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high / difficult access

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Report on:

Mauao Slopes Earthquake Damage & Revised Risk Assessment

Client: Tauranga District Council

July 2004

Avalon Report No: 0453

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1 INTRODUCTION

Avalon specialises in offering Geotechnical Engineering consultancy and contracting services in difficult and high access environments.

Avalon has carried out engineering geological investigation and rockfall hazard/risk assessments on Mauao, on behalf of Tauranga District Council (TDC), since February 2003.

In July 2003 [3] Avalon presented a Rockfall Hazard report to TDC.

In November 2003 a drill and blast operation was carried out to scale a major and unacceptable rockfall hazard identified on the bluff above the campground.

In July 2004 [3] Avalon presented a quantitative Rockfall Risk report to TDC.

The Bay of Plenty experienced a swarm of over 100 earthquakes between 18 and 22 of July 2004.

On 20 July [redacted], contacted [redacted] with Avalon and requested Avalon visit site to investigate earthquake damage and stability problems.

[redacted] of Avalon spent the day of the 22 July 2004 inspecting the tracks and slopes.

This report presents the findings of the 22 July 2004 inspection and is intended to be read in conjunction with Avalon's July 2003 Rockfall Hazard Assessment report [1] and July 2004 Draft Risk Assessment Report [2].

1 Avalon Industrial Services Ltd. Mauao Rock Slopes & Rockfall Hazards. Report to TDC, 12 July 2003.

2 Avalon Industrial Services Ltd. Mauao Rockfall Hazards; Risk Assessment & Management. Draft Report to TDC, 26 June 2004.

2 THE EARTHQUAKES

The earthquake swarm incorporated over 100 earthquakes between 18 and 22 of July 2004.

The most significant eighteen individual events had intensities between magnitude 3.0 and 5.4 and originated at around 5km depth 20km north-west of Kawerau.

In addition to the shallow earthquakes; on 20 July there was a magnitude 4.8 event centred 40km north of Taupo at around 170km depth which was also felt in Tauranga.

Six earthquakes were generally perceived in Tauranga. Anecdotal reporting suggests moderate to strong ground shaking, MM (Modified Mercalli) intensity V to VI.

The recorded local instrument intensity is unknown but there appears to have been only very light structural damage reported and on this basis we could assume the maximum local MM intensities may have been V to VI with peak ground accelerations being 0.05 to 0.15g.

The return period for a MM intensity VI event in Tauranga appears likely to be around 10 years (after Smith & Berryman 1992).

3 GROUNDWATER

The Bay of Plenty region received 250mm of rainfall in the few days immediately prior to the earthquakes.

Mauao's colluvial soils appear likely to have been near saturated. The 23 July inspection (5 days following the worst of the rainfall) noted surface seepage not seen on any previous inspections.

The saturated nature of the soils will certainly have resulted in the earthquakes triggering more soil failures than would have been the case if dry.

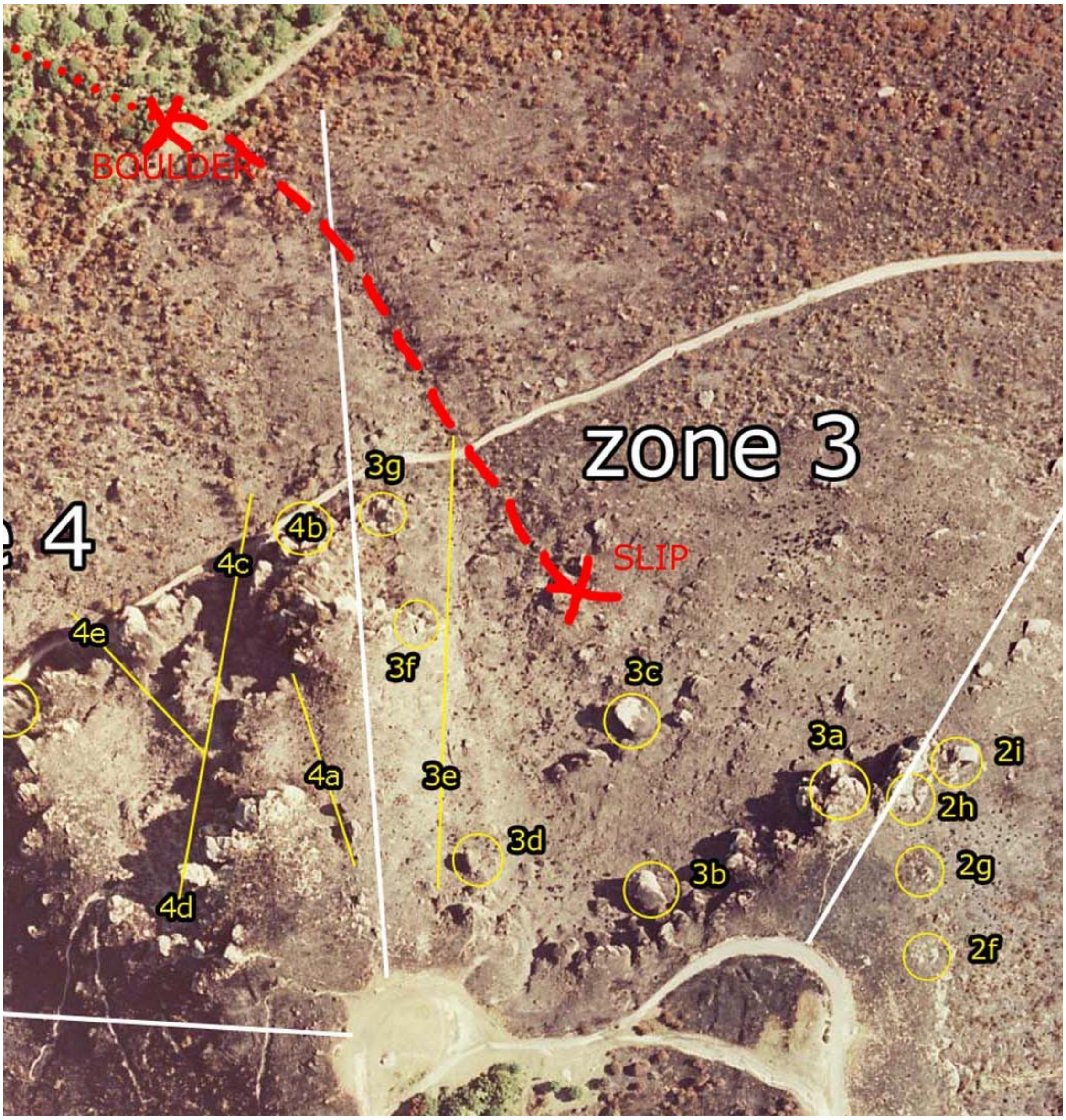
4 EFFECTS ON MAUAO'S SLOPES AND TRACKS

4.1 Shallow surface slips on colluvial slopes

Many small (typically under 1m² in area) very shallow (typically maybe 200mm) slip/rain scour scars are present on the slopes. Exactly how many of these are specifically attributable to the recent earthquakes is uncertain as rain scour has been relatively rapid on these slopes since the January 2003 fire.

A few larger slips in the colluvium were located which had clearly occurred in the preceding few days.

The most significant of these involved a few cubic meters of soil and rock and occurred in the colluvium on the slopes above the northern Oruahine track (zone 3), approximately mid way between column 3c and the intersection of gully 3e and the track. See the following photographs.



Photograph 1. Slip location and rockfall trajectory.

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This slip released one boulder of around $0.6m^3$, a few around $0.3m^3$ and a few around $0.15m^3$, in addition to a quantity of soil and smaller rocks. This created a significant hazard.

Photograph 2. Slip source.

Photograph 3. Track impact damage

Photograph 4. The main boulder.

All but one (a $0.3m^3$) of the rocks crossed the Oruahine track (causing impact damage to the track).

The $0.6m^3$ boulder came to rest just above the bushline having travelled around 85m vertically and 135m horizontally.

One 0.3m³ rock appears to have penetrated the bushline and possibly was the initiator of a secondary soil slip in the slope approximately 10m above the Base track. The secondary slipped material (including the initiating rock) came to rest on the Base track.

4.2 Movements on the rock outcrops

Inspection of the outcrop rock columns and bluffs revealed a number of areas that appeared to have failed recently; however, clear evidence of impacts below was difficult to locate (recent scaling has also revealed 'fresh' looking rock).

One in-situ boulder was found to have moved into a far less stable position due to the earthquakes. See photograph 5.

This is a rock of approximately 0.075m³, a few metres down from the crest of the bluff in zone 2, between 2b and 2c and has obviously been shaken outwards to the point where it appears very near toppling (similarly unstable boulders are relatively common but this ones position is definitely attributable to the recent events).

Photograph 5. Rock outcrop movements.

4.3 Shallow surface slips from track cut slopes

The most obvious earthquake damage to track users has been the numerous small slips (mostly under 1m³ total volume) from the cut slopes immediately adjacent to the tracks.

At least fifteen individual small shallow circular overslips of 1m³ to 3m³ in volume were found. The slip material had failed from the colluvium exposed by the track cuts and debris now rests on the tracks. These track side slopes were over-steepened during track construction (to create a level track platform).

These slips generally pose little or no hazard to track users as they will be observed and persons could reasonably easily step out of the path of any active slip.

These slips have not been sufficiently large to spill material over the tracks and on down the slope.

The following photographs show typical examples.

Photograph 6, 7, 8 & 9. Typical track cut slips.

Photograph 10 & 11. More typical track cut slips.

4.4 Slips in track fill

At two localities tension cracks indicate potential underslips of up to 10 m^3 volume.

Photograph 12. ‘Dropout’ in north-western Oruahine track.

The photograph above shows a slip in the fill base on the north-western Oruahine track below the climbing crag.

The other dropout was located on the 4WD track just below the hairpin bend lookout (again in placed fill).

Both these underslips dropped no more than 100mm before locking up and do not appear to present an immediate hazard. Had they failed completely some of the material released could potentially have threatened tracks below.

5 COMPARISON WITH JUNE 2004 DRAFT RISK ASSESSMENT

Avalon's draft Risk Assessment report (section 6.4.2) makes the following comments regarding seismically induced rockfall frequency:

The 10% in 50 years earthquake ground acceleration on Mauao's upper slopes has been determined in section 6.3 at 0.7g. The quantity and size distribution of boulders likely to be released in such an earthquake are a matter of engineering judgment and is difficult to estimate with certainty.

0.7g is a severe event and violent ground shaking would result.

Considering a typical slope source area (steep bluff or colluvium) of, say, 20m wide x 10m high, what quantity of rock might fall in such an event?

As a first estimate it has seemed reasonable to imagine the release (from 200m²) of, say, one larger boulder, ten smaller boulders and one hundred 150mm rocks.

The sources area for rockfall (the steep upper slopes) were estimated earlier in this report as 13,500m².

Based on this the 10% in 50 years earthquake might release a minimum of:

- 67 larger (1m) boulders
- 670 smaller (300mm) boulders
- 6,700 (150mm) rocks.

The 10% in 50 years earthquake will have a return period of around 500 years therefore might contribute a mean:

- 0.1 larger (1m) boulders per year
- 1 smaller (300mm) boulders per year
- 10 (150mm) rocks per year

All boulder sizes quoted are side dimensions unless specifically stated as being m³.

As already noted; lower intensity, shorter return period earthquakes clearly also have potential to induce rockfall, particularly (considering topographical amplification) on the upper slopes of Mauao and in fact may contribute more risk than the less frequent larger events.

The actual risk presented by the more frequent lower intensity events was not pursued any further (in the draft report) due to the fact that; although they potentially contributed a significant level of risk, the rockfall estimates used were very much based on judgment and not expected to be any more accurate than, say, a factor of two.

The cumulative annual rockfall risk presented by the smaller events was certainly anticipated as being in the same order of magnitude as the 10% in 50 years event and in any case well within the factor of ten considered by the sensitivity analysis.

Now we have valuable direct evidence of the effects of one of the more frequent lower intensity events and it is considered very much worth comparing this event with the draft assessments assumptions and reassessing the risk in the light of this new data.

Slips in the cut slopes directly above the tracks are not considered a risk as it seems reasonable to assume track users would be aware of them and could move out of the impacted area relatively safely.

The recent earthquakes, a 10 year return period event, can be seen to have initiated failure of, as a minimum, approximately:

- One larger (0.6m) boulder,
- Six smaller (300mm) boulders
- ?? (150mm) rocks

Some additional rockfall will no doubt have occurred but will not have been positively detected on our site inspection.

To follow the method used in section 6 of the draft risk report it seems reasonable to simplify and assume:

- 0.67 1m boulders
- 6.7 300mm boulders
- 67 150mm rocks

The following MM return periods are quoted from Smith & Berryman (1992) for Tauranga:

MM Intensity	*Return period*	*Tauranga g*	*Mauao g*
VI	10 years	0.092 to 0.18g	0.3?
VII	42 years	0.18 to 0.34g	0.5?
VIII	180 years	0.34 to 0.65g	1?

Avalon's draft risk report was based on the most recent (2003 "Lifelines" study) data and assumed a 500 year return period for a Tauranga 0.35g (Mauao 0.7g) event. It was assumed that this would release sixty seven 1m boulders, 670 300mm boulders and 6,700 150mm rocks.

Looking at the shorter return period events also we might consider:

MM Intensity	*Return period*	*Mauao peak g*
VI	10 years	0.3
VII	100 years	0.5
VIII	500 years	0.7

With the following rockfalls being initiated:

MM	*Return Period*	*1m boulders*	*300mm boulders*	*150mm rocks*
VI	10 years	0.67	6.7	67
VII	100 years	6.7	67	670
VIII	500 years	67	670	6700

The risk calculations in section 8 of the draft risk report have been re-run taking into account this new empirical data on rockfall generated by lower intensity events.

6 REVISED SEISMIC ROCKFALL FREQUENCY

The total seismic risk has been revised as the cumulative risk from each of the three events.

	Quantity of rocks		
Return	*1m*	*300mm*	*150mm*
10 years	0.67	6.7	67
100 years	6.7	67	670
500 years	67	670	6700

	Annual component		
Return	*1m*	*300mm*	*150mm*
10 years	0.067	0.67	6.7
100 years	0.067	0.67	6.7
500 years	0.134	1.34	13.4
Total annual	*0.268*	*2.68*	*26.8*

Boulder dimension	*Draft report seismic*	*Revised estimate seismic*
1m boulders	0.13	0.26
300mm boulders	1.35	2.68
150mm rocks	13.5	26.8

It can be seen that, in the light of the new data, the total annual seismic rockfall being considered is now 2.7 times our previous estimate.

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7 REVISED TOTAL ROCKFALL FREQUENCY

The total rockfall is composed of the erosional and seismically (and for northern Oruahine track human) induced components.

The following are the previously used and revised totals (excluding human).

Boulder dimension	*Draft report total*	*Revised estimate total*
1m boulders	0.34	0.46
300mm boulders	3.35	4.68
150mm rocks	33.5	46.8
total	*37.2*	*51.9*

The total estimated rockfall (excluding human activity) has thus been increased 40% over the first estimate.

A significant risk upgrade but well within the initial calculations margin of uncertainty and not sufficient to change the overall conclusions of the risk assessment process.

The initial sensitivity analysis in section 8.5 of the draft risk report considered a maximum rockfall rate of 1000% of the first estimate.

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8 REVISED RISK ESTIMATION

The following table presents calculations based on the revised risk:

Mauao Rockfall Revised (26 July 2004) Risk Calculation		
NON EARTHQUAKE (Natural) ROCKFALL		
Assumed annual rockfall (all of Mauao); 1m boulders		0.2
Assumed annual rockfall; 300mm boulders		2
Assumed annual rockfall; 150mm rocks		20
Total annual rockfall		22.2
EARTHQUAKE ROCKFALL		
Annual average earthquake rockfall, all of Mauao, 1m boulders		0.26
Annual average earthquake rockfall, all of Mauao, 300mm boulders		2.68
Annual average earthquake rockfall, all of Mauao, 150mm rocks		26.8
Total average annual earthquake rockfall, all of Mauao		29.74
MAUAO TOTAL ANNUAL ROCKFALL (Excluding human activity)		
1m boulders		0.46
300mm boulders		4.68
150mm rocks		46.8
COMBINED TOTAL ROCKFALL FREQUENCY (Excluding human activity)		
Assumed rockfall frequency per m^2 source area; 1m boulders		0.000034
Assumed rockfall frequency per m^2 source area; 300mm boulders		0.000347
Assumed rockfall frequency per m^2 source area; 150mm rocks		0.003467
1. SOUTH EASTERN WAIKORERE TRACK		
Assumed rockfall frequency per m^2 source area; 1m boulders		0.000034
Assumed rockfall frequency per m^2 source area; 300mm boulders		0.000347
Assumed rockfall frequency per m^2 source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m^2)	m^2	2,000
Total annual rockfall from source area		7.69
Proportion of 1m boulders reaching the affected track section (%)	%	100%
Proportion of 300mm boulders reaching the affected track section (%)	%	100%
Proportion of 150mm boulders reaching the affected track section (%)	%	100%
Number of 1m boulders reaching the affected track section		0.07
Number of 300mm boulders reaching the affected track section		0.69
Number of 150mm boulders reaching the affected track section		6.93
Total annual rockfall reaching the affected track section		7.69
Length of affected track section (m)	m	200.00
Time to walk track (at 2km/hr) (minutes)	min	6

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Stopping time (minutes)	min	0
Total time on affected track section (minutes)	min	6
Total time on affected track section (years)	years	1.14E-05
Ratio person length (1m) to affected track section		5.00E-03
Probability of rock coinciding with one person traverse		4.39E-07
Vulnerability (to fatality)		0.10
Probability of fatality per person traverse		4.39E-08
Number of visitors to track section per year		50000
Probability of a fatality per year		2.20E-03
Return period of a fatality		455
2. NORTHERN WAIKORERE TRACK		
Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed rockfall frequency per m² source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m²)	m²	500
Total annual rockfall from source area		1.92
Proportion of 1m boulders reaching the affected track section (%)	%	100%
Proportion of 300mm boulders reaching the affected track section (%)	%	50%
Proportion of 150mm boulders reaching the affected track section (%)	%	10%
Number of 1m boulders reaching the affected track section		0.02
Number of 300mm boulders reaching the affected track section		0.02
Number of 150mm boulders reaching the affected track section		0.17
Total annual rockfall reaching the affected track section		0.21
Length of affected track section (m)	m	330.00
Time to walk track (at 2km/hr) (minutes)	min	10
Stopping time (minutes)	min	0
Total time on affected track section (minutes)	min	10
Total time on affected track section (years)	years	1.88E-05
Ratio person length (1m) to affected track section		3.03E-03
Probability of rock coinciding with one person traverse		1.19E-08
Vulnerability (to fatality)		0.10
Probability of fatality per person traverse		1.19E-09
Number of visitors to track section per year		50000
Probability of a fatality per year		5.93E-05
Return period of a fatality		16870
3. EASTERN ORUAHINE		
Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed rockfall frequency per m² source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m²)	m²	2,500
Total annual rockfall from source area		9.62
Proportion of 1m boulders reaching the affected track section (%)	%	90%
Proportion of 300mm boulders reaching the affected track section (%)	%	10%
Proportion of 150mm boulders reaching the affected track section (%)	%	0%
Number of 1m boulders reaching the affected track section		0.08

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Number of 300mm boulders reaching the affected track section		0.00
Number of 150mm boulders reaching the affected track section		0.00
Total annual rockfall reaching the affected track section		0.08
Length of affected track section (m)	m	645.00
Time to walk track (at 2km/hr) (minutes)	min	19
Stopping time (minutes)	min	0
Total time on affected track section (minutes)	min	19
Total time on affected track section (years)	years	3.68E-05
Ratio person length (1m) to affected track section		1.55E-03
Probability of rock coinciding with one person traverse		4.38E-09
Vulnerability (to fatality)		0.10
Probability of fatality per person traverse		4.38E-10
Number of visitors to track section per year		50000
Probability of a fatality per year		2.19E-05
Return period of a fatality		45704
4. NORTHERN ORUAHINE		
Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed rockfall frequency per m² source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m²)	m²	4,500
Total annual rockfall from source area		17.31
Proportion of 1m boulders reaching the affected track section (%)	%	100%
Proportion of 300mm boulders reaching the affected track section (%)	%	50%
Proportion of 150mm boulders reaching the affected track section (%)	%	10%
Number of 1m boulders reaching the affected track section		0.15
Number of 300mm boulders reaching the affected track section		0.16
Number of 150mm boulders reaching the affected track section		1.56
Total annual rockfall reaching the affected track section		1.87
Length of affected track section (m)	m	200.00
Time to walk track (at 2km/hr) (minutes)	min	6
Stopping time (minutes)	min	0
Total time on affected track section (minutes)	min	6
Total time on affected track section (years)	years	1.14E-05
Ratio person length (1m) to affected track section		5.00E-03
Probability of rock coinciding with one person traverse		1.07E-07
Vulnerability (to fatality)		0.10
Probability of fatality per person traverse		1.07E-08
Number of visitors to track section per year		50000
Probability of a fatality per year		5.33E-04
Return period of a fatality		1874
5. WESTERN ORUAHINE		
Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed natural rockfall frequency per m² source area; 150mm rocks		0.003467
Additional 150mm rockfall due to human activity		
Additional annual rockfall (in this zone); 150mm rocks		20
Source area of bluffs/cliffs/steep colluvium (m²)	m²	4,500

Additional rockfall frequency per m² source area; 150mm rocks		0.004444
Total 150mm rockfall frequency		0.007911
Total annual rockfall from source area		37.31
Proportion of 1m boulders reaching the affected track section (%)	%	100%
Proportion of 300mm boulders reaching the affected track section (%)	%	100%
Proportion of 150mm boulders reaching the affected track section (%)	%	100%
Number of 1m boulders reaching the affected track section		0.15
Number of 300mm boulders reaching the affected track section		1.56
Number of 150mm boulders reaching the affected track section		35.60
Total annual rockfall reaching the affected track section		37.31
Length of affected track section (m)	m	150.00
Time to walk track (at 2km/hr) (minutes)	min	5
Stopping time (minutes)	min	0
Total time on affected track section (minutes)	min	5
Total time on affected track section (years)	years	8.56E-06
Ratio person length (1m) to affected track section		6.67E-03
Probability of rock coinciding with one person traverse		2.13E-06
Vulnerability (to fatality)		0.10
Probability of fatality per person traverse		2.13E-07
Number of visitors to track section per year		50000
Probability of a fatality per year		1.06E-02
Return period of a fatality		94

6. EASTERN BASE TRACK

Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed rockfall frequency per m² source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m²)	m²	7,000
Total annual rockfall from source area		26.93
Proportion of 1m boulders reaching the affected track section (%)	%	50%
Proportion of 300mm boulders reaching the affected track section (%)	%	0%
Proportion of 150mm boulders reaching the affected track section (%)	%	0%
Number of 1m boulders reaching the affected track section		0.12
Number of 300mm boulders reaching the affected track section		0.00
Number of 150mm boulders reaching the affected track section		0.00
Total annual rockfall reaching the affected track section		0.12
Length of affected track section (m)	m	1000.00
Time to walk track (at 2km/hr) (minutes)	min	30
Stopping time (minutes)	min	15
Total time on affected track section (minutes)	min	45
Total time on affected track section (years)	years	8.56E-05
Ratio person length (1m) to affected track section		1.00E-03
Probability of rock coinciding with one person traverse		1.02E-08
Vulnerability (to fatality)		0.20
Probability of fatality per person traverse		2.04E-09
Number of visitors to track section per year		200000
Probability of a fatality per year		4.08E-04
Return period of a fatality		2448

7. WESTERN BASE TRACK		
Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed rockfall frequency per m² source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m²)	m²	6,500
Total annual rockfall from source area		25.01
Proportion of 1m boulders reaching the affected track section (%)	%	90%
Proportion of 300mm boulders reaching the affected track section (%)	%	10%
Proportion of 150mm boulders reaching the affected track section (%)	%	0%
Number of 1m boulders reaching the affected track section		0.20
Number of 300mm boulders reaching the affected track section		0.00
Number of 150mm boulders reaching the affected track section		0.00
Total annual rockfall reaching the affected track section		0.20
Length of affected track section (m)	m	500.00
Time to walk track (at 2km/hr) (minutes)	min	15
Stopping time (minutes)	min	15
Total time on affected track section (minutes)	min	30
Total time on affected track section (years)	years	5.71E-05
Ratio person length (1m) to affected track section		2.00E-03
Probability of rock coinciding with one person traverse		2.28E-08
Vulnerability (to fatality)		0.20
Probability of fatality per person traverse		4.55E-09
Number of visitors to track section per year		200000
Probability of a fatality per year		9.10E-04
Return period of a fatality		1099
8. CAMPGROUND		
Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed rockfall frequency per m² source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m²)	m²	1,000
Total annual rockfall from source area		3.85
Proportion of 1m boulders reaching the affected area	%	50%
Proportion of 300mm boulders reaching the affected area	%	0%
Proportion of 150mm boulders reaching the affected area	%	0%
Number of 1m boulders reaching the affected area		0.02
Number of 300mm boulders reaching the affected area		0.00
Number of 150mm boulders reaching the affected area		0.00
Total annual rockfall reaching the affected area		0.02
Width of affected area (m)	m	200.00
Stopping time (hours per person per day)	hrs	12
Stopping time per person day relative to 1 year	yrs	1.37E-03
Ratio person length (1m) to affected areas width		5.00E-03
Probability of rock coinciding with one person day's stay		1.17E-07
Vulnerability (to fatality)		0.50
Probability of fatality per person per day's stay		5.83E-08
Probability of fatality for one person staying on site 12 hrs/day all year		2.13E-05
Number of camp sites in affected area		50

Number of persons per site		4
Occupancy rate		50%
Number of person days stay on site per year		36500
Probability of a fatality per year		2.13E-03
Return period of a fatality		470

9. HOT POOLS

Assumed rockfall frequency per m² source area; 1m boulders		0.000034
Assumed rockfall frequency per m² source area; 300mm boulders		0.000347
Assumed rockfall frequency per m² source area; 150mm rocks		0.003467
Source area of bluffs/cliffs/steep colluvium (m²)	m²	500
Total annual rockfall from source area		1.92
Proportion of 1m boulders reaching the affected area	%	50%
Proportion of 300mm boulders reaching the affected area	%	0%
Proportion of 150mm boulders reaching the affected area	%	0%
Number of 1m boulders reaching the affected area		0.01
Number of 300mm boulders reaching the affected area		0.00
Number of 150mm boulders reaching the affected area		0.00
Total annual rockfall reaching the affected area		0.01
Width of affected area (m)	m	200.00
Stopping time (hours per person per day)	hrs	2
Stopping time per person day relative to 1 year	yrs	2.28E-04
Ratio person length (1m) to affected areas width		5.00E-03
Probability of rock coinciding with one person visit		9.72E-09
Vulnerability (to fatality)		0.20
Probability of fatality per person per visit		1.94E-09
Number of visitors per year		50000
Probability of a fatality per year		9.72E-05
Return period of a fatality		10283

Revised Mauao Rockfall Risk Summary

Location	*Probability of fatality per person visit*	*Return period for fatality (years)*
SE Waikorere	4.39E-08	455
N Waikorere	1.19E-09	16870
E Oruahine	4.38E-10	45704
N Oruahine	1.07E-08	1874
W Oruahine	2.13E-07	94
E Base track	2.04E-09	2448
W Base track	4.55E-09	1099
Campground	5.83E-08	470
Hot pools	9.72E-09	10283

9 EROSIONAL SCOUR UPDATE

Whilst inspecting for earthquake damage it was noted that, as anticipated, significant erosional scour and channelling has locally taken place in the colluvium.

Sand has been washed away locally leaving rocks in very marginally stable locations. A significant amount of rockfall must have been generated over the previous year via this process.

Photograph 13. Scoured colluvium, location 3f

Photograph 14. Scoured colluvium camp bluff, location 1a

Photograph 14. Scoured channels in colluvium below camp bluff, location 1a

10 HUMAN AND ANIMAL ACTIVITY UPDATE

Whilst carrying out the site inspection we noted many more rabbits and burrows than seen on previous visits. These rabbits are clearly hindering TDC's replanting scheme.

The current level of rabbit activity must be increasing the rockfall risk although to what degree is difficult to quantify. Poisoning and other rabbit control measures are being undertaken and are highly recommended from a rockfall risk perspective.

Whilst inspecting the slopes above the north western Oruahine track, above the popular rock climbing areas, we found a new eyebolt type anchor had been installed in the large boulder at location 4g. See the following photograph:

Photograph 15 a & b. Boulder at 4g and the eyebolt recently installed.

The boulder itself is more stable than it might appear (an unsuccessful attempt was made to move it using 2m bars during the March 2003 scaling operation).

The problem is that this eye could only be used for rope protection to allow persons to exit a climbing route via this colluvial slope, or possibly as a 'top roping' anchor. Either of these activities would be extremely likely to initiate rockfall and pose a completely unacceptable risk considering the public track lies directly on the fall line below.

It would be extremely difficult to use this anchor without initiating rockfall.

The quantitative risk analysis only takes into account 20 single rockfalls per year initiated by human activity.

If persons are regularly present on these slopes then the level of human initiated rockfall would need to be revised and the rockfall risks re-calculated.

The anchor was removed by Avalon during our inspection.

11 CONCLUSIONS & RECOMMENDATIONS

The recent earthquakes effects were consistent with what would have been anticipated by Avalon's previous reports.

Rockfall is an active and ongoing process and does pose a very real risk on Mauao.

The most significant recent seismically induced rockfall occurred in an area identified as high risk (the northern Oruahine track).

A number of boulders up to $0.6m^3$ failed and were channelled down a gully (3e). This gully was proposed in previous reports as a potential location for a catch fence.

It appears likely that the rock mass removed in the controlled blast (November 2003) on the 'camp bluff' (item 1a of Avalon's July 2003 report) would have had a relatively high (over 50%) probability of failure in the recent earthquakes.

A revised rockfall risk calculation (taking into account new data from the recent seismic events) has lead to a slightly increased numerical assessment of the risk; a 40% increase overall, excluding human activity. Well within the margins of uncertainty due to assumptions which had to be made in the initial analysis.

Human/animal activity remains an area of serious concern and should be monitored.

Our investigation found newly installed climbers anchorages in locations whereby their use would most be likely to initiate rockfall. The risks posed (by human activity) may have been underestimated in the risk analyses to date. Any measures which can be taken to reduce the risk of human induced rockfall are highly recommended.

The numerical risk is still considered to lie within the upper bounds established by the initial sensitivity analysis in Avalon's draft risk assessment report.

The conclusions and recommendations of the draft Rockfall Risk Assessment and Hazard Management report stand.

The slopes are now in a condition where a rock scaling operation would be very beneficial (the post fire rock scaling was in March 2003). The vast majority of rock to be removed could be removed by hand, without the use of crowbars etc.

The recommended ongoing annual rock scaling/hazard monitoring program should be established to be undertaken towards the end of winter/early spring and catch fences should be investigated.