Management of hazards	Areas managed to ensure safe environment for visitors.	Areas managed to provide recreational use but degree to which areas can be modified will be dependent on the need to protect significant natural and cultural values	Areas managed to provide recreational use but degree to which areas can be modified will be dependent on the need to protect natural and cultural values	Generally areas managed to protect natural and cultural values. Areas are not modified to control hazards.	
General Hazard Inspection Frequency	6 months. Specific facilities will require regular inspection according to Standards/Legislation	6 months. Specific facilities will require regular inspection according to Standards/Legislation	6 months. Specific facilities will require regular inspection according to Standards/Legislation	12 Months	Not required

(reproduced from PWS' Visitor Risk Management Policy, PWS P- 002, June 2008)

Of particular interest for DOC, I note that

b) the risk target is set in terms of the ratio of a calculated risk score to an "acceptable" score, neither of which is a specific risk parameter/level, and

c) broad expectations for hazard management are laid out in parallel with target risk scores.

Risk Scoring: The NSCA-based method calculates a risk score as the product of three factors:

- Consequence
- Exposure, and
- Probability

These are assessed and scored as follows:

Consequence (the severity of harm most likely to occur) is assigned values as follows

1000	Catastrophe	Numerous fatalities / Damage > $5m / Major disruption to activities
400	Disaster	Multiple fatalities / Damage $1m to $5m.
150	Very Serious	Fatality / Property Damage $1/2m. to $1m.
60	Serious	Serious Injury (amputation, perm disability) / Damage $5,000 to $1/2m.
25	Important	Casualty Treatment (disabling injury) / Damage to $5,000
10	Noticeable	First Aid treatment (minor cuts, bruises) / Minor Damage

Exposure (the frequency with which the initiating breakdown event occurs) is given values of

5	Very rare	No occurrence yet recorded / only momentary event
10	Rare	Occurs once in 10 yrs / happens for a brief period
15	Infrequent	Occurs monthly to yearly / happens for 1/100 of time
30	Occasional	Occurs weekly to monthly / happens for 1/20 of time
50	Frequent	Occurs daily / happens for 1/10 of time
100	Continuous	Occurs many times daily / happens most of the time

Probability (likelihood of the selected consequence, given the breakdown event) has values of

100	Almost certain	Most likely and expected result / <1:10 chance
50	Quite possible	Quite possible, not unusual / 1:10 to 1:100 chance
25	Unusual but possible	Unusual but possible event / 1:100 to 1:1000 chance
10	Remotely possible	Remotely possible coincidence / 1:1000 to 1:10,000
5	Conceivable	Has not happened after many years / 1:10,000to 1:100,000
2	Practically impossible	Has not yet happened anywhere / >1:100,000 chance

The risk acceptability score or priority rating is then calculated as

$$\frac{\text{(Consequence score x Exposure Score x Probability score)}}{\text{Visitor Safety Rating V (=100x risk level as in Fig A2.2)}}$$

A priority rating >10 requires attention, below 10 is considered tolerable

There are several interesting features of this approach, in particular

a) The consequence scale combines injury, fatality and multiple fatality consequences into a single metric rather than attempting to calculate a specific risk parameter, and

b) The exposure and frequency scales compress a very wide range of outcome frequencies into a narrower range of risk scores.

While these issues might limit the application of this specific approach for DOC, the great advantage of this approach is that it is quick and simple to apply, and wraps up a lot of different risk issues (e.g. different levels of injury, individual vs larger groups at risk) into a single score. The approach is illustrated in the two examples below.

A2.2.3 Example 1 – St Patrick's Head Walking Track

This track exposes visitors to the risk of falling from cliffs, with the particular concern being an inexperienced visitor present in wet or icy conditions slipping and falling. This was assessed prior to mitigation as shown in Table A2.3.

Table A2.3: Assessment of St Patrick's Head Track

Parameter	**Assessment for this site**	**Score**
Consequence (C)	Very serious (single fatality is the worst outcome)	150
Exposure (E)	Frequent (some sort of significant slip or trip likely to be a daily event based on visitor numbers)	50
Probability (P)	Unusual but possible (0.1% to 1% chance of slip proving fatal)	25
Visitor safety rating (V)	'Substantial' based on clear hazards present and need for significant activity by visitor to reach the hazard	10,000
Priority Rating	= (C x E x P) / V	**19**

The online tool used to calculate this score then prompts the user to consider whether C, E and P in turn could be reduced. In this case C was not reducible, E would be reducible only by restricting access which was undesirable, whereas P could be reduced by fitting a handrail. This reduced the assessment of P to "Remotely Possible" with a score of 10 rather than 25, and reduced the priority rating to 8 which was deemed acceptable.

A2.2.4 Example 2 – Bruny Island Lighthouse

This is another example of a cliff-top setting where visitor numbers are high (10-100,000/year) and the lighthouse is relatively easily accessed from the car park. Although there is no official cliff-top track there is something of an "unofficial" path towards the cliff edge. Warning signage is in place. The ratings assessed here before controls were

- C = 150 (very serious – a single fatality is the outcome of concern as in example 1)
- E = 15 (a slip near the cliff edge considered likely on a monthly-yearly basis)
- P = 5 (conceivable but very unlikely), or possibly 10 (remotely possible)
- V = 3000 (lower than the previous example because of the easier accessibility and higher visitor numbers)
- Priority Rating = CxExP/V = 4 (or possibly 8 using the higher value of P).

Since the priority rating was below 10, this was not an immediate priority. However, the large numbers of visitors, uncertainty over P, and unease about the existence of an informal track to the cliff edge led to options for further risk control being considered. The best option identified was to replace the informal track with a proper track leading to a safe viewing area. This option was costed so that it could then be considered alongside other "desirable but not essential" risk reduction options across PWS Tasmania.

A2.2.5 Influencing Visitor Behaviour

PWS Tasmania uses a wide range of visitor communication strategies that are familiar to DOC. Plentiful information about general backcountry hazards and about site-specific hazards is provided on the web site and in brochures and other media to assist in planning visits. Information and warning signage is used at sites, with increasing efforts to use visual indications of hazards to assist visitors who may not speak fluent English, and with the extent and vigour of warnings broadly scaled to the risk.

Tasmania has a number of well-established multi-day hiking tracks broadly analogous to those in New Zealand. The most challenging of these is the Overland Track, a 6 day hike from Cradle Mountain to Lake St Clair through rugged, mountainous terrain with the only entry/exit points at either end. A number of fatalities have occurred over the years, largely through exposure to freezing weather. Advice on requirements for the track has become more rigorous over the years, PWS Tasmania staff provide a detailed checklist of equipment required and question walkers if there are any doubts regarding hiker's preparation. Even with this level of proactivity the risk is still present – in the most recent near fatal incident the (overseas, non-English speaking) hiker had the required equipment but apparently did not know how to use it.

A2.2.6 Accident, Incident and Usage Data

Visitors to Tasmanian parks are required to purchase a pass and to display it on entry, providing PWS Tasmania with a good basic source of information on visitor numbers (though many people purchase passes providing access to all parks over a period of weeks or months, and access is not monitored at many parks outside the peak season, so visitor number information is necessarily somewhat approximate).

PWS Tasmania record all the accidents and incidents affecting visitors of which they are aware. There is high confidence that incidents requiring hospitalisation are reliably recorded, as the Tasmanian ambulance service routinely notify PWS Tasmania of any incident they attend in a park. Road and other accidents attended by the police are less reliably recorded, as in many cases the police are focused on the follow-up and prosecution of offenders rather than on providing PWS Tasmania with information on accident root cause to assist in prevention efforts.

A2.2.7 PWS Tasmania - Summary

PWS Tasmania deals with a range of conditions broadly similar to DOC's, and faces many of the same issues albeit on a somewhat smaller scale. It has better established means of measuring visitor numbers and recording and reporting visitor injury incidents than DOC by virtue of the greater control of access to parks. Broadly similar measures are used to assist visitors in planning a safe visit, and in understanding hazards when they get to site. Perhaps the most interesting

aspect for DOC is the risk scoring system used to assess risk tolerability at individual sites and determine priorities for action, though this would not be suitable as it stands for DOC's current purpose of deciding on tolerability levels in relation to more severe but infrequent natural hazard events.

A2.2.8 Further Information

PWS Tasmania: https://parks.tas.gov.au/

A2.3 Parks Canada

Respondents:
Alain Nantel (Manager, Visitor Services, Activities, Safety & Visitor Use Management)
Sebastien Marcoux (National Visitor Safety Advisor)

A2.3.1 Parks Canada Background

Parks Canada (PC) is responsible for 48 National Parks, 175 National Historic Sites, 4 Marine Conservation areas and an Urban park. The principal objectives of PC relate to conservation and providing access for visitors, with conservation the clear first priority.

PC operates under the Minister of Environment and Climate Change Canada, with 34 regional offices and a national (deliberately **not** "head") office which provides policy leadership and coordinates across the parks. PC has over 5000 staff and deals with approximately 25m person-visits per year of which about 16m are to the National Parks themselves.

A2.3.2 Policy & Practice in relation to Visitor Safety

PC is clear that visitors are responsible for their own safety, but recognises the important role it has to play in informing visitors about hazards (both general outdoors/back country hazards and site-specific ones). PC has overall responsibility for Ground search and rescue within the parks. Everywhere in Canada, the responsibility for maritime SAR and aeronautical SAR remains the responsibility of the Canadian Coast Guard and the Department of National Defence respectively. As in New Zealand this is carried out in cooperation with other agencies (including aerial S&R, coastguard, ambulance service and volunteer mountain rescue bodies), Parks Canada collaborates with national and international SAR partners to both meet its own responsibilities and assist others meeting theirs as part of an efficient National SAR Framework.

PC has a manager whose portfolio includes coordinating the visitor safety program across all the parks. A few parks have dedicated SAR response teams. While they may not be involved in every incident within the parks (e.g. road traffic accidents may sometimes be dealt with by police and/or ambulance services without PC even knowing about them), they are centrally involved in all incidents involving search and rescue and are very unlikely to be unaware of significant visitor accidents. The Manager and an Advisor for the Visitor Safety Program operate within the national office providing leadership and coordination on visitor safety – facilitating local offices and staff in providing clear and consistent messages to visitors is a core part of the role.

Core activities to promote visitor safety involve dissemination of advice via the central and local park web sites, and maintenance of signage, tracks, other visitor facilities and the parks generally. PC is "plugged in" to Adventure Smart via its links with mountain rescue and other S&R organisations.

Depending on the situation PC may be more or less interventionist in actively discouraging visitors from venturing beyond their capabilities. Temporary closures are used regularly in various contexts, and activities or facilities may from time to time be stopped altogether or relocated. Such decisions are generally based on PC general principles and on a pragmatic,

qualitative evaluation of risks rather than on quantitative risk assessment, though engineering assessment is used as appropriate. See the examples below for illustrations.

PC is outward-looking and well aware of practices in the USA, the UK and New Zealand (among others). One particular example of NZ good practice they would be interested to develop in Canada is DOC's trip planning app.

A2.3.3 Examples

a) Tailoring Intervention to Circumstances

The **West Coast Trail** is one of Canada's flagship walks along the coast of Vancouver Island. The 75km trail is demanding, involving over 100 ladders to be climbed and substantial sections wading through mud and rivers. Some 80-100 people are evacuated from it annually because of injury. This trail probably represents the peak of PC's intervention to deter inappropriate hikers and ensure those who set out are well prepared. The website carries very heavy warnings about the hazards to be encountered and the requirement for hikers to be well-prepared. Hikers may be offered voluntary pack checks to help trim weight and ensure the mandatory items are on board, must attend a mandatory 1-hour briefing before setting out, and access is controlled via a booking system similar to that used for the New Zealand Great Walks.

Tsunami risk is an issue on the West Coast Trail and in several other PC parks and camp sites. To date this has not been considered a reason for re-routing trails or closing camp sites, but at-risk locations are well provided with hazard warnings and instructions to move rapidly to high ground in the event of earth movement.

b) Temporary Closures

Avalanche risk is a key issue at many parks, and PC have an extensive programme of work to address it. The risk is constantly re-evaluated and localised avalanche bulletins are updated daily. PC works with regional and national partners to ensure consistency in rating and communication strategies (Avalanche Canada, the Canadian Avalanche Association, Kanaskis Country Rangers, etc). Some high profile backcountry areas adjacent to key transport corridors are closed for access during active management (avalanche control). Active Management is performed specifically for the transport corridors and not for recreation.

Beaches and other coastal areas are occasionally closed when known major weather systems are approaching. In this as in many other cases there is a close synergy between actions taken in the interests of visitor safety, and actions to ensure that visitors have an enjoyable experience. Visitor satisfaction is closely monitored and well-reported, so provides a valuable metric by which to gauge progress.

Wildlife (bears, cougars, wolves) can pose significant threats to visitors. In addition to the substantial advice provided on PC web sites, some areas (including trails or campsites) are closed at the time of maximum berry fruiting because of the known high risk of encounters with hungry animals.

The avalanche closure decision process is perhaps the best formalised, however the Human Wildlife Coexistence program also has guidelines to assist the decision making process surrounding controlling access to area. The decision making processes linked to storm and other environmental concerns are more localised; the other examples involve simpler consideration of the likely intersection of "substantial hazard" with "people highly likely to be present".

c) Stopping/Relocating Activities/Facilities

From time to time particular activities are brought under scrutiny as to whether they should be permitted in National Parks. **Base jumping** is a recent case in point; it has been banned within PC National Parks from 2016. Safety of participants was not a major factor in this decision (jumpers are very clearly highly aware of the risk they face and willing to accept it). Safety of rescue teams was a consideration, but the key arguments in support of the ban were

a) The incompatibility of base jumping with PC's core values, and
b) The absence of a Canadian governing body or sport association to define and disseminate good practice.

Another recent closure decision involved a campsite that suffered major damage in a **landslide**. Here as in several of the examples above visitor safety had some weight in the decision, but equally important was the high likelihood that the quality of visitors' experience would be compromised and that PC would face recurring problems if the site was reinstated at the same location.

On a more "everyday" note, PC has a well-developed process for dealing with potentially **dangerous trees**. Where the risk to visitors is considered too high, action is taken to reduce it, but that action is tailored to local circumstances. If the conservation value of the trees in question is high then trails or campsites may be re-routed or re-located; if the conservation value is lower then it may be appropriate to fell the trees in question.

As in the temporary closure examples above, none of these decisions rely on quantitative risk assessment. PC's other values and priorities were also important both in making the decision to reduce risk (in the first 2 cases) and in particular in selecting the risk reduction strategy to pursue (for the trees).

A2.3.4 Accident, Incident and Usage Data

Because access to National Parks is controlled and is subject to a fee, numbers of visits/visitors are well collected and recorded. Similarly, the reservation system for major trails such as the West Coast trail ensures that good records of numbers of users are available.

The presence and involvement of Visitor Safety staff in dealing with visitor incidents across the National Parks ensures that similarly good quality records are available of accidents and incidents involving visitors. A new incident recording and reporting system was introduced in 2017 and is used to generate detailed annual reports on incidents and injuries (though not specifically on fatalities). These reports are used to help prioritise areas to be addressed across the parks system.

Significant manual effort will be required to extract details of fatal incidents over a longer period than the last 2 years (which will be necessary to provide sufficient data for any sort of analysis). It is hoped that details of fatalities may be made available during the course of this project to enable the Canadian national parks to be compared with those in New Zealand in terms of fatality risk per visitor-day spent in parks.

A2.3.5 Summary

Parks Canada has at heart a similar philosophy to DOC on visitor safety – that the visitor is responsible, but that PC has an obligation to help them make informed decisions and manage their own risk.

Decisions about "how safe is safe enough" are not generally based on specific quantitative visitor risk information, but are generally more pragmatic and in many cases are made easier to resolve by reference to PC's other core values and priorities.

Parks Canada has much better access to data on visitor numbers, accidents and incidents than does DOC by virtue of (a) charging for and thus control of access to parks, and (b) the presence of dedicated visitor safety staff across the parks, providing near certainty of PC staff knowing of any significant accidents and incidents affecting visitors (with some exceptions e.g. for road accidents).

A2.3.6 Further Information

Parks Canada: https://www.pc.gc.ca/en/index

West Coast Trail: https://www.pc.gc.ca/en/pn-np/bc/pacificrim/activ/activ6a

Appendix 3: DOC Staff Risk - Worked Examples

These two examples illustrate quite different situations. In both cases the risk estimates should be treated as illustrative rather than definitive.

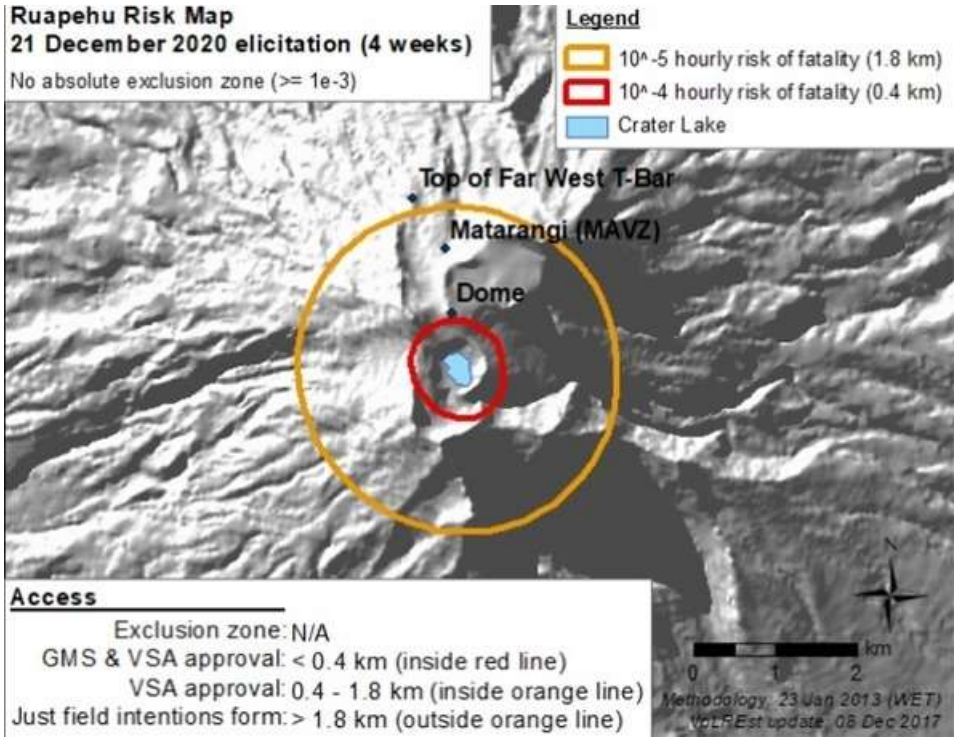
In the first, a DOC-maintained monitoring station is vital to the operation of the lahar warning system at the Ruapehu ski field, yet is situated in an area at significant risk from volcanic activity. Regular maintenance of the station is required for smooth operation, along with occasional unplanned visits in the event of the station failing. The key issue here is thus the planning of maintenance visits without placing staff at undue risk.

The second example relates to a rescue service operated by DOC in Aoraki National Park. In any rescue service situations are going to arise where staff place themselves at risk in the course of carrying out a rescue. In an extreme case a rescuer might legitimately accept a very high personal risk in return for a high chance of saving a life or lives. Even in the most extreme case though a degree of assessment is necessary to avoid the chance of success being outweighed by the nightmare outcome of the rescuer adding themselves to those requiring rescue. In situations that are reasonably foreseeable (as in this case) a more considered assessment could and should be made to help decide the most appropriate rescue response and approach.

Scenario 1: Ruapehu monitoring

DOC maintain a volcanic monitoring station at Matarangi which provides information vital to the successful operation of the lahar risk warning system at the nearby skifield. . The normal level of background risk of death from volcanic hazards at the station is about $7x10^{-7}$ per hour. At times of elevated volcanic activity the risk can be significantly higher – in December 2021 for example an assessment indicated a risk level of a little above 10^{-5} per hour as illustrated in Figure A3.1.

Figure A3.1 Matarangi Assessed Risk, December 2021



The station is not manned but regularly requires a visit of between 1 and 5 hours for maintenance, as well as occasional visits for unplanned maintenance to repair faultes. The question thus arises of whether/how a maintenance schedule can be devised without exposing staff to excessive risk.

At times of normal (quiet) volcanic activity the risk to staff can be assessed as follows:

(a) Per day of maintenance: Fatality risk = Hours spent in at risk area x $7x10^{-7}$
= $7x10^{-7}$ to $3.5x10^{-6}$

Taking the worst case this would push the daily fatality risk into the "High" guidance level. The activity would be permitted but would require senior level approval within DOC.

(b) Per year: Fatality risk = No. maintenance visits x ($7x10^{-7}$ to $3.5x10^{-6}$)

So if 4 maintenance visits were required, for example, the fatality risk would lie roughly in the range from $3x10^{-6}$ to $1.4x10^{-5}$. Taking the worst case, the risk would again lie in the "High" guidance level, so no higher approval would be required than for a single maintenance visit if planning up to 4 visits per year. The total natural hazard risk contributed would be a modest fraction of the current annual fatality risk to DOC staff from all sources

At times of higher volcanic activity the risk could be significantly greater. Taking the December 2021 example cited above, the risk per visit would be estimated to lie in the range 10^{-5} to $5x10^{-5}$ or even a little higher. This would take the daily risk into the "Extreme" guidance level, requiring approval from the highest level within DOC. Such approval would take into consideration

a) The need for and benefit of the maintenance visit. For example a routine scheduled maintenance visit (while the station was perfectly operational) would almost certainly be deferred until the volcanic activity level had dropped. If the station were not operational the benefit of restoring operation (most notably by restoring the lahar warning system to the ski area) would have to be weighed against the risk to staff.

b) Optimisation of the visit, in terms of achieving the required functionality of the station in minimum time, getting to and from it as safely as possible, and enabling the staff involved to minimise their risk exposure throughout.

c) What other natural hazard risk exposure the staff had in the course of their duties

Scenario 2 Rescue from a moraine wall at Aoraki

DOC run an alpine rescue team at Aoraki-Mount Cook. On occasions the team carry out rescues using a system called Human External Cargo Load (i.e. involving someone attached to a rope under a helicopter) for rescuing people stuck on moraine walls. A typical situation might involve walkers on Tasman Moraine who are off route walking back from Ball Shelter. The terrain is illustrated in Figure A3.2

Figure A3.2 (a) Moraine Wall by Tasman Lake, and (b) Looking down the moraine (~300m)

Staff involved in such a rescue face several hazards, including

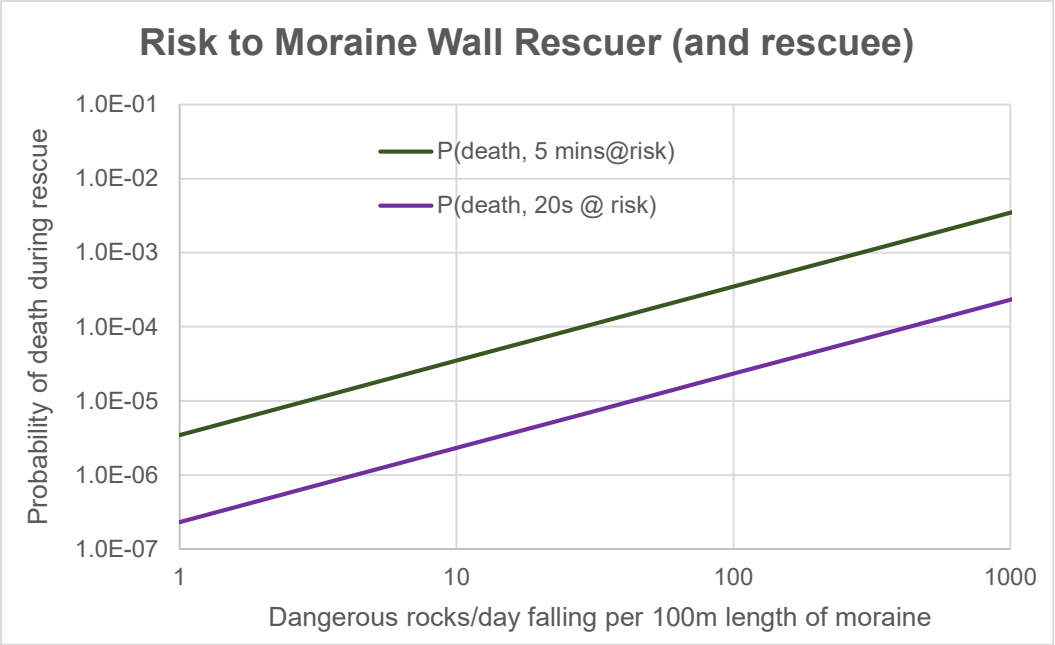
a) Helicopter accidents flying to and from the site from the SAR base (approx. 12 minutes)
b) Helicopter or line accidents during Human External Cargo time below the helicopter (approx. 15 minutes), and
c) Risk from rockfalls while on the moraine (approx. 5 minutes to secure subjects).

The rescuers have a choice of spending time to secure and stabilise subjects prior to extraction (the 5 minute exposure) or doing a snatch and go which, while not ideal particularly if someone is injured, cuts rescuer exposure time down to 20 seconds or less.

The key natural hazard here is (c) above, that of being struck by rockfalls whilst on the moraine. This depends on how often rocks fall; a simple assessment showing the risk from spending either 5 minutes or 20 seconds in the at-risk area on the moraine wall is shown in Figure A3.3.

The rockfall risk is clearly potentially very significant. Towards the right hand side of the figure (which would correspond to a rescuer waiting for an hour to be rescued experiencing many dozens of rocks falling within 50m either side of their position) even the snatch and go option could involve individual fatality risk in excess of 10^{-4}. (Note that the risk to the person requiring rescue would be much higher – if waiting an hour or more their chance of being killed could reach or exceed 10%, or several 10's of %if they were immobile and unable to take evasive action from approaching rockfalls.)

Figure A3.3: Risk from Exposure to Rockfalls on Moraine Wall



Assumptions used to generate Figure A3.3:
Chance of being in the path of a single boulder falling randomly within 100m of wall = 0.01
Chance of death if in the path of a boulder = 0.1(this assumes the at-risk person is outdoors, able to detect approaching rocks and dodge them).

For relatively stable parts of the moraine wall (less than about 10 dangerous rocks falling per 100m length of wall per day) the risk to a rescuer spending 5 minutes on the moraine would fall into the "High" guideline area. Any higher rate of rockfalls would take it into the "Extreme" area. Even for much higher rockfall rates, though, the risk could be kept within the whole annual natural hazards risk "budget" for a DOC staff member (of $3x10^{-4}$) by limiting the rescue to a "snatch and go" operation. While this risk is very high it seems not unreasonable in a situation where a stranded person might be facing a risk of death of 10's of % per hour that a rescue service would accept risk at this scale, so long as the probability of a successful outcome was high.

Purely from a natural hazard point of view the "snatch and go" approach appears preferable in every case to the rescuer spending several minutes on the moraine securing the rescue.

However, even with the best equipment and best trained pilots and staff, the risk of travel by helicopter is significant – of the order of 10^{-5} risk of death per trip or higher. Carrying loads below helicopters ("aerial work" generally), and operating around awkward terrain are well-recognised additional risk factors. Rushing the extraction of someone from the moraine might well thus involve adding a significant element of risk to the Human External Cargo phase of the operation.

The rescue approach thus needs to strike a balance between minimising time at risk on the moraine, and maximising the chance of success of the whole operation. For example if the party awaiting rescue had not seen or heard any significant rockfall while awaiting rescue, and the

rescue party had not seen any rockfall in several minutes flying along the 1km length of the moraine wall next to Tasman Lake, it might reasonably be assumed that the rockfall rate was towards the left hand rather than the right hand side of Figure A3.3. In such circumstances it might be considered preferably to take a few minutes at risk on the moraine to ensure the party being rescued was safely and securely attached to the helicopter in order to avoid additional risk following a "snatch and go" rescue.

This example illustrates both (a) the need for flexibility in dealing with rescue situations, where special guidance and training are provided for dealing with the foreseeable eventuality of very high personal risk situations, and (b) the need to think more widely than just the natural hazard context when considering the risks to staff and others, and the best way to address them.